THE

# QUARTERLY JOURNAL

OF THE

# GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

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

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## VOLUME THE TWENTY-SECOND.

1866.



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## PART THE FIRST.
## PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

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LONDON:
LONGMAN, GREEN, READER, AND DYER.
ARIS:—FRIED. KLINCKSIECK, 11 RUE DE LILLE; J. ROTHSCHILD, 14 RUE DE BUCI.
LEIPZIG, T. O. WEIGEL.

SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.

MDCCCLXVI.

# List

OF THE

## *OFFICERS*

OF THE

# GEOLOGICAL SOCIETY OF LONDON.

Elected February 16th, 1866.

### President.

Warington W. Smyth, Esq., M.A., F.R.S.

### Vice-Presidents.

Sir P. de M. G. Egerton, Bart., M.P., F.R.S.
Prof. T. H. Huxley, F.R.S. & L.S.
Sir Charles Lyell, Bart., D.C.L., F.R.S.
Prof. A. C. Ramsay, F.R.S.

### Secretaries.

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

### Foreign Secretary.

R. A. C. Godwin-Austen, Esq., F.R.S.

### Treasurer.

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

### COUNCIL.

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P. Martin Duncan, M.B.
Sir P. de M. G. Egerton, Bart., M.P., F.R.S.
Earl of Enniskillen, D.C.L., F.R.S.
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John Evans, Esq., F.R.S., F.S.A.
R. A. C. Godwin-Austen, Esq., F.R.S.
William John Hamilton, Esq., F.R.S.
Prof. T. H. Huxley, F.R.S. & L.S.
J. Gwyn Jeffreys, Esq., F.R.S.
Prof. T. Rupert Jones.
M. Auguste Laugel.
Sir Charles Lyell, Bart., D.C.L., F.R.S.
John Carrick Moore, Esq., M.A., F.R.S.
Prof. John Morris.
Sir R. I. Murchison, Bart., K.C.B., F.R.S.
Robert W. Mylne, Esq., F.R.S.
Joseph Prestwich, Esq., F.R.S.
Prof. A. C. Ramsay, M.A., F.R.S.
Warington W. Smyth, Esq., M.A., F.R.S.
Capt. T. A. B. Spratt, R.N., C.B., F.R.S.
Lieut.-Col. R. Strachey, R.E., F.R.S. & L.S.
Rev. Thomas Wiltshire, M.A., F.R.A.S.

---

### Assistant-Secretary, Librarian, and Curator.

H. M. Jenkins, Esq.

### Clerk.

Mr. P. G. Ritchie.

### Library and Museum Assistant.

Mr. R. Tate.

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# GEOLOGICAL SOCIETY OF LONDON.

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*ANNUAL GENERAL MEETING*, *FEB.* 16, 1866.

## REPORT OF THE COUNCIL.

The Council of the Geological Society of London are glad to be able to announce, in laying their Annual Report before the Fellows, that a very large addition to the number of Fellows, similar to that noticed at the close of the last two years, has been made during the past year.

During 1865 as many as 66 new Fellows were elected; but of these only 45 had paid their fees up to the end of the year, making with 11 previously elected, who paid their fees last year, a total of 56 new Fellows. On the other hand, the numbers of the Society have been reduced by the death of 17 Fellows, the resignation of 5, and the removal of 4, giving a net increase of 30 ordinary Fellows.

The Society has recently had to deplore the loss of its only remaining Fellow of Royal Blood—the late King of the Belgians.

Four Foreign Members and one Foreign Correspondent have been reported as deceased.

One Foreign Correspondent was elected during 1865 in the place of one deceased.

The total number of the Society at the close of 1864 was 1092; at the close of 1865, 1117.

The prosperous condition of the Society is indicated by its increasing Income, as well as by the augmentation in its numbers. The Income of the past year has exceeded the expenditure by £268 10*s.* 3*d.*, although the disbursements include the special expenditure on account of the Bequest-fund for the new edition of the Greenough Map.

The funded property of the Society remains the same as at the last Anniversary, namely £4560.

The Council have to announce the completion of Vol. XXI. of the Quarterly Journal, and the publication of the first part of Vol. XXII.

The New Edition of the Greenough Geological Map was completed at the commencement of the year; it has already met with a satisfactory sale, and can be obtained at the Society's Apartments, or of the agent, Mr. Stanford.

Among other donations made to the Society since the last Anniversary, the Council have to make special mention of a marble bust of Dr. Bowerbank, F.R.S., F.G.S., presented, in accordance with his wish, by the Committee of the Bowerbank Testimonial Fund.

The Council regret to have to report the sudden death, in December last, of the Society's clerk, Mr. G. E. Roberts; they have recently appointed Mr. P. G. Ritchie to fill the vacant office.

The Council have awarded the Wollaston Medal to Sir Charles Lyell, Bart., F.R.S., in recognition of the highly important services he has rendered to Geology by his various original works, and for the masterly and philosophic manner in which he has treated the subject, both in developing the principles and in expounding the elements on which the Science is founded; and the balance of the proceeds of the Wollaston Fund to Henry Woodward, Esq., F.G.S., F.Z.S., to assist him in his researches on the Fossil Crustacea.

## *Report of the Library and Museum Committee*, 1865–66.

### *The Museum.*

The additions made to the Society's collections since the last Anniversary have not been so numerous as in previous years; they consist chiefly of specimens of rocks and minerals from foreign countries. The more important donations are the following:—1st. An extensive collection of Rocks and Minerals from Roslagen, on the east coast of Sweden, illustrating the structure of magnetic iron-ores and associated rocks and minerals, as well as the relation of granitic veins to these ores, presented by Hilary Bauerman, Esq., F.G.S. 2nd. A series of Devonian Plants from Gaspé, Lower Canada, presented by Principal J. W. Dawson, LL.D., F.G.S. 3rd. A collection of Jurassic Fossils, chiefly Brachiopoda, from Normandy, including a series of minute fossils from the Leptæna-beds, presented by Ralph Tate, Esq., F.G.S. 4th. A collection of Metamorphic Rocks, exhibiting traces of organic remains, from the Alps, presented by Sign. Crescenzo Montagna. And 5thly, a collection of Devonian Corals from Poland, presented by Sir R. I. Murchison, Bart., K.C.B., F.G.S.

The chief additions made to the "British Collection" during the year are: 1st a series of Rhomboidal Specimens of Clay-ironstone and Iron-sandstone from the Collingwood Quarry, Kent, and the Clanmullen Quarry, near Edenderry, King's County, presented by Sir J. F. W. Herschel, Bart., F.G.S., and Capt. T. Longworth Dames; and, 2ndly, specimens of siliceous casts of corals from the Carboniferous Limestone of County Dublin, presented by H. B. Brady, Esq., F.G.S.

Satisfactory progress has been made since the last Anniversary in the renaming of the specimens in the British and Foreign Collections; though more work of this kind would have been done, but for the encouraging fact that last year the collections were consulted to a much greater extent than was formerly the case. This is probably owing in some measure to the recent increase in the number of the Fellows, but it is doubtless due in some degree to the more accessible and increasingly useful state of the collections.

The Sharpe Collection of Corals, chiefly Palæozoic, which originally occupied 18 drawers, has been thoroughly examined, the specimens named by Dr. Duncan, and placed upon tablets by Mr. Tate, and the duplicates taken out. Owing to the economy of space thus obtained the collection now occupies but 10 drawers.

The Committee recommend that the duplicates of these and other British fossils should be offered to the Museum of Practical Geology.

The Zoological Catalogue of the whole of the Coral-collections is now in hand, and will shortly be completed. The formation of type-collections of fossils belonging to other classes of animals is in contemplation, and the zoological collection of Echinodermata has been commenced. Some additions have been made to the nucleus of the collection of Polyzoa; but in this and in other type collections there is a great want of specimens to illustrate certain types of structure.

Twelve drawers containing fragile fossils, such as those of the Red Crag, have been fitted with glass, and the cleaning, remounting, and naming of the specimens are in progress.

The Collection of Bordeaux Miocene Fossils, occupying 11 drawers, has been thoroughly examined and arranged, the specimens have been placed upon tablets, and the duplicates removed; and the drawers containing the collection have been fitted with glass.

The following table contains a summary of the work done in the Museum during the past year, in naming and arranging collections of fossils.

| | | Drawers. |
|---|---|---|
| England | Red Crag | 2 |
| ,, | Gault | 2 |
| ,, | Lias | 1 |
| ,, | Inferior Oolite | 9 |
| *Bavaria | Jurassic | 3 |
| Bordeaux | Miocene | 11 |
| Normandy | Jurassic & Cretaceous | 4 |
| Gosau | Cretaceous | 1 |
| *Zoological Collection of Corals | | 10 |
| Zoological Collection of Echinoderms | | 3 |
| *Miscellaneous Corals | | 1 |
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In concluding their Report the Committee desire to express their opinion that the especial thanks of the Society are due to Dr. Duncan for his energetic and well-sustained labours in the Museum

* Corals, named by Dr. Duncan.

during the last three years; and to record their satisfaction with the manner in which Mr. Tate has discharged his duties in the Museum during the past year.

J. GWYN JEFFREYS.
THOS. WILTSHIRE.
R. ETHERIDGE.

*The Library.*

The chief additions made to the Library by purchase last year are Coquand's 'Géologie et Paléontologie de la Province de Constantine,' Massalongo's 'Saggio Fotografico di alcuni animali e piante fossili dell' Agro Veronese,' Etallon and Thurmann's 'Lethæa Bruntrutana,' Stoppani's 'Petrifactions d'Esino,' and Huxley and Hawkins's 'Atlas of Comparative Osteology.' Amongst the donations Dr. Hochstetter's Geology of New Zealand, the accompanping volume on the Palæontology of the Islands, and the second volume of M. Barrande's 'Système Silurien de la Bohême' are more especially worthy of mention.

The Map-collection has received some very valuable additions, including the large geological map of the country round Bristol, in 19 sheets, presented by the author, W. Sanders, Esq., F.R.S., F.G.S.; a complete copy of the "Geologische Karte der Rheinprovinz und der Provinz Westfalen," presented by Herr von Dechen, For. Mem. G.S., through Sir R. I. Murchison, Bart., K.C.B., F.G.S.; the "Carte géologique de l'Espagne et du Portugal, presented by the authors, MM. de Verneuil, For. Mem. G.S., and C. Collomb; several sheets of the Geological Survey-map of Great Britain and Ireland, presented by the Director-General, Sir R. I. Murchison, Bart., K.C.B., F.G.S., and of the Ordnance Survey-map of Great Britain, on the 1-inch and 6-inch scales, presented by the Director-General, Col. Sir Henry James, F,G.S., and some of the sheets of the Geological Survey-map of the Netherlands, presented by His Excellency the Minister for the Netherlands.

The Committee beg to recommend that a larger sum should be expended annually in the purchase of Geological books than has hitherto been voted for that purpose. They find that last year not more than about £25 was expended in the purchase of books, and about £30 for binding.

The Committee suggest the appointment of a standing Library Committee, to meet on the first meeting-day of the Society in every alternate month.

The Assistant-Secretary reports that he has received much assistance from Mr. Horace Woodward in doing the current work of the Library, and in making Diagrams for the Evening-meetings.

J. GWYN JEFFREYS.
THOS. WILTSHIRE.
R. ETHERIDGE.

*Comparative Statement of the Number of the Society at the close of the years* 1864 *and* 1865.

| | Dec. 31, 1864. | Dec. 31, 1865. |
|---|---|---|
| Compounders | 156 | 167 |
| Contributing Fellows | 373 | 395 |
| Non-contributing Fellows | 472 | 469 |
| | 1001 | 1031 |
| Honorary Members | 3 | 3 |
| Foreign Members | 48 | 44 |
| Foreign Correspondents | 39 | 39 |
| Personage of Royal Blood | 1 | 0 |
| | 1092 | 1117 |

*General Statement explanatory of the Alteration in the Number of Fellows, Honorary Members, &c. at the close of the years* 1864 *and* 1865.

| | | | |
|---|---|---|---|
| Number of Compounders, Contributing and Non-contributing Fellows, December 31, 1864 | | | 1001 |
| *Add* Fellows elected during former year and paid in 1865 | | | 11 |
| *Add* Fellows elected and paid in 1865 | | | 45 |
| | | | 1057 |
| *Deduct* Compounders deceased | | 8 | |
| Contributing Fellows deceased | | 6 | |
| Non-contributing Fellows deceased | | 3 | |
| Contributing Fellows resigned | | 5 | |
| Contributing Fellows removed | | 4 | |
| | | — | 26 |
| | | | 1031 |
| Number of Personages of Royal Blood, Honorary Members, Foreign Members, and Foreign Correspondents, December 31, 1865 | | 91 | |
| *Add* Foreign Correspondent elected in 1865 | | 1 | |
| | | 92 | |
| *Deduct* Personage of Royal Blood deceased | 1 | | |
| Foreign Members deceased | 4 | | |
| Foreign Correspondent deceased | 1 | 6 | |
| | | — | 86 |
| | | | 1117 |

## Deceased Fellows.

*Personage of Royal Blood* (1).

His Majesty the King of the Belgians.

*Compounders* (8).

The Earl of Ilchester.
Samuel Cartwright, Esq.
Henry Christy, Esq.
W. G. Prescott, Esq.
F. W. Simms, Esq.
Dr. S. P. Woodward.
Sir J. W. Lubbock, Bart.
Lovell Reeve, Esq.

*Residents and other Contributing Fellows* (6).

E. L. Richards, Esq.
Dr. H. Falconer.
J. Macdonnell, Esq.
T. E. Blackwell, Esq.
W. B. Mitchell, Esq.
G. E. Roberts, Esq.

*Non-contributing Fellows* (3).

Lieut.-Col. T. E. Sampson.
T. Hutton, Esq.
Nicholas Wood, Esq.

*Foreign Members* (4).

Dr. C. H. Pander.
Prof. K. von Raumer.
M. C. von Oeynhausen.
Dr. J. G. Forchhammer.

*Foreign Correspondent* (1).

Dr. Albert Oppel.

## Fellows Resigned.

*Residents and other Contributing Fellows* (4).

Lord Dufferin.
Dr. G. C. Wallich.
George Whitmore, Esq.
B. de Courcy Nixon, Esq.

*Non-contributing Fellow* (1).

E. H. Sheppard, Esq.

## Fellows Removed.

*Residents and other Contributing Fellows* (4).

Rev. F. F. Statham.
H. T. James, Esq.
Mark Fryar, Esq.
Dr. J. Winter.

*The following Persons were elected Fellows during the year* 1865.

January 11th.—George Elliott, Esq., 23 Great George Street, Westminster, S.W.; Robert Hannah, Esq., 2 Alfred Place West, South Kensington, S.W.; Henry Robinson, Esq., Assoc. I.C.E., 2 Delahay Street, Westminster, S.W., and Carlton Hill, St. John's Wood, N.W.; Robert P. Roupell, Esq., Q.C., 13 Park Lane, Hyde Park, W.; Captain John Sackville Swann, H.M. 22nd Regt., Malta; and John Edmund Thomas, Esq., C.E., Rhayader.

—— 25th.—William Grylls Adams, Esq., M.A., Lecturer on Natural Philosophy in King's College, London; and Capt. Stewart Smyth Windham, 14 Connaught Place, W.

February 8th.—Capt. William Arbuthnot, 25 Hyde Park Gardens, W.; Robert Bell, Esq., Professor of Geology in Queen's College, Canada West; William Henry Leighton, Esq., 2 Merton Place, Chiswick; and Viscount Milton, F.R.G.S., of Wentworth Park, and 4 Grosvenor Square, W.

—— 22nd.—C. Gainer, Esq., M.A., St. Mary's Hall, Oxford; John Wesley Judd, Esq., 2 Burngreave View, Sheffield; Francis R. Spry, Esq., Ashford, near Hornsey; The Hon. Arthur Strutt, 88 Eaton Square, W.; and Samuel Long Waring, Esq., The Oaks, Norwood.

March 8th.—The Rev. T. H. Browne, High Wycombe, Berks; Thomas Grange Hurst, Esq., Mining Engineer, Backworth, Northumberland; and W. R. Williams, Esq., Mining Engineer, Dolgelly, North Wales.

—— 22nd.—Henry Turner, Esq., Mottingham, Kent.

April 5th.—Henry Clark Barlow, M.D., Newington Butts, S.E.; Townshend Monckton Hall, Esq., Pilton Parsonage, near Barnstaple; John Lawson, Esq., C.E., 34 Parliament Street, S.W.; William Milnes, Esq., Blackheath, Kent, and Yeolm Bridge, South Devon; J. Samuel Perkes, Esq., C.E., Belvedere House, West Dulwich, S.; and Minos Claiborne Vincent, Esq., C.E., Frankfort, Ohio, U.S.

—— 20th.—J. W. Conrad Cox, Esq., B.A., 4 Grove Hill, Woodford, N.E., and 32 Westbourne Place, Eaton Square, W.; Henry K. Jordan, Esq., Tenby House, Cotham, Bristol; and Thomas J. Sells, Esq., M.R.C.S., Guildford, Surrey.

May 10th.—Absalom Bennett, Esq., Marazion, Cornwall; Joseph Brown, Esq., Q.C., of the Middle Temple, 54 Avenue Road, Regent's Park, N.W.; The Rev. John Magens Mello, M.A., Incumbent of St. Thomas's Brampton, Chesterfield; and George Noakes, Esq., 3 Grosvenor Villas, St. Bartholomew Row, Holloway, N.

—— 24th.—James Philip Baker, Esq., Wolverhampton; George William Cline, Esq., 38 Albermarle Street, Piccadilly, W.; James Coutts Crawford, Esq., Wellington, New Zealand; Theodore H. Hughes, Esq., of the Geological Survey of India; and Charles Ottley Groom Napier, Esq., Bristol.

June 21st.—Samuel Bailey, Esq., Mining Engineer, The Pleck, Walsall; William Keene, Esq., Sydney, New South Wales; and the Rev. Benjamin Waugh, Newbury, Berks.

November 8th.—Thomas William Danby, Esq., B.A., Downing College, Cambridge; William Poole King, Esq., Avon Side House, Clifton, Bristol; James L. Lobley, Esq., 50 Lansdowne Road, Kensington Park, S.W.; John Richardson, Esq., C.E.; James Clifton Ward, Esq., Clapham Common; and Samuel Hansard Yockney, Esq., M.I.C.E.

—— 22nd.—Robert Lightbody, Esq., Ludlow, Salop.

December 6th.—W. Phipson Beale, Esq., 27 Victoria Street, S.W.; Henry Braddon, Esq., 5 Dane's Inn, Strand, W.C.; Captain Robert Clipperton, H.B.M. Consul at Kertch; Tellef Dahll, Esq., Kragere, Norway; R. A. Eskrigge, Esq., 24 The Albany, Old Hall Street, Liverpool; Hugh Frederick Hall, Esq., Liverpool; Hedworth Hylton Jolliffe, Esq., Merstham, Surrey; Edward Myers, Esq., 29 Summer Hill Terrace, Birmingham; George Pycroft, Esq., M.R.C.S.E., Kenton, Exeter; Ferdinand Stoliczka, Ph.D., of the Geological Survey of India, Calcutta; Erwin Harvey Wadge, Esq., Stradbrook Hall, Blackrock, Co. Dublin, Ireland; Henry Augustus Ward, Esq., Professor of Natural Sciences in the University of Rochester, New York; and Frederick Williams, Esq., M.P., Goonvrae, near Truro.

—— 20th.—Hugh Leonard, Esq., C.E., Calcutta; William Lyon, Esq., J.P., Wellington, New Zealand; Moses Pullen, Esq., Painswick, Gloucestershire; and Charles Stavely Rooke, Esq., M.I.C.E., 12 Bleinham Terrace, Leeds.

*The following Person was elected a Foreign Correspondent during the year* 1865.

March 8th.—Prof. C. Nilsson, of Stockholm.

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

*British Specimens.*

Two Fossil Plants from the Coal-measures of Dudley; presented by H. Beckett, Esq., F.G.S.

Rhomboidal specimens of Clay Ironstone and Iron-sandstone from the Collingwood and Clanmullen Quarries; presented by Sir J. F. W. Herschel, Bart., F.R.S., F.G.S., and Capt. T. Longworth Dames.

Twelve specimens of Lead and Copper from various localities; presented by J. W. B. Owen, Esq., M.A.

Siliceous Casts of Corals from the Carboniferous Limestone near Dublin; presented by H. B. Brady, Esq., F.G.S.

*Foreign Specimens.*

Rock-specimens from Peru; presented by R. Spruce, Esq.

Cast of *Ovibos moschatus*, Blainv.; presented by M. E. Lartêt, For. Mem. G.S.

A Collection of Rocks and Minerals from Roslagen, Sweden; presented by H. Bauerman, Esq., F.G.S.

Fourteen specimens of Devonian Plants from Gaspé; presented by Dr. J. W. Dawson, F.R.S., F.G.S.

Five specimens of Cannel Coal from New South Wales; presented by the Rev. W. B. Clarke, M.A., F.G.S.

Devonian Corals from Poland; presented by Sir R. I. Murchison, Bart., F.R.S., F.G.S.

Jurassic Fossils from Normandy; presented by Ralph Tate, Esq., F.G.S.

Tertiary Echinoderms from Trinidad; presented by R. J. L. Guppy, Esq.

## Maps, Charts, etc., presented.

Carte Géologique de l'Espagne et du Portugal, par MM. E. de Verneuil et E. Collomb. 1849 à 1862; presented by the authors.

Karten und Mittheilungen des Mittelrheinischen Geologischen Vereins. Section Darmstadt, von R. Ludwig, 1864; presented by the author.

Geological Survey of Victoria. Sheets 3 and 15; presented by A. R. C. Selwyn, Esq.

Mapa geológico de la Provincia de Madrid, por Don Casiano de Prado, For. Mem. G.S.; presented by the author.

Map of the Bristol Coal-fields and country adjacent, in 19 sheets, geologically surveyed by William Sanders, F.G.S.; presented by the author.

The Chain of Mont Blanc, from an actual survey in 1863–64, by A. Adams-Reilly, A.C., F.R.G.S. 1865; presented by the author.

Geological Map of Scotland, by Sir R. I. Murchison and A. Geikie; presented by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S.

Geological Sketch-Map and sections of the Province of Wellington, New Zealand, by J. Coutts Crawford, F.G.S.; presented by the Geological Survey of New Zealand.

Geologische Karte der Rheinprovinz und der Provinz Westfalen, by Dr. H. von Dechen; presented by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S.

Geologische Karte der Provinz Victoria, by A. R. C. Selwyn; presented by Dr. A. Petermann.

Geological Survey of Great Britain and Ireland. England. Nos. 4, 6, 7, 9, 45 (N.E. &S.E.), 46 (N.W. & S.W.), 52, 81 (N.W. & S.W.), and 89 (S.E.).—Scotland. Nos. 33, 34, and 41.—Ireland. Nos. 99, 114–117, 118, 122–127, and 133–135.—England. Section No. 65.—Ireland. Explanations of Sheets Nos. 102, 112, 144, 146, 147, 153, 157, and 163–175.

Sveriges geologiska Undersökning. Nos. 6 to 13. 1863–64; presented by Dr. A. Erdmann.

Seventy-five Miscellaneous Charts, published by the Dépôt de la Marine; presented by the Dépôt de la Marine.

Ordnance Survey of Great Britain. Maps, 6-inch scale:—Northumberland, Sheets 15, 72, 73, 79–82, 85–87, 91–95, 100–103, 106, 106*a* & *b*–108, 110, 111. Stirlingshire, Sheets, 8, 20–26, 28–30, 32, 33, 35, 36. Dumbartonshire, Sheets 2–4, 6–14, 16–18, 23, 26. Roxburgshire, Index-sheet. Lanarkshire, Sheet 6. Forfarshire, Sheets 1–7, 9–18, 22, 23, 40, 41, 43–46, 48–55.—Ordnance Survey of England. 1-inch scale:—Sheets 98, 99, 105, 110.—Ordnance Survey of Ireland. 1-inch scale:—Sheets 7, 8, 14, 18, 37, 90, 121.

Geological Survey Maps of Holland. Sheets 3, 4, 8, 11, 17; presented by His Excellency the Minister for the Netherlands.

Geologisk kart over Christiana Omegn, af Theodor Kjerulf. 1864; presented by the Royal University of Christiana.

Carte Agronomique des environs de Paris, par M. Delesse; presented by the author.

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Four Photographs of Fossils from Queensland and New South Wales; presented by W. Keene, Esq., F.G.S.

Photograph of *Telerpeton Elginense*; presented by the late G. E. Roberts, Esq., F.G.S.

Diagram showing the mode of construction of the Seismometer, by Lieut.-Col. C. Ramstedt; presented by the author.

The following Lists contain the Names of the Persons and Public Bodies from whom Donations to the Library and Museum have been received since the last Anniversary, February 17, 1865.

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

Abbeville, Imperial Society of Emulation of.

Basel, Natural History Society of.

Belgium, Geological Survey of.

Berlin. German Geological Society.

Berwick. Natural History Field-club.

Bombay, Geographical Society of.

Boston, Museum of Comparative Zoology of.

——, Natural History Society of.

Breslau. Silesian Society for Fatherland Culture.

Brussels. Royal Academy of Sciences of Belgium.

Caen. Linnean Society of Normandy.

Calcutta. Geological Survey of India.

——, Bengal Asiatic Society at.

Cambridge (Mass). American Philosophical Society.

—— ——. American Academy of Arts and Sciences.

Cherbourg, Society of Natural Sciences of.

Christiana, Royal University of.

Darmstadt. Geological Society of the Middle Rhine.

Dijon, Academy of Natural Sciences of.

Dublin. Geological Survey of Ireland.

Dublin. Royal Irish Academy.
——. Royal Society.
——. Royal Geological Society of Ireland.

Edinburgh, Geological Society of.
——, Royal Society of.
Exeter. Devonshire Association.

France, Acclimatization Society of.
——, Geological Society of.

Geneva, Physical and Natural History Society of.
Glasgow, Geological Society of.

Heidelberg, Natural History Society of.

Lausanne. Vaudoise Society of Natural Sciences.
Leeds, Philosophical and Literary Society of.
Liverpool, Geological Society of.
——. Lancashire and Cheshire Historic Society.
——, Philosophical Society of.
London, Anthropological Society of.
——, Art Union of.
——. British Association.
——, Chemical Society of.
——. Geological Survey of Great Britain.
——. Geologists' Association.
——. Institute of Actuaries of Great Britain and Ireland.
——. Institute of Civil Engineers.
——, Linnean Society of.
——, Mendicity Society of.
——, Microscopical Society of.
——. Palæontographical Society.
——, Photographic Society of.
——. Ray Society.
——. Royal Asiatic Society of Great Britain.
——, Royal Astronomical Society of.
London, Royal College of.
——, Royal Geographical Society of.
——, Royal Horticultural Society of.
——. Royal Institution of Great Britain.
——, Royal Society of.
——. Secretary of State for War.
——, Zoological Society of.
Lyons, Imperial Academy of Sciences of.

Madrid, Academy of Sciences of.
Manchester, Geological Society of.
Melbourne, Public Library of.
——. Royal Society of Victoria.
Milan, Society of Natural Sciences of.
Montreal, Natural History Society of.
Moscow, Imperial Academy of Naturalists in.
Munich, Academy of Sciences of.

Neuchatel, Society of Natural Sciences of.
Nova Scotian Institute.

Padua, Royal Academy of Sciences of.
Palermo, Institute of Natural Sciences of.
Paris. Academy of Sciences.
——. Dépôt Général de la Marine.
——. School of Mines.
——. Institute of the Provinces.
Philadelphia. Academy of Natural Sciences.
——. American Philosophical Society.
Plymouth Institution.
Presburg, Natural History Society of.

St. Petersburg, Imperial Academy of.

Shanghai. North China branch of the Royal Asiatic Society.
Southampton. Ordnance Survey.
Stockholm. Royal Swedish Academy.

Tasmania, Royal Society of.
Teign Naturalists' Field-club.
Toronto. Canadian Institute.
Turin. Alpine Club.
——. Royal Institute of Lombardy.

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

Warwickshire Naturalists' Field-club.
Washington. Patent Office.
——. Smithsonian Institution.
Wurtemburg, Natural History Society of.

Yorkshire (West Riding). Geological and Polytechnic Society.

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

Adams-Reilly, A., Esq.
Ansted, Prof. D. T., F.G.S.
American Journal of Science and Arts, Editor of the.
Archiac, Vicomte A. d', For.Mem. G.S.
Athenæum, Editor of the.

Bagot, A. H., Esq.
Barrande, M. J., For.Mem.G.S.
Bauerman, H., Esq., F.G.S.
Beckett, H., Esq., F.G.S.
Benecke, M. E. W.
Bianconi, Prof. G.
Binney, E. W., Esq., F.G.S.
Bischof, Prof. G., For.Mem.G.S.
Blanford, H. F., Esq., F.G.S.
Boucher de Perthes, M., For.Corr. G.S.
Boult, J., Esq.
Brady, H.B., Esq., F.G.S.
Brown, R., Esq.

Campbell, J. F., Esq.
Carter, Dr. H. J.
Catullo, Sign.
Charnock, Dr. R. S.
Christy, the Executors of the late H., Esq., F.G.S.
Clarke, Rev. W. B., F.G.S.
Codrington, T. Esq., F.G.S.
Colliery Guardian, Editor of the.
Collomb, M. E.
Crawford, J. C., Esq., F.G.S.

Dames, Capt. T. L.
Dawkins, W. B., Esq., F.G.S.
Dawson, Dr. J. W., F.G.S.
Delesse, Prof. A., For.Mem.G.S.
Deshayes, Prof. G. P., For.Mem. G.S.
Duncan, Dr. P. M., Sec.G.S.

Edwards, Dr. H. Milne- For. Mem.G.S.
Egerton, Sir P. de M. G., Bart. F.G.S.
Erdmann, Dr. A.

Favre, M. A.
Fonvielle, M. de.
Foote, R. B., Esq.
Forchhammer, the late Prof. G., For.Mem.G.S.
Fuhlrott, Prof. C.

Garrigou, M. F.
Gastaldi, Sign. B., For.Corr.G.S.
Geinitz, Dr. H. B., For.Mem.G.S.
Goeppert, Dr. H. R., For.Mem. G.S.
Groot, M. C. de.

Guilbert, M. L.
Gümbel, Herr Bergm., For.Corr. G.S.
Gunn, Rev. J., F.G.S.
Guppy, R. J. L., Esq.
Gutzeit, T. von.

Haast, Dr. J., F.G.S.
Haswell, G. C., Esq.
Hauer, F. R. von., For.Corr.G.S.
Hébert, Prof. E., For.Corr.G.S.
Heer, Dr. O., For.Corr.G.S.
Helmersen, Gen. G. von, For. Mem.G.S.
Herschel, Sir J. F. W., F.G.S.
Hind, Prof. H. Y.
Hochstetter, Dr. F.
Hon, M. H. Le.
Hull, E., Esq., F.G.S.

Intellectual Observer, Editor of the.

James, Col. Sir H., F.G.S.
Jervis, W. P., Esq., F.G.S.
Jones, Prof. T. R., F.G.S.
Jordan, H. K., Esq., F.G.S.
Journal of the Society of Arts, Editor of the.

Karrer, Dr. F.
Keene, W., Esq., F.G.S.
King, Prof. W.
Kirkby, J. W., Esq.
Kœnen, Baron von.
Kokscharow, M. N. von.
Koninck, Prof. L. de, For.Mem. G.S.

Lankester, E. R., Esq.
Lartêt, M. E., For.Mem.G.S.
Lartêt, M. L.
Laube, Dr. G. C.
Laugel, M. A., F.G.S.
Lavizzari, Dr. L.
Lentillac, M. de.
Liebig, Baron J. von.
Locke, J., Esq.
Logan, Sir W. E., F.G.S.
London Review, Editor of the.

Longman and Co., Messrs.
Luca, Sign. S. de.
Ludwig, M. R.
Lyell, Sir Charles, Bart., F.G.S.

Mackie, S. J. Esq., F.G.S.
Marès, Dr. P.
Marmora, Gen. A. della.
Martin, M. J.
Martins, Dr. C., For.Corr.G.S.
Maw, G., Esq., F.G.S.
Mining and Smelting Magazine, Editor of the.
Montagna, M. C.
Mortillet, M. G. de.
Murchison, Sir R. I., Bart., F.G.S.

Nägeli, Dr. C.

Omboni, Sign. G.
Oppel, the late Dr. A., For.Corr. G.S.
Owen, J. W. B., Esq.

Page, D., Esq., F.G.S.
Parker, W. K., Esq.
Perrey, M. A.
Petermann, Dr. A.
Phillips, Prof. J., F.G.S.
Ponzi, Sign. G.
Prado, Sign. C. de, For.Mem.G.S.

Quetelet, M. A.

Ramstedt, Lieut.-Col. C.
Reader, Editor of the.
Renevier, M. E.
Reuss, Dr. A. E., For.Corr.G.S.
Roberts, the late G. E., Esq., F.G.S.
Romanofski, M. G.

Sanders, W., Esq., F.G.S.
Seeley, H. Esq., F.G.S.
Selwyn, A. R. C., Esq.
Sismonda, Prof. A., For.Mem. G.S.
Soulby, T., Esq.
South, Sir J.
Spratt, Capt. T. A. B., F.G.S.

Spruce, R. Esq.
Stoliczka, Dr. F., F.G.S.
Studer, Prof. B., For. Mem. G.S.
Suess, Prof. E., For.Corr.G.S.

Tate, G. Esq., F.G.S.
Tate, R. Esq., F.G.S.
Tawny, E. B., Esq., F.G.S.
Tennant, Prof. J., F.G.S.
Theobald, Prof.
Trübner and Co., Messrs.
Tylor, A., Esq., F.G.S.
Tylor, E. B., Esq.
Verneuil, M. E. de, For.Mem. G.S.

Waagen, Dr. W.
Watelet, M. A.
Whitaker, W., Esq., F.G.S.
Winchell, Prof. A.
Winkler, Dr. T. C.
Winslow, Dr. C. F.
Wood, Rev. H. H., F.G.S.
Wood, S. V., jun., Esq., F.G.S.

*List of* PAPERS *read since the last Anniversary Meeting, February 17th,* 1865.

1865.

February 22nd.—On the Lower Silurian Rocks of the South-east of Cumberland and the North-east of Westmoreland, by Prof. R. Harkness, F.R.S., F.G.S.

———— Note on the Volcanic Tufa of Latacunga, at the foot of Cotopaxi; and on the Cangáua, or Volcanic Mud of the Quitenian Andes, by R. Spruce, Esq.; communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S.

———— On the Discovery of Flint Implements in the Drift at Milford Hill, Salisbury, by Dr. H. P. Blackmore; communicated by J. Evans, Esq., F.R.S., F.G.S.

March 8th.—A Description of the Echinodermata from the Strata on the South-east Coast of Arabia, and at Bagh on the Nerbudda, in the Collection of the Geological Society, by P. Martin Duncan, M.B., Sec.G.S.

———— On the Fossil Contents of the Genista Cave, Gibraltar, by G. Busk, Esq., F.R.S., F.G.S., and the late Hugh Falconer, M.D., F.R.S., F.G.S.

March 22nd.—Notes on the Caves of Gibralter, by Lieut. C. Warren, R.E.; communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S.

———— On the asserted Occurrence of Human Bones in the ancient Fluviatile Deposits of the Nile and the Ganges, with comparative Remarks on the Alluvial Formation of the two Valleys, by the late Hugh Falconer, M.D., F.R.S., F.G.S.

April 5th.—On some Tertiary Deposits in the Colony of Victoria, Australia, by the Rev. J. E. T. Woods, F.L.S., F.G.S.; with a Note on the Corals, by P. M. Duncan, M.B., Sec.G.S.

———— On the Chalk of the Isle of Thanet, by W. Whitaker, Esq., B.A., F.G.S.

———— On the Chalk of Buckinghamshire, and on the Totternhoe Stone, by W. Whitaker, Esq., B.A., F.G.S.

———— On the Chalk of the Isle of Wight, by W. Whitaker, Esq., B.A., F.G.S.

1865.

April 26th.—On the Character of the Cephalopodous Fauna of the South-Indian Cretaceous Rocks, by Dr. Stoliczka, Ph.D.; communicated by the Assistant-Secretary.

—————— On the Growth of Flos Ferri, or Coralloidal Arragonite, by W. Wallace, Esq.; communicated by W. W. Smyth, Esq., F.R.S., F.G.S.

—————— Notes accompanying some Rhomboidal Specimens of Iron-Sandstone, &c., presented to the Society, by Sir J. F. W. Herschel, Bart., K.C.H., F.R.S., F.G.S.; with a Note, by Capt. T. L. Dames; communicated by Sir C. Lyell, Bart., F.R.S., F.G.S.

May 10th.—On the Azoic and Palæozoic Rocks of Southern New Brunswick, by G. F. Matthew, Esq.; communicated by J. W. Dawson, LL.D., F.R.S., F.G.S.

—————— Results of Geological Observations in Baden and Franconia, by Dr. F. Sandberger, For.Corr.G.S.

—————— On the Changes rendered necessary in the Geological Map of South Africa by recent Discoveries of Fossils, by R. N. Rubridge, M.B., F.G.S.

May 24th.—Additional Observations on the Raised Beach of Sangatte with reference to the Date of the English Channel, and the presence of Loess in the Cliff Section, by J. Prestwich, Esq., F.R.S., Treas.G.S.

—————— On the Superficial Deposits of the Valley of the Medway, with remarks on the Denudation of the Weald, by C. Le N. Foster, D.Sc., F.G.S., and W. Topley, Esq., F.G.S.

June 7th.—Note on *Ovibos moschatus*, Blainville, by M. E. Lartêt, For.Mem.G.S.

—————— On some Additional Fossils from the Lingula-flags, by J. W. Salter, Esq., F.G.S.; with a Note on the Genus Anopolenus, by H. Hicks, Esq., F.G.S.

—————— On some New Species of Crustacea belonging to the Order *Eurypterida*, by Henry Woodward, Esq., F.G.S., F.Z.S.

—————— On the Discovery of a New Genus of *Cirripedia* in the Wenlock Limestone and Shale of Dudley, by Henry Woodward, Esq., F.G.S., F.Z.S.

—————— On a New Genus of *Eurypterida* from the Lower Ludlow Rock of Leintwardine, Shropshire, by Henry Woodward, Esq., F.G.S., F.Z.S.

June 21st.—On the Carboniferous Rocks of the Valley of Kashmere, by Capt. H. Godwin-Austen; with Notes on the Carboniferous Brachiopoda, by T. Davidson, Esq., F.R.S., F.G.S.; and an Introduction and Résumé, by R. A. C. Godwin-Austen, F.R.S., For. Mem.G.S.; communicated by R. A. C. Godwin-Austen, Esq., F.R.S., &c.

—————— On the Mammalian Remains found by E. Wood, Esq., near Richmond, Yorkshire, by W. B. Dawkins, Esq., M.A., F.G.S.; with an Introductory Note on the Deposit in which they were found, by E. Wood, Esq., F.G.S., and G. E. Roberts, Esq., F.G.S.

1865.

November 8th.—On the Submerged Forest-beds in Porlock Bay, by R. A. C. Godwin-Austen, Esq., F.R.S., For.Sec.G.S.

———— On the Marine Origin of the 'Parallel Roads' of Glen Roy, by the Rev. R. Boog Watson, B.A., F.G.S.

November 22nd.—On Impressions of Selenite in the Woolwich Beds and London Clay, by P. Martin Duncan, M.B., Sec.G.S.

———— On the Relation of the Chillesford Beds to the Norwich Crag, by the Rev. O. Fisher, M.A., F.G.S.

December 6th.—On the Western Limit of the Rhætic Beds in South Wales, and on the position of the Sutton Stone, by E. B. Tawney, Esq., F.G.S.; with a Note on the Corals of the Sutton Stone, by P. Martin Duncan, M.B., Sec.G.S.

———— Notes on a Section of the Lower Lias and Rhætic Beds near Wells, Somerset, by the Rev. P. B. Brodie, M.A., F.G.S.

December 20th.—On the Conditions of the Depositions of Coal, by J. W. Dawson, LL.D., F.R.S., F.G.S.

1866.

January 10th.—On the Origin and Microscopic Structure of the so-called Eozoön-Serpentine, by Prof. W. King and Dr. T. H. Rowney; communicated by Sir R. I. Murchison, Bart., F.R.S., F.G.S.

———— Supplemental Notes on the Structure and Affinities of *Eozoön Canadense*, by W. B. Carpenter, M.D., F.R.S., F.G.S.

January 24th.—Notes on Belgian Geology, by R. A. C. Godwin-Austen, Esq., F.R.S., For.Sec.G.S.

February 7th.—On the Mode of Formation of certain Lake-basins in New Zealand, by W. T. Locke Travers, Esq.; communicated by Sir C. Lyell, Bart., D.C.L., F.R.S., F.G.S.

———— On the Occurrence of Dead Littoral Shells in the Bed of the German Ocean, forty miles from the coast of Aberdeen, by Robert Dawson, Esq.; communicated by T. F. Jamieson, Esq., F.G.S.

———— On the Glacial Phenomena of Caithness, by T. F. Jamieson, Esq., F.G.S.

After the Reports had been read, it was resolved,—

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

It was afterwards resolved,—

1. That the thanks of the Society be given to W. J. Hamilton, Esq., retiring from the office of President.

2. That the thanks of the Society be given to Dr. Meryon, J. Carrick Moore, Esq., and Sir R. I. Murchison, retiring from the offices of Vice-Presidents.

3. That the thanks of the Society be given to Warington W. Smyth, Esq., retiring from the Office of Secretary.

4. That the thanks of the Society be given to Robert Chambers, Esq., the Rev. Robert Everest, Sir John Lubbock, and Dr. Meryon, retiring from the Council.

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

## OFFICERS.

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*PRESIDENT.*

Warington W. Smyth, Esq., M.A., F.R.S.

*VICE-PRESIDENTS.*

Sir P. de M. G. Egerton, Bart., M.P., F.R.S.
Professor T. H. Huxley, F.R.S. & L.S.
Sir Charles Lyell, Bart., D.C.L., F.R.S.
Professor A. C. Ramsay, F.R.S.

*SECRETARIES.*

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

*FOREIGN SECRETARY.*

R. A. C. Godwin-Austen, Esq., F.R.S.

*TREASURER.*

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

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## COUNCIL.

H. W. Bristow, Esq., F.R.S.
P. Martin Duncan, M.B.
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John Evans, Esq., F.R.S., F.S.A.
R. A. C. Godwin-Austen, Esq., F.R.S.
W. J. Hamilton, Esq., F.R.S.
Professor T. H. Huxley, F.R.S. & L.S.
J. Gwyn Jeffreys, Esq., F.R.S.
Professor T. Rupert Jones.
M. Auguste Laugel.
Sir Charles Lyell, Bart., D.C.L., F.R.S.
John Carrick Moore, Esq., M.A., F.R.S.
Professor John Morris.
Sir R. I. Murchison, Bart., K.C.B., F.R.S.
Robert W. Mylne, Esq., F.R.S.
Joseph Prestwich, Esq., F.R.S.
Professor A. C. Ramsay, F.R.S.
Warington W. Smyth, Esq., M.A., F.R.S.
Capt. T. A. B. Spratt, R.N., C.B., F.R.S.
Lieut.-Col. R. Strachey, R.E., F.R.S. & L.S.
Rev. Thomas Wiltshire, M.A., F.R.A.S.

# LIST OF

# THE FOREIGN MEMBERS

## OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1866.

Date of Election.

1818. Professor G. C. Gmelin, *Tübingen.*
1819. Count A. Breuner, *Vienna.*
1819. Signor Alberto Parolini, *Bassano.*
1822. Count Vitaliano Borromeo, *Milan.*
1823. Professor Nils de Nordenskiöld, *Helsingfors.*
1827. Dr. H. von Dechen, *Bonn.*
1828. M. Léonce Elie de Beaumont, Sec. Perpétuel de l'Instit. France, For. Mem. R.S., *Paris.*
1829. Dr. Ami Boué, *Vienna.*
1829. J. J. d'Omalius d'Halloy, *Halloy, Belgium.*
1839. Dr. Ch. G. Ehrenberg, For. Mem. R.S., *Berlin.*
1840. Professor Adolphe T. Brongniart, For. Mem. R.S., *Paris.*
1840. Professor Gustav Rose, *Berlin.*
1841. Dr. Louis Agassiz, For. Mem. R.S., *Cambridge, Massachusetts.*
1841. Professor G. P. Deshayes, *Paris.*
1844. William Burton Rogers, Esq., *Boston, U.S.*
1844. M. Edouard de Verneuil, For. Mem. R.S., *Paris.*
1847. M. le Vicomte B. d'Archiac, *Paris.*
1848. James Hall, Esq., *Albany, State of New York.*
1850. Professor Bernard Studer, *Berne.*
1850. Herr Hermann von Meyer, *Frankfort-on-Maine.*
1851. Professor James D. Dana, *New Haven, Connecticut.*
1851. General G. von Helmersen, *St. Petersburg.*
1851. Hofrath W. K. Haidinger, For. Mem. R.S., *Vienna.*
1851. Professor Angelo Sismonda, *Turin.*
1853. Count Alexander von Keyserling, *Dorpat.*
1853. Professor L. G. de Koninck, *Liége.*
1854. M. Joachim Barrande, *Prague.*
1854. Professor Karl Friedrich Naumann, *Leipsic.*
1856. Professor Robert W. Bunsen, For. Mem. R.S., *Heidelberg.*
1857. Professor H. R. Goeppert, *Breslau.*
1857. M. E. Lartêt, *Paris.*
1857. Professor H. B. Geinitz, *Dresden.*
1857. Dr. Hermann Abich, *Tiflis, Northern Persia.*
1858. Dr. J. A. E. Deslongchamps, *Caen.*
1858. Herr Arn. Escher von der Linth, *Zurich.*
1859. Professor A. Delesse, *Paris.*
1859. Dr. Ferdinand Roemer, *Breslau.*
1860. Dr. H. Milne-Edwards, For. Mem. R.S., *Paris.*

1861. Professor Gustav Bischof, *Bonn.*
1862. Señor Casiano di Prado, *Madrid.*
1862. Baron Sartorius von Waltershausen, *Göttingen.*
1862. Professor Pierre Merian, *Basle.*
1864. Professor Paolo Savi, *Pisa.*
1865. M. Jules Desnoyers, *Paris.*

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## LIST OF

# THE FOREIGN CORRESPONDENTS

## OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1866.

Election.
1863. Professor Beyrich, *Berlin.*
1863. M. Boucher de Perthes, *Abbeville.*
1863. Herr Bergmeister Credner, *Gotha.*
1863. Professor Daubrée, *Paris.*
1863. M. Desor, *Neuchâtel.*
1863. Professor Favre, *Geneva.*
1863. Signor Gastaldi, *Turin.*
1863. Dr. C. T. Gaudin, *Lausanne.*
1863. M. Paul Gervais, *Montpellier.*
1863. Herr Bergmeister Gümbel, *Munich.*
1863. Franz Ritter von Hauer, *Vienna.*
1863. Professor E. Hébert, *The Sorbonne, Paris.*
1863. Rev. Dr. O. Heer, *Zurich.*
1863. Dr. Moritz Hörnes, *Vienna.*
1863. Dr. G. F. Jäger, *Stuttgart.*
1863. Dr. Kaup, *Darmstadt.*
1863. Dr. Theodor Kjerulf, *Christiana.*
1863. M. von Kokscharow, *St. Petersburg.*
1863. Dr. Leidy, *Philadelphia.*
1863. M. Lovén, *Stockholm.*
1863. Lieut.-Gen. Count Alberto Ferrero della Marmora, *Turin*
1863. Count A. G. Marschall, *Vienna.*
1863. Professor G. Meneghini, *Pisa.*
1863. M. Morlot, *Berne.*
1863. M. Henri Nyst, *Brussels.*
1863. Il Marchese Lorenzo Damaso Pareto, *Genoa.*
1863. Professor Pictet, *Geneva.*
1863. Signor Ponzi, *Rome.*
1863. Professor Quenstedt, *Tübingen.*
1863. Professor F. Sandberger, *Bavaria.*
1863. Signor Q. Sella, *Turin.*

1863. Dr. F. Senft, *Eisenach.*
1863. Dr. B. Shumard, *St. Louis, Missouri.*
1863. Dr. Steenstrüp, *Copenhagen.*
1863. Prof. E. Suess, *Vienna.*
1863. Marquis de Vibraye, *Paris.*
1864. M. J. Bosquet, *Maestricht.*
1864. Dr. Charles Martins, *Montpellier.*
1865. Dr. C. Nilsson, *Stockholm.*

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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."

1831. Mr. William Smith.
1835. Dr. G. A. Mantell.
1836. M. L. Agassiz.
1837. { Capt. P. T. Cautley. / Dr. H. Falconer. }
1838. Professor R. Owen.
1839. Professor C. G. Ehrenberg.
1840. Professor A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron L. von Buch.
1843. { M. E. de Beaumont. / M. P. A. Dufrénoy. }
1844. The Rev. W. D. Conybeare.
1845. Professor John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. The Rev. Dr. W. Buckland.
1849. Mr. Joseph Prestwich, jun.
1850. Mr. William Hopkins.
1851. The Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. { M. le Vicomte A. d'Archiac. / M. E. de Verneuil. }
1854. Dr. Richard Griffith.
1855. Sir H. T. De la Beche.
1856. Sir W. E. Logan.
1857. M. Joachim Barrande.
1858. { Herr Hermann von Meyer. / Mr. James Hall. }
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Prof. Dr. H. G. Bronn.
1862. Mr. Robert A. C. Godwin-Austen.
1863. Prof. Gustav Bischof.
1864. Sir R. I. Murchison.
1865. Mr. Thomas Davidson.
1866. Sir Charles Lyell.

## Trust-Account.

| Receipts. | £ | s. | d. | Payments. | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| Balance at Banker's, January 1, 1865, on the Wollaston Donation-fund | 31 | 12 | 10 | Award to Mr. Salter | 21 | 2 | 10 |
| Dividends on the Donation-fund for 1865 on £1084 1*s.* 11*d.* Reduced 3 per Cents. | 31 | 16 | 10 | Cost of striking Gold Medal awarded to Mr. Davidson | 10 | 10 | 0 |
| | | | | Balance at Banker's (Wollaston-fund) | 31 | 16 | 10 |
| | £63 | 9 | 8 | | £63 | 9 | 8 |

## Valuation of the Society's Property; 31*st December*, 1865.

| Property. | £ | s. | d. | | | | Debts. | £ | s. | d. |
|---|---|---|---|---|---|---|---|---|---|---|
| Due from Longman and Co., on acc. of Journ. Vol. XXI. | | | | 48 | 12 | 0 | Balance in favour of the Society | 5775 | 2 | 3 |
| Due from Subscribers to Journal | | | | 80 | 0 | 0 | | | | |
| Due for Authors' Corrections in Journal | | | | 25 | 0 | 0 | | | | |
| Balance in Banker's hands, Dec. 31, 1865 | | | | 381 | 18 | 9 | | | | |
| Balance in Clerk's hands | | | | 228 | 9 | 1 | | | | |
| Funded Property:— | | | | | | | | | | |
| Consols, at 95 | 4801* | 3 | 7 | 4561 | 2 | 5 | | | | |
| Arrears of Admission-fees (considered good) | | | | 130 | 0 | 0 | | | | |
| Arrears of Annual Contributions (ditto) | | | | 320 | 0 | 0 | | | | |
| | | | | £5775 | 2 | 3 | | £5775 | 2 | |

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

JOSEPH PRESTWICH, *Treas.*

*Feb.* 7, 1866.

* Including the balance of £300 remaining from the Greenough and Brown Bequest-fund.

## INCOME EXPECTED.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Due for Subscriptions on Quarterly Journal (considered good) | 80 | 0 | 0 | | | |
| Due for Authors' Corrections | 25 | 0 | 0 | | | |
| Due for Arrears (See Valuation-sheet) | 450 | 0 | 0 | | | |
| | | | | 555 | 0 | 0 |
| Ordinary Income. | | | | | | |
| From Resident Fellows, &c., and Non-residents of 1859 to 1861 | 700 | 0 | 0 | | | |
| Admission-fees (supposed) | 350 | 0 | 0 | | | |
| Compositions (supposed) | 300 | 0 | 0 | | | |
| | | | | 1350 | 0 | 0 |
| Dividends on Consols | | | | 140 | 0 | 0 |
| Sale of Transactions, Proceedings, Library-catalogues, and Ormerod's Index | 15 | 0 | 0 | | | |
| Sale of Quarterly Journal | 140 | 0 | 0 | | | |
| Due from Longman and Co. in June | 48 | 12 | 0 | | | |
| | | | | 203 | 12 | 0 |
| Due from the Bequest-fund on account of monies expended on Map, Library, and Museum | | | | 238 | 14 | 11 |
| Sale of Geological Map | | | | 150 | 0 | 0 |
| | | | | £2637 | 6 | 11 |

JOSEPH PRESTWICH, TREAS.

*Feb.* 7, 1866.

*the Year* 1866.

## EXPENDITURE ESTIMATED.

| | £ | *s.* | *d.* | £ | *s.* | *d.* |
|---|---|---|---|---|---|---|
| General Expenditure: | | | | | | |
| Taxes and Insurance | 90 | 0 | 0 | | | |
| House-repairs | 20 | 0 | 0 | | | |
| Furniture | 20 | 0 | 0 | | | |
| Fuel | 35 | 0 | 0 | | | |
| Light | 30 | 0 | 0 | | | |
| Miscellaneous Printing, including Abstracts | 25 | 0 | 0 | | | |
| Tea for Meetings | 20 | 0 | 0 | | | |
| Miscellaneous House-expenses | 85 | 0 | 0 | | | |
| Stationery | 25 | 0 | 0 | | | |
| | | | | 350 | 0 | 0 |
| Salaries and Wages: | | | | | | |
| Assistant-Secretary | 200 | 0 | 0 | | | |
| Clerk and Accountant | 90 | 0 | 0 | | | |
| Assistants in Museum and Library | 145 | 0 | 0 | | | |
| Porter | 90 | 0 | 0 | | | |
| Housemaid | 40 | 0 | 0 | | | |
| Occasional Attendance | 12 | 0 | 0 | | | |
| Collector | 20 | 0 | 0 | | | |
| | | | | 597 | 0 | 0 |
| Library | 150 | 0 | 0 | | | |
| Museum | 50 | 0 | 0 | | | |
| | | | | 200 | 0 | 0 |
| Diagrams at Meetings | 5 | 0 | 0 | | | |
| Miscellaneous Scientific Expenditure | 40 | 0 | 0 | | | |
| | | | | 45 | 0 | 0 |
| Publications: Quarterly Journals | 550 | 0 | 0 | | | |
| ,, Transactions | 5 | 0 | 0 | | | |
| | | | | 555 | 0 | 0 |
| ,, Geological Map | | | | 130 | 0 | 0 |
| Due to Collector and Clerk | | | | 50 | 18 | 2 |
| | | | | 1927 | 18 | 2 |
| Balance in favour of the Society | | | | 709 | 8 | 9 |
| | | | | £2637 | 6 | 11 |

*Income and Expenditure during the*

RECEIPTS.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| Balance at Banker's January 1, 1865 .............. | | | | 225 | 10 | 5 |
| Balance in Clerk's hands ditto .............. | | | | 116 | 7 | 2 |
| Compositions received .......................... | | | | 389 | 0 | 6 |
| Arrears of Admission-fees ...................... | | | | 75 | 12 | 0 |
| Arrears of Annual Subscription .................. | | | | 124 | 19 | 0 |
| Admission-fees, 1865 ............................ | | | | 283 | 10 | 0 |
| Annual Contributions for 1865, viz.— | | | | | | |
| Resident Fellows .........£ | 552 | 6 | 0 | | | |
| Non-Resident Fellows ... | 42 | 10 | 6 | | | |
| | | | | 594 | 16 | 6 |
| Dividends on Consols ............................ | | | | 141 | 0 | 8 |
| Publications: | | | | | | |
| Sale of Transactions ...................... | 7 | 3 | 6 | | | |
| Sale of Journal, Vols. 1–6 ................ | 1 | 11 | 4 | | | |
| " Vols. 7–12 ................ | 4 | 4 | 9 | | | |
| " Vols. 13–15 .............. | 4 | 9 | 0 | | | |
| " Vol. 16 ................ | 2 | 0 | 0 | | | |
| " Vol. 17 ................ | 1 | 17 | 10 | | | |
| " Vol. 18 ................ | 2 | 11 | 0 | | | |
| " Vol. 19 ................ | 4 | 12 | 0 | | | |
| " Vol. 20 ................ | 15 | 8 | 2 | | | |
| " Vol. 21 ................ | 64 | 18 | 7 | | | |
| | | | | 108 | 16 | 2 |
| Longman and Co., Sale of Journal in 1864 ........ | | | | 51 | 1 | 6 |
| Sale of Geological Map .................. | 12 | 12 | 0 | | | |
| Sale of Library-catalogues ................ | 1 | 9 | 6 | | | |
| Sale of Ormerod's Index .................. | 1 | 0 | 0 | | | |
| | | | | 15 | 1 | 6 |
| | | | | £2125 | 15 | 5 |

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

(Signed) THOS. WILTSHIRE, ALFRED TYLOR, } *Auditors.*

*Feb.* 7, 1866.

*Year ending December* 31*st*, 1865.

EXPENDITURE.

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| General Expenditure: | | | | | | |
| Taxes | 51 | 18 | 4 | | | |
| Fire-insurance | 3 | 0 | 0 | | | |
| New Furniture | 1 | 19 | 4 | | | |
| House-repairs | 15 | 0 | 3 | | | |
| Fuel | 33 | 0 | 0 | | | |
| Light | 28 | 17 | 10 | | | |
| Miscellaneous House-expenditure | 86 | 16 | 5 | | | |
| Stationery | 24 | 13 | 2 | | | |
| Miscellaneous Printing | 20 | 1 | 0 | | | |
| Tea for Meetings | 17 | 15 | 8 | | | |
| | | | | 283 | 2 | 0 |
| Salaries and Wages: | | | | | | |
| Assistant-Secretary | 200 | 0 | 0 | | | |
| Clerk | 90 | 0 | 0 | | | |
| Library and Museum Assistants | 139 | 0 | 0 | | | |
| Porter | 90 | 0 | 0 | | | |
| Housemaid | 40 | 0 | 0 | | | |
| Occasional attendants | 8 | 15 | 0 | | | |
| | | | | 567 | 15 | 0 |
| Library | | | | 53 | 19 | 4 |
| Museum | | | | 8 | 15 | 6 |
| Miscellaneous Scientific Expenses | | | | 32 | 2 | 1 |
| Publications: | | | | | | |
| Geological Map | 25 | 5 | 2 | | | |
| Journal, Vols. 1–6 | 2 | 11 | 10 | | | |
| „ Vol. 19 | 0 | 6 | 0 | | | |
| „ Vol. 20 | 8 | 7 | 6 | | | |
| „ Vol. 21 | 520 | 11 | 2 | | | |
| | | | | 557 | 1 | 8 |
| Over-credited Arrears of Admission-fees in 1864 | | | | 12 | 12 | 0 |
| Balance at Banker's, Dec. 31, 1865 | | | | 381 | 18 | 9 |
| Balance in Clerk's hands, Dec. 31, 1865 | | | | 228 | 9 | 1 |
| | | | | £2125 | 15 | 5 |

# PROCEEDINGS

AT THE

## ANNUAL GENERAL MEETING,

## 16TH FEBRUARY, 1866.

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### AWARD OF THE WOLLASTON MEDAL.

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THE Reports of the Council and Committees having been read, the President, WILLIAM JOHN HAMILTON, Esq., F.R.S., delivered the Wollaston Medal to Sir CHARLES LYELL, addressing him as follows:—

Sir CHARLES LYELL,—I need hardly say that it is with very great satisfaction that I find it has fallen to my lot to be the means of placing in your hands this Wollaston Medal, which the Council have unanimously awarded to you in recognition of the highly important services you have rendered to the study of Geology by your various original works, and for the masterly and philosophical manner in which you have treated the subject, both in developing the principles and in expounding the elements on which the science of Geology is founded.

More than five-and-thirty years have now elapsed since you published the first edition of the 'Principles of Geology,' in which you attempted to explain the former changes of the earth's surface by reference to causes now in operation, and by giving a full and detailed view of the modern changes of the earth and its inhabitants. During this period you have published no less than nine editions of this work. In 1838 you published the first edition of the 'Elements of Geology,' consisting of an expansion of the 4th Book of the 'Principles of Geology,' and containing a description of the monuments of *ancient* changes, Geology in the strictest sense, namely, a detailed account of the successive formations of the earth's crust and their imbedded fossils from the oldest crystalline rocks to the beds of the Post-tertiary epoch. Of these 'Elements' you published the sixth edition last year, and I need not here repeat what I stated on a former occasion respecting the vast amount of additional information it contains as compared with former editions. Indeed, considering the rapid progress of geological study and the close attention you have always paid to every new discovery in all quarters of the globe, it could not well be otherwise. It is impossible to calculate the effect produced by these numerous publications; but it is interesting to record the fact that I have read on more than one occasion that a perusal of Lyell's 'Elements' has been the first means of calling the attention of persons previously unacquainted with the subject to the study of this branch of science and to the eager investigation of the geological features of the country where they resided.

I must also take this opportunity of alluding to the great services you have rendered to the study of Tertiary Geology in helping to clear away the uncertainty which prevailed before 1830 respecting the true chronological sequence of those fossiliferous beds which in England, France, and Italy overlie the chalk formation, and in many of which a greater or less number of species are found identical with recent or living forms. With the assistance of M. Deshayes you prepared comparative lists of the fossil shells found in the different Tertiary formations, and of the identical living species, and you ascertained that in proportion to their greater antiquity they invariably contained a smaller percentage of living forms. On this you founded that peculiar classification with which your name must ever be associated. The terms Eocene, Miocene, Pliocene, and Post-pliocene will always remain as a memorial of the services you have rendered to geological science. And although subsequent discoveries have shown that the lines of demarcation between these groups cannot be so sharply drawn as was at first supposed, and that the breaks previously believed to exist have been filled up by newly discovered groups of strata, it must not be forgotten that you always anticipated that such would be the case; you never admitted the doctrine maintained by some geologists that these breaks, both in the Tertiary and in the older formations, were the marks of real interruptions and catastrophes breaking the regular series of events in the geological history of the crust of the earth and of its inhabitants. The nomenclature which you introduced has been of immense service in enabling us to arrange and coordinate the different groups of Tertiary deposits which occur in so many localities of the European area as well as in other portions of the earth's surface.

Allow me once more to express the sincere pleasure and satisfaction I experience in placing this Medal in your hands.

Sir Charles Lyell, on receiving the Medal, replied as follows:—

The list of British and foreign geologists who have received the Wollaston Medal during the last thirty years has been honoured by so many distinguished names that I cannot but feel highly gratified that the Council has thought mine worthy of being added to the number. I acknowledge with sincere thanks the flattering terms in which you have spoken of my scientific labours and writings, and I only trust that you have not greatly overrated their value. I can at least assure you that as I grow older I become more and more conscious of my inability to keep pace with the ever-increasing rate at which geology is expanding, together with the numerous sciences which are so intimately connected with it.

## AWARD OF THE WOLLASTON DONATION-FUND.

The President then addressed Mr. H. WOODWARD, as follows:—

Mr. WOODWARD,—I have much pleasure in handing to you the balance of the proceeds of the Wollaston Fund, which the Council have awarded to you with the view of assisting you in your researches on the fossil Crustacea. The evidences of industry and zeal which you have already shown in this field of palæontological research, both in the many interesting communications which you have made to this Society and in your other publications, lead us to expect still more important results from your continued investigations. It is this division of labour which tends finally to perfection. And while Mr. Davidson has taken the fossil Brachiopoda under his special charge, Dr. Wright the Echinoderms, and Mr. Salter has done the same with the Trilobites, we gladly leave the remaining Crustacea in your hands, in the confident hope that you will treat them with the same success, and work out their natural affinities and geological limitations with the same credit to yourself and benefit to science, which they have already manifested in their respective fields of operation. While assuring you of my own entire satisfaction at this award, I will only add the expression of my sincere wishes for your future prosperity and success.

Mr. WOODWARD replied as follows:—

Mr. PRESIDENT,—In returning thanks to you and to the Council for the honour conferred upon me, I cannot but recall the names of the many able and distinguished geologists who in former years have received the Wollaston Fund, and feel sure it is owing more to your friendly consideration than to my own desert that I am thus favoured.

Palæontologists have never had greater opportunities for work than at the present time, when so many fresh districts are being explored, yielding new series of organisms dissimilar from, but related to, the living forms around us.

We younger naturalists and geologists have an immense advantage over our predecessors, for we enjoy the results of their labours, and find that they have made the way light and the path smooth beneath our feet. New fossils, however, turn up continually, and must be described; and better examples of old ones, furnishing fresh material for comparison, need to be examined.

With the encouragement which you have been pleased to bestow, I hope to add some useful material to the ancient history of the Crustacea, which it is my pleasant task to investigate.

# THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

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

I now proceed, in accordance with the practice hitherto observed by my predecessors, and before entering on those observations respecting the recent progress of geological investigation which it is my duty to lay before you, to read the Obituary Notices of some of those Fellows of the Society whom we have lost during the past year.

Mr. Henry Christy was the second son of the late Mr. William Miller Christy, of Woodbines, Kingston-upon-Thames, and was born on the 26th of July, 1810. His early life was devoted to business, and he succeeded his father as a Director of the London Joint-Stock Bank. A taste for antiquarian researches led him, however, at an early period to undertake many extensive journeys and expeditions with the view of studying the antiquarian remains of various districts, and the primitive habits and customs of the more remote tribes of the human race.

In 1856 he accompanied Mr. Edward Tylor to Mexico. The result of their travels was published by Mr. Tylor in 1861 in a work called 'Anahuac.' He subsequently visited the United States, Canada, and British Columbia, picking up information wherever he could find it respecting the habits of the wilder tribes and the earlier inhabitants. Subsequently he visited the East, Algeria, and the north of Africa, Spain, Italy, France, and the Scandinavian kingdom.

It was at a later period, however, that he turned his attention to that branch of his antiquarian pursuits which brought him into close relationship with this Society, of which he became a Member in 1858. Carrying back his researches into the antiquity of man's presence on the earth, he was brought into close contact with the relics of the last period of geological history, when Mammalia, now extinct, appear to have lived during the Postglacial period as the cotemporaneous inhabitants in caves and forests of the first tribes of the human race which dwelt in Western Europe.

The discoveries of Abbeville and of Amiens which had been so ably worked out by Mr. Prestwich, induced Mr. Christy to enter upon a new field of inquiry; and, in conjunction with his friend M. Lartêt, he turned his attention to the caves in the south of France, to which several French geologists had recently been devoting their time and thoughts, and were endeavouring to unravel the mystery which at first attached to the discovery of undoubted human implements, and the works of human hands, in close juxta-position with the remains of extinct Mammalia.

Mr. Christy's exertions were chiefly directed to the examination, with his friend M. Lartêt, of the numerous caves which are to be found along the banks of the Vezère in the Department of the Dordogne. The enormous collection of materials obtained from these caves, consisting of flint instruments of an entirely different character from those of Amiens and Abbeville, of bones of Reindeer, Bos, and other animals, would appear incredible to those who had not witnessed the actual discovery and the immense stores collected on the spot. They have been distributed, with the greatest liberality, by Mr. Christy and M. Lartêt to the various public museums and private collections in Europe.

In the spring of last year Mr. Christy proceeded, with other Members of the Geological Society, to visit some interesting caves of the same character as those in the Dordogne, which had been recently discovered in Belgium, near Dinant on the Meuse; and it was whilst proceeding thence to Switzerland, with M. and Madame Lartêt, that he was attacked by inflammation of the lungs, which carried him off in a few days. He died on the 4th of May, at La Palisse, Allier, at the age of 54. He will be long regretted by all who knew him for his social qualities no less than for his scientific attainments.

Sir John William Lubbock, the son of Sir John W. Lubbock, was born on the 26th March, 1803. He was educated at Eton and at Trinity College, Cambridge, where he took his degree in 1825. He was a first-rate mathematician, and for many years was devoted to the pursuit of science, particularly that of astronomy, in connexion with which he investigated many questions respecting the action of the tides, the theory of the moon and the perturbation of the planets, and the determination of the distance of a comet from the earth, and the elements of its orbit. He was Treasurer to the Royal Society from 1830 to 1835, and again from 1838 to 1845, and was for many years Vice-Chancellor of the University of London. In 1834 the Royal Society awarded him one of their Royal Medals for his paper "On the Tides," and in 1848 the Astronomical Society gave him a testimonial for his "Researches on the Theory of Perturbation." In 1836 he delivered the Bakerian Lecture "On the Tides at the Port of London." He was elected a Fellow of this Society in 1848. He contributed many papers on scientific subjects to most of the learned Societies in England, which were published in the Philosophical Transactions, the Memoirs of the Royal Astronomical Society, the Philosophical Magazine, the Transactions of the Cambridge Philosophical Society, and the Reports of the British Association.

In addition to these communications he published several important works on astronomical and mathematical subjects between the years 1830 and 1840, including 'A Treatise on Probability' and an 'Elementary Treatise on the computation of Eclipses and Occultations,' in 1835; 'Remarks on the Classification of the different branches of Human Knowledge,' in 1838; an 'Elementary Treatise on the Tides,' in 1839; and 'On the Heat of Vapour,' and on 'Astronomical Refraction,' in 1840. In this year he succeeded to the Baronetcy on the death of his father, and from this period appears to have withdrawn himself somewhat from the active pursuit of scientific investigations. That they were not altogether given up is proved by the fact that he became a Fellow of this Society in 1848, in which year he also communicated to the Society an interesting paper "On change of Climate resulting from a change in the Earth's Axis of Rotation." This paper, which derives additional interest from the discussions which have been recently carried on, was fully discussed by Sir H. Delabeche in his Anniversary Address of the same year *. Sir John Lubbock died at High Elm, Farnboro', Kent, on the 20th of June, 1865, at the age of 62.

Mr. Nicholas Wood was born in 1795. Having from an early age directed his attention to mining engineering, he became one of the most distinguished colliery-viewers in the north of England. This did not prevent his pursuing many branches of scientific investigation, amongst the most important of which was the encouragement he gave from a very early date to the introduction of the railway system. He it was who first wrote upon the subject, and showed how the tramways which had been used for local purposes might be made available for more general travelling. Under his auspices the Stephensons became famous and the locomotive engine was perfected, and he will ever hold high rank wherever the science of the nineteenth century, in the development of which he took so great a share, is known.

In 1831 he read before the Natural History Society of Newcastle-on-Tyne a paper "On the Geology of Northumberland and Cumberland," illustrated by a map and numerous sections, exhibiting the true coal-fields, the Millstone-grit, and Mountain-limestone districts. He also pointed out the effect of a remarkable dyke in dislocating or throwing down a portion of the Newcastle coal-field so as to render it available for mining in a district where, in the ordinary range of the strata, no coal would otherwise have been found. The value of these illustrations was great in a practical point of view, and the merit of such researches was enhanced by the comparative infancy of the science.

In 1844 Mr. Wood proposed at a meeting at Newcastle the registration of mining operations, the importance of which, in a geological no less than a commercial point of view, can hardly be exaggerated. In founding the Northern Institute of Mining Engineers at Newcastle in September 1852, Mr. Wood delivered an address which comprises a review of many of the most important subjects connected with practical coal-winning. He was eminently practical in his views, and it is worthy of special notice that in this address he placed geology in a prominent position. He said that the study of Geology and all its concomitant branches of science—Mineralogy, Chemistry, Mechanical Philosophy, Pneumatics, and Mechanics—are all subjects which might usefully and profitably occupy the time and attention of all the members of the Institution, and of the meetings of the Institution collectively. He also added suggestions for the collection of plans and records as a means of cultivating and extending geological science.

* See Quart. Journ. Geol. Soc. vol. v. pp. 4 and lxxxiv.

In November 1855 he advocated the formation of a mining school, in which naturally his attention was chiefly absorbed by the local attractions of the North of England Coal-fields. At the same time he recorded his due acknowledgment of the efforts made to establish an Office of Mining Records in London, which, first taken up by Sir Henry Delabeche, and subsequently promoted by Sir R. Murchison, was then ripening into what it has since become—a valuable school of mining science.

In 1855 he gave an excellent account of the sinking for coal through the Magnesian Limestone, accompanied by detailed sections. In 1863, together with Mr. Boyd, he prepared a geological paper on the Wash or Drift in the county of Durham, tracing the denudation over a great extent of country. He was elected a Fellow of this Society in 1843, and was also a Fellow of the Royal Society. He died on the 19th December 1865, in his 71st year.

Mr. Lovell Reeve, the son of Mr. Thomas Reeve, of Ludgate Hill, was born April 19, 1814. After distinguishing himself at school by his proficiency in Greek and Latin, he was at the age of 13 bound apprentice to a grocer on Ludgate Hill, where the accidental arrival of a sailor with a handkerchief of shells, of which he became the purchaser, led to his becoming an ardent student of natural history. From this small beginning his collection gradually increased, and in this he was assisted and encouraged by forming an acquaintance with a Mr. Walker, a compositor, also a zealous conchologist, as well as with Dr. Gray of the British Museum. In 1833 he attended the third meeting of the British Association at Cambridge, and in the Natural-History Section he was appointed Conchologist to a general exploring-expedition into the fens between Cambridge and Ely.

When his seven years of apprenticeship were over he proceeded to Paris, where he made his first contribution to the literature of Conchology, in the form of a paper "On the Classification of the Mollusca." This was read at a meeting of the Academy of Sciences. On his return to London he devoted himself with increased earnestness to his favourite study, and in a short time produced his 'Conchologia Systematica,' in two 4to volumes, illustrated by 300 plates of shells, published by Messrs. Longman in 1840–41. But the cost of publishing this expensive work exhausted his funds, even to the sacrifice of his share in his deceased father's property.

About this time the fortunate and almost accidental purchase of a valuable collection of shells at Rotterdam, made with great care at the Moluccas by the Dutch Governor, General von Ryder, enabled Mr. Reeve to return to his favourite occupation. By these and other means he was soon enabled to undertake the publication of an illustrated work on the species of shells, entitled 'Conchologia Iconica,' the value of which has been recognized by every palæontologist who is aware of the importance of accurate delineation of living species for the purpose of comparison with specimens of extinct forms. It was a fortunate moment when Mr. Lovell Reeve undertook this work. Mr. Hugh Cuming had just returned home from his long expedition round the world, bringing with him vast stores of Mollusca collected during his years of wandering; many of these were altogether new to science, and the publication of them was looked forward to with the greatest interest both by palæontologists and conchologists. This great work has been continued with almost uninterrupted regularity since 1843 down to the present time.

In 1850 Mr. Lovell Reeve published a useful elementary work entitled 'Elements of Conchology, an introduction to the Natural History of Shells and of the Animals which form them.' He subsequently became, on his removal to Henrietta Street, Covent Garden, the publisher of many other works on natural history, and was afterwards the proprietor of the 'Literary Gazette,' which he edited with great ability from 1850 to 1856. He became a Fellow of this Society in 1853, and regularly presented to our Library the successive Monographs of the 'Conchologia Iconica.' His last, and by some considered his best, work, on the 'Land and Freshwater Mollusks of the British Isles,' was published in 1863. It contains much useful information "on the geographical distribution in other parts of the world of the species indigenous to this country, and on the relation which this distribution bears to climate, soil, and other local circumstances." He was a man of a most amiable disposition, and bore with exemplary patience for eighteen months the acute sufferings caused by a most painful illness. He died on the 18th of November, 1865.

Dr. S. P. Woodward, the son of Mr. Samuel Woodward of Norwich, was born September 17th, 1821. By his death the Society has experienced a very serious loss. His sound knowledge and assistance, both as a naturalist and a palæontologist, were always at the service of the Society or of its Fellows. From his earliest infancy his constitution was weak and delicate, and he showed his inclination for the study of natural history by beginning to form a collection of insects before he was eight years old; and when he had scarcely attained the age of ten years he assisted in publishing an account of the *Trichiosoma lucorum* in Loudon's 'Magazine of Natural History,' with an engraving of the insect in all its stages. In the following year he began the study of land and freshwater shells, and commenced the formation of his father's collection. To these pursuits he soon added the study of botany, after which entomology was given up, and he became a constant and zealous cultivator of botany and malacology, which were never relinquished.

In 1838 he came to London to complete his education at the London University, and soon obtained an appointment in the Library of the British Museum. In 1839 he succeeded Mr. Searles Wood, whose health had compelled him to resign, as Sub-Curator in the museum of this society, under Mr. Lonsdale. From this time he added palæontology to his other studies, and laboured assiduously in the arrangement of our collections and the improvement of the museum until 1845, when he was appointed Professor of Botany and Natural History, including Geology, at the Royal Agricultural College at Cirencester.

He was one of the founders of the Cotteswold Naturalists' Field Club, and in 1848 was appointed First-class Assistant in the Department of Geology and Mineralogy in the British Museum. He subsequently received the appointment of Examiner for the Council of Military Education, as well as Examiner in Geology to the University of London. He was a constant contributor to various scientific and literary periodicals, and the pages of our own journal contain many valuable productions from his pen. In 1854 he communicated to this society a highly interesting paper "On the Structure and Affinities of the Hippuritidæ," in which many of the peculiar characters of these remarkable fossils were for the first time clearly brought together. With regard to the fossils to which they may be said to bear the closest resemblance, Mr. Woodward showed, while repudiating the doctrine of transmutation, that it might be assumed that the Cretaceous *Hippurites* are connected with the Oolitic *Dicerata* and Tertiary *Chamæ.* After describing the structure of the *Hippurites* and other allied genera, of which numerous woodcuts and plates of engravings serve as illustrations, he proceeds to give their affinities. He points out the successive opinions of various palæontologists, from Parkinson and others, who considered them as *Orthoceratites*, to the time when Prof. Quenstedt placed them in a more natural position, between the *Chamaceæ* and the *Cardiadæ*, The fact of their being bivalves had already been satisfactorily established.

In 1856 he gave us a description of a new *Orthoceras* from China, one specimen of which measured 29 inches in length. They, however, occurred only as longitudinal sections in thin plates of limestone, artificially worked down for some artistic or domestic purpose, and brought from some place distant 200 miles from Shanghae. Enough, however, of the shell remained to enable Mr. Woodward to describe its structure and to ascertain the series of changes which it had undergone.

In 1860 he assisted Capt. Spratt in naming the recent shells from Bessarabia, as well as the fossil shells from the lower freshwater deposits of Bessarabia, lists of which are published in our journal of that year.

He also contributed several papers to the 'Proceedings of the Zoological Society,' to the 'Intellectual Observer,' and to the 'Annals of Natural History.' The article on Volcanos in the 'Encyclopædia Britannica' was written by him; and for many years he prepared Reports on the Proceedings of the Geological Section of the British Association.

But, perhaps, the most important and valuable work which he contributed to science is the 'Manual of Recent and Fossil Shells,' published 1851 to 1856. It is an excellent text-book, and full of original matter. The Supplement, containing a detailed account of the geographical distribution of living Mollusca, as well as of the distribution in time of the fossil species, is deserving of the highest commendation. He also assisted Prof. Owen in the preparation of that portion of his 'Palæontology' which comprises the Invertebrata.

His health had been gradually declining for the last few years, and he died at Herne Bay, July 11th, 1865.

Mr. George Roberts was born at Kidderminster, and for upwards of five years held the office of Clerk to this Society, of which he became a Fellow in 1864. He was the author of numerous papers both on geological and other interesting subjects. These he communicated to the Geological Society, the 'Geological Magazine,' and other periodicals; many of them showed great talent and boldness in taking up original views. He died at Kidderminster, 20th December, 1865.

We have also to deplore the loss of other Members of the Society, amongst whom I may mention the names of Samuel Cartwright, Col. Sampson, Thomas Young, J. R. Macdonnell, F. W. Simms, W. B. Mitchell, and T. Hutton.

Amongst the Foreign Members whom we have lost I must mention the name of Dr. Christian Pander, who was born at Riga on the $\frac{12}{24}$th July, 1794. He was the son of a wealthy banker. His education was commenced in the Gymnasium of his native town. In 1812 he entered the University of Dorpat to study medicine, but left in 1814, in order, like so many of his countrymen, to complete his education at Berlin and Göttingen. With his great love for natural history he became so engrossed in the study of the preliminary sciences that he never reached the point of practical medicine. He devoted himself to original investigations, and established a chemical laboratory in his own house. In 1816 he went to Würzburg, and there began his remarkable investigations respecting the development of the chick in the egg, which led the way to a long series of microscopical investigations respecting the general course of the development of animal bodies. Professors Döllinger and D'Alton were his collaborateurs in this great work. On its completion he undertook, with Prof. D'Alton, a long journey through France, Spain, Holland, and England, principally with the view of visiting the great anatomical museums of Europe, but also for the purpose of collecting marine animals on the sea coast. On his return home Pander was attached as naturalist to the Embassy sent to Bokhara in 1820 under the direction of Baron Meyendorff. In 1822 he was attached to the Imperial Academy of Sciences of St. Petersburg, and in 1823 he became a regular member of it in the zoological branch. While employed in systematically arranging the objects of the zoological collection, he undertook the examination of the geological formations in the neighbourhood of St. Petersburg, as well as their fossil remains. He thus became, by his work entitled 'Contributions to the Geognosy of the Russian Empire' (1831), the founder of our knowledge of those formations, now called Silurian, to which Strangways and

Eichwald had first called the attention of geologists. In 1827 he resigned his appointment and withdrew to his paternal property of Zarnikau in Livonia. But even here he could not resist the attractions of natural history. The sandy soil of Livonia contains numerous remains of the scales and teeth of animals of a very early period, of which the determination was most difficult. Pander collected great quantities of these teeth and other fragments, and was the first to recognize that they must have belonged to lost species of cartilaginous fishes. But the difficulties of the position in which he was placed, in a district where the publication of his plates was almost impossible, and where his only object was the satisfaction of his own scientific inclinations, led to his being anticipated by Sir R. Murchison in making known the character of this Devonian formation with its cartilaginous fishes.

In 1842 he was appointed to the School of Mines and settled in St. Petersburg, whence he carried out several geological expeditions in Livonia, Esthonia, Central Russia, and in the Ural, the chief object of which was to study the palæontological character of the older formations, and to select the best spots for establishing experimental works for coal after fixing the geological horizon of the coal-beds of Russia. We are also indebted to Pander for the important and practical explanations respecting the beds and contents of the Ural coal-field. He died on the $\frac{10\text{th}}{22\text{nd}}$ September, 1865, after long suffering from a painful disorder. He will be long regretted as one of the truest of friends and most simple-minded and unselfish of scientific men. Science was to him the love of his heart, and he never could be induced to use it for the furtherance or improvement of his own position.

Karl von Raumer was born at Wörlitz, near Dessau, on the 9th April, 1783. In 1797 he attended the Joachimsthal Gymnasium in Berlin, and was at this early age distinguished for his love of art and poetry as well as science. In 1801 he commenced his academical career at Göttingen, where, contrary to his own inclinations, he devoted himself to his legal studies. At the same time he attended Blumenbach's lectures, and became a great proficient in music. He worked and read hard, and his education was at this time literary rather than scientific. In 1803 he removed to Halle. Here he remained a year longer than the parental programme had originally contemplated, for the purpose of attending the lectures of Prof. Steffens. This first awoke his love for natural history, which subsequently became the ruling passion of his life. Deeply interested by Steffens's lectures on the internal history of the earth (this was in 1805), he was greatly excited by the grand idea therein developed, that the earth also had its history. He now learnt, for the first time, that Werner had founded his history of the development of the earth on his observations on existing mountain forms. In 1805 he went to Freiberg to attend Werner's lectures, where the great naturalist gradually weaned him from his philosophical and historical inclinations to the earnest and engrosing study of mineralogy. He remained at Freiberg until 1808. At this period of his life, at the age of twenty-three, he is described as a most engaging and fascinating person. He became intimate with Varnhagen and Schleiermacher, and was the constant companion of Schubert and of Engelhardt.

The battle of Jena produced a great effect on his outer and inner life. Overwhelmed by the sad fate of his country, he looked for consolation, first, to his mineralogical studies, and then began his geological explorations with Engelhardt, exploring the Erzgebirge and the mountains on the Rhine between Cologne and Strasbourg, and subsequently the formations in the neighbourhood of Paris. Here a remarkable change took place in his ideas. His hatred towards the conquerors of his country, and the reading of the works of Pestalozzi and others, engendered the idea of exerting himself for the improvement of the education of young Germany, and of raising a more fertile produce from the rotten soil.

After another visit to the Syenitic formation of the Erzgebirge, he proceeded to visit Pestalozzi, at Yverdon, and became a teacher in his establishment. But here a sad disappointment awaited him. Only a few weeks had passed away before he was undeceived and became aware of the total want of method in the system, and of the germs of destruction and decay which it contained; Pestalozzi confessed it himself, and in May 1810 Raumer left him a sadder but a wiser man. In Nürnberg he again met Schubert, who encouraged him to publish the results of his former explorations under the title of 'Geognostical Fragments.' The unexpected success of this, his first publication, led to his being appointed Professor of Mineralogy at Breslau, in 1811, and councillor of the mining establishment there. But this publication also bore bitter fruit, and led to a temporary estrangement between him and his beloved teacher Werner. He had proved in this work that the sequence of the beds of the older rocks which Werner had laid down was by no means of universal application, and that this very Erzgebirge, which Werner had considered as the type of all mountain-formations, was itself a remarkable exception. He was himself astonished at the result, but the followers of Werner were indignant. The quarrel was made up in 1814.

The commencement of his duties in Breslau, notwithstanding the fact that his brother, the historian, Frederic v. Raumer, was one of his colleagues, was attended with great difficulties, for want of a good mineralogical collection. The investigation of the Silesian mountains, in 1812, was a more agreeable occupation, and in 1813 he published his work 'On the Granite of the Riesengebirge.' But the spring of this year brought another change. The appeal of the king to arms for the liberation of the country found an echo in his heart. He entered the Landwehr, became aide-de-camp to General Gneisenau, took part in the battle of Leipzig and other minor engagements, and was employed on many important and confidential missions. On the 4th of May, 1814, he was most honourably dismissed by the king, and a few days afterwards was decorated with the Order of the Iron Cross.

He returned to his duties at Breslau, where he spent several happy years, until the unfortunate events of 1817 and the excesses of some of the Burschenschafts again caused troubles in his happy circle. Raumer had ever taken a lively interest in the development of young men, and had encouraged the use of gymnastics, or "Turnen;" and as some of the excesses of the times were connected with the gymnastic societies, Karl v. Raumer was most unjustly looked upon with suspicion even by some of his most intimate friends.

This led him to seek another appointment, and in 1819 he was named Professor of Mineralogy at the University of Halle. He had now completed his most important geological work, 'The Mountains of Lower Silesia, of the County Glatz, of part of Bohemia and Oberlausitz, geologically represented.' The merits of this work have been fully recognized by all subsequent competent observers. He remained at Halle until 1823, but even here his position was not altogether satisfactory. This was the period of the reactionary persecution of the so-called demagogic tendencies of the students of the German Universities. Much as Raumer had encouraged the development of youthful energies, no one was more opposed than he was to their excesses; and it grieved him to see what was, in fact, only occasional excrescences of the new growth looked upon as the main object of the new movement. But his protection of the students was of no avail, and he himself was looked upon with suspicion; this determined him to leave Halle, and for a time he undertook the management of a private school at Nürnberg. Here he was again disappointed; circumstances over which he had no control led to the breaking up of the institution in 1826, and Raumer again found himself without a post. But in the following year Schubert's removal to Munich opened the way to his appointment at the University of Erlangen, where he passed a happy and honourable existence for the remainder of his life. His influence over the students was great, and amongst his colleagues were many who had been his pupils in former years. Here he published his 'Manual of Universal Geography' ('Lehrbuch der allgemeinen Geographie'), so highly prized by Alexander v. Humboldt; his 'Palæstina,' no less highly spoken of by Karl Ritter; and his 'History of Pædagogik (or science of education) from the restoration of Classical Studies,' a work of universal estimation. His principal duties at Erlangen were to lecture on natural history and mineralogy, for the latter of which he formed an excellent collection. He retained his faculties, both of body and mind, almost to the last moment of his life, and died on the 2nd of June, 1865, beloved and regretted by all who knew him.

Having as yet failed in obtaining any obituary notice respecting the other Foreign Members whom we have lost, I can here only mention their names:—Charles v. Oeynhausen of Westphalia, who will be well remembered by many of our older geologists as having visited this country upwards of thirty-five years ago, when he explored the highlands of Scotland and the Isle of Sky under the guidance of

Prof. Sedgwick and Sir Roderick Murchison; Dr. Forchhammer of Copenhagen, born at Husum in 1794 (he was President of the Polytechnicum in Copenhagen, and died on the 14th December, 1863); and Dr. Oppel of Munich, who was elected a Foreign Correspondent only two years ago: he was a Member of the Academy of Sciences, and Conservator of the Palæontological Museum of Munich; he died on the 23rd of December, 1865.

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I shall now proceed to lay before you some account of the progress of our science during the past year, and of the principal works which have been published at home and abroad bearing in any way upon the advance of geological knowledge. But here, at the very outset of my task, I find it necessary to claim your indulgence. Were I to allude, however briefly, to every work and every memoir to be found in the many scientific publications of Europe and America, every one of which contains new and interesting matter, you would only have to listen to a dry and uninteresting catalogue. I have therefore been compelled to make a selection of such as appeared to me most interesting or important; and here it is that I must claim your indulgence, if I have failed in the due appreciation of their relative merits. I cannot but fear that I may have overlooked many works of great value, while I may possibly have given undue attention to others less deserving of such notice. I will only add that I have endeavoured, as far as possible, to arrange the different notices according to geological chronology, beginning with the oldest formations.

I must, however, preface my remarks with an account of some of the Geological Surveys which have been carried on in different parts of the world.

### *Geological Survey of the United Kingdom.*

I learn from Sir Roderick Murchison that, with respect to England, the progress made by the Geological Survey under Prof. Ramsay chiefly relates to the south-eastern and northern counties, 483 square miles having been surveyed in the former, and 510 in the latter. In Scotland 332 square miles have been surveyed; for the most part in the Carboniferous strata, and in that highly metamorphosed and difficult ground occupied by Old Red Sandstone and Silurian, south of Ayr and Dalmellington. These areas, with tracts of minor extent in detached parts of England, make a total of 1500 square miles for Great Britain.

The publication of the maps relating to the geology of England has necessarily been delayed by the insertion in the old copper-plates of the lines of railroad and other additions, which the public have called for. The sanction of the Treasury having at length been obtained, Sir Henry James is now occupied in improving the topography of the electrotype-plates for the Geological Survey, and inserting thereon the lines of all railways and the degrees of latitude and longitude.

In Ireland, Mr. Jukes reports that 1037 square miles have been surveyed, and that four new sheets have been issued, making the total number that have been published 102.

On what may be viewed as an important new feature in classification, it will interest geologists to know that, in considerable tracts, extending over large parts of Somersetshire and Gloucestershire, the Rhætic or Penarth beds are being elaborately laid down by Mr. Bristow; whilst, as is well known to the Society, Mr. Dawkins and Mr. Etheridge have completed sections which accurately define the contents and succession of the fossil remains in this peculiar deposit.

Amongst the memoirs published by the Geological Survey, none perhaps will be found more useful than the 'Catalogue of the Collection of fossils in the Museum of Practical Geology,' by Professor Huxley and Mr. Etheridge, published during the past year, with an explanatory introduction by Prof. Huxley. I would gladly have given some account of this most interesting preface, containing a clear exposition of some principles of natural history, as well as the application of natural history to the study and elucidation of fossils, or palæontology; but to do justice to such a subject it would be necessary to quote almost every line of every page. Such a proceeding would be impossible; it would also, I trust, be unnecessary, for the book itself must find its way into the hands of every British geologist at least. I must therefore content myself with recommending it to your special notice, not only on account of the matter it contains, but for its close and logical reasoning, and the pleasing style in which it is written.

*Geological Survey of Canada.*

As the Geological Survey of Canada progresses, under the direction of Sir W. E. Logan, the exertions of the surveyors have been rewarded by the discovery of many new forms of animal life. These have been described and published from time to time by Mr. Billings, the palæontologist to the Survey. The volume for 1865, now before me, contains amongst other matter several articles on the discovery of these fossils, viz. new species of fossils from the limestones of the Quebec group, from Point Lévis and other localities in Canada East. Amongst the new fossils here described is a new *Orthis*, a new genus called *Clisospira*, *Ophileta* 2 species, *Murchisonia* 3 sp., *Pleurotomaria* 1 sp., *Cyrtoceras* 4 sp., *Dikelocephalus* 7 sp., *Olenus* 1 sp., *Bathyurus* 3 sp., and *Cheirurus* 1 sp. The next article is on new species of fossils from the Quebec group in the northern part of Newfoundland. The north-western coast of Newfoundland, from Cape Norman to Bonne Bay, on the Gulf of the St. Lawrence. a distance of about 180 miles, is composed altogether of Lower Silurian limestones, slates, quartzites, and sandstones. The width of this belt of Silurian rocks is from five to ten miles. The fossils show that these rocks belong to the Potsdam and Quebec groups, the former having a thickness of about 2000 feet, while the Quebec group is about 6600 feet in thickness.

The author gives a table of the different members of this series of rocks abridged from the measured sections published in the 'Geology of Canada.' Amongst the principal fossils here described, beginning with the Protozoa, are *Calathium*, a new genus, 4 sp., *Trachyum* 2 sp., *Stomatopora* 2 sp., fragments of *Crinoidea*, *Stenaster Huxleyi*, *Lingula* 3 sp., *Acrotreta* 1 sp., *Orthis* 3 sp., with portions of others, *Strophomena* 2 sp., *Camarella* 3 sp., *Rhynchonella* 1 sp., *Euchasma* 1 sp., *Eopteria* 1 sp., *Ctenodonta* 1 sp. Amongst the Gasteropoda are *Holopea* 1 sp., *Straparollina* 1 sp., *Subulites* 1 sp., *Pleurotomaria* 12 sp., *Murchisonia* 9 sp., *Maclurea* 11 sp., and opercula of three more, *Ophileta* 2 sp., *Helicotoma* 4 sp., *Ecculiomphalus* 3 sp., *Metoptoma* 1 sp. Of Cephalopoda, *Orthoceras* 8 sp., *Piloceras* 3 sp. Of *Nautilus* 4 new species are provisionally named. Amongst the new species of Crustacea are *Bathyurus* 4 sp., *Bathyurellus* 6 sp., *Dolichometopus* 2 sp., *Asaphus* 3 sp.; *Nileus* 3 sp., *Illænus* 5 sp., *Harpides* 2 sp., *Lichas* 1 sp., *Shumardia* 1, *Cheirurus* 6 sp., *Amphion* 3 sp., *Triarthrus* 1, *Telephus* 1, *Encrinurus* (?) 1, *Remopleurides* 2, *Ampyx* 4, *Agnostus* 2. Entomostraca: *Leperditia* 3, *Beyrichia* 1.

The next article or memoir contains a description of new fossils from the Quebec group in Eastern Canada, with some others previously described, and some from other formations. Most of these species were discovered after the former memoir, describing the new fossils from Point Lévis, &c. had been printed. The new species are—*Lingula* 1, *Orthis* 4, *Camarella* 3, *Eopteria* 2, *Murchisonia* 1, *Metoptoma* 1, *Helicotoma* 1, *Ophileta* 1, *Bellerophon* 1, *Orthoceras* 10, *Cyrtoceras* 1, *Asaphus* 2, *Bathyurellus* 3, *Amphion* 2, *Cheirurus* 4, *Remopleurides* 1, *Harpes* 1, *Illænus* 4, *Harpides* 1, *Calathium* 1. Other species still remain to be described; but even the list which I have given above will suffice to show how rich a mine of Silurian forms still remains to be worked out in these old formations, and how far we still are from a complete knowledge of their fossils.

Another interesting work which has reached us from the other side of the Atlantic is 'A Preliminary Report on the Geology of New Brunswick, together with a Special Report on the distribution of the Quebec Group in that Province,' by Henry Youle Hind, formerly Professor of Chemistry and Geology in the University of Trinity College, Toronto. After giving in the introductory chapter a detailed statement of all that had been hitherto published by other geological explorers in the province, Mr. Youle Hind briefly states the result of the last season's work.

1. He describes the approximate breadth of the Quebec group, the great metalliferous formation of North America, in various localities.

2. Having paid particular attention to the circumstances under which the Albertite in Albert County has originated, he has come to the conclusion that it is an inspissated petroleum, and that it has originated from underlying Devonian rocks, probably of the same age as those yielding the vast stores of petroleum in Canada and the United States.

3. The ascertained existence of the true Coal-measures within the limits of the province is very important.

4. The view formerly entertained respecting the granite belt passing through the province must be greatly modified. Instead of one broad belt it consists of a series of very narrow belts, with intervening schists and metalliferous slates. This granite is of Devonian age, and it is probably not an intrusive rock, but consists of highly altered sedimentary strata. The same remark applies to much of the granite in Charlotte, King's, and Saint John counties, which are also probably metamorphosed sedimentary rocks.

These views, with others of great interest, are more fully detailed in the work itself, the first chapter of which describes the leading geographical features of the province, while the second contains a geological sketch of the same region. The sedimentary rocks of New Brunswick belong to the following great divisions:—1, Recent and Post-pliocene; then a great break to 2, Triassic (?); 3, Carboniferous; 4, Devonian; 5, Upper Silurian; 6, Middle Silurian; 7, Lower Silurian. All the beds below the Carboniferous have been very much disturbed. This chapter also contains some interesting observations respecting the origin of granite and the different characters of the granite belts traversing the province, many of which, while admitting the intrusive character of others, the author supposes to be metamorphosed or altered sedimentary strata belonging to the Quebec group. Mr. Hind says, p. 50, "They have probably been altered in position, and belong to the class named by Professor Hunt 'Indigenous rocks;' and there are valid reasons for supposing that much of the granite of New Brunswick consists of altered sedimentary strata, changed by metamorphism into plastic felspathic sandstones and granitoid gneiss, then, by a further metamorphism, partly into plastic granite and in part retaining traces of the stages of their metamorphism." He also shows, by the presence of graphite, that the metamorphism of many sedimentary rocks was not accompanied by a great elevation of temperature, and he concludes these observations by this statement:—"The opinions which necessarily associate high temperature with the occurrence of crystalline rocks, or of rocks which have undergone metamorphic action, are no longer tenable." However novel these views may appear to many geologists, I cannot refrain from saying that I believe they will ultimately prove to be correct; I have long entertained an opinion that the early plastic state of the earth was due to aqueous rather than to igneous causes. It is a question well deserving consideration, and which, I hope, will soon be taken up by some one whose chemical and physical knowledge will enable him to do justice to such an important question.

The two following chapters are devoted to the consideration of the Carboniferous series. The following details will afford some idea of the Coal-fields of the eastern provinces of British North America:—

| | | |
|---|---|---|
| 1. | Upper Coal series, unproductive ........ | 3300 feet. |
| 2. | Middle Coal series, productive .......... | 4000 ,, |
| 3. | Lower Carboniferous or Gypsiferous series.. | 6000 ,, |

The base consists of red sandstone interstratified with beds of a coarse calcareous conglomerate, reposing in many places, nearly horizontally, on granite of Devonian age. Chapter V. is devoted to the consideration of Albertite and the Albert shales. This remarkable mineral, respecting the nature of which such different opinions were entertained some time ago, is now shown to be an inspissated petroleum, occupying fissures in the Lower Carboniferous rocks along the anticlinal axes, and injected from below at two distinct periods under considerable pressure. The author concludes by showing that its source lies beneath the Albert shales—in other words, beneath the Lower Carboniferous series—and that it is consequently of Devonian or prior origin, and probably proceeds from rocks of the same age as those which yield the petroleum of Pennsylvania, Ohio, and Canada.

The sixth chapter describes the rocks of the Devonian series, with a full account of its vast mineral wealth, consisting of iron-ores, copper, and argentiferous galena. These rocks are traversed by many intrusive trap-dykes, having a general course from east to west. Some of these traps are copper-bearing. The seventh chapter contains an account of the Upper and Middle Silurian series, while the eighth describes the Lower Silurian series, of which the Quebec group is the most important. Of this the author says:—"Not only is the Quebec group the great metalliferous formation of North America, but its remarkable thickness (7000 feet) and complexity, coupled with the extraordinary manner in which it was deposited and brought to the surface, all unite to make it one of the most interesting and important formations of the entire geological series, with perhaps the single exception of the Coal-measures. Not only does it comprise a great variety of useful rocks, but it contains in remunerative quantities iron, copper, nickel, cobalt, antimony, lead, zinc, chromium, arsenic, titanium, silver, and gold." There are some interesting remarks respecting the chemical origin of the metals of the Quebec group, taken from Professor Hunt's work 'On some points of American Geology,' in which it is suggested that they were originally brought to the surface in watery solutions, from which they were separated by the reducing agency of organic matter in the form of sulphurets, or in the native state, and mingled with the contemporaneous sediment in various forms. The intervention of intense heat, sublimation, and similar hypotheses, to explain the origin of metallic ores is considered to be uncalled for, and reference is made to the beautiful experiments of De Senarmont and Daubrée. The different developments and contents of the Quebec group are more fully described in the ninth chapter. In the following chapter much information will be found respecting the effects of glacial action in modifying the surface of the country, in many parts of which boulders of great size and in considerable quantities are found. The rocks, too, are everywhere scratched, striated, and polished. In accounting for these phenomena, Mr. Hind gives the preference to the theory of a glacial covering rather than to the iceberg theory. A comparatively slight elevation of the country, rising gradually to the north, would account for all these phenomena by the theory of a glacial covering more satisfactorily than the depression necessary to explain them under the iceberg theory. In the latter case a depression of 5000 feet would be required, whereas there is no evidence of any greater depression than about 600 feet having taken place. The direction of the moving mass of ice appears, on the evidence of the *striæ* observed in New Brunswick, to have been nearly north and south; but as these *striæ* can only show us the last record of the moving mass, there is no reason for supposing that its direction may not have varied under different conditions at former periods.

*Geological Survey of India.*

Under the able superintendence of Professor Oldham, the Geological Survey of India has been prosecuted with as much ardour and zeal as was compatible with the difficulties of the country and the limited means at his disposal; this latter difficulty was, however, reduced by an increased rate of allowance for travelling expenses having been subsequently accorded by the Viceroy. Other difficulties were also caused by several members of the staff being detached for special service.

Amongst the more interesting results of the past season, as appears from the 'Annual Report,' is the discovery, by Mr. Medlicott in Assam, that, to the south of the River Brahma-poutra, there are widely-spread and highly valuable beds of Coal, of most excellent quality, superior to any other known Indian coals, which offer promise of yielding a plentiful supply of good fuel. In Central India, Mr. Mallet has carried out a careful revision of the boundaries of the Vindhyan rocks to the north of the Nerbudda valley, and has extended his survey to the western extremity of the same valley. Mr. Hackett has completed the geological examination of the country included in the first sheet of the Gwalior map. Mr. Mallett and Dr. Stoliczka have been employed in working out the structure of the higher Himalayan regions. The fossils from Spiti and Rupshu had been long known, but much confusion and uncertainty existed respecting the exact localities from which they were obtained; these have now been worked out on the spot, and the results will soon be published. It is, however, already known that undoubted representatives of acknowledged European series—the Silurian, Carboniferous, Triassic, Rhætic, Lower and Middle Lias, Jurassic (probably of three distinct periods), and Cretaceous—have been proved to occur in these mountain heights. The fossils have been carefully examined, and the 200 varieties or so-called species have been reduced to 164. Amongst the Cephalopoda alone no less than 24 out of 54 supposed species must be suppressed, having been already described under different names. In Bombay the progress of the Survey has been delayed by various causes, but much good work has also been done there. The Survey of the Nerbudda valley has been completed, as well as of a large tract of country south of that river. The prevailing surface-rock of the district, except the alluvial deposits, is, as in the Deccan area, trap; the basement or bottom rocks are chiefly granitic or gneissic. Between these two formations the principal beds are sandstones and limestones of Cretaceous age; and to this series probably belongs the great Mahadeva group of the Puch-murri Hills.

In Madras the examination of the quartzites of the Cudapah and Kurnool districts has been satisfactorily continued by Messrs. King and Foote.

The regular issue, at the stated intervals of three months, of the successive parts of the 'Palæontologia Indica' has been steadily maintained during the past year. The four parts issued have been in continuation of the description of the splendid series of fossil Cephalopoda from the Cretaceous rocks of Southern India. No less than 148 species have been described in this series, thus distributed: *Belemnites* 3 species, *Nautili* 22, *Ammonites* 93, *Scaphites* 3, *Anisoceras* 11, *Helicoceras* 1, *Turrilites* 6, *Hamites* 2, *Hamulina* 1, *Ptychoceras* 3, and *Baculites* 3—a most remarkable fauna from a single district. Of these, 38 are identical with species known in Europe and elsewhere, and of these 38 species not less than 32 belong to the Middle Cretaceous series of Europe.

Amongst the memoirs of the Geological Survey of India I will only further allude to the geological sections across the Himalayan Mountains from Wangtu Bridge on the River Sutlej to Sungdo on the Indus, with an account of the formations in Spiti, accompanied by a revision of all known fossils from that district, by Dr. Ferdinand Stoliczka.

I must also notice, however briefly, an account by Professor Huxley of vertebrate fossils from the Panchet rocks near Ranigunj, in Bengal, also published in the 'Palæontologia Indica;' they consist of numerous fragmentary and sometimes rolled bones, the majority of which are vertebræ. There are, however, some teeth, small portions of crania, with fragments of detached lower jaws. They are of very great interest, as being the first remains of Vertebrata yet discovered in the great group of rocks associated with the coal-bearing formations of Bengal. They were discovered by Messrs. Blanford and Tween in a stratum of conglomerate-sandstone exposed in the Damuda river near Deoli, fifteen miles west of Ranigunj. They appear to have been probably terrestrial, certainly not marine; and Professor Huxley is disposed to consider them as either of Triassic age or as belonging to that fauna which will some day be discovered as filling up the apparent break between the Palæozoic and Mesozoic forms of life—an opinion which coincides with that already expressed by Dr. Oldham and Mr. Blanford.

And while on the subject of Indian geology, I may here allude to an account of the Palæozoic and Secondary fossils collected by Col. Richard Strachey in the Northern Himalaya, recently published by Messrs. Salter and Blanford. They are chiefly derived from Niti and its neighbouring passes. A large proportion of the Silurian fossils are from Guneejunga in the Chorhoti Pass, at an elevation of 17,000 to 17,500 feet above the sea. The existence of these fossils was first made public by Col. Strachey in a paper read before the Geological Society in 1851 *, in which the physical features of the mountain district are fully described, and the generic characters of the fossils are indicated by Mr. Salter. In the work now under consideration Mr. Salter says, "With regard to the Palæozoic rocks of India so little was known at the time of Col. Strachey's researches that to have secured a fossiliferous base was a great stride in the geology of India. The list of genera furnished by myself to the paper above quoted sufficiently indicated the presence of a Lower Silurian group, which, while its fossils agreed in general character with those of Europe, was quite distinct in species. This fact supplies another proof of the existence, at this early period, of marine natural-history provinces like those of the present day. The subdivision of the old ocean-fauna, easily recognizable over many areas of Silurian rocks, becomes less conspicuous in the Devonian, especially in the upper part, and had become nearly obliterated in Carboniferous times."

Mr. Salter observes that the Silurian species are all new. Of Trilobites there are eight species, all except one belonging to well-known European genera, the forms resembling those in our own slate rocks; they represent seven genera, one of which, *Prosopiscus*, is new; *Tentaculites* and *Serpulites* also occur. The Cephalopoda are but few, yet their general characters remind us of those of other Silurian regions. Eight species are described, belonging to six genera: *Nautilus* (?), *Cyrtoceras*, *Lituites*, *Orthoceras*, *Theca*, and *Bellerophon*; they are almost all from the Chorhoti Pass. The Gasteropoda comprise ten species, representing six genera, and are also chiefly from the same pass. The Lamellibranchiata are but few, and represent three or four species of the genus *Ctenodonta*. The Brachiopoda are here also, as Mr. Salter observes, the most abundant shells of the Silurian deposit; under generic forms familiar to every student of the older rocks, and (although identical with none of them) representing even the common species of Wales and Shropshire, they stamp the formation as accurately as if we could trace the connexion of the beds themselves. This coincidence of numerous genera, and, so far as we know, of specific groups peculiar to the Lower Silurian, is very remarkable and satisfactory when such remote districts are compared. Twenty-six species are here described, belonging to the following genera: *Lingula* 2, *Leptæna* 5, *Strophomena* 9, *Orthis* 6, with several varieties of *O. Thakil*, besides other species not sufficiently perfect to admit of a satisfactory description. Bryozoa are also abundant, and appear to have been precisely of the same nature in the Indian as in the European areas: as in our own slate rocks, the narrow bifurcating forms and broad foliaceous species are found together. Two species of *Sphærospongia* occur amongst the Amorphozoa. Crinoid stems of several species have also been found, but none perfect enough to be worth describing. The genera *Chætetes* and *Heliolites* have also been found amongst the Zoophyta.

* Quart. Journ. Geol. Soc. vol. vii. p. 292.

The Carboniferous fossils brought home by Col. Strachey are neither abundant nor well preserved; nor are the collections of M. Gerard and Prof. Oldham much better. These, as well as those collected by Dr. Fleming in the Punjab, have already been described. Mr. Davidson enumerates no less than twenty-eight species of Brachiopoda, of which thirteen are identical with British fossils. Only two new species are here described by Mr. Salter, *Chonetes Vishnu* and *Aviculopecten hyemalis*.

The fossils of the Triassic series are particularly interesting; they are chiefly Cephalopoda, representing the Upper Triassic group so well developed in the Austrian Alps. The extended study of these beds by continental geologists has, as Mr. Salter shows, only confirmed the impression they first gave, that their fossils were an intermediate group between the primary and secondary systems of life. The Himalayan fossils of this age are but few; but the most striking and common forms among them are the species most characteristic of the same strata in the Alps. This opinion of Mr. Salter has been confirmed by Prof. Süss of Vienna, who says that the Hallstadt beds of the Carinthian Alps have a peculiar band of dark shale, tenanted almost exclusively by two fossils, viz. *Halobia* (*Avicula*) *Lommeli*, Münst., and *Ammonites floridus*, Wülfen. It is singular to find that these are the two most conspicuous fossil species in the Himalayan series, mixed with several other decidedly European forms, such as *Ammonites Aon*, *A. Ausseeanus*, *A. coangustatus*, and *A. diffisus*, Hauer; and in all these cases the Tyrol and Himalayan specimens have the minutest points of structure identical. The *Natica subglobulosa* and the two species of *Orthoceras* are also identical.

In the case of the Brachiopoda, probably the inhabitants of deeper water, it is shown that the characteristic shells *Athyris Deslongchampsii*, *A. Strohmeyeri*, *Rhynchonella retrocita*, and *Waldheimia Stoppani* are all identifiable, and were easily recognized by Prof. Süss, who has described them. The same forms occur in the Spiti Pass, and Prof. Oldham has found in that region a great distinction between the lower mass of strata inclosing the Triassic fauna and that above it, which is loaded with Oolitic and Triassic types.

Mr. Salter here figures a remarkable fossil brought home in abundance by Dr. Gerard from the same locality, closely allied to, if not identical with, *Spirifera Keilhavii*, Von Buch, a shell characteristic of the Mountain-limestone in Arctic regions.

Thus we find the Triassic rocks of India not only forming, as it were, a link between the Palæozoic and Secondary rocks, but containing many species identical with those of the more northern regions of Europe. Undoubtedly there is much in this to confirm the opinion so often entertained by palæontologists, although it may sometimes have been carried too far and maintained too dogmatically, namely, that in the earlier stages of organic life the same species were more widely distributed than at present, and that over widespread areas there was less variety of form, both of species and of genera, than we meet with now. Nor is it a sufficient answer to this theory to say that the older formations are difficult to explore, that many forms may have been destroyed by subsequent metamorphism, and that we must be necessarily ignorant of most of the species which existed in the earlier periods of the world's history. To a certain limited extent such may be the case; but if there really existed in the Palæozoic period the same diversity of form in distant areas as we find prevailing in the present day, it would be a strange coincidence, and contrary to every doctrine of probability, to find among the forms which had escaped destruction, and which had come under the notice of the geologist, precisely those which were either identical or analogous in different areas. Is it not, on the other hand, more probable that during the Palæozoic period, when the first sedimentary deposits were formed in the waters of the ocean, the conditions of life were more similar over a larger portion of the earth's surface than during any subsequent period, when partial disturbances, dislocations, and other changes had destroyed that uniformity which at first prevailed?

But I must return to the Himalayan fossils. Mr. Salter publishes a list of the fossils from the Upper Triassic (Keuper) rocks in the Himalayas, with the respective localities in Europe of such as are identical; from which it appears that, out of thirty-six species, fourteen occur in the Keuper beds of the Austrian Alps. Amongst the species described are—*Ammonites* 11 species, *Orthoceras* 1, *Natica* 1, *Monotis* 1, *Pecten* 2, *Lima* 1, *Exogyra* 1, *Athyris* 2, *Rhynchonella* 1, *Waldheimia* 1, *Spirifera* 2. Mr. Salter remarks on the singular fact that scarcely one of the Triassic fossils obtained from the Spiti district, and brought home last year by Prof. Oldham, corresponds with those of the Niti Pass, though 100 miles nearer to the Alps. He suggests that in the Spiti valley we may probably have a different and an older group.

The Cephalopoda of the Jurassic rocks are next described by Prof. Blanford of Calcutta; they consist of nineteen species, of which eighteen are Ammonites and one a Belemnite. The identity of Indian species with those of Europe does not appear so great as in the case of the underlying rocks. The author says that, with the exception of *Ammonites biplex*, Sow., and *A. triplicatus*, Sow., no well-identified European species occurs among Col. Strachey's fossils, although many of the latter are closely allied to European types.

Mr. Salter then proceeds to describe the Gasteropoda and Bivalves from the same range of strata; these, however, are of great thickness, and, as he observes, probably include several members of the Jurassic series. The fossils here described are—*Turbo* 1 sp., *Chemnitzia* 1, *Ostrea* 2, *Avicula* 1, *Monotis* 1, *Pecten* 6, *Lima* 2, *Inoceramus* 1, *Modiola* 1, *Myophoria* 1, *Nucula* 1, *Mactromya* 1, *Cardium* 1, *Astarte* 1, *Cucullæa* 1, *Anatina* 1, *Terebratula* 3, *Rhynchonella* 2. The work concludes with an interesting postscript by Mr. Blanford, referring to the works of Prof. Oppel and Dr. Stoliczka, the latter of whom has recently visited the Spiti valley, and has made a more complete examination of the fossiliferous formations of that part of India than had been accomplished by any previous visitor; he also corrects some errors of nomenclature which had crept into former notices, and refers to some discussion which had arisen respecting the authenticity of certain specimens. He also observes that the *Spirifera Rajah,* supposed to be identical with *S. Keilhavii,* does *not* occur in the same beds with Triassic Ammonites, but in beds decidedly below them, and is therefore probably of the same relative age as the "Carboniferous" of Europe. The work is illustrated by 23 plates of fossils, in which all the new species are engraved.

Another volume of the works of the Palæontographical Society has been published during the past year (vol. for 1863), containing portions of four monographs. The first is the continuation of Mr. Salter's "Monograph of British Trilobites," and specially the second part, which contains the Silurian and Devonian forms, with 8 plates. The genera here discussed are—*Amphion, Staurocephalus* 3 sp., *Deiphon* 1, *Calymene* 9, *Homalonotus* 13. The author then commences the group of the *Asaphidæ,* of which only one species of the genus *Ogygia* is here described.

The next work is the second portion of the sixth part of Mr. Davidson's "Monograph of British Brachiopoda," viz. the Devonian, with 11 plates. The genera described in this part are—*Atrypa* 3 sp., *Rhynchonella* 16, *Camarophoria* 1 (Mr. Davidson is disposed to consider this to be the same species as Prof. Phillips's *Terebratula rhomboidea* and the Permian form *C. globulina*, Schlot.), *Pentamerus* 2, *Davidsonia* 1, *Strophomena* 1, *Streptorhynchus* 4, *Leptæna* 3, *Orthis* 5, *Chonetes* 2, *Strophalosia* 1, *Productus* 4, *Discina* 1, *Lingula* 1, *Calceola* 1. In concluding this monograph Mr. Davidson observes that 91 so-called species have been described and illustrated, but of these only 65 have been named with certainty; 14 more are probably good species, but they are not yet sufficiently made out; the remaining 12, indicated merely for the sake of reference, will probably have to be placed as synonyms of some of the other 79 species. He then points out which of these species extend upwards into the Carboniferous beds, and concludes with some interesting observations on the geological, geographical, and palæontological distribution of the species, and on the sequence of the different beds of the Middle Devonian group, which, as well as those of the Lower Devonian, are extremely complicated.

The third paper in this volume is the commencement of a valuable "Monograph of British Belemnitidæ," by Prof. Phillips. His memoir commences with an historical account of the progress of discovery respecting this group of Cephalopoda from the time when Belemnites were first so called by Georgius Agricola in 1546, when they were considered as of animal origin, down to the period of the more recent discoveries of Buckland, Owen, and Mantell, when their true place in nature, as belonging to the great family of Cephalopoda, was satisfactorily established by the discovery of specimens in which the fossil ink-bag and other characteristic parts of the animal and its sheath have been preserved.

Prof. Phillips then proceeds to describe the structure of the *Be-*

*lemnitidæ.* The most commonly preserved portion in the fossil state is the posterior or caudal portion of the guard or sheath, which was originally considered as the Belemnite *par excellence,* until it was subsequently discovered that as this guard extended forwards it formed a conical cavity filled with a shell of similar form, gradually expanding forwards, divided by many shelly plates, and pierced by a small pipe or siphuncle near one edge. This is called the phragmocone, and is rarely found complete; when such, however, is the case, it is covered by a thin conical shell distinct from the substance of the guard, and called "conotheca" by Huxley. With regard to the guard itself Prof. Phillips observes, that it is necessary that it should be carefully observed in three distinct aspects, viz. the dorsal and ventral faces, as well as along the axis or apical line. Although specimens are extremely rare in which the phragmocone and guard are found together completely, yet in specimens from the Lias of Lyme Regis and of Yorkshire the structure of the phragmocone in relation to the guard has been sufficiently ascertained to justify a restoration of the whole shell.

The author then proceeds to describe the classification of the Belemnitidæ, but this chapter is unfinished; and no plates or illustrations, except woodcuts, are given in this portion of the monograph.

The next paper is the "Monograph of the Fossil Reptilia of the Liassic formation," by Prof. Owen: part first, Sauropterygia. The work commences with a detailed account of *Plesiosaurus dolichodeirus,* followed by *P. homalospondylus, P. rostratus* (Owen), and *P. rugosus* (Owen), and is accompanied by 16 plates. The merit of these osteological papers of Prof. Owen is so well known that it is unnecessary for me to say more than that the detailed description appears to exhaust whatever can be said respecting these extinct reptiles, their mode of entombment, and the resulting positions in which they have been found.

Although I do not, as a rule, purpose alluding to the papers which have been read at our evening meetings, yet there are some which appear to be of sufficient interest to justify my noticing them on the present occasion. The organic structure of the *Eozoön Canadense* to which I alluded last year, has been called in question by Prof. W. King and Dr. Rowney in a paper recently read before the Society. Having examined numerous specimens of Eozoönal Serpentine from various localities, the authors consider that the appearances which Dr. Carpenter and others have pronounced to be organic, and closely to resemble foraminiferal structure, are purely of mineralogical origin. They consider the "skeleton" to be identical with the calcareous matrix of certain minerals, as Chondrodite, Pargasite, &c. The "proper wall" of the chambers is not an independent structure, in their opinion, but only the surface-portion of the granules of chrysotile crystallized into an asbestiform layer. The dendritic and other forms which were described as representing the "canal system," are considered by them to be tufts of metaxite, or some allied variety of chrysotile; and these and other

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forms are, in their opinion, nothing but imbedded imitative crystallizations, quite distinct from the foraminiferal structure with which they have been compared. From these and other considerations they conclude that Eozoönal Serpentine is a metamorphic rock, and they throw out the suggestion that it may, in many cases, have also undergone a pseudomorphic change—that is, it may have been converted from a gneissoid calcareous diorite by chemical introductions or eliminations.

Dr. Carpenter maintains the correctness of his former views. In a paper read on the same evening he showed that a recent siliceous cast of *Amphistegina* from the Australian coast exhibited a perfect representation of the "asbestiform layer." He then showed that this asbestiform layer exhibited in *Eozoön* a series of remarkable variations, which can be closely paralleled by those which are found in the course of the "tubuli" in the shells of existing Nummuline foraminifera, and are associated with a structure exactly similar to the lacunar spaces intervening between the outside of the proper wall of the chambers and the intermediate skeleton by which they became overgrown, formerly inferred by the author to exist in *Calcarina*. With regard to the opinions advanced by Prof. King and Dr. Rowney, he stated that even if the dendritic passages hollowed out in the calcareous layers, and the arrangement of the minerals in the Eozoön limestone could be accounted for by inorganic agencies, there still remained the Nummuline structure of the chamber-wall, to which no parallel can be shown in any undoubted mineral product.

The question is certainly one of great importance, and, considering the minute microscopical structure and the mineral as well as metamorphic change which the rocks have undergone, it is still involved in some obscurity. It were much to be desired that the gneissoid rocks from other localities should be carefully examined; for if the organic theory be true in the case of old Laurentian gneiss, we ought to expect a fuller confirmation of it in the gneissic rocks of a still younger age. And though it may perhaps be considered rash in one who has not examined the various specimens microscopically beyond seeing some of Dr. Carpenter's preparations, I am bound to say, almost against my own convictions, that the balance of argument at present is in favour of the views laid down by Dr. Carpenter, Dr. Dawson, and Mr. Sterry Hunt. I should add that Dr. Carpenter also stated that he had recently detected *Eozoön* in a specimen of Ophicalcite from Bohemia, in a specimen of gneiss from near Moldau, and in the serpentinous limestone from Bavaria.

With reference to this subject, Prof. A. Sismonda has published an account of some organic impressions found on a mass of gneiss derived from one of the boulders in the diluvium which overlies the Lias formation north of Rezzago in the Brianza. This block must have been brought down from the Alps, and Prof. Sismonda considers that it probably came from the Valtellina, the mountains of which consist of this same form of gneissic rocks. When first discovered, some years ago, it was supposed to be an insect; but more careful investigations recently made, particularly by M. Brongniart, whom he consulted, have proved it to be of vegetable origin. M. Brongniart concluded that it was a portien of an *Equisetum*, very analogous to *E. infundibuliforme*, of the Carboniferous period, but possibly a new species. From these considerations Prof. Sismonda concludes that the gneiss in question is a metamorphic rock of the Carboniferous period, and suggests the propriety of further search for fossil remains in these crystalline rocks of the Alps.

M. Barrande has published, during the past year, a second volume of his important work on the Silurian System of the centre of Bohemia. It is the first series of the Cephalopoda, and consists of 107 plates with corresponding explanations. In a short preliminary notice M. Barrande states that the Silurian Cephalopoda of Bohemia will occupy 350 plates; this large quantity of matter renders it necessary to publish them in separate large numbers or livraisons. The present number forms the first series of the plates devoted to this class. It contains about 200 species, representing the ten following genera:—*Goniatites*, *Nothoceras*, *Trochoceras*, *Nautilus*, *Gyroceras*, *Hercoceras*, *Lituites*, *Phragmoceras*, *Gomphoceras*, and *Ascoceras*. The two other genera, *Orthoceras* and *Cyrtoceras*, which complete the family of the Silurian Nautilidæ of Bohemia, are much richer in species, and will fully occupy the plates of the second and third series, with the exception of such as will represent the features of the general study of the Nautilidæ. The text belonging to these ten genera will be shortly published; the author has therefore confined his observations on them, for the present, to a tabular statement pointing out their vertical distribution in the different formations and their principal subdivisions.

One of the most remarkable results of an examination of this tabular statement is the great preponderance of forms which are characteristic of the formation, or *étage*, E. Of 202 species here figured, 155 belong to this formation, and only 47 to G, 8 to F, and 2 to D, and at the other end of the series only 2 to H. Looking at individual genera, out of 70 species of *Gomphoceras*, 61 belong to the formation E. The only remarkable exception to this rule is the genus *Goniatites*; out of 17 species, 15 belong to the formation G, which, with the formations E, F, and H, belong to the Upper Silurian System, and constitute M. Barrande's "faune troisième." Besides this wonderful development of Cephalopoda in this Upper Silurian System of Bohemia, their rapid diminution is no less surprising. Only two species remain in *étage* H, a *Goniatite* and a *Gyroceras*, and these are only found in the lowest subdivision of the *étage*.

M. Barrande has also published during the past year a third part of his work entitled 'Défense des Colonies,' comprising a general consideration of the *étages* G and H, with special reference to the neighbourhood of Hluboçep, near Prague. The necessity for this publication is stated to be the erroneous views entertained by MM. Lipold and Krejci respecting the stratigraphical conditions of the neighbourhood of Hluboçep and Litten. I shall not presume on this occasion to discuss the general question of M. Barrande's Colonial System, but shall endeavour to confine myself to a general sketch of the contents of the work and of the objects which he has in view. The *étages* G and H, it is well known, represent the upper portions of the Upper Silurian formation, or the "faune troisième" of M. Barrande. The work is divided into two parts; the first is devoted to the general description of the *étages* G and H on the surface of the Bohemian basin. The first two chapters give the results of his stratigraphical and palæontological investigations with regard to these two groups and their subdivisions. In the third chapter he points out their topographical extent, and shows their horizontal and vertical relations by means of two sections across the upper division and the zone of the colonies, the one following the valley from Tachlovitz to Radotin, and the other through the quarries of Dvoretz and Branik, near Prague. In the fourth chapter the author endeavours to ascertain whether the *étages* G and H are represented in the Silurian basins of other countries; and in the fifth chapter he discusses the connexions which exist between the fauna of the *étages* G and H and the Devonian fauna. The second part contains an account of his special observations respecting the phenomena of the *étages* G and H in the neighbourhood of Hluboçep, with remarks on the adverse criticisms of MM. Lipold and Krejci respecting the stratigraphical arrangement of the beds in question.

The colonial system of M. Barrande is too well known to geologists to render it necessary for me to make any further allusion to it than to refer you to the last edition of Sir R. I. Murchison's 'Siluria,' p. 400. The anticolonial argument which MM. Krejci and Lipold have brought forward, founded on the stratigraphical appearances of the different formations in the neighbourhood of Hluboçep, is thus stated by the author:—

1. There are evident dislocations at Hluboçep in the *étages* G and H.

2. These dislocations have produced a mechanical intercalation of the schistose beds of H amongst the limestones of G, showing appearances perfectly resembling those of the colonies.

3. The colonies are therefore naturally explained by simple dislocations and mechanical intercalations.

These statements M. Barrande emphatically denies. He shows that the supposed existence of these dislocations is solely founded on a want of careful observation. Independently of the synclinal fold already pointed out, along the axis of the basin, and the anticlinal fold, now described in the heights of Divçi Hrady, these pretended dislocations and their supposed effects are purely imaginary.

Nor does the locality of Hluboçep offer any intercalation whatever of the schists of H amongst the limestones of G; on the contrary, this locality shows on each side of the synclinal axis of the valley the regular and symmetrical series of the formations of the *étages* G and H, without any appearance of mechanical origin which could reproduce the stratigraphical and palæontological alternation of the colonies. The series of formations near Hluboçep is of a purely sedimentary and normal origin, independent of all dislocation or disturbance of the ground.

The process by which the author supports his views may be succinctly stated as follows:—He shows, in the first place, that the *étage* G consists of three subdivisions, the lowest, *g* 1, being a purely calcareous bed, *g* 2 being a band of argillaceous schists with calcareous nodules, passing, by a gradual increase of the calcareous element, into the overlying bed *g* 3, consisting of limestone resembling altogether the bed *g* 1, the whole forming such a complete system of superposition and gradual passing of one into the other, as altogether to preclude the possibility of the bed *g* 2 being an intercalation of the overlying *étage* H, which consists entirely of argillaceous schists. This *étage* is also separated into three subdivisions, *h* 1, *h* 2, and *h* 3, in which the calcareous element appears to be altogether wanting. There is no gradual passage between G and H; the transition is sharp and well defined.

The author then proceeds to describe the palæontological contents of the *étages* G and H, and their subdivisions. By these means he has been enabled to point out the true distinction of the different beds, for which the petrographical and stratigraphical evidence alone was not sufficient. Thus the two calcareous bands *g* 1 and *g* 3, so closely resembling each other in a petrographical point of view, are shown, by the numerous tabular statements of their respective faunas, to be entirely distinct. These tables show that, with the exception of the Cephalopoda, all the classes (p. 55), including the Fish, Crustacea, Pteropoda, Gasteropoda, Brachiopoda, Acephala, Radiata, and Vegetables, are represented by a much larger number of species in *g* 1 than in *g* 3. On the other hand, the Cephalopoda are more numerous in *g* 3 than in *g* 1 in the proportion of 3 to 2; and, moreover, in bed *g* 3 the Cephalopoda alone contain about four times as many forms as all the other classes together in the same bed; besides which these two beds contain very few species common to both.

With regard to the four schistose beds, *g* 2, *h* 1, *h* 2, and *h* 3, the distinction is equally clear; *h* 2 and *h* 3, being unfossiliferous, are easily separated from the others; and with regard to *g* 2 and *h* 1, although they contain eleven species common to both, a much greater number of species are peculiar to each.

| | Peculiar to *g* 2. | | Peculiar to *h* 1. |
|---|---|---|---|
| Trilobites …… | 3 | …… | 0 |
| Cephalopoda…. | 4 | …… | 1 |
| Pteropoda…… | 1 | …… | 0 |
| Gasteropoda …. | 2 | …… | 0 |
| Brachiopoda …. | 6 | …… | 1 |
| Acephala …… | 7 | …… | 3 |
| Radiata …… | 4 | …… | 0 |
| Vegetables …. | 0 | …… | 2 |
| | 27 | | 7 |

But these two formations are also easily distinguished by their rocks; the schists of *g* 2 contain numerous calcareous nodules of a light colour, which are altogether wanting in the bed *h* 1, where the calcareous element only appears at its base in thin bands, and with an entirely different petrographical character from that of the nodules above mentioned. Thus there is sufficient evidence to prevent the possibility of mistaking these two beds, *g* 2 and *h* 1.

In the next chapter (3rd) the author describes the stratigraphical relations between the *étages* G and H and the other *étages* of the Bohemian basin. The different sections from various localities are given in great detail, and several faults are described, the explanation of which, when the adjacent beds were unfossiliferous, was a work of much labour and time. I must refer you to the work itself (p. 102) for an account of the fault of Branik and the adjacent colony of Branik, where, in the midst of the *étage* D 5, consisting of unfossiliferous beds of grey schists and quartzites of great thickness, thin fossiliferous bands occur, more or less charged with calcareous matter, containing several species of fossils, which peculiarly characterize the lower beds of *étage* G; thus, according to Mr. Barrande's theory, foreshadowing by colonization the future characteristic population of the overlying beds. Other colonial appearances are described, as well as a section showing the complete series of the thin bands of *étage* G, with the overlying *étage* H, in regular conformable stratification.

In the fourth chapter the author enters into a detailed consideration as to how far the *étages* G and H are represented in other Silurian basins. The countries thus noticed are England, Russia, Sweden, Norway, Thuringia, Saxony, Franconia, the Harz, France, Spain, Sardinia, and the United States of America.

M. Barrande observes that he still adheres to the opinion, published in his 'Notice préliminaire,' and confirmed twelve years ago in his 'Esquisse Géologique' (Syst. Sil. &c., Book I.), that, although there was a complete general correspondence between the great Silurian divisions of Bohemia and England, a more detailed comparison of local forms proves that the different *étages* in each country did not correspond with each other. Comparing the Upper Silurian formation of England with the *faune troisième* of Bohemia, viz. the *étages* E, F, G, H, he says that the fossils which characterize the upper division in England and in Bohemia, taken as a whole, constitute, both by their analogies and their identities, whether generic or specific, one simple general fauna, which he calls "faune troisième." At its commencement in each country this fauna shows a close and intimate resemblance; but, owing to local conditions, or other unknown causes, it has undergone in each country a different development, as is shown both by the unequal distribution of each class and by the modifications caused by the extinction and progressive renewal of species. The consequence of this divergence gradually increasing in time has been, that the beds which form the upper portion of the upper division are connected together by a *minimum* of palæontological relations, so that no individual parallelism can be established between them, although they all belong to the same period of time, during the deposition of the Silurian system.

The author then gives a table showing the vertical distribution of 57 Upper Silurian species which have been recognized as identical in the two countries, and shows that out of this number belonging to the "faune troisième," 32 had already existed in the lower division, or "faune seconde," of England, whereas none of them are found in the "faune seconde" of Bohemia; this fact alone he considers sufficient to prove the possibility of his colonies, as these 32 species coexisting with the "faune seconde" of Bohemia might have immigrated into the Bohemian basin and have dwelt there temporarily during the existence of this fauna. Of these 57 species, 50 occur in the Wenlock beds and 27 extend into the Ludlow beds, whereas in Bohemia 51 of them are found in the *étage* E, and only 12 appear in *étage* F; only five extend into *étage* G and one into H. Thus showing that *étage* E contains almost all the palæontological connexions hitherto recognized between the "faune troisième" of England and Bohemia, whereas the few identities occurring in the three *étages* F, G, and H, merely serve to show that they are really constituent parts of the same Upper Silurian division.

After describing the different connexions between the "faune troisième" of Bohemia and the other countries mentioned above, the author observes that these comparative statements are the only means available for ascertaining how far the last phase of the Bohemian "faune troisième" contained in the *étages* G and H is represented in other countries. By way of comparison, he enounces the chief distinctive characters of this phase as follows:—

1. Intermittent or sporadic presence of fish, and particularly the armoured type, the first appearance of which belongs to *étage* F.

2. Predominance of the genera *Dalmanites* and *Bronteus* amongst the Trilobites, and the presence of the genus *Calymene*. The genus *Dalmanites* is only represented by the group of *D. Hausmanni*.

3. The reappearance and relatively new development of the nautiliform Cephalopods generally, and particularly of the genera *Phragmoceras* and *Gomphoceras*, characterized by their contracted opening.

4. Development of the group of *Nautilina*, representing the genus *Goniatites*, which made its first appearance in the *étage* F.

5. Sporadic appearance of *Cardiola retrostriata* in the *étage* H.

These characters are nowhere found all together in any horizon of the Upper Silurian division in the Palæozoic regions of the two continents; but their absence shows itself in very different degrees in the different countries compared with Bohemia. In the neighbouring regions of Saxony, Thuringia, and Franconia no trace has hitherto been found of the last phase of the "faune troisième," whereas the earlier phase has now been distinctly recognized. The Silurian deposits of these regions appear to belong to the great Palæozoic zone of the north, as England, Russia, and the Harz, the faunas of which, notwithstanding their greater distance, bear a very marked resemblance to the phase of the *étages* G and H. Sweden and Norway are in the same category. France, Spain, and Sardinia, although showing clear evidence of the existence of the first phase, are also deficient of all trace of the last phase, only in France the formations which are classed as Lower Devonian contain numerous fossils similar to the forms found in the different *étages* E, F, and G.

In England, the Isle of Oesel, and the Harz, the characters of the fauna of the *étages* G and H are partially represented; but in England, amongst the six genera of fish found in the Ludlow and Passage-beds, there are none of the *cuirassés* or armoured types. The Trilobites are almost entirely wanting; the Dalmanites of the groups *D. Hausmanni* and *Bronteus* are not represented. The same is the case with the Nautilidæ with the contracted mouth. Goniatites are unknown, as well as *Cardiola retrostriata*.

The United States of America form another category, showing the principal characters which distinguish the fauna of the *étages* G and H, viz., the sporadic appearance of the armoured fish, the existence of the genus *Calymene* amongst the Trilobites, a greater development of the Dalmanites type, and the reappearance and relative abundance of the Nautilidæ; thus the most complete representative hitherto known of the *étages* G and H is found in the State of New York.

The fifth chapter is devoted to the consideration of the connexion between the *étages* F, G, and H of the Silurian basin of Bohemia and the Devonian formations. After alluding to the evidence which he has given that the lower calcareous *étage* E contains by itself a fauna almost as complete as that which is distributed in different beds in other countries between the Lower Silurian and the Devonian, the author proceeds to show that it would be a great error to suppose that the upper *étages* F, G, H could belong, at least partially, to the Devonian period. He shows, by carefully analyzing the different classes of fossils contained in these three *étages*, that, although they certainly do contain some species common to the Devonian fauna, they are totally deficient in those forms which have hitherto been considered as essentially characteristic of the three subdivisions of the Devonian system, and that, on the other hand, they contain many forms of a true Silurian character.

The result of this examination shows that although the typical forms of many Devonian species made their first appearance in the Silurian formation, and although, as in the case of the Nautilidæ, the analogies brought forward would appear to show a greater connexion between the Devonian faunas and the *étage* E than with the *étage* G, no identical species, either of Trilobites, Nautilidæ, or Goniatites, occur in the two formations; the same may be said of Pteropoda and Gasteropoda. Of Brachiopoda there are 2 species common to *étage* G and the Devonian beds. *Cardiola retrostriata* is a remarkable instance of connexion between the Devonian phase and the youngest Silurian phase, as well as between the older and younger phases of the Upper Silurian; and M. Barrande thus sums up the result of his examination :—

1. The last phase of the "faune troisième" contained in the *étages*

G and H is more or less closely connected in all classes of fossils with the former phases of this fauna contained in the underlying *étages* E and F.

2. Notwithstanding certain general connexions between these same upper *étages*, G and H, of the basin of Bohemia and the three great Devonian subdivisions, there is no such affinity between the faunas of the two formations as would justify our considering them as representing, under different appearances, contemporaneous deposits. And with regard to the apparent paradox that the "faune troisième" during its later phase, nearest in point of time to the Devonian fauna, is less closely connected with it than with the lower *étages* E and F, he observes that his investigations prove that each class of fossils shows a greater or less number of specific connexions, without counting the constant generic connexions between the *étages* E and F and the overlying G and H; and consequently that, in a palæontological point of view, the *étages* G and H completely maintain their Silurian character, and are only associated with the Devonian beds by those ordinary points of resemblance which occur during any given geological epoch to announce the following period. I have already pointed out the object of the second portion of this work; but I cannot take leave of M. Barrande, to whom I fear I have hardly done full justice, without making one observation.

Whether the colonial theory of M. Barrande be right or wrong, it is impossible not to see in all his observations a confirmation of that argument which has often been supported in this room, and to which I have myself more than once ventured to allude, viz., that in formations of the same age, although separated geographically by greater or less distances from each other, we must not expect to find the same species or even genera always appearing at any given geological horizon simultaneously. The various conditions of life, the depth of the sea, the different proportions of calcareous or siliceous or argillaceous elements in the deposit, must have produced a difference in the organic contents of the formation—a difference which may often have shown a greater intensity in neighbouring regions than in such as are separated by greater distances in space. The difference caused by distance in time has always been appreciated by geologists; but that caused by distance in space has sometimes been overlooked, not so much perhaps of late years as formerly, when the identity or non-identity of fossil contents was looked upon as the all-sufficient reason for synchronizing or separating formations occurring at a considerable distance from each other.

Amongst the more important discoveries of last year I must notice that of Professor Huxley, who, in examining some reptilian remains found in the Kilkenny Coal-field, ascertained the existence of not less than six genera, five of which are certainly new, while the sixth, according to Profesor Huxley, may or may not be identical with the *Anthracosaurus* of the Scotch Carboniferous rocks.

The five new genera have been defined in a notice communicated to the Royal Irish Academy by Dr. Wright, on behalf of Professor Huxley and himself, under the names of *Urocondylus, Ophiderpeton, Ichthyerpeton, Keraterpeton,* and *Lepterpeton. Ophiderpeton* is remarkable for its extremely elongated and snake-like form; *Icthyerpeton* for its fish-like body and short limbs; while *Urocondylus, Keraterpeton,* and *Lepterpeton* have Salamander-like forms and well-developed limbs. In all, the vertebræ are abundantly ossified, and there are no traces of persistent branchial arches, so that they present very important differences from *Archægosaurus.* The authors then show that four of these five genera present unmistakeable remains of the ventral dermal armour characteristic of the Labyrinthodonts, and that from this and other circumstances there can be little doubt that they all belong to that group of extinct Amphibia.

Professor Huxley informs me that, up to the time when these discoveries were made, eight genera, in all, of higher organization than fishes were known to occur in rocks of Carboniferous age in Europe, and five in America. Of the eight European genera, only *Archægosaurus, Pholidogaster,* and *Anthracosaurus* were known by more than mere fragments; nor do we possess at this moment a knowledge of the nature of the limbs in any one of these genera, except *Archægosaurus.* The five American genera *Baphetes, Raniceps, Dendrerpeton, Hylerpeton,* and *Hylonomus* were much more fully known; and it was a curious problem whether further research in Europe would tend to reveal the existence during the Coal-period of small Amphibia with well-ossified vertebræ and well-developed limbs, like the American forms, or whether it would show that the Labyrinthodonts of the European area rather adhered to the Archægosaurian type already known to occur in Europe, but not hitherto found in America.

So far as the Irish discoveries have yet gone they prove the existence, during the Carboniferous epoch of Europe, of Amphibia which, are analogous to, though altogether distinct from, the "homotaxic" American Labyrinthodonts,—analogous to them in the degree of ossification of the skeleton and development of the limbs,—different from them not only in detail, but in the existence of such types as *Ophiderpeton* and *Ichthyerpeton,* which have at present no parallel either in America or elsewhere.

The discoveries of the last five years show that the Labyrinthodont Amphibia were as largely represented and as well developed in the Carboniferous as in the Triassic formation. Three genera are known from the Permian formation of Europe, and five from Asiatic, African, and Australian rocks of an age which, if not certain, may safely be assumed to be between the Carboniferous and Lower Mesozoic periods.

Professor Huxley concludes these observations by the following remark:—"putting all these facts together, it would appear that the Labyrinthodonts represent the first rope of the bridge which will one day be suspended across the gulf which at present separates the Palæozoic from the Mesozoic fauna."

This interesting discovery in Ireland affords additional confirmation of the correctness of the theory which assumes that new forms of animal life, either as species, as genera, or as classes, were created or made their appearance on our earth at the time when the conditions of life were best suited to their existence, and that they were formed with an organization adapted to the external conditions under which they were to live. When we analyze the great Carboniferous deposits, and recognize in them the vast tracts of ancient swamps and marshes covered with the rich and luxuriant vegetation which they formerly presented, subject to the gentle oscillation by which they were alternately submerged beneath the ocean and slightly raised above the level of its waters, we find, as in the great dismal swamps in some of the Southern States of North America, the very conditions of life most suitable for reptilian existence; and precisely on this horizon they appear to have come into existence not in one or two vague forms developed out of previously existing ones, but, as it is now shown, in a great variety of new forms, all belonging to the same reptilian class, varying in different hemispheres, but presenting those peculiar characteristics which constituted them the fit inhabitants of low swampy regions, clothed with an abundant yet varied vegetation. Future discoveries will, no doubt, in time add to the list of genera and to our more perfect knowledge of the reptilian fauna of the Carboniferous age. In the mean time we may congratulate ourselves on this great addition to our knowledge of this fauna, for which we are indebted to the zeal and acumen of Professor Huxley and Dr. Wright.

In the 'Bulletin de la Société Géologique de France'* will be found an interesting account of the history of the discussion respecting the Carboniferous formation of the Alps, by Prof. Alphonse Favre, of Geneva, in which he describes the progress of the discussion which so long prevailed respecting the age of the anthraxiferous formation of the Alps, in consequence of the apparent intermixture or alternation of beds containing vegetable impressions, supposed to indicate a Carboniferous period, with beds containing Belemnites, supposed to be of Jurassic age. You all, no doubt, remember the numerous memoirs published on this subject, and of which a very full account was given by M. Scipion Gras in a former volume of the 'Bulletin.'

M. Favre has taken up the subject, and has carried on the history to the latest times. He divides it into four periods. I need not trouble you here with any notice of the first two; and, with regard to his third period, I will only observe, that it extends from 1858 to 1860, and contains an account of all the observations which tended to prove the existence of the Triassic formation and of the Infralias, as well as the consequences which resulted from this discovery. He shows that the existence of these two formations created such a break between the Lias and the Coal-formation, that it was no longer possible to admit that the beds in question could belong to the same age. The Trias was even discovered at Petit Cœur, so that this locality could no longer be claimed as a proof of the union of the

* 2me sér. vol. xxii. p. 59.

Lias and the Coal-formation, and the battle-field of the discussion was removed to St. Jean de Maurienne. The fourth period extends from 1860 to 1863. It began with the discovery of Nummulites at Maurienne, and continued to the close of the discussion. Then it was that the recognized presence of the Trias and the Infralias, as well as the position of the Nummulites found in a formation hitherto considered by M. Scipion Gras as anthraxiferous, combined with the mineralogical character of the rocks, their stratigraphical position, so long misunderstood owing to the numerous contortions of the beds, and the fossils which they contained, proved the presence of the real Carboniferous formation in the Alps.

The fact was generally admitted at the meeting of the French Geological Society at St. Jean de Maurienne in 1861. The same results were applied to Dauphiné and Provence; and finally M. Heer, who had so completely mastered the mystery of the fossil flora of Switzerland, published in 1863 a memoir respecting the flora of the Carboniferous formation in Switzerland and Savoy, in which he showed that not one single plant of the Carboniferous formation of the Alps was found either in the Lias or in the Trias.

Is it not a curious fact, observes M. Favre, that it required thirty-five years of discussion and of argument to clear up a point of Alpine geology? It has led, however, to a much better knowledge of details; and now questions relating to the age of a formation can be solved as well in the Alps as in the neighbouring countries, and the charge of backwardness can no longer be maintained against the geology of the Alps.

In concluding this *précis*, M. Favre gives a list of the various geologists who had adopted the different views respecting the age of the anthraxiferous beds of Switzerland. In this list he places my name amongst those who referred this formation to the Lias. Now, although there can be no discredit in being placed in the same category with such names as Elie de Beaumont, Sismonda, Collegno, Roget, &c., I think it right to say that the only part I took in the discussion was this, that in the anniversary address which I delivered from this chair in 1856, after giving a sketch of M. Scipion Gras's memoir on the subject, I stated, on the strength of the alleged superiority of evidence derived from the fauna of a formation as to its age, over that derived from its flora, that "the weight of evidence appears to be in favour of referring the whole formation to the Jurassic rather than to the Carboniferous period."

M. Favre also adds that, if the discussion had terminated in the contrary sense, the whole question of palæontology would have had to be seriously modified. If it had been proved that the coal plants were still living during the Liassic period, the value of fossil botany would have been destroyed, as it would no longer have served to characterize a formation. The labours of Prof. Heer have saved us from this catastrophe.

With reference to this question I may also direct your attention to another memoir in the same number of the 'Bulletin' by M. Lory, in which he endeavours to explain the stratigraphical anomaly of Petit Cœur in the Tarantaise. The locality is a very limited one, and the phenomena cannot be explained by inversion of the strata, or by a turning over of the different beds. After describing the principal facts, he shows that the anomalous position of these beds, which had caused so much difference of opinion amongst geologists, was owing to two faults, one general and the other local, and to the slipping or sliding-in of overlying beds into the cavities thus caused, and so bringing the Upper Lias beds in immediate contact with the Coal-measures, and even the underlying crystalline rocks.

Neither time nor space would allow me to go through the numerous works which the industry of the German geologists have produced on those portions of the secondary series, the Triassic and Liassic formations, which are so extensively developed in the Alps and in Germany itself. It would require volumes to do justice to them all. I must therefore confine myself to a slight allusion to some of the more interesting memoirs which have come under my notice; and in doing this I feel it is impossible to withhold an expression of admiration at the zeal and energy with which these investigations have been pursued in so many different parts of Germany. It is not that one eminent palæontologist has directed his attention to this subject, but a whole army of eager and enthusiastic explorers, animated by the recent rapid accumulation of facts, by the discovery of new fossils, and by the greater accuracy with which the different fossil-bearing strata have been distinguished, seem to have come forth from every corner of Germany, each taking up some special branch, and in the end almost overwhelming us with the mass of accumulated results.

Professor Gümbel has published a very important memoir on the geological conditions of the Triassic district of Franconia. After describing the topographical features of the district under consideration, he gives a general account of all its geological features, showing that the crystalline rocks (Urgebirgs-felsarten) of the Odenwald form the basis of the whole system. The Silurian, Devonian, and Carboniferous systems are wanting in this district. The conglomerates of the Dyas (Rothtodtliegendes) rest immediately on the Urgebirge and form the basis of the Triassic formation (Bunter Sandstein, Muschelkalk, and Keuper), which fills up the whole region between the crystalline rocks of the Odenwald and the Hercynian mountain-system. It is well known that all the rocks of the Franconian Alps rest upon this Triassic surface, and form a kind of insular continent in the Keuper district.

The different beds and rocks throughout this region, with their characteristic fossils, are then carefully described; after which the author makes the following general remarks:—"The long period of time during which the massive rocks of the Jurassic formation were gradually deposited in eastern Franconia, passed away without leaving any additions to the rock-formations in the greater part of the western district. Western Franconia was a continent of dry land during this period of the formation of the earth's crust. Not until the Tertiary period did this district again share in those changes and convulsions which were constantly going on—sometimes here and sometimes there—over the whole surface of the earth. It is, however, comparatively only a small portion of the Franconian region which took part in these changes during the Tertiary period; but the new formations are of so gigantic a character that they make up in intensity for what may be wanting in extent. To these phenomena belong the volcanic formations, which were developed within the district of the Rhön mountains; they form a link in that great chain of volcanic operations which connects the central mountains of Bohemia through the Fichtelgebirge on the one hand, and through the Vogelsgebirge and the Westerwald on the other, with the Siebengebirge.

Dr. Waagen has endeavoured in a short memoir to give us a general classification of the beds of the Upper Jurassic formation, taking as his basis the classification of English geologists, as the first which was founded on a more accurate knowledge of the different beds, although he doubts whether the names which were sufficiently appropriate in the localities to which they were originally applied, are equally so when applied to large areas where the same beds either assume a different petrographical *facies* or are characterized by a distinct or abnormal fauna. After describing the various local horizons from the Portland Stone to the Oxford Clay, he endeavours to establish a comparison between the English beds and those on the continent, which are assumed to be their representative zones. The following table shows how he groups these formations:—

| | Local Horizons. | English Divisions. |
|---|---|---|
| Kimmeridge Group. | Zone of *Trigonia gibbosa* .. | 1. Portland Stone.<br>2. Portland Sand. |
| | Region of *Orbicula latissima* and *Acanthoteuthis speciosa* .. | |
| | Region of *Ammonites mutabilis* and *Exogyra virgula* ...... | 3. Kimmeridge Clay. |
| | Region of *Ammonites alternans* and *Rhynchonella inconstans* | |
| Oxford Group. | Region of *Cidaris florigemma* ...... | 4. Upper Calcareous Grit.<br>5. Oxford Oolite. |
| | Region of *Ammonites Martelli* ...... | 6. Lower Calcareous Grit. |
| | Region of *Ammonites biarmatus* .... | 7. Oxford Clay. |

I must also notice the work of Dr. Ferdinand Stoliczka, entitled 'A Revision of the Gasteropoda of the Gosau beds in the Eastern Alps.' This memoir was written in Calcutta, where the author is one of that band of geologists who, under the superintendence of Prof. Oldham, are working out the geology of India. Having collected in the Gosau district a vast amount of material before his departure for the East Indies, he has been induced to publish his observations in consequence of what he considers the great errors in Herr Zekeli's account of the Gosau Gasteropoda; and it was with a view of rescuing geological science from these errors, some of which are pointed out, that he undertook the critical examination of these species, which have been too hastily increased in number by Zekeli from 124 to 193 species.

With regard to this formation, I will only quote one sentence from Dr. Stoliczka's work, to show one *facies* of the Gosau deposit. "It is well known that during some one of the elevations of the calcareous rocks of the Alps, after the deposition of the Lower Chalk, the calcareous crust was cracked and opened out in numerous directions. These fractures extended downwards to the 'bunter Sandstein.' The sea of the Upper Chalk period penetrated these openings, took up its material chiefly from the 'bunter Sandstein,' and deposited it again under a somewhat altered form. This is the reason why our Gosau beds generally rest immediately on the 'bunter Sandstein,' and why it is often no easy task to decide what is Gosau deposit and what belongs to the 'bunter Sandstein.' The occurrence of fossils affords the easiest and safest solution of the question. The Gosau beds were thus deposited in bays and inlets of the sea, which, however, had a far greater extension than now appears; not only the abundance and variety of the fauna, but positive proof derived from the conditions of the deposit leave no doubt on this point. Mighty rivers soon emptied themselves into these bays, and drove away the true marine fauna. A peculiar molluscous fauna developed itself at the mouth of these rivers with species of *Cerithium*, *Potamides*, *Nerita*, and *Omphalia*, accompanied no doubt by numerous fish and gigantic Saurians." He further shows that, under the influence of this great addition of fresh water, the water itself became brackish, or alternately marine and lacustrine. By degrees, the marine fauna was checked and driven more towards the middle of the sea, where it was powerfully developed in the neighbourhood of islands or in other favourable localities.

I would also have given some account of the following papers, had time permitted:—

"On the Cephalopod family *Acanthoteuthis*," by Prof. Ed. Suess, read at the meeting of the Imperial Academy of Sciences on March 16, 1865.

"On the Formation of the Bunter Sandstein and Muschelkalk in upper Silesia and its Fossils," by Dr. Henry Eck.

"On the Tithonic Etage," by Prof. Oppel of Munich, published in the journal of the German Geological Society, 1865. This formation is intermediate between the Upper Jurassic and Lower Cretaceous beds, and the author defines it more strictly as occurring between the Kimmeridge and lower Neocomian beds. It refers to certain Alpine deposits containing Cephalopoda, probably corresponding with Portland, Purbeck, and Wealden beds, but of which the exact parallelism has not yet been sufficiently made out.

"On the Fauna of the St. Cassian beds, being a Supplement to the Palæontology of the Trias of the Alps," by Gustav Laube, in two parts, the first of which contains a description of the *Spongitaria, Corals, Echinidæ*, and *Crinoidæ*, with 10 plates; the second part contains the *Brachiopoda* and *Bivalves*, also with 10 plates.

"The position of the Raibl beds in the Franconian and Suabian Keuper," by Prof. F. Sandberger.

With reference to the much discussed question of the true position of the *Avicula-contorta* beds, to which I alluded on a former occasion, I find in the 'Bulletin de la Société Géologique de France,' 2nd ser. vol. xxii. p. 369, an interesting communication by M. Jules Martin, entitled "The Rhætic formation or *Avicula-contorta* zone; its petrographical, stratigraphical, and palæontological constitution in the different parts of Europe where it has been studied." Dissatisfied with many of the results of previous investigations, M. Martin determined to go fully into the whole question, the result of which has since been published. In the meantime he here gave a general *résumé* of what appeared to him the real state of the case, after examining the data observed in different countries in a mineralogical, stratigraphical, and palæontological point of view.

After describing the mineralogical character of the beds in question in different parts of Europe, he comes to the conclusion that the petrographical constitution of the zone is always dependent on the nature of the underlying beds, or of the coasts which were washed by the seas of this distant period. A coarse sandy conglomerate when in contact with the crystalline rocks, becomes a fine sand when it succeeds the grit of the Keuper, and marly limestone when it rests upon the variegated marls and other argillaceous beds. Thus it often happens that the lower beds resemble, and even alternate with, the Keuper for a certain time, and then in the upper portion pass by a regular transition into the overlying Lias. Mineralogically, therefore, there is no evidence to show that it belongs to the Lias or to the Keuper absolutely.

The same may be said respecting the stratigraphical evidence. With the exception of a few local cases of a very limited character, there does not appear to have been any violent or cataclysmal disturbance, either at the beginning or at the end of the *Avicula-contorta* period. In general, these beds are found to be in a position of conformable stratification, both with the Keuper and with the Lias.

The palæontological evidence is more important. M. Martin has carefully examined all the lists given by the different authors who have written on the subject, and endeavours to show how many species and genera are common to the Keuper and the *Avicula-contorta* zone, how many are peculiar to this zone, and how many it contains in common with the overlying Lias. After eliminating useless synonyms, he proceeds to examine the geological limits now known of the 149 genera, to which belong the 535 species which form the fauna of this formation. He thus finds that only 12 of these genera, containing 37 species, belong to the Palæozoic and Triassic formations, and appear for the last time in this zone; that 47 other genera, comprising 71 species, appear here for the first time, and extend in great numbers into the Jurassic series; that some are peculiar to this horizon, and that the remainder are common both to the overlying and underlying beds. From these lists alone, we find that the greater preponderance of forms connects this zone with the Lias rather than with the Keuper. He then analyzes the different classes with the same general result, except in the case of the Brachiopods, which show a greater affinity to the Keuper than to the Lias.

Again, looking at the question with regard to species, he finds a far greater number identical with the Lias than with the Keuper, and this with reference to the *flora* as well as to the *fauna*. The next question is whether this zone is to be considered as a distinct formation or merely as the lowest member of the Liassic series. There can be no doubt, according to M. Martin, that the number of organic forms which appear for the first time at this horizon is too great and too important not to be considered as characteristic of a distinct epoch; at the same time it is essentially Jurassic in its character, and should therefore be considered as the lowest member of the Jurassic series. The author concludes his paper with a series of propositions involving in a concise manner the arguments above recorded, but which it is hardly necessary to repeat on this occasion. I will merely add that he gives a list of sixteen species common to the *Avicula-contorta* zone and to the Trias, as well as another list of fifty-seven species common to this zone and the Liassic formation.

Dr. Benecke, of Heidelberg, in his work on the "Trias and Jura in the Southern Alps," published during the present year at Munich in the 'Geognostisch-palæontologische Beiträge,' has taken another view of this question, and endeavours to show, in opposition to the views of Renevier, Stoppani, and others, that the Rhætic beds including the *Avicula-contorta* zone, should be referred to the Trias rather than to the Lias. He denies that the Infralias possesses that peculiar character which justifies its being considered as a distinct formation intermediate between the Trias and Lias. But, independently of this question, the work of Dr. Benecke contains much valuable information respecting the stratigraphical details of these formations, and the comparison of those of Lombardy with those of Southern Germany. Nor is the palæontological element overlooked. The forms of animal life of the different strata are carefully compared, and the whole argument is mainly based on sections which he has himself observed in the different districts he describes.

On a former occasion I gave you some account of the observations of M. Renevier on the Infralias or Rhætic beds in the neighbourhood of the Lake of Geneva. He has since published an account of the geological formation of the Oldenhorn, a peak which rises to the height of 3124 metres a little to the eastward of the Diablerets. A short notice of this will not, I think, be uninteresting, as giving a clear explanation of some of the complicated structures of the secondary beds in this portion of the Alpine chain. After describing the orographical limits of what he calls the *massif* of the Oldenhorn, which is separated by a fault from the Col de Pillon on the north or north-west, he describes the different formations of which the northern slope of the mountain consists. These are broken into several alternating anticlinal and synclinal masses, or, as he calls them, *combes* and *vallons*, or saddles and troughs as they are sometimes called. It forms a portion of the Cretaceous and Nummulitic zone of the Alps. The principal nucleus of the formation is Neocomian, partially covered over by the Urgonian limestone, resting on which are occasionally found fragments of the Nummulitic beds, these generally occur in the troughs formed by the synclinal arrangement of the Urgonian limestone. Without going into all the details given by the author, it may suffice to say that these beds, which are sometimes seen in an almost horizontal position, become, higher up the mountain, completely vertical or even sometimes slightly inverted towards the north. This alternation is repeated several times.

This remarkable arrangement, he observes, is precisely similar to the saddles and troughs of the Jurassic chain, with this difference, that the system of contortion which in the Jura has a horizontal base, must be referred in the Alps to a highly inclined base line, so that the two sides of a trough which in the Jura "are symmetrically inclined, become in the Alps the one horizontal, and the other vertical." This is well shown in his section of the Sanetsch, where he has drawn an inclined ideal base line, which, when placed in a horizontal position, reduces the Alpine contortions and inversions to simple Jurassic undulations; by this means the structure of the Alpine beds is wonderfully simplified, and throws an interesting light on the mode of elevation of the chain of the Alps. Here, at least, it appears that the elevation of the Alps presents two principal elements. The first action formed the undulations of the beds, producing a structure analogous to that of the Jura; by the second, the whole mountain-mass underwent an unequal amount of elevation starting from the centre of the chain, producing an inverse effect on the undulating beds, raising up and overturning some, while others were brought into a horizontal position. This semi-jurassic orography has given him the key to other stratigraphical arrangements in the Alps, even more complicated and unusual.

The author then proceeds to describe the various formations, the most recent of which is the Nummulitic, which consists of four distinct beds, and, as I have observed, always occurs in the troughs formed by the synclinal Urgonian limestone. He mentions various points where it is seen, and the different fossils by which it is characterized. Several species of *Cerithium* are abundant in the lowest bed.

The next formation is the Urgonian. No traces of the Cenomanian, Gault, Aptian, or Rhodanian have been here found. The Urgonian formation consists chiefly of a white compact limestone. In its fracture it is slightly crystalline, sometimes white, but more frequently of a greyish hue, and except by its fossils is often hardly to be distinguished from the Nummulitic limestone. Wherever the Urgonian beds are broken through in the anticlinal saddles, a mass of brown schists rises up below them. The author attributes them to the Neocomian formation on account of the fossils they contain, as *Belemnites pistiliformis*, Blainv., *B. dilatatus*, Blainv., *Ostrea rectangularis*, Röm., a *Hamite*, and a *Terebratula* resembling *T. pseudojurensis*, Leym; at the same time he is not prepared to say that other older beds may not also be associated with the Neocomian.

To the N. or N.W. of the Oldenhorn rises the Col de Pillon, separated by a fault which follows the line of the river Dard to a well known spot called Sur Pillon. The beds to the north of this fault consist of alternating bands of gypsum and *Corgneule* or Rauchwacke, which, in accordance with the views of Prof. A. Favre, the author considers as belonging to the Triassic group. He has traced them to a considerable distance from the Plan des Isles to the eastward. It is difficult to make out their stratification; M. Renevier suspects that they represent repeated undulations of the same beds. They are in part concealed under erratic deposits, and appear to be overlain by the sandstones, schists, and conglomerates of Palette du Mont, the highest point of the mountain-mass to the north, and which is laid down as Flysch. No fossils have been found in these beds, nor in the gypsum or *Corgneule* of the Col de Pillon. The latter is generally more or less cellular, and the gypsum varies from white to grey.

Amongst the valuable works which have been published in Switzerland, I may also mention that of W. A. Ooster on the "Pétrifications remarquables des Alpes Suisses," in which he gives a full synopsis of all the fossil Echinoderms which have hitherto been discovered in the Alps of Switzerland. The work is illustrated by twenty-nine plates of fossils, and professes to give a description of all the species hitherto known, from the Infraliassic beds upwards to the Tertiary formations, amounting in the whole to 193 species, which are thus distributed:—Trias 3, Infralias 4, Lias 4, Jurassic 27, Cretaceous 93, and Tertiary 62 species.

In the last year's volume of the 'Zeitschrift der Deutschen Geologischen Gesellshaft' will be found an interesting account of a visit to the copper-mines of Monte Catini in Tuscany, and to some other places in their neighbourhood, by Herr von Rath, of Bonn. The mineralogical and physical features of the country are well pourtrayed, as well as the different geological formations. The sterile aspect of the Pliocene clay-hills, on which every attempt at cultivation has failed, is graphically described, and we have also a full account of the Borax Lagoons (Lagoni) of Monte Cerboli.

There is, however, one passage in this memoir which has surprised me. In describing the well-known statuary marble of Carrara, which belongs to the Lias formation, the author says that in the Apuan Alps the finest statuary marble occurs in large lenticular masses, which are surrounded by a husk or crust containing much mica or talc and other substances, and are imbedded in the common crystalline limestone. This husk is called "Madre-macchia;" and the more it is developed, the purer is the marble within.

This is precisely the manner in which the pure white alabaster of Florence is found in the gypsum-quarries of Castellina, as I have already described it *. I have also visited the marble-quarries of Carrara but never observed this peculiar structure there. No doubt the marble varies much in quality in different localities and on different hills, but it always occurs in large amorphous fissured masses, all trace of stratification being removed by the metamorphism it has undergone. If the author has not, as I suspect, confounded the structure of the alabaster with that of the statuary-marble, it will be a curious coincidence to find that both occur under such similar circumstances. The explanation of this structure given by the author is no doubt correct, viz., that during the metamorphosis of the limestone or gypsum, the foreign particles mixed up with it were driven out by chemical action and formed the Madre-macchia; and the more this was done, the more perfect was the marble or alabaster.

Prof. Reuss has published in the 'Transactions of the Imperial Academy of Sciences at Vienna,' a paper on a portion of the fauna of the Upper Oligocene formation of Germany, viz. the Foraminifera, Anthozoa, and Bryozoa. The author's former works on these minute forms are well known; and, after alluding to the previous partial publications of other authors, he observes that, owing to the large mass of materials placed in his hands by numerous palæontologists as the results of recent investigations, including all the known German localities of Upper Oligocene beds, he has been enabled to compile a complete view of the whole Foraminiferous, Anthozoan, and Bryozoan fauna of the Upper Oligocene. Should future researches lead to the discovery of a few more species, they would only fill up gaps, but in no way effect any important change in the general view of the question. Before describing the individual species he makes the following remarks :—

1. *Foraminifera.*—Hitherto 142 species have been observed, with two remarkable varieties. Of these only 5, which, moreover, are very scarce, belong to the division with siliceous shells; 16 species have a thick calcareous shell without pores; the great majority, viz., 121 species, have a calcareous poriferous shell.

From the table of genera it appears that the Rhabdoideæ (with 21 species), the Cristellarideæ (with 25 species), the Polymorphinideæ (with 40 species), and the Rotalideæ (with 19 species) are the most abundant. The genera containing the greatest number of species are, *Cristellaria*, *Robulina*, *Globulina*, *Polymorphina*, and *Rotalia*. He then adds a list of those species which are the most abundant and characteristic of the whole fauna, the more so as they are almost all peculiar to the Upper Oligocene.

* Quart. Journ. Geol. Soc. vol. i. p. 282.

He then arranges all the species in a tabular form, showing not only their vertical range in the different Tertiary stages in which they occur, but also their horizontal development, viz. the different Upper Oligocene deposits in which they have hitherto been found. This list shows that the Ahnegraben near Cassel has alone afforded 88 species, the greater part of which are only found in few localities. Very few species have a wide distribution. With regard to the vertical distribution, 67 species have been found only in the Upper Oligocene, to which they seem peculiarly to belong; 47 species descend into the Middle Oligocene or Septaria Clay, and of these 5 reach the Miocene, 3 the Pliocene, and 1 species is still living. Altogether the Upper Oligocene has 42 species in common with the Miocene, 5 of which extend into the Pliocene and 10 are still living.

"Taking all these facts into consideration," observes Prof. Reuss, "we come to this conclusion, that the Foraminiferous fauna of the Upper Oligocene beds is very peculiar, and easily recognized under all circumstances. The marks of distinction are partly common, partly special: the former rest on the remarkable preponderance of various *Polymorphinideæ* and *Cristellarideæ*, and on the abundance of the otherwise scarce *Flabellinæ*; the latter on the numerous species peculiar to the Cassel beds, amongst which the above-mentioned 17 species are remarkable, partly for the great abundance of individuals, and partly for their distribution over almost all the Upper Oligocene localities."

The author then gives a description of all the observed species, with their situation, history, and localities, and adds five well-executed plates of figured illustrations.

2. *Anthozoa*.—Only seven species have hitherto been found which can safely be referred to the Cassel beds; others may perhaps be found by other authors, but the characteristic evidence is still incomplete. Of these 7 species, 3 belong to the *Caryophyllideæ*, 3 to the *Turbinoliæ*, and 1, viz. *Cryptaxis alloporoides*, to the *Madriporideæ*. Fragments of other species have, however, been found too imperfect to describe, and authors have also quoted some which Prof. Reuss has not had an opportunity of examining; the whole number is therefore probably greater. The author then gives a detailed account of the different species at present known to him.

3. *Bryozoa*.—These are much more numerous in the Cassel beds alone. The author is already acquainted with 73 species, and there are probably others. A tabular statement of their different localities then follows, from which it appears that they are very unequally distributed. Thirty-seven species have been found at Astrupp and 28 at Luithorst. It is, however, worthy of notice, that many of these Bryozoa extend through several stages of the Tertiary formation, and they must therefore have continued to exist through a long period of time. This is in direct opposition to the opinion of F. A. Römer, who has stated that each species of Bryozoa is peculiar to one Tertiary formation, and that any one Bryozoon is sufficient to fix the age of the formation in which it is found. This Prof. Reuss considers to be an error. Then follows the detailed

account of the individual species. It must also be stated that the work is accompanied by 15 plates of illustrations.

Although perhaps more interesting in an ethnological than in a geological point of view, we cannot altogether exclude from our notice the phenomena attending the first appearance of Man on our planet. The discoveries of the last few years have satisfactorily shown that the opinions formerly entertained of a great break existing between the period when the now extinct races of Mammalia dwelt in our land, and the first creation of Man, are no longer tenable. Here also we have been obliged to give up the theory of great breaks between successive formations. As we find a gradual passage from one geological formation to another evidenced by the *gradual* dying out of the pre-existing forms of animal life, and the *gradual* introduction of newer, and generally higher, forms (although we do not yet understand the law of such progressive changes), so, when we come to the most recent, or Quaternary, periods in geological chronology, we find evidence of Man's existence on the earth before the final disappearance of those varied forms of mammalian life which have hitherto been generally looked upon as belonging to the final period of the geological cycle. Thus Man of the present day is connected by an almost unbroken series of links with the recently discovered Foraminifera of the Laurentian gneiss. Let me not, however, be supposed to be thereby giving in my adhesion to the doctrines of development, either to that of Lamarck or to the more recent and captivating views of Mr. Darwin.

Since, then, we must now admit human remains, and the evidences of human existence, as belonging to the last period of geological history, I cannot refrain from alluding to some of the publications which have recently appeared on this subject.

Dr. Felix Garrigou, of Tarascon, has published an interesting work on the old Quaternary alluviums and the bone-caves of the Pyrenees and of the West of Europe. After pointing out that different caves contain different animal remains generally, in accordance with the various positions of the caves, he shows that some caves contain as many as three distinct beds characterized by their different contents, as, *e. g.*, the cave of Mas-d'Azil.

The first period is characterized by *Ursus spelæus*, *U. priscus*, *Felis spelæa*, *Hyæna spelæa*, *Elephas primigenius*, *Rhinoceros tichorhinus*, *Megaceros hibernicus*, *Cervus elaphus*, *Bos primigenius*, *Bison europæus*, and sometimes *Cervus tarandus*, &c. The second period is that in which the Reindeer is most prominent; with it are found the Horse, *Megaceros hibernicus*, *Cervus elaphus*, *Bos primigenius*, Aurochs, Sheep, Chamois, Bouquetin, Wolf, and Fox, and a third species of *Canis*, perhaps intermediate between these two last, but no domesticated animals. The fauna of the third or prehistoric period, found at the entrance of caverns and in beds overlying those which contain the Reindeer, consists of *Ursus arctos* (still living in the Pyrenees), three species of *Bos* (domesticated), the Goat, Sheep, *Sus scrofa palustris*, *Sus scrofa ferus*, *Cervus elaphus*, Roebuck, Bouquetin, Chamois, Wolf, Fox, domestic Dog, Hare, Blackcock, &c.

The author then observes that, "as the stratigraphical and palæontological researches point to three distinct periods from the commencement of the Quaternary epoch down to the historic times, so the study of the remains of human industry, so constantly recurring with the different faunas described above, also prove that these divisions are correct;" and he assumes that from the commencement of the Quaternary epoch there are in the south of France three great distinct phases in the palæontological history of this period, as well as in the history of the civilization of the peoples which have lived since the commencement of that epoch.

1. In the first great phase, Man was the cotemporary of the great Cave Bear, and of all those animals which have been shown as accompanying this great mammifer. The bones of these animals lie together, broken by man, either in the old Quaternary alluviums of the sub-Pyrenean valleys, in caves, situated from 150 to 250 metres above the level of the present valleys. The remains of human industry found with the remains of these extinct mammifers indicate an early art somewhat resembling that of the stone implements of Abbeville.

2. During this first phase the great Carnivora and Pachydermata became extinct. The Reindeer, owing to favourable conditions, increased and multiplied, and became characteristic of a second phase, during which Man had not yet learnt to domesticate animals. But human industry had made considerable progress: the flints are prepared with art and neatness, and bones are worked with more intelligence, as they show traces of sculpture and drawing. The Reindeer and its accompanying fauna are found in grottos situated near the foot of the mountain, and at a lower level than those which contain the *Ursus spelæus*; they are also found in some caves in beds overlying those which contain the mammifers of the older period.

3. The third phase is characterized by a fauna consisting chiefly of domesticated animals, the remains of which are found at the mouths of caves in the bottoms of the valleys, and sometimes in a soil which forms beds overlying those containing either the great Cave Bear or the Reindeer. Man has learnt to polish stones, they are only occasionally cut; he is acquainted with agriculture, but has not yet learnt the use of metals.

The author then applies these principles, with the same results, to the other parts of France, as well as to Belgium and the west of Germany, and concludes with a chronological review of the various Mammalia composing the old Quaternary fauna, to serve as a basis for the geological history of Man, which the author subdivides into various epochs, from the doubtful Pliocene of Chartres to the earliest historic period, and concludes with a sketch of some of the geological causes which have led to the cave-phenomena of the Pyrenees, and a statement of the different heights at which these caves occur, for which I must refer you to the work itself.

In continuation of his great work on 'Paléontologie Stratigraphique,' M. d'Archiac has published another volume, entitled 'Leçons sur la faune Quaternaire,' which the editor considers as a continuation of the 'Introduction à l'étude de la Paléontologie Stratigraphique,' already published. It may also be considered as the first application of the method recommended by him, and, strictly speaking, as the commencement of his course of lectures, the object of which is the exposition of the characters and of the distribution of the fossil floras and faunas which have been successively developed on the surface of the earth. In attempting to give a slight sketch of this interesting work, I pass over the first lecture, which gives a *résumé* of the first portion of his course. The second lecture describes the Quaternary fauna of the eastern and central parts of France. After alluding to the evidence of glacial action in the mountains of the Vosges, the author states that the Quaternary deposits which fill up the depression between these mountains and the parallel chain of the Black Forest on the eastern border of the Rhine, consist of three principal members.

1. The ancient alluvium, or loess, forms the uppermost or most recent member.

2. Beneath this are beds of transported pebbles and blocks, which, derived from the Vosges and the Black Forest, are connected with the glacial phenomena of those chains.

3. These again rest on a deposit of rolled pebbles, designated as the *Alpine erratic deposit*, or Alpine diluvium, occupying the bottom of the great valley of the Rhine.

These three deposits represent three successive epochs. The loess is found on the flanks of the hills rising to a greater elevation in proportion as we ascend the Rhine valley. At Bonn it is found at an elevation of only 65 metres, between Heidelberg and Heilbron at 260 metres, and on the flanks of the volcanic mountain of the Kaiserstuhl it rises to the height of 400 to 450 metres. It contains about 20 species of land and freshwater mollusca, most, if not all, of which belong to living species. In its lower beds have been found the bones of extinct Mammalia, *Elephas primigenius*, *Rhinoceros tichorhinus*, Ox, Horse, and Deer. In the second deposit have only been found a few species of freshwater shells, but in great abundance. The third member or *Alpine deposit* is remarkable for the great number of bones of extinct Mammalia found in it, including, besides those just mentioned, *Ursus spelæus*, *Hyæna spelæa*, *Cervus megaceros*, *Equus adamiticus*, *Bos priscus*, and *Cervus priscus*.

He then compares the loess of the Rhine with the old alluvium of the north of France; the second deposit is compared to certain portions of the basin of the Seine, where beds of transported pebbles and red sand without fossils are found; and, lastly, the sands with rolled pebbles forming the bottom of the plain of the Rhine are the same as those which occupy the lower portions of the valleys of the north of France and of Belgium, containing the same fossils and offering the same physical characters, being exclusively composed of the detritus of rocks which form the respective basins of each depression.

Following this arrangement, the author describes the Quaternary deposits of the different geological regions of France, giving full historical details of their progressive discoveries and of their respective authors. He then proceeds to discuss in the same way the organic remains found in the caverns and osseous breccias in different parts of France.

In describing the caverns of Arcy near Vermenton in Burgundy, he states that in 1858 M. de Vibraye undertook the careful exploration and examination of one of these caverns. He made out the existence of three distinct layers or formations, and in the lowest, containing the remains of *Ursus spelæus, Hyæna spelæa, Rhinoceros tichorhinus,* &c., he found a human jaw, still retaining two teeth *in situ,* in immediate contact with the bones of the extinct Mammalia. All the characters of the substance of this jaw were identical with those of the bones with which it was associated and very different from those found in either of the overlying beds. With such evidence he observes that it is almost impossible to resist the conclusion that Man was the cotemporary of these extinct animals.

The author also shows, with reference to the caverns of other parts of France, and especially in Languedoc and in the Pyrenees, that incontestable evidence has been found, not only of the existence of Man during the later periods when the Reindeer abounded all over France and the great Mammalia appear to have become extinct, but even during the period of their existence; and in concluding his chapter on the caves and osseous breccias of the Pyrenees, he observes that, in the valleys of the basin of the Ariége alone, the elements of human chronology from the earliest Quaternary epoch, viz., that of the *Ursus spelæus* down to the time of the lacustrine habitations of Switzerland, are such as have nowhere else been found within so small a space; and he adds that, notwithstanding these accumulated proofs, there are persons who still refuse to believe in the contemporaneity of Man with the great extinct species of Mammalia. "But," he adds, "the history of science shows us at every step instances of this opposition to the introduction of new ideas contrary to old theories, and which wound the opinions and *amour propre* of individuals; let us not therefore be astonished at what we see around us on this question, but let us hope everything from time and perseverance in inquiries, which will ultimately get the better of these oppositions as they have already done of so many others."

The author then proceeds to examine these Quaternary deposits on the northern and southern flanks of the Alps with the same general results, those of the Mediterranean, Asia, North and South America, Australia, and New Zealand, giving in every case an account of the most recent discoveries bearing on this important and complicated question; and he shows, in conclusion, that the phenomena observed in America and Australia confirm the observations made in Europe and Asia, viz., that the fauna of the great extinct Mammalia characterized by the *Elephas primigenius, Rhinoceros tichorhinus, Ursus spelæus,* &c. must be separated from the fauna of the present day. At the same time the difference between the characters of the Quaternary fauna, when compared with those of the existing fauna, are by no means the same in different classes: in the lower marine animals, as well as in the land and freshwater mollusca, the differences are very slight; amongst the mammifers it is generally the contrary. The analogy of the Quaternary and modern faunas is subject to its own particular law in each natural division; it is the more striking in proportion as the animals under consideration are of smaller size. If we examine the fossil Mammalia of the southern hemisphere, either by orders, by families, or by genera, we first find that the animals are larger than their congeners of the present day; and secondly, that the species which are identical with those of the present day, or nearly so, are the smallest.

After alluding to the theory of Prof. Owen in his Memoir on the Megatherium, in which he endeavours to explain why the races of smaller forms of animals have had a more prolonged existence than those of greater size, viz., because they could more easily accommodate themselves to those changes in the conditions of life under which the larger forms could no longer exist, he observes that, as a general rule, we find in the different classes of fossil animals the duration of species, and even of genera, is in an inverse ratio to their size and mass, whereas the normal life of individuals is generally in a direct ratio to their size.

"It is," he observes, in conclusion, "a mere question of time, for which man, still new on the surface of the earth, has no chronometer to enable him to measure the periods of existence of the beings which surround him. Palæontology, it is true, reveals to us the existence of gigantic reptiles in past ages, which have successively appeared and disappeared; and the small animals, their cotemporaries, have equally undergone the inevitable law of the renewal of types, both large and small, and of their continual replacement. It is true, we do not observe this movement about us; we are disposed to believe that organic nature, which, since the beginning of creation, has never ceased to modify itself, has become immoveable since Man's appearance, that the laws of succession have been replaced by mere laws of preservation; in a word, that creation is complete and finished.

"This, undoubtedly, is an illusion, caused by this fact, that the few dozen centuries which constitute our history are not sufficient to bear witness to any important changes; but if study and observation have taught us anything, it is this, that the history of the whole human race is of no more account in the history of nature than the life of those ephemeral insects of which a single day beholds the birth, the reproduction, and the death."

An interesting Monograph has been lately published by Dr. G. A. Maack, entitled 'Palæontological Inquiries respecting hitherto unknown *Lophiodon* Fossils from Heidenheim on the Hahnenkamme in Central Franconia, together with a Critical Review of all the hitherto known species of the genus *Lophiodon*.' In describing the historical development of this genus, the author remarks that the great gap which exists between the Ruminants and Multungula (Vielhufer) of the existing fauna has been in a great measure filled up by the discovery of fossil remains. The contrast hitherto supposed to exist between these different types has been removed by means of the fossil remains of the now extinct Elasmotheria, Palæotheria, Lophiodonta, Anthracotheria, &c. The object of this memoir is to describe more fully than has yet been done the peculiar zoological position of the genus *Lophiodon*, and its connexion with, and difference from, allied genera, so far as it can be done with the help of the hitherto discovered fossil remains.

He then proceeds to describe all the known species of *Lophiodon*, and begins by subdividing the genus into the five following subgenera, according to the different structure of the teeth in each separate species:—1. *Coryphodon*, Owen; 2. *Tapirotherium*, Blainv., this is the typical form to which Cuvier gave the name of *Lophiodon* in 1822, although Blainville had already named it in 1817; 3. *Pachynolophus*, Pomel.; 4. *Lophiotherium*, Gervais; and 5. *Tapirulus*, Gervais.

The next subject to which the author directs his attention is the examination of the *Lophiodon* remains of Heidenheim. This important discovery was made by Rütimeyer not long ago, and Dr. Maack has been enabled to examine and compare about forty well-preserved teeth, besides fragments of teeth, jaws, and bones. These are all carefully described, and some curious anomalies in the structure of the different teeth are pointed out. Thus he observes that neither the molar nor premolar teeth of his new species, *L. rhinocerodes*, would, either in form or structure, give any clue as to what the canine or incisor teeth were; on the contrary, we should be greatly misled if we attempted, from the remarkable resemblance between the molar teeth of *Tapir* and *Lophiodon*, to infer a similar resemblance between the canine and incisor teeth of both animals.

He then discusses the zoological position of the genus *Lophiodon*, and shows, as a necessary consequence of recent discoveries, and of which he gives Rütimeyer the chief credit, that it belongs to the great family of *Pachydermata omnivora*, and concludes that *Lophiodon* is not connected with *Tapir* and *Palæotherium*, although in the structure of its teeth it combines many characters of these two genera, but that it is more closely allied to the genera *Chæropotamus*, *Hyopotamus*, and *Anthracotherium*.

With regard to the geological age of the beds in which *Lophiodon* has been found, he comes to the conclusion, that this genus, with its cotemporaries, formed a peculiar fauna, the remains of which are buried in the clays, lignites, marls, freshwater conglomerates, and marine limestones of the age of the *calcaire grossier* of Paris. The work is illustrated by fourteen plates, chiefly representing the different teeth in various positions.

I think it may be interesting to allude here to a new theory respecting the transport of erratic blocks recently published by Count Keyserling*.

Finding great difficulty in accounting for many of the phenomena which accompany the erratic blocks which cover the level lands of

* Mélanges physiques et chimiques tirés du Bulletin de l'Acad. Imp. des Sciences de S. Pétersburg, tome v.

Livonia by the usually adopted theory of glaciers or of floating icebergs, Count Keyserling calls attention to phenomena recently observed on the shores of the gulf of Pernau as affording a more satisfactory explanation, showing a movement of ice from the sea-level inland and uphill.

During the first frosts of 1863, a vast field of ice, from 2 to 2½ feet thick, had formed itself on the shore, extending far out to sea. The water then rose about 4 feet, owing to the milder weather, covering the field of ice. This was subsequently raised by the water, and formed a free-floating field of ice of enormous extent. A violent storm on the 15th and 16th of January drove this field of ice against the shore, and forced it with great power over the land. Similar occurrences, but on a much smaller scale, had previously taken place; but now, owing to the much greater thickness of the ice, the event assumed an intensity which had not been observed for several generations; three peasants' dwellings on the promontory of the Tackerort were so suddenly invaded by the ice and destroyed, that the inhabitants lost all their property, and had only time to escape with their lives. The ice here rose 60 feet above the level of the sea; in other places, where the shore was less steep and only 12 feet above the sea, the ice came upon a fir-wood, broke the stems (some of which were 13 inches in diameter), threw them down, and covered them with an unbroken coat of ice. Wherever the floating field of ice encountered a steep precipice, it rose up like a sheet of paper, its free edge rose over the land, and then, turning over, fell partly into the sea and partly in fragments over the land and was pushed further in. On the flat shore of Heuschläger the ice was driven 1023 feet inland, carrying with it a vast quantity of stones; at the same time, stones were everywhere raised out of the sea by the ice and driven on shore.

When Count Keyserling himself visited the spot, he found a block of granite, weighing about 60 poods (2160 pounds), lying amongst the blocks of ice, 30 feet above the level of the sea, and which had evidently been raised by the ice from the bottom of the sea, thus confirming the generally received opinions respecting the transport of stones by means of ice. In another spot, where there is a land-cliff 30 feet high, he found a heap of ice-blocks 10 feet thick, which had been generally tilted into an almost vertical position. Their upper surfaces were covered with gravel and stones; the lower surface was pure ice, and had originally formed the upper surface of the field, thus showing that the broken masses of ice had been completely overturned by the violent pressure.

"If now," adds Count Keyserling, "we could suppose that during the period of the great erratic phenomena the same circumstance took place, but on a larger scale, so that fields of ice of many hundred square miles and 4 feet thick were periodically driven over the land, we should have a natural explanation of the scratched surfaces in parallel lines, and also of the non-marine character of the erratic deposits." He considers that these phenomena show how blocks of stone out of the sea can be pushed by ice into places far beyond the reach of the water, and how deposits may be formed along the coasts high above the level of the sea resembling true inundations on the shore.

As an appendix to these observations of Count Keyserling, Prof. Baer, of the Academy of Sciences, has added some interesting remarks of his own respecting huge boulders which he had himself seen in various spots along the coast of Finland and the adjacent islands, some of which are of great size, and all of which, he was told by the inhabitants, had been driven into their present position by the pressure of the great fields of ice. He then proceeds to give an account of the island Laven Lari, on the coast of Esthonia, where he considers that erratic phenomena are still going on, although the chief events took place at a far distant period. He compares the present form and outline, and its accumulation of gravels and boulders, with those given in older maps, and believes that the map of Spafariew, published in 1822, on data obtained in 1813, although not absolutely correct, is yet sufficiently so as to justify the assumption that the differences in the two maps represent the changes which have taken place in the last quarter of a century. The reports of the inhabitants respecting the movements of the ice would appear to account for these changes, which are closely connected with the facts communicated by Count Keyserling.

At the same time Prof. Baer admits that other causes of this change of form may possibly have come into play; as the inhabitants alluded to the conviction of the gradual rising of their island above the level of the sea, without, however, giving any satisfactory reasons. In conclusion, Prof. Baer states, as the result of his observations, that very large boulders are only seldom moved by ice; moderate sized ones more frequently; but that small blocks, particularly near the level of the sea, are so frequently moved and heaped together by ice, that they escape the notice of the inhabitants, and yet produce important changes in the outlines of the flatter island in the course of a century. Thus erratic phenomena are continued even to the present day, although the distribution of the superficial boulders appears to point to an enormous lapse of time.

But there are other erratic blocks found buried in the soil far inland, which can hardly be referred to the action of the present sea and its floating ice, and these extend as far as Moskow. In the Gulf of Finland also are great masses of blocks which reach so near the surface of the water as to cause serious impediments to navigation. The Professor concludes by distinguishing still existing or recent erratic phenomena from others which may be called diluvial, and considers the floating ice and the present level of the sea, or perhaps one slightly elevated, as a sufficient explanation of the former. With regard to the older erratic or diluvial phenomena he has no suggestion to make, but advocates the necessity of further local observations.

Don Casiano di Prado has published during the past year 'A Physical and Geological Description of the Province of Madrid.' On this occasion I need only refer to the second or geological portion of the work. He says that in this province are found remains of the organic life of the Silurian period in beds which rise to a height of

2000 mètres, and this formation was not again submerged until about the commencement of the Cretaceous period; but before the close of this period both these formations were again raised above the surface of the sea, and there is not the slightest evidence that they were ever again submerged, as the Tertiary deposits which rest upon the Cretaceous have been entirely, or at least for the most part, formed at the bottom of a great freshwater lake. The Quaternary or diluvial beds were also formed in fresh water, and at a period when this lake had been partially filled up and drained.

The series of formations is therefore far from complete in the province. Of the Palæozoic period, the Devonian, Carboniferous, and Permian are wanting; of the Mesozoic or Secondary period there are no traces of the Triassic, Jurassic, and a portion of the Cretaceous beds; and of the Tertiary period only the Miocene occurs, there being no certain evidence either of Eocene or Pliocene. The result is, that the formations which are found in the province of Madrid are Plutonic, consisting exclusively of granitic and gneissic rocks, Silurian, a portion of the Cretaceous, part of the Tertiary, the Quaternary, and recent formations.

The author then describes these different rocks, commencing with the granite, which occurs principally in three distinct masses, lying in a N.E. and S.W. direction. But there are also numerous granitic islets in the gneissic rocks, many of which are so small that it has been impossible to lay them down on a geological map; they extend into the provinces of Toledo, Segovia, and Avila, and even into those of Salamanca and Cáceres, forming one of the most extensive granitic regions of the peninsula. He then describes in great detail all the different varieties of granite, passing into kaoline, syenite, pegmatite, micaceous porphyry, and many others; also the external forms and structure of these masses, many of which are very remarkable, caused chiefly by the unequal decomposition of the rock. Isolated peaks and pillars, from 12 to 26 mètres in height, have been thus produced, and the "mountain of the seven peaks" has been crowned with its seven isolated craggy rocks. These granite masses are often traversed by fissures of various width, but sometimes large enough to be used as threshing-floors by the peasants.

The author then enters into long details respecting the origin and decomposition of the granite. He adopts the modern views that water was no less necessary to its formation than fire, and thinks that it must have formed the first crust of the earth, though he is hardly prepared to say whether the granite of Madrid belongs to this primordial granite, or to those masses which have been subsequently erupted; but there is no doubt that much of it belongs to the erupted class. Some of the phenomena accompanying this process show that not only have great disturbances and dislocations taken place, but that the more recent and easily decomposed granites contain blocks of an older period, and of a harder and more compact nature.

The gneiss is less extensively developed than the granite, but occurs under a great variety of forms, as micaceous, felspathic, quartzose, amphibolic, &c., all of which are described by the author; it sometimes contains masses and veins of granite, in other places it is interstratified with calcareous bands or nodules, metamorphic, and so charged with magnesia as to be useless for burning. It is generally stratified, and rises into more rugged crests and crags than the granite, though this is not so much the case in the province of Madrid itself as in the neighbouring districts.

With regard to the origin of the gneissic rocks which were formed by sedimentary action, the author observes that they are not all of the same age. In the province of Madrid the gneiss is decidedly metamorphic and contains beds of limestone which do not occur in the Silurian formation. The gneiss has undergone much less decomposition than the granite, although it appears to have been eroded on a very large scale. This strikes Don Casiano as worthy of notice, inasmuch as the granite contains 30 per cent. of quartz, whereas in the gneiss this latter substance is almost entirely wanting, and of the three component elements of both these rocks the quartz is the least subject to decomposition. Other remarkable instances of the decomposition of the gneiss are then described and commented on; but my space and your time will not allow me to enter further into their consideration.

The author then describes the Silurian formation, which, however, is not of any great extent in this province; it consists chiefly of slates, sandstone, and quartzite, the former being most preponderating. Roofing-slate does not occur here, though it is found in the neighbouring provinces of Segovia and Guadalajara. The amount of denudation in former periods has been very great, and the quartzites which alternate with the slates having offered greater resistance to this action are now seen standing out and forming rough and rugged crests. After describing the principal strikes of these beds, which oscillate from N. 20° E. to N. 22° W., and the metamorphic action to which they have been exposed, the author proceeds to describe the fossils which have been found in them.

These are very scarce in the province of Madrid, though many casts of *Graptolites* have been found in that of Segovia. Those described here are:—*Cruziana* six species; *Scolithus*, *Orthoceras*, *Lingula*, one each. Several forms of *Acephala* have also been met with, but in too imperfect a condition to allow of their being satisfactorily determined. These are followed by an account of the veins and minerals which occur in the granite, gneiss, and Silurian beds; these are both metalliferous and non-metalliferous. The latter consist chiefly of pegmatite, quartz, and diorite: the metalliferous veins contain a little silver, galena, sulphate of barytes, fluorspar, and iron pyrites. These metals occur sometimes in detached masses or nodules, and sometimes disseminated throughout the whole substance of the rock. Between the years 1841 and 1860 there was a great development of mining enterprise, but the results were anything but satisfactory.

The author then describes in detail the various minerals found in the granitic, gneissic, and Silurian rocks, and concludes this portion of his work with an account of the different systems of elevation which prevail throughout these formations. The direction of the principal mountain-chain which traverses the peninsula from Lisbon to the Pico de Grado, passing through the provinces of Segovia, Soria, and Guadalajara, is from E. 27° N. to W. 27° S.; four other important mountain-chains run nearly parallel to it, although slightly obliquely. The author then, taking up the views of M. Elie de Beaumont, endeavours, I think somewhat hastily, to refer these different lines of elevations to the different systems laid down by the great French geologist in the European region: thus he refers the chains of the Guadarama, La Gata, and La Estrella, the mean direction of which is E. 39° N., to the System of Westmoreland, which throughout Europe oscillates between N.E. and E.N.E. But it is unnecessary to pursue this question any further.

*Cretaceous formation.*—In the district under consideration Don Casiano has found only one of the four groups into which M. d'Archiac divides this formation, namely, the Lower Chalk (*craie tuffeau*), the second in descending order. He has found no trace either of the white chalk immediately above, or of the gault immediately below, or of the fourth or lower group. It is found only in narrow and contorted bands in certain spots; this is all that remains of the greater extent of ground it must have originally covered, except such portions as may be concealed by the Tertiary and Quaternary deposits, and which towards the south may extend continuously into the province of Cuenca. There is no appearance that the Cretaceous sea ever extended further west than the Mota del Cuervo in this last-mentioned province, or Quintanar de la Orden in that of Toledo, or Quijorna in that of Madrid, Espinar in that of Segovia, or the river Luna in the province of Leon. In this ancient sea the Sierra, or mountain-chain of Guadarama, formed one peninsula, which terminated towards the east, not far from the Pico de Grado, and another smaller, within the province of Madrid. The author then describes the different bands which he has examined; their dip is generally S.E., and they are of no very great breadth or length, but are naturally broader where the dip is less. One of these bands, in the neighbourhood of Atalaya del Vellon, has been broken through at the spot where its strike is curved round, forming a gorge of a few metres in breadth, at the bottom of which the mica schist (*micacita*) on which the chalk rests is exposed.

The prevailing rock in this formation is limestone, varying much both in colour and in structure, being occasionally quite spathose or crystalline; very little of it can be used either for building-purposes or for lime. It is sometimes argillaceous or marly. Chalk-marl occurs in some of the beds, as well as sandstones, apparently Greensand. In this and in the lower beds a few traces of lignite occur, which in former times, and especially in the reign of Charles III., gave rise to the most extravagant expectations respecting the coal of Manzanares, which was said to be superior to that of England, because it contained more sulphur! The greatest thickness of the Cretaceous formation is about 300 metres, but in many places it has been reduced by denudation to from 20 to 25 and even 17 metres.

A description of one section given by the author as seen between Madrid and Burgos, before entering Molar, will suffice to give an idea of the superposition of the beds. They dip 30° S.E. The base consists of a few metres of arenaceous beds resting on the gneiss, having in the middle a thin band of limestone. These are followed in ascending order by a considerable thickness of limestones of various qualities, succeeded by a thick mass of marls and argillaceous limestone, and thin beds of limestone containing an irregular tabular vein of manganese; the whole being followed by the diluvial gravels. In some places, as at Atalaya del Vellon, marly beds are interstratified with the lower arenaceous beds. After describing the general form and structure of the principal masses of this formation, which has a general inclination of from 20° to 50° to the E., N.E., and S.E., according to the great bend to which these beds have been subjected, circling as it were round a central point, the author notices the principal escarpments and ravines, and some of the numerous and extensive caverns met with in this province.

He then proceeds to describe the fossils of the formation. These are very few, but, as he observes, sufficient to identify this formation as the second group or Lower Chalk. The following are the species found and described by Don Casiano:—*Astarte striata* Sow.; *Arca Cenomanensis*, d'Orb.; *Mytilus Verneuili*, a new species resembling *M. alternatus*; *Lima cretosa*, Duj.; *Lima dichotoma*, Reuss; *Avicula pectinoides*, Reuss; *Avicula Villanovana*, a new species; *Pecten tricostatus*, Bayle; *P. quinquecostatus*, Sow.; *Sphærulites squamosus*, d'Orb.; *Hemiaster Fourneti*, Desh.; *Nucleolites lacunosus* (?), Agas., in bad condition; *Arca*, new species, resembling *A. Tailleburguensis*; *Terebratula*, probably a new species. The author also mentions other genera, of which he discovered fragments too imperfect to enable him to give their specific denomination, as a claw of a Crab, the cast of a *Tilostoma*, three species of *Cardium*, a *Cardita*, *Cyprina*, *Arca*, *Mytilus*, *Modiola*, two species of *Ostrea*, several *Rudistes*, and two small Echinodermata.

It may be here observed that the general *facies* of this list, imperfect as it is, corresponds with the fact mentioned by Sir C. Lyell in the last edition of 'The Elements of Geology'*, that in the rocks of the Cretaceous era in the south of Europe *Ammonites* are scarcely ever found, and the genera *Hamites*, *Turrilites*, *Scaphites*, and perhaps *Belemnites*, are entirely wanting; while, on the other hand, genera belonging to the great family of the *Rudistes* of Lamarck are generally abundant.

*Tertiary formation.*—This forms one of the three great belts into which the province of Madrid is divided, both geologically and geographically, extending from N.W. to S.E. Its thickness is considerable, but, owing to the effects of denudation, it is very variable; in some places, however, it is known to attain a thickness of about 340 metres without reaching the base. It is not a marine formation. The only fossils hitherto found are of terrestrial or freshwater

* 'Elements of Geology,' by Sir C. Lyell, 6th edit. p. 334.

origin, and they appear to belong to the Miocene period; consequently there was here a vast freshwater lake, extending from the Sierra de Guadarama to the Sierra Morena and Montes de Toledo, and even to the mountains of Valencia and Murcia, although in this direction it is somewhat difficult to fix its limits. The rocks of which it consists are limestones of different varieties, clay, gypsum, marls, sands and gravels, siliceous beds (*pedernal* flint), magnesite, and conglomerate or pudding-stone; the three former are the most abundant, and they are not associated with any plutonic or volcanic rock in the province. A considerable portion of the upper bed has been removed by denudation; by this means, and owing to the violent action of the rivers during the Quaternary period, the physical aspect of the country has been greatly modified. Low plains and narrow valleys have been formed, which have been again partially covered up by diluvium. In other places where the beds, which are generally horizontal, have not been affected by denudation, they form vast upland plains, called wildernesses or deserts (*páramos*); but where the upper bed of limestone has been removed by denudation the surface is much more irregular. Generally speaking, the structure or arrangement of this formation is simple enough where the strata are horizontal; but this is not generally the case, as the author proceeds to show in detail, and particularly in some places where the inclination of the strata is almost vertical.

This formation may be separated into three divisions. Limestone prevails in the upper almost exclusively; the middle division, which has the least thickness, consists chiefly of clay and gypsum, and the lowest consists of sandstones and conglomerates. The author then describes in great detail various localities where these different beds are found alternating with each other, and varying even within short distances, the chief peculiarity being that the gypsum always occurs in the central beds. The best building-stone in the province is quarried in the neighbourhood of Colmenar de Oreja; the quarrymen give a different name to each band. Some are better than others; but all are rather apt to split, and great care is necessary in using them for building-purposes to see that the blocks are placed in their natural position.

The siliceous deposits are the most irregular in the whole formation. Sometimes the silex forms large masses in the clay; sometimes it occurs as small angular blocks. Near Vicálbaro rounded blocks of the same substance are found, and in one spot large irregular nodules or slabs of flint form in the clay an irregular bed, which is extensively quarried and used in Madrid.

In order to account for the great variations which occur in these beds even within short distances, the author refers to a suggestion thrown out by M. d'Archiac, namely, that the material for these rocks was supplied from copious mineral springs, and is not alone the result of matter transported by the streams from the surrounding hills. But this explanation does not appear to him sufficient, even without taking into account those rocks which could not have been formed in this manner; and he observes that this variation is the more remarkable, inasmuch as it does not occur in the older rocks, which are generally persistent for great distances and throughout their whole thickness, except in the case of the conglomerates.

Amongst the special phenomena which the author describes in this formation, may be mentioned the great inclination of the upper limestone beds in certain localities, also that the disturbances in the stratification of the zone of clays and gypsum are much more distinct than in the upper zone of limestone; they present numerous undulations more or less abrupt in their stratification. On the left bank of the Jarama are the soda-mines of Protectora, 4 or 5 kilometres east of Crempozuelos; the beds are horizontal and consist of clays and gypsum. The sulphates of soda and of soda and lime which are worked, occur chiefly in the clays extending through a thickness of about 15 metres; they occur either in detached masses in cracks and hollows, or disseminated throughout the whole mass. One of these cracks is very remarkable, having an undulating course in a more or less horizontal direction. Other local disturbances and unconformabilities of the different strata are described; they are probably owing to some agitation of the waters of the lake during the process of deposition. The origin of these rocks is attributed to mechanical or chemical causes, and sometimes to a combination of the two. The origin of the gypsum appears to the author more involved in difficulty. Was it derived from springs of water which held it in solution, or was it the result of metamorphic action? The gypsum of Madrid is found in beds and in the crystalline form of selenite. Masses of both kinds occur also in the argillaceous beds; sometimes only loose plates of selenite occur, at others it occurs in veins either single or intersecting each other, and in many other forms. The saccharoid gypsum or alabaster is scarce in this province, but it abounds in the neighbouring province of Guadalajara, where it forms large masses or nodules, which are enveloped in a red argillaceous covering or coat*.

The formation of silex and resinite was also probably owing to springs containing it in solution. The emission of silex during this period must have been enormous, for almost all the Tertiary limestones contain it in large proportions, as much as 20, 30, or 40 per cent. Magnesia and salts of soda are also abundant; but rock-salt does not exist in this province, although it is found in the neighbouring province of Toledo, on the south side of the Tagus, and in the district of the Ebro at Remolinos, province of Zaragoza. Here the beds of rock-salt are of great thickness, it being, as the author observes, a remarkable fact that this substance, originally derived from the sea (?), should occur so abundantly in a freshwater formation.

The author next describes in detail the different minerals found in this formation, many of which are interesting, and might be made of great commercial importance; they are quartz, flint or silex, resinite (both opal and hyalite), nitre, salt, sulphate of soda, thenardite,

* See Description of Nodules of Alabaster in the Mines of Castellana in Tuscany, by W. J. H. Quart. Journ. Geol. Soc. vol. i. p. 282.

glauberite, carbonate of lime, sulphate of lime, magnesite, argile, and traces of lignite. With regard to its palæontology, the author states that, strange as it may appear, not a single fossil shell has been found of which it was possible to determine the species: the fossils belong to the genera *Helix*, *Lymnæa*, *Planorbis*, and *Paludina*. *Melanopsis* has been found in the neighbouring provinces of Guadalajara and Toledo. This is an interesting fact, inasmuch as Spain is the only European region in which a true living *Melanopsis* is found, if we except *M. buccinoides* or *prærosa*, which is found in Greece, but belongs to the Asiatic provinces, being abundant in many parts of Asia Minor.

With regard to the land and freshwater shells of this Tertiary formation, the author observes that he has only found casts of them; and after pointing out the importance of local monographs of different Tertiary districts in Spain, he observes that, "if a geologist would devote himself for several years exclusively to the study of the Tertiary formations of the peninsula, he has no doubt but that he would discover numerous fossils of many classes."

Mammalian remains, however, have been found in a better state of preservation, and these are decidedly characteristic of the Miocene age. No bones have been found in the upper or limestone zone in this province; but they occur in the underlying marls and in the neighbouring province of Toledo, near Barcience. The characteristic species which the author has met with are *Mastodon angustidens*, *M. tapiroides*, *Palæotherium Aurelianense*, and *Hipparion*, and a questionable case of *Anoplotherium murinum*. For better identification the author has added engravings of most of the dental remains which he found; and in addition to those mentioned above is a molar tooth of *Rhinoceros Matritensis*, Lartet, a molar of *Sus*, probably *S. Lockarti*. *Sus palæochœrus* has also been found near Madrid, but the author had not seen it, as well as molars of *Palæomeryx*, probably *P. Bojani*.

The author then describes the different elevatory actions to which the Cretaceous and Tertiary formations have been subjected. These have evidently been both partial and general; but, as the author observes, much remains to be done, in Spain particularly, to enable the geologist to reduce the elevatory phenomena to anything approaching a perfect system. The concluding portion of the work is devoted to a minute examination and description of the deposits of the Quaternary or Diluvial period; the various phenomena attending them and the different rocks of which they are composed are analyzed with great care. Traces of glacial action are uncertain; the author rather inclines to the belief that the Diluvial beds owe their origin to aqueous causes; a certain amount of stratification is generally visible. The Diluvium may be separated into three divisions; the uppermost, which is most seen in this province, consists of sands, the second of marls and clay, and the third or lowest of gravel or stone. These are the terms usually applied by the workmen; but, as the author observes, there are clays and gravel in the uppermost, gravel and sand in the second, and sand in the lowest beds. He then describes the successive changes and phenomena which took place during this period, tending to the deposition and formation of the different beds; he also alludes to the great changes which the older rocks themselves, which form the Diluvium, have undergone during this period. The quartz and quartzites are generally only changed into rolled pebbles, although some blocks of quartzite are to be seen with traces of a conical structure, as if they had been violently struck with a heavy blow; this is shown on the outside by circular fissures which penetrate into the interior, expanding more and more from the centre; the feldspar and Silurian slates are reduced to an argillaceous state. Even the blocks of granite have so completely lost their coherence that they can be cut through with the spade or mattock. The same thing occurs with the limestone, and even with gneiss, which is generally so little liable to decomposition. One of the most remarkable diluvial phenomena in this district is, that the calcareous rocks, after losing their coherence by the operation of diluvial agents, and being scattered amongst the sands and clays, did not become mixed up with them, but remained quite isolated, although reduced to a soft earthy state. Very few cases of hard rock occur in the Quaternary beds, although the author observed a few small bands or patches of conglomerate or pudding-stone cemented together by a calcareous or ferruginous matrix. Calcareous tuff is very scarce. There are very few caverns of any importance in the limestone rocks in this district. There is only one worth noticing, called the Cueva del Reguerillo, in the Ponton de la Oliva; it contains numerous stalactitic and stalagmitic formations. No bones, ancient or modern, have been found in it; but as yet no excavations have been made in the stalagmitic bottom, although in the neighbouring provinces of Segovia and Guadalajara there are several caverns from which objects of great interest have been collected. The author does not say what they were.

The palæontological discoveries in this Quaternary formation are extremely poor in Spain, in the province of Madrid almost *nil*; tusks and bones of an elephant were found by M. Graells near San Isidro. This probably belongs to a new species; for the author states that Dr. Falconer, who saw the remains in Madrid, at once declared that they did not belong to either *Elephas primigenius*, or *E. africanus*, or *E. armenianus*. Another lower jaw with three molar teeth, also found near San Isidro, probably belongs to *Cervus elaphus*. *Cervus tarandus* has not yet been found in Spain, and it is remarkable that these two species are never found inhabiting the same locality.

The author concludes with an account of some flint hatchets found in the diluvium of San Isidro, as far back as 1850, in the gravel and below the beds containing the elephant bones, and with some remarks on the antiquity of man, on the recent and vegetable soils, and on the remains of pre-historic times. He feelingly alludes to the difficulties he has had to contend with in the total absence of all geological observations on this district before he undertook his task; and every geologist will sympathize with his last words—"I always started from Madrid with my knapsack and hammer cheerful and full of joy, on my return I never entered its gates without a vague feeling of sadness."

I have much pleasure in stating that four more parts of the work of Major Crescenzo Montagna, entitled 'Generazione della terra,' to which I alluded on a former occasion, have since been published; they are written in the same moderate and careful spirit as the former ones. The author has avoided all extreme and exaggerated views. He adheres to the generally received opinions respecting the fixity of species, and protests strongly against the doctrine of transmutation and the Darwinian theory. In the 16th and 17th chapters of the fourth book will be found some interesting considerations respecting the appearance and disappearance of species on the surface of the earth. He rejects the doctrine of great breaks in the order of succession of animal life, as well as of those cataclysmal paroxysms which are supposed to have caused them; on the contrary, he finds a passage of genera, and even of species, from one formation to another; many species have survived the causes which led to the destruction of others, and have continued to live on together with the newly created forms. And with regard to the introduction of new and the extinction of old species, he points to many causes which may have occasioned the latter phenomena; but he maintains that man in his present state of knowledge is unable to understand how new forms have been brought into existence, except by the will and law of the Creator. With regard to the extinction of species he has, however, committed one serious geographical error when he states (p. 335), "Quite recently, according to Lyell, the extinction of the Dodo has been noticed, a bird which at no very distant period was an inhabitant of the British Isles."

He protests in the strongest language against the doctrine of transformation of species, and considers the idea that a mollusk could become a fish, or a lizard a man, as worthy only of a madman, and as giving but poor evidence of the progress of civilization at the present time.

In a subsequent passage, however, he bears testimony to Mr. Darwin's great merits in showing to what an extent the *variety* of species does sometimes extend, and in endeavouring to get rid of the endless multiplication of species which some naturalists endeavour to set up on the strength of slight variations of form and markings, which are really only the result of local conditions or a change of geographical position.

The work is accompanied by numerous plates, drawn and engraved by the author himself. It is, however, to be regretted that the work has not been more expeditiously completed, as the last numbers have not yet been published.

In the Bulletin of the Geological Society of France for last year*, M. Boué has published a paper giving his reasons for now modifying some of his views respecting his classification of Turkish Geology, published in 1840. Human knowledge, he says, advances by the

* Bull. de la Soc. Géol. de France, deuxième série, vol. xxii. p. 164.

discovery of new facts as well as by the application of new theories. He shows that this has been the case in every branch of science. Zoology, propped up by comparative anatomy, is now a very different science from what it was; it is the same in the case of geology, both theoretical and practical. About 20,000 works or memoirs have as yet appeared on geological geography, the publication of which, during the last fifty years, shows a kind of geometrical progression. The range of geological science increases in proportion as we discover new facts, and these again increase the number of formations and the limits of their successive beds.

M. Boué then points out the difficulties he had to contend with when he made his expeditions into Turkey, partly owing to the social and physical condition of the country itself, and partly to the total absence of all knowledge respecting the physical features of the country and the want of correct maps. Even the geology of the neighbouring countries with which that of Turkey in Europe is connected, namely, the Eastern Alps, the Carpathians, and Transylvania, was but imperfectly known at that time. Thanks to the Geological Institute of Vienna, these points have now been clearly made out, and we have the means of instituting a more satisfactory comparison between the formations of the two districts; but a new expedition into Turkey in Europe is much wanted. In the meantime, M. Boué endeavours in the following propositions to point out some of the errors contained in his former works:—

1. He is convinced of the existence of the *Palæozoic system* in Turkey in Europe, not only along the Bosphorus and in the central portion of the chain which runs along the coast of the Black Sea, the Little Balkan, but also in the centre of Upper Mœsia, and in the middle of Bosnia, about Voinitza, towards Trawnik and Kiseliak.

2. If the old Carboniferous formation appears to be wanting in Turkey, the *Trias* of the Alps and the Carpathians, with its peculiar *facies*, exists in many places, as in the south-east of Servia, in Western Bulgaria and Upper Mœsia (part of Servia), and in parts of Bosnia. He does not believe it exists in Epirus or Albania. It is probably covered up by younger formations in the Herzegovina. M. Hauer has found a trace of it at the southern extremity of Austrian Albania.

3. The Alpine Lias, that compact and partly dolomitized limestone characterized by *Megalodon*, appears to occupy a considerable portion of Turkey, particularly in Bosnia and Servia, and many other localities which are mentioned by the author with more or less certainty.

4. Various *Jurassic beds*, which, for want of evidence, cannot be more specially described, occur in the mountains of the Bannat and Servia, and in the south-west of Servia, in Bosnia, and in Mount Pindus, now Mezzovo, and in the chain of Agropotamos [query Aspropotamos?]. He also is of opinion that the beds of Kössen and of Hierlatz occur in Bosnia.

5. The *Dolomitic* formation forms a serrated and sometimes double ridge between the Prokletia and the Albanian Drino as far as Vronatz

in Central Bosnia, as well as in the south of Montenegro, in Macedonia, and in other places. He thinks it was a mistake to class these rocks with the Cretaceous system, on account of their close resemblance to the dolomites of the Tyrol and of the Eastern Alps. He is inclined to adopt the view of M. Richtofer, that the dolomites are the remains of coral-reefs partly denuded and considerably mineralized.

6. The *Neocomian* system appears to be very abundant in Turkey particularly in the Balkan, Upper Eastern Macedonia, Western Dardania, and in Servia, probably also in Bosnia. It is very fossiliferous.

7. The *Cretaceous* formation with *Orbitolites* traverses the whole of Bulgaria a short distance to the north of the Balkan. It also occurs in the centre of Servia, with many fossils.

8. The *Gosau* formation is found occasionally in Turkey, particularly in Eastern Servia and in Bosnia, characterized by *Tornatella gigantea*. Limestones with *Nerinæa* are also found in Upper Albania.

9. The *Cretaceous* system with *Rudistes* occurs in considerable masses throughout Western Turkey and in Macedonia, as well as in Servia. It is marked by bands of fossils on several plateaux of the limestone-mountains of Bosnia, Upper Albania, and Mount Pindus, as well as in the south-west of Macedonia.

10. The *Chalk-marl* with *Belemnites* has only been observed in Western Bulgaria.

11. The *Eocene arenaceous beds* of the Carpathians and Vienna, or the Tertiary flysch, is well developed in Central Servia, Western Bulgaria, Epirus, and Southern Albania along the coast.

12. The *Nummulitic system* occurs in parts of Albania towards Epirus, in the west of Thessaly, Southern Albania, and in the Herzegovina, as well as in the neighbourhood of Varna, in Bulgaria, and in Eastern Thrace.

13. The *Miocene* formation, or rather the *Neogene* of Vienna, is found with its clays and fossiliferous limestones in the great Servian valleys, in the basins of the Nish and Upper Drin, and in numerous other basins throughout the country.

14. Erratic blocks are doubtful.

15. The author also mentions several places where the Eocene beds have been pierced by serpentines, diorites, and metalliferous porphyries.

In the 'Smithsonian Contributions to Knowledge' for 1865 will be found an interesting work by Dr. Leidy on the Cretaceous Reptiles of North America. The author had originally intended to include an account of the fossil fishes, and thus to form a monograph of the extinct vertebrata of the Cretaceous period; but this he found was impracticable at present. No other vertebrata, birds or mammals, have been found in the Cretaceous deposits of any part of America. Most of the fossil remains described in his memoir were obtained in New Jersey; many were found in the Greensand, which is largely excavated for agricultural purposes, and others were obtained from limestone beds. The Cretaceous formations constitute a large tract of country, extending through the States of New Jersey, Maryland, and Delaware; they appear in isolated patches in North and South Carolina and in Georgia. More extensively developed in the western portion of the latter state, they curve in a wide crescent-shaped tract through Alabama, Mississippi, and Tennessee, to the mouth of the Ohio river. Thence, passing in a narrow band through Arkansas, they afterwards expand to an enormous extent, and occupy a great portion of the region between the Mississippi river and the Rocky Mountains, reaching north into the British possessions and south into Mexico.

Then follows a very detailed account of all the species hitherto found in the United States, the most characteristic of the Crocodilian remains being a nearly entire skull of *Thoracosaurus neocesariensis*. The species described are 28 in number, belonging to 23 genera, viz. 18 Saurians and 5 Chelonians. The work is illustrated by 20 beautifully executed lithographic plates, and the author anticipates that, when the western and southern Cretaceous regions shall have been explored, many additions will be made to these remains, nearly all of which have been obtained from the eastern border.

I stated last year that M. Jules Marcou had discovered and described a remarkable deposit of fossil plants in the Nebraska territory, which, from its position, appeared to be unequivocally Cretaceous, although the forms were considered by Professor Heer to be of decidedly Miocene character. I have now before me an interesting notice on the position of these leaf-beds of the Nebraska by MM. Capellini and Heer, the former of whom visited and examined them in 1863, while the latter gives a detailed account of the species. Notwithstanding his first conviction that the beds containing the vegetable impressions belonged to a Tertiary formation, M. Capellini was convinced by subsequent examinations that they occurred at the base of the Cretaceous beds, well marked by the abundance of *Inoceramus problematicus*. The vast extent of country over which these beds occur in an undisturbed horizontal position precludes the possibility of any inversion of the strata.

The following observations of Professor Heer, before describing the species, will be read with interest. The collection consists of 16 species (all leaves), four of which are badly preserved. They are all dicotyledonous, and we may in all probability refer 1 to the genus *Ficus*, 1 to *Salix*, 1 to *Diospyrus*, 2 to the genus *Populus*, and 2 to *Magnolia*. These are all living genera, and are also found in the Tertiary formation. Comparing these Nebraska plants with the Cretaceous plants of Europe, we find no identical species; even the greater part of the genera are different. The Cretaceous flora of Hainaut in Belgium, and those of Blankenburg and Quedlinburg, are also quite different. The Cretaceous flora of Moletein in Moravia offers a greater resemblance; it contains 2 species of *Ficus* and 2 of *Magnolia*. There exists, therefore, a certain relationship between the Nebraska flora and that of the Upper Chalk of Europe, although there are no identical species. Hitherto, however, the genera which characterize the Cretaceous flora of Europe have not been found at Nebraska.

If we compare the plants of the Nebraska with the Tertiary plants we find no identical species, but seven genera (*Populus, Salix, Ficus, Platanus, Andromeda, Diospyrus, and Magnolia*), which are both Miocene and still living; thus the flora of the Nebraska is more closely connected with the Tertiary than with the Cretaceous flora of Europe. We must also remember that we are acquainted with only a small number of the American species, and, on the other hand, that the Cretaceous flora of Europe is more allied to the Tertiary flora than was generally supposed. In the Cretaceous flora of Moletein in Moravia are found *Ficus* and *Magnolia*, which resemble Tertiary species; one of the *Myrtaceæ*, resembling the *Eucalyptus rhododendroides*, Mass., of Monte Bolca; a *Juglans*, and a *Laurinea*, analogous to those of the Tertiary flora; a *Pinus*, and two other *Coniferæ* belonging to the genus *Sequoia*, very abundant in Europe and America during the Miocene period, and which is now found only in California.

As the Cretaceous fishes more closely resemble the Tertiary than the Jurassic fishes, the Upper Cretaceous flora is also quite distinct from the Jurassic, and is more allied to the Tertiary flora; and it appears that in America there is a closer connexion between the Tertiary and the Cretaceous floras than in Europe.

It is very remarkable that the plants of the Nebraska bear so much resemblance to the living flora of America, whilst the Cretaceous flora of Europe has rather an Indo-Australian character. Thus it appears that since the Chalk period the flora of America has not undergone so great a change as the flora of Europe; and whilst the Cretaceous flora of Europe is altogether different from the living European flora, that of Nebraska contains eight genera which are still living in America; and it is remarkable that the greater part of them are still found in the same latitude.

I find in one of the last numbers of the 'Proceedings of the American Philosophical Society, held at Philadelphia'*, an interesting account by Mr. Lesley of a recent discovery of Lignite in iron-ore at Pond Bank, in Franklin County, Pennsylvania, and in which he describes the importance of the discovery in a theoretical point of view. Only one similar discovery had before been made, namely, in Vermont, and, as Mr. Lesley observes, they reopen the discussion of the age of the present Silurian, Devonian, and Carboniferous surfaces, and suggest an entire revolution in the generally accepted modes of regarding the production of Appalachian topography. The Lignite was struck in a shaft 40 feet below the surface; it contains large logs of wood, which is partly converted into a brilliant cannel coal, and the rest of it into common brown coal. Its extent is by no means considerable; and Mr. Lesley, dissenting from the views of Professor Hitchcock, describes it as a mere plug of coal thrust vertically downwards into a mass of clay. It is closely associated with

* Vol. ix. p. 463.

the great belt of iron-ore or hæmatite which extends along the great valley for many hundred miles in Pennsylvania and Virginia; but he is anxious to show that the Lignite and the iron-ore are neither of the same age nor possessed of any structural attribute common to both.

Mr. Lesley considers that it is the extreme rarity of these Lignite apparitions in one of the most wonderfully continuous, extensive, and valuable ore-belts of the world that gives them all their importance; and, notwithstanding the contrary assertions of Dr. Hitchcock, he maintains the importance of carefully separating these sporadic occurrences of Lignite from the general occurrence of the iron-ore.

In describing the principal features of the great ore-belt of the Atlantic States along the Great (Lower Silurian) Valley, which begins in Canada and ends in Alabama, he shows that it belongs geologically to the Lower Silurian limestone formation. It consists, however, of two parts—the one stratified as the Silurian limestones themselves, the other as a surface-wash over the basset edge of the first. The date of this latter may be Tertiary, or even later. The stratified portions must be of Lower Silurian age; but the metamorphism which they have undergone *in situ*, productive of stratified clays and ores, may date from any time subsequent to the formation of a surface-topography approximately identical with that which now exists. The actual change of the original Lower Silurian calcoferriferous sandstones and slates *in situ* into limonite-clay beds *in ipso situ*, stratified as before, but charged with an additional percentage of the oxides from a former higher surface now eroded, and with this extra charge of iron and manganese carried by percolation down to, and crystallized against, their foot rock, may have required an immense time for its completion, and was no doubt going on *pari passu* with the degradation of the surface by slow erosion from higher to lower levels. He then shows that this long era of iron-ore concentration in the Lower Silurian slates could not have commenced until after the close of the coal-era, and probably at a much later period.

The author then describes the exact geological position of the two great belts of iron deposit, the one at the point of contact between the Lower Silurian limestone and the overlying slate-formation, formerly a deposit of ferruginous mud; the second between the underlying slate and the lowest sandy layers of the limestone, lying along the foot and part way up the side of the south mountain. In one of these deposits in Pennsylvania the lignite has been found.

He then alludes to the system of underground caverns, which may, without much exaggeration, be called a single cave, extending for a thousand miles and including chambers, some of which, like Weir's Cave, have acquired a world-wide celebrity. Many of the brooks descending from the mountain-sides sink into these caverns. The river drainage on the surface and the cavern system below tell one story, namely, *the extra dissolubility of this particular horizon of Lower Silurian rocks.* The fissures which are now being enlarged into caves, and the caves which are fast growing into catacombs, their roofs every now and then falling so as to produce funnel-shaped sink-holes in the fields, and sometimes in the roads, receiving leaves, fruit, branches, shells, and other substances with every great spring-freshet —all these once had their analogues in time past.

The author then submits that, by thus reconstructing the older surfaces, we obtain a reasonable explanation of the sporadic masses of lignite, two of which are now known to exist in, or rather near, the iron-ore. It is only necessary to suppose a sink-hole so formed and so stopped up below as first to receive and then to retain an accumulation of forest-trash, and we have the thing ready made to our hand. The author then proceeds to describe in detail the ore-banks of Mont Alto, and the relationship of the lignite to the ore. The ore is in fact nothing but the residue of the Silurian slates and sandy limestone beds after decomposition and dissolution, after the lime has been washed out and their carbonated and sulphuretted iron has been hydrated and peroxidized, the muddy slates forming the present deposits of small ore with white and red clay, while the sandy limestone formed the present harder siliceous rock ore-belts. He concludes with some statistical details respecting the enormous masses of hæmatite contained in this remarkable formation.

As showing the intensity of geological changes now in operation, M. Jules Marcou gives an account, in the 'Bulletin de la Soc. Géol. de France,' of the result of his observations on the Falls of Niagara after an absence of fifteen years. Some of these changes are very remarkable. Looking at the falls from the Victoria point on the Canada shore, he says that he could not observe any sensible change in the fall on the left of the spectator, which is the American fall; but he was much struck with the changes which had taken place in the great fall to the right, known as the Canadian or horseshoe fall. The horseshoe form, which was tolerably regular in 1850, has been greatly modified, being considerably worn away and deepened in the centre. The table rock has almost entirely disappeared; also the tower known by the name of Terapine is nearer to the edge of the fall, on which side the mass of water appears to have increased, while it has diminished in volume near the table rock; there also appears to be a slight diminution in the volume of water passing by the American fall, between the American side and Goat Island.

He thus tabulates the results of his observations:—

1. The American fall retreats very slowly, and, compared with the Canadian fall, might be said to be almost stationary.

2. The volume of water in the American fall is constantly decreasing, and will continue to decrease in proportion as the Canadian fall retreats; and when the latter shall have reached the islands of the Three Sisters, viz., in eight or ten centuries, no more water will pass by the American fall. Goat Island will be joined to the mainland.

3. The Canadian fall is rapidly retreating, although it is impossible to give any rule of its annual retrograde progression, which varies from year to year.

4. The mass of water in the Canadian fall increases as it diminishes in the American fall, besides which it is leaving the Canada shore,

and is carried more towards Goat Island and the centre of the *horse-shoe*; from which he concludes that the retrograde movement of the Canadian fall will be more and more accelerated; that the valley of denudation of the river will approach Goat Island, and will then turn to the east with an abrupt angle as at the whirlpool, and that another whirlpool will be formed at the very spot where the Canadian fall is now placed.

He concludes his paper with some remarks respecting the stratigraphical relations of the rocks through which the river flows above and below the falls.

Amongst the more important works which deserve notice on an occasion like the present, I must not omit the 'Geological Description of New Zealand,' by Dr. Hochstetter, who, as geologist, accompanied the expedition of the Austrian frigate 'Novara' round the world. The work consists of a large quarto volume in two parts, the first of which is called 'The Geology of New Zealand,' the second 'The Palæontology of New Zealand.' In the very interesting introduction to this work Dr. Hochstetter shows that the three islands belong to one and the same system, marked by a characteristic line of elevation from S.W. to N.E. interrupted by Cook's Straits between the two principal islands. This mountain-chain of true alpine character forms the backbone of the islands, and is said to consist of zones of stratified and unstratified mountain-masses of different ages, which have been raised by plutonic action. It is accompanied, in the northern island at its western base, and in the southern island at its eastern base, by zones of volcanic rocks, which have been affected down to the latest periods by deep-seated igneous action. The lofty formations of the volcanic zones, and new Tertiary and Quaternary sedimentary deposits, have given to these islands their present form; which is, however, even now undergoing constant changes, both from earthquakes and from still continuing elevations and depressions. The geological maps of these islands, even in their still imperfect state, as compared with the detailed geological maps of western Europe, show a very great variety of formations; and although it may not yet be possible to establish an exact parallelism between them and the order of formations in Europe, there is already sufficient evidence to prove that the stratified rocks of Europe have here their representatives from the oldest metamorphic formations to the newest sedimentary deposits, and that the eruptive formations extend from the oldest plutonic rocks to the most recent volcanic lavas.

He considers that New Zealand, with its peculiar living fauna and flora, differing so completely from the neighbouring regions of Australia, the South-Sea Islands, and South America, is admirably adapted for testing the correctness of the theory of Professor Agassiz, that no specific identity can be shown between animals living at a great distance from each other, even when they existed contemporaneously; but that rather genera of the same family, even when belonging to different geological periods, are more closely allied to each other when they belong to the same latitudes than those of the same geological age, but which are derived from different geographical zones.

With regard to the marine fauna, it appears from Dr. Zittel's examination of the fossils that the molluscous fauna of the younger Tertiary deposits is closely allied to the living fauna, very much in the same proportion as that of the Subapennine formation of Italy is allied to the existing fauna of the Mediterranean. The same genera occur, both fossil and living, and even the species are not unfrequently identical; at the same time they have a great resemblance to the Tertiary fossils of Chili and Patagonia described by Sowerby and D'Orbigny, *i. e.* to a fossil fauna of the same age and from the same degree of latitude.

But if we consider the remains derived from older formations, we find that the *Ammonites, Belemnites, Inoceramus,* &c. of the northern island, which belong to the upper beds of the Mesozoic period (Jura and Chalk formation), so closely resemble European forms of the same age, that one is almost tempted to look upon them as European species; more particularly the *Belemnites,* belonging to the group of the *Canaliculati,* D'Orb., so completely agree with the *Belemn. canalicalatus,* Schloth, that it is almost impossible to find sufficient differences to justify the adoption of a new name. Moreover, the oldest fossiliferous beds which are found on the southern island, not far from Nelson, contain the genera *Monotis* and *Halobia,* which cannot be distinguished from the European forms *Monotis salinaria* and *Halobia Lommeli,* Wissm., from the Trias of the Alps.

Dr. Hochstetter observes that these facts, if confirmed, would go to prove that the faunas of former periods show an affinity and a correspondence in the northern and southern hemispheres which do not exist in the now living faunas—a conclusion hardly in accordance with the above-quoted views of Agassiz, but quite in harmony with the more generally prevailing opinion, that the older the formations are, the greater is the resemblance in their fossil remains, even in districts at a great distance from each other.

He then gives a general view of all the different formations, with their respective subdivisions in New Zealand, from which he concludes that "at the period when the neighbouring Australia, which was (at least so far as relates to those portions which consist of Palæozoic formations) one of the oldest continents of the earth, rose above the waters of the ocean, certain portions of New Zealand also appeared as rugged land above the ocean; in a different form, it is true, from what it now presents, and possibly in connexion with vast continental masses which have long ago been again submerged. But while Australia, in its eastern and western portions, has been little, if at all, disturbed since the conclusion of the Palæozoic period, so that animals and plants could live and reproduce themselves in an unbroken sequence down to the present day, New Zealand, on the contrary, was, even to the most recent period, the theatre of gigantic terrestrial disturbances and powerful terrestrial conflicts, which, continually changing the original form of the land, have gradually given it its present configuration.

After these general views, the author proceeds to give a detailed account of all the geological features of the north and south islands, describing first the physical features of the different regions, and then their respective geological formations in the following order:—1. Palæozoic; 2. Mesozoic; 3. Cainozoic, divided into brown coal-beds and marine deposits; 4. Post-tertiary formations; 5. Volcanic.

Amongst the volcanic phenomena hot springs and *fumarole* are most remarkable, and developed to an extent which can only be compared with the analogous phenomena in Iceland. Both the chemical and mechanical features in these hot springs are identically the same, notwithstanding the vast distance by which they are separated. Another remarkable fact is, that the crystalline, or metamorphic rocks, as well as the igneous rocks, as granite, syenite, &c., which form so important a feature in the southern island, are altogether wanting in the northern island.

The second part of this work contains, as I have said before, an account of the Palæontology of New Zealand, and consists of the following monographs:—

I. Remains of Fossil Plants, with 5 plates, by Dr. Franz Unger.

II. Fossil Mollusca and Echinodermata, with 10 plates, by Dr. Karl Zittel. The Brachiopods, by Edward Suess.

III. The Foraminifera of the Tertiary Greensand of Orakei Bay, near Auckland, with one plate, by Felix Karrer.

IV. Fossil Bryozoa from the Tertiary Sandstone of Orakei Bay, near Auckland, with 4 plates, by Dr. Ferdinand Stoliczka.

V. The Foraminifera of the Tertiary Marl of Whaingaroa Harbour (Auckland), with 4 plates, by Dr. Guido Stache.

VI. Report on an almost perfect skull of *Palapteryx*, with 2 plates, by Dr. Gustav Jaeger.

Dr. Stache concludes his interesting monograph (No. V.) with some important generalizations, and shows that this foraminiferous fauna belonged to two groups, evidently derived from two different sea-depths; and with regard to their geological age, he shows that they bear the greatest resemblance to the Neogene fauna of the Vienna basin, whilst at the same time there are indications of an older period, approaching the Upper Oligocene beds of the north of Germany.

I must now direct your attention to a work entitled 'Frost and Fire,' by Mr. J. F. Campbell, which will be read with satisfaction by all who are interested in the physical causes which have led to the structure of the earth's surface. Although the style of the work is somewhat quaint, and the arguments occasionally slightly obscure, we cannot but admire the energy and perseverance with which the author pursued his researches after the causes, whether heat or cold, frost or fire, which have been at work as the tools and forces which have shaped the earth's crust, either by denudation, deposition, or upheaval.

Starting from various physical calculations, balloon observations, and the temperature on high mountains, he assumes that a low temperature exists in the space through which the earth travels. Descending from these outer regions, through "air," "water," and "rocks," to mines, he finds that the temperature increases towards the earth's centre, while hot springs and lava-currents indicate still greater heat below the mines thus reached. Thus between attainable limits we find cold outside and heat inside the earth's crust composed of ponderable materials, all of which, either separately or combined, can, and do, exist in three conditions—namely, gaseous, fluid, and solid. Many of these materials are gaseous when heated, solid when cooled, and fluid at intermediate temperatures. Each melts and freezes, or solidifies at definite degrees of heat, and they vary in dimension and specific gravity according to temperature. Heat is force, according to modern views; and rays from the sun, from luminous substances thrown out from the earth, and from artificial sources of light, include heat-rays, and are consequently mechanical forces. Thus force radiates with light and heat from heated centres, causing expansion, and separating particles from each other.

Many examples of this action are given by the author in illustration of these views, drawn partly from natural phenomena, and partly from experiments ingeniously contrived by himself; a full description of the cooling of silver is given at p. 346, vol. ii., as one of the neatest experiments to illustrate the cooling of a molten mass. The same forms which he has observed growing on cooling slag, iron, silver, &c., he finds repeated on a larger scale in cold lavas, in hot and cold mountains, and in old igneous rocks in Iceland. He also alludes to the experiments recently made respecting the sun's atmosphere and the substances supposed to exist there, and to the gradual cooling of the different bodies which form our planetary system; and assumes that the earth, which is intermediate in size, is also in an intermediate state, partly fluid, partly solid, cooling, but still hot within.

Thus he assumes from the facts brought forward that an igneous foundation is the base on which the sedimentary rocks were deposited and now rest; he also assumes that air and water, steam and ice, moved by the two opposing forces, heat within and cold without, levitation and gravitation, have worn down the outer crust of the globe, and have sorted the *débris*, while movements in the igneous foundation, and heat radiating and transmitted from it have disturbed and altered the sedimentary deposits; he also considers that these causes have greatly diminished in intensity since they first began to act on the crust of the globe. He has illustrated by numerous drawings and descriptions the marks made by rivers, waves, currents, glaciers, &c., as well as those made by other denuding agents still at work.

He also assumes that in late geological periods the earth has cooled so far as to freeze water everywhere at the surface, were it not for heat radiating to it from the sun. We have reached a partial glacial period, and the position and extent of ice on the earth now depend on the amount of heat absorbed from the sun, and on movements in the igneous foundation or centre of the earth.

Some interesting experiments are also shown towards the end of the second volume to illustrate the effects of the earth's rotation on the currents of the ocean, and thus point out the course which arctic currents would have taken at a period when a larger portion of the northern hemisphere was submerged. The traces of these ancient currents are to be found in the scratchings and striæ which mark the rocks of Scandinavia and Great Britain, and other parts of Europe. There is no ice near the equator; perpetual ice near the poles, and more in winter than in summer, because of the earth's position; but it is owing to subterranean movements that ice formerly extended to lower latitudes in certain portions of the globe. Thus he shows that in consequence of a recent elevation of the fundamental rocks of Europe, and a probable sinking elsewhere, the waters which formerly covered certain parts of the surface have changed their position. The arctic stream, which flowed south and west, was thus diverted from those districts in Western Europe which have been raised above the level of the sea to the western side of the Atlantic; and with it have been carried those vast masses of ice and snow which formerly scratched and striated with their rocky contents the surface of Scandinavia and North-western Europe, depositing great boulders on their way, and which now condense, chiefly on Greenland, Labrador, Newfoundland, and North America.

Having thus endeavoured to explain the general theory of the author, I will merely state that the first volume is chiefly devoted to an account of the denudation of the earth's surface, the engines by which this has been effected, viz., frost and ice, and the tools which have actually done the work, glaciers, icebergs, and Arctic currents, as represented in Scandinavia, Iceland, Switzerland, and elsewhere.

The second volume continues the history of the same subject of denudation in the British Islands and America; and the author then proceeds to consider the question of deposition, the result or counterpart of denudation, inasmuch as the material removed by denudation from one place must be deposited somewhere else. Finally, the question of upheaval is also examined, and its causes and results duly considered; this, of course, is considered as the effect of the other great agent in modifying the earth's surface, viz., fire or heat. It is illustrated by many observations and experiments, drawn from the furnace and the smelting-works. These results are shown to be identical with the effects produced by volcanic action, indicating the existence of great central heat, causing disturbance of the earth's surface by earthquakes, and producing upheaval of vast regions by the expansion of subterranean matter.

But without going further into these dynamic questions, or discussing the probable correctness of some of his physical assumptions, I will merely refer to one point, to which Mr. Campbell's attention seems to have been particularly directed, I mean the striation and grooving of rocks by ice-action. Deeply interested in this question by the similarity of evidence found in so many countries, and the apparent parallelism of these striæ over vast regions of the earth, he has collected, partly by his own personal exertions and partly from the writings of others, a mass of evidence by which he has endeavoured to throw light on the causes of these phenomena. Thus, working his way back by analytical reasoning, calling to his assistance meteorological as well as geological evidence, the laws of physical science, and the counteracting influence of the two opposing forces heat and cold, he comes to the conclusion that these marks are the result of glacial action; and by further reasoning on the various phenomena above alluded to, he concludes that they have been caused by ice borne by an arctic current flowing from north-east to south-west. The denudation of the rocks in many parts of Sweden is enormous, but rivers and weathering will not account for this. The author observes (vol. i. p. 103) that "on the watershed not far from Tann Foss at the roadside (at a height which Robert Chambers estimates at 2000 feet) the clearest marks of glacial action are still perfectly fresh on rocks, in spite of weather and rivers. These marks prove that ice travelled over the hills from north-east to south-west, now 2000 feet above the present sea-level, at the place where streams now part and run to the Baltic and to the Atlantic."

As Scandinavia is now generally admitted to be rising from the sea, there is nothing preposterous in assuming that the greater part, if not the whole, of Sweden may once have been covered up by the waves of an arctic sea, in which currents must have existed, flowing, as now, in different directions, from north and south, according to those physical laws by which the movements of the ocean-currents are still regulated.

But the question of land-glaciers flowing down from high regions, and partly excavating the valleys down which they flow, and leaving their marks also in the shape of scratchings and striæ on the rocky flanks of the valleys, is not overlooked by the author; and on this subject also much valuable information may be gleaned from the pages in question. I will only add, that the many illustrations contained in this volume, and the quaint sources from which the author has sometimes drawn them, render his work one of great interest, and which it is impossible to peruse without deep thoughts and suggestions being forced on the reader's mind.

Before concluding these observations, I wish to bring to your notice one or two points which appear to me to merit the serious attention of geologists in the present day. Prof. Ramsay, in his Anniversary Address from this chair, alluded to the breaks in succession of the British Palæozoic and Mesozoic strata, and suggested the probability that these breaks represented periods of time even longer than those to which the various existing fossiliferous formations of Great Britain bear witness. Dr. Bigsby also not long ago brought under our notice a very interesting paper on missing sedimentary formations from suspension or removal of deposits, in which he has pointed out many of the breaks or gaps which occur between older and younger rocks, caused either by the subsequent removal of the intervening or missing beds, or because the older beds had been raised above the sea during the deposition elsewhere of the intermediate beds. Now it is well known that these breaks or gaps are only local; and the remark has been already made that, if we could only get a sufficient number of sections from all parts of the world, all these local gaps would be filled up, and we should have one unbroken sequence of formations, occurring in some part or other of the earth's surface, from the lowest Silurian or even Laurentian beds to the most recent Tertiary or Quaternary deposits. It would be an interesting task for any geologist to undertake to supply this want, and to point out the gradual succession of beds where they can be found, showing how they pass almost insensibly from one into the other, as the Rhætic beds are now shown to form an intermediate zone or passage from the Keuper to the Lias. We should then see by what almost insensible gradations the crust of the earth has been successively formed, and what were the conditions of life, or some of them at least, which led to the gradual introduction of new forms of life in some places, and their partial extinction in others. And as we have now learnt to recognize the fact that the extinct Mammalia of the Postglacial period had not all ceased to exist before the first appearance of man, we should also probably learn that at no period of the earth's history were all the forms of life destroyed before the introduction of new ones; but that a partial renewal only took place, and that somewhere or other the witnesses of one period lived on with the new creations to keep up an unbroken chain in the history of organic life from its earliest dawn to the present day.

Another point to which I would invite attention is one of greater difficulty; it requires the serious aid of chemistry, mineralogy, and the laws of physical forces. The study of the older crystalline and metamorphic rocks has of late years greatly occupied the attention of many of those geologists who have examined the chemical and mineralogical conditions of formations. We are told that heat alone could not have produced the results we see; that water was an essential element in all these metamorphic operations; and we find, in the works of Sterry Hunt, Daubrée, Evan Hopkins, Delesse, Desor, and others, that even a high degree of temperature was not always necessary to produce these changes. Many of those results which have hitherto been considered as the effect of igneous action, are now believed to be owing to chemical action continued through long periods of time. It therefore appears that the time is come when it is desirable to investigate this question; whether the theory of central incandescent heat is tenable? Whether the plastic condition of the earth, to which its oblate spheroidal form has been attributed, be not owing to an aqueous rather than to an igneous origin? Water is an essential element in every rock, not only mechanically but chemically; and without attempting to revive the doctrine of the Wernerian school, it may be questioned whether we have not sometimes been disposed to overlook the importance of the part it has played in the construction and solidification of our earth.

Another important subject arising out of this question, or rather accompanying it as a corollary, would be, whether the solidification of the earth began at the circumference, after its formation, as is assumed by the advocates of the central-heat theory, or whether the formation of the earth may not have commenced with a central nucleus consisting of an aqueous paste, gradually increasing in size as matter was deposited around it from the circumambient fluids and gases which filled the solar space before solid matter was aggregated round those spots which now form the planets in our solar system. It is a bold, perhaps even a rash thought, to go back to a period before the earth was formed; and yet such a period must have existed, or the earth would be eternal, which we have no right to assume. I will also venture to suggest one other question.

Assuming the possibility of an aqueous origin, and eliminating the theory of central heat, can we not account for all the volcanic and igneous phenomena which we find on the surface of the earth by chemical action taking place at a comparatively moderate distance below the surface? We know that heat and combustion can be thus produced, and we know that all the elements which are necessary for its production must have been contained within the earth's sphere.

But I will say no more on a question which requires so much close examination and cautious investigation. I recommend it to your consideration, in the hope that at no distant period some one will venture to grapple with it in earnest, and either point out the probability of what I have suggested, or prove its impossibility.

In conclusion, allow me to trespass on your time for a few moments longer, for the purpose of expressing my thanks to every Fellow of the Society, and particularly to the Members of the Council, for the kind support and assistance which, during the time I have occupied the chair, I have invariably met with at their hands. I am well aware of my many shortcomings, but, having ever taken a lively interest in the prosperity of the Society, I trust that this has not suffered during my Presidency. I look with confidence to the rapid increase of our Members, in the hope that that is the best proof that your interests have not suffered at my hands. I congratulate you on the choice of my successor, which you have this day made, feeling confident that, with such a President as you have to-day elected, the Society will continue to flourish as it has hitherto done, to add fresh laurels to its brow, and that it will continue to hold that high estimation in the opinion of men of science in every country which it can confidently boast of having hitherto invariably enjoyed.

THE

# QUARTERLY JOURNAL

OF

# THE GEOLOGICAL SOCIETY OF LONDON.

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## PROCEEDINGS

OF

## THE GEOLOGICAL SOCIETY.

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November 8, 1865.

Thomas William Danby, Esq., B.A., Downing College, Cambridge; William Poole King, Esq., Avon Side House, Clifton, Bristol; James L. Lobley, Esq., 50 Lansdowne Road, Kensington Park; John Richardson, Esq., C.E.; James Clifton Ward, Esq., Clapham Common; and Samuel Hansard Yockney, Esq., Mem. Inst., C.E., were elected Fellows.

The following communications were read:—

### 1. *On the* Submerged Forest-beds *of* Porlock Bay. By R. A. C. Godwin-Austen, Esq., F.R.S., For. Sec. G.S.

Contents.



#### § I. Geology of the District.

Porlock Bay is the seaward opening of a small valley; from Hurlston across to Gore Point is a distance of about three miles; its extent inland is five miles. The valley is bounded on the N.N.E. by North Hill (1030 ft.), Grabbist (960 ft.) separating it from the



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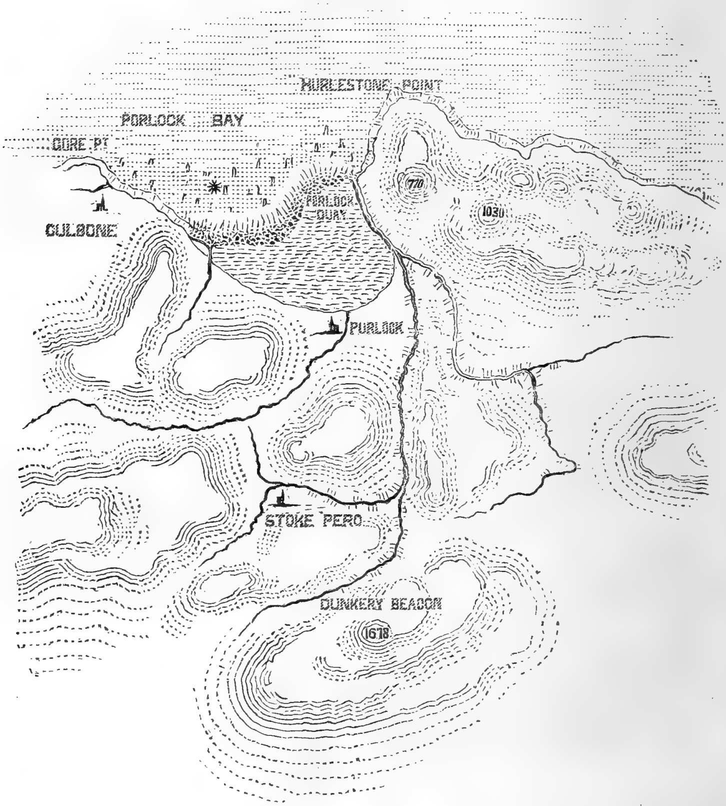
Minehead valley; on the S.S.W. rise Dunkerry Beacon (1678 ft.) and Porlock Hill; from its position, amidst some of the highest ground of the West of England, it presents some exquisite scenery, and has many points of geological interest.

In common with the broad valley between the Quantocks and the

*Sketch-map of the neighbourhood of Porlock.*




* Submerged Forest-beds.

Exmoor range, it affords the clearest evidences that the North Devon and Somerset ranges had acquired their elevations antecedently to the accumulation of "Red Conglomerate," as also of the Glacial conditions under which the materials of that Conglomerate were brought together. Surmounting these is the best exhibition to be met with in this county of the beds of the earliest Jurassic period—Sinémurien* (those to which the names Rhætic and Penarth have been given).

The range which bounds the Porlock valley on the S.W. extends from the Foreland, by Countesbury to Culbone and Oare, and is the highest land of Somerset. The mineral character of this great mass is very distinct from that of the grey slaty rocks, with calcareous bands and an abundant though obscurely preserved marine fauna, which extend from Linton southwards in ascending order. From the valley of the East Lyn to that of Porlock the rocks consist of hard splintery sandstones, grits, and pebble-beds, with partings of compact shales—the whole series being of various shades of red. It is the only portion of the North Devon and Somerset Palæozoic series which bears any resemblance to the "Old Red Sandstone" group of Wales and Gloucestershire. In many respects these rocks recall characters of parts of the Coal-measures, or of the Lower Wealden beds.

No animal remains have ever been met with from any part of the beds of the Countesbury series; plants have been found, and I have seen specimens which, though insufficient for description, left no doubt as to a terrestrial vegetation.

It is difficult to fix the place of the Countesbury rocks in the great Palæozoic series. The thought that they might belong to the true "Old Red Sandstone" age made me examine the sections along the East Lyn valley; but whereas the true "Old Red" everywhere in the West of England passes up into the Carboniferous group, this older Red, after one or two alternations, is surmounted by the marine Devonian series.

The pebble-beds and coarse grits of the Countesbury rocks indicate a shingly coast-line at no great distance. The absence of animal remains, and the presence of terrestrial plants, suggest that these may have been the depositions of a lacustrine area, older than the marine Devonian series of Southern Europe; yet, for all that, they need not be older than the lower "Old Red" of Glamorgan, Monmouth, and Hereford.

The great mass of the Countesbury and Dunkerry range has been produced by a great flexure, of which the steep slope is on the N.N.E. with an angle of 28°. The nature of the beds, and their highly inclined positions, are alike favourable for their deep disintegration.

## § II. The Forest-beds.

1. *Introduction.*—The whole of the coast-line of Britain is fringed with submerged forest-ground. Large tracts of it occur in the west: in Cardigan, St. Brides, and Swansea bays. On the south side of the Bristol Channel are those of the great Bridgewater levels, which extend seawards, well described by the late L. Horner, Dr. Buckland, and Mr. Conybeare; subsequently by Sir Henry De la Beche in his Report on Devon and West Somerset.

It has been long known that there was "submerged forest"

* Quart. Journ. Geol. Soc. vol. ii. p. 5.

beneath Porlock Bay: it is indicated in the Ordnance Map of Great Britain, as also in the Admiralty chart. Sir H. De la Beche gives the following short account of it:—

"At Porlock a small submarine forest is well exhibited at very low tides, the stumps of trees, which appear chiefly oaks, standing in the positions in which they grew. The present action of the sea has bared these trees, by removing the sand and silt which once covered them, as can be seen by the continuation of the same bed of vegetable matter inland, beneath sand and silt, behind the present shingle beach, that merely reposes on the inclined plain of the submarine forest*."

From a recent examination, the evidences of geological changes at this place appeared to me to require somewhat fuller detail than is given in the above; besides which, they better serve to illustrate the nature and order of oscillations of small amount, which have taken place at times shortly antecedent to the present, than do the instances of Bridgewater or Swansea bays.

The Porlock valley, viewed from any of the heights around, presents at its lowest level a line of coarse shingle, ridged up above ordinary high water by gales and high tides.

Within this barrier are grassy flats. Further in, these are bounded by a rise in the ground of from 10 to 15 feet; above this the surface of the ground slopes gently towards the hills, forming an under-terrace to them of variable width, being broadest and thickest opposite the openings of the deep gullies which score the rounded forms of these hill-sides.

These features are severally connected with the geological history of the valley.

Within the shingle ridge, broad water-courses have been cut across the salt-pastures, and good sections of the under-terrace may be seen along the water-courses, and in the low cliff from Porlock Quay eastwards. Beyond the shingle, and when tides are low, and the coast has been swept clean, the Forest-beds are well exhibited.

The chronological order is as follows (in descending order):—

Shingle bank.
Marine silt.
Surface of Plant-growth.
Fresh-water mud-deposit.
Forest-growth.
Angular detritus.

2. *The Shingle.*—The shingle-beach requires passing notice in respect of its position. It is composed wholly of the siliceous rocks of the coast from Porlock westward, and forms a ridge round the bay. On the land-side it ends abruptly, as if encroaching on the meadows; seawards it thins away, so that at extreme low water but little shingle remains, and in the offing the sea-bed is composed of sand and fragmentary shells.

The shingle, where now thickest, has been heaped up upon the surface of the meadows, no marine shingle of earlier date is any-

* Report on the Geology of Cornwall, Devon, and West Somerset, p. 419.

where to be seen on the inner or land-side, and the series of deposits which it overlies show that, with reference to past conditions, the most recent change has been one of slight depression.

3. *Marine silt.*—On the land-side of the shingle ridge is an expanse of salt-meadows, which at present are but occasionally, partially, and for short intervals covered with water; their level is at the very upper limit of the Bristol Channel waters. From the materials thrown out from the dykes cut across this flat, as also in the sections thus exhibited, the nature of the subsoil is well seen, consisting of mud-deposits. Of these the uppermost is of a yellowish-brown colour, and contains the shells of *Scrobicularia piperata*, with the valves united, and of all ages. The presence of these shells shows that the lower part of the Porlock valley was at one time in the condition of a mud-flat, wholly covered by the sea at every tide, perhaps even permanently covered—that they were then at or near the low-water level, or that the area was then depressed to the extent of the difference between high and low water; the range of *Scrobicularia piperata* being from low water to four fathoms beneath.

Beneath the Scrobicularian mud of the meadows is a band of vegetable matter, and under that a dark tenacious clay; these are better seen on the coast.

4. *Surface of Plant-growths.*—At low water, and when the coast has been swept clean of shingle, there is presented an expanse of mud-deposits, with the stumps of trees studded about. The mud-deposits occur in patches, owing to the action of the breakers, which cut out portions; around these patches are good sections.

The uppermost mud-deposit, that with the Scrobiculariæ, is not very resisting, so that it occurs only occasionally over the area left by the tide; enough, however, remains to show that it was at one time spread out continuously, with a like composition and under the same conditions as are presented by the beds beneath the meadows; as such it passes down beneath the present lowest water-level. Under the yellow mud-deposit is a dark band, and when the mud has been removed, the surface presents a layer of matted vegetable matter, seemingly composed of roots. This seam is in places several inches thick; on the underside roots descend into the subjacent clay, showing that it has been an old surface of plant-growths.

The stools of trees project slightly above the level of this old land surface; and *upon* it lie the trunks of trees. In every instance that I examined, the surface of plant-growths was interposed between the prostrate trunks and the underlying blue clay. There were stems measuring from 10 to 20 feet and more in length. They were mostly, if not altogether, the remains of trees which had died, and become bare of bark, some much decayed before they fell; they projected above the surface, and had not sunk into it, or the surface was firm, and not in the condition of a soft morass, when the trees fell upon it.

The roots and long leaves seemed to belong to an Iris, such as the common "Yellow Flag."

5. *Blue Mud-deposit.*—This is a very tenacious mass, resisting the action of the sea. It is of variable thickness, increasing as it passes down seawards. After most diligent search I was unable to find any evidence as to the nature of this deposit, whether freshwater or marine; in this respect it resembles the blue-clay deposit of the Bridgewater levels; from the abundance of diffused vegetable matter it has the appearance of being of freshwater origin.

It might seem at first sight, as indeed it did to Sir H. De la Beche, that the trees of the submerged forest had grown in this blue mud, from the manner in which they stand out of it; but the mud-deposit *surrounds* the stools of the trees, which never send roots into it; and wherever the mud has been removed the trees are seen to be rooted in the beds beneath. The accumulation of the mud has been subsequent to the forest-growth. The uniform level at which the trees have been cut off may, perhaps, indicate the level of the water which deposited the blue mud, and killed the trees at the same time.

6. *Submerged Forest.*—The interval left bare by the tide may, under favourable conditions, be seen studded thickly by the stools of large trees—some bare, some covered by a thick growth of seaweed, some just projecting above the mud-beds. Some are of large size; one measured 2 feet in diameter. The largest trees were the oaks, which may be distinguished by the black colour of the wood; others, when split open, are red, probably alders; from their dimensions both must have grown under favourable conditions *.

The prostrate trunks lay generally N.W., S.E., or away from the opening of the valley; they had been broken off without tearing up their roots.

7. *Angular detritus.*—The flooring upon which the blue mud-deposit lies, for as far out as it can be traced, is of coarse angular rocks, instead of some form or other of water-worn materials, as might have been expected; these consisted only of fragments of the splintery quartzose rocks of Dunkerry, of all sizes, with their edges and points as sharp, their surfaces as clean as if just broken; all thrown together in the greatest confusion. Part of this rugged appearance may have been produced by the tides having washed away some of the finer materials. All the trees are rooted in this detritus; it was the surface on which they grew, and had established themselves antecedently to the changes here noticed. The nature of this accumulation, if I am right in my explanation, renders the Porlock Bay forest-beds of more geological interest than the more extensive tracts of Bridgewater or Swansea.

A thick coating of angular débris covers the surface of all the hill-ranges of North Devon and Somerset; it is always strictly local, and is simply the product of the breaking up of the surface to a great depth. In places the mass of débris is *in situ*,—merely detached; but along some of the new roads which have been cut about the sides of these ranges, sections are exposed, showing that

* Large oak and alder characterize the Porlock valley, at present higher up as along the course of the Horner stream.

great masses or "trainées" of the débris have come down from above, cutting deep channels through the detritus at lower levels.

These accumulations of angular detritus along the lower slopes are of great thickness; the materials have also been carried forward to considerable distances, more particularly in advance of deep glens. The high ground from Countesbury to Dunkerry (1678) and Porlock Hill has everywhere good illustrations of the character of these masses of detritus.

A section of such beds is to be seen in a low cliff extending eastwards from Porlock Quarry, and serves to connect the detrital materials of the interior of the country with the beds beneath the bay. It is a section of part of the under-terrace already noticed.

This section, which has a depth of from 10 to 12 feet above the level of the shingle, shows an accumulation of earthy materials, angular fragments of all sizes, all derived from the rocks of Porlock Hill. There is to be noticed a sort of horizontal arrangement resulting from interbedded lines of finer materials, and showing successive accumulation. On either side of the place at which a stream comes down to the coast, cutting through the thickness of angular materials, there are to be seen, mixed with it, some water-worn, partially rounded blocks; these indicate the course of a torrential stream from the high grounds above (as at present), but occasionally of greater volume.

This accumulation of angular materials is referable to like bygone conditions as have been already indicated for the whole of the rest of the West of England (Quart. Journ. Geol. Soc. vol. vii. pp. 121–131). It is a condition of surface presented everywhere by that portion of this country, and of Europe, which was not submerged during the great subaqueous depression of the Northern hemisphere. In geological history it belongs to the subaërial phenomena of the "Glacial Period," and represents the whole of the variable conditions of that long interval of time.

## III. Conclusion.

Reversing the order of superposition, the sequence of change at this place is as follows:—

1st. The formation of angular detritus, and its accumulation at lower levels.—Highest relative level.

2nd. Forest-growths established on detrital beds.—Trees of great age.

↓ 3rd. Accumulation of freshwater mud, resulting probably from a depression of the level of the land.—Trees killed.

↑ 4th. Surface of water-plant growths on mud-deposit, or nearly dry surface, on which the trees fell.

↓ 5th. Deposit of sea-mud, with *Scrobicularia*.—Area depressed below the sea-level.

↑ 6th. Conversion into meadow, at the level of the highest springs at present.

↓ 7th. Shingle.

It may be inferred from Sir H. De la Beche's description that he had not had opportunities of distinguishing the two surfaces of plant-growths, nor the remarkable floor of angular materials on which the forest-bed is rooted. It is not stated whether the "silt and sand" of the "inclined plane" was freshwater or marine.

The succession of changes here indicated corresponds with that of numerous other localities at which I have had opportunities of examining the evidence in the West of England. The Porlock example, in addition, seems to fix a relative date for a part, namely, as being subsequent to the great subaërial weathering of the surface during the Glacial Period. The elevation of the land was greater at that time than at present, but by how much we have no means of determining.

The difference of level within which the land has oscillated since then need not be estimated at more than 40 feet, the range between high and low water on the Bristol Channel coast being taken at 33 feet. It is certain that such forest-growths as pass on all sides *beneath* the line of low water could not have lived at the high-water level, but a rise of 50 feet would convert the upper part of the Bristol Channel into land-surface. The greatest depth at which submerged land-surface has been ascertained is about 120 feet; a rise of such amount would place the *whole* of the Bristol Channel in the condition of dry land, and such probably it was at the time of the forest-growths.

The line of the Bristol Channel is that from which the amount of depression of the British area in the West increased progressively northwards, corresponding to the line of the Thames valley in the East. There is clear evidence that the line of the English Channel was occupied by sea during the "Cold Period" (Quart. Journ. Geol. Soc. vol. vii. p. 135); and at the Newcastle Meeting of the British Association I indicated to what extent this unsubmerged area of the South of England was affected by that depression. Like evidence may now be derived from the coasts of North Devon and Somerset.

The lowest and oldest beds beneath the Bridgewater levels are of sands and subangular gravel, made up of all the materials of all the hill-ranges which send their streams towards that depression, from the grauwacke of Exmoor and the Quantocks up to the Chalk inclusive.

From the great extent of the old alluvia of this area of drainage, the volume of the rivers must at some time have been very great, and as no part of it was comprised by the line of circumpolar submergence, these alluvia are referable to the subaërial conditions of the whole of the Glacial Period. The great gravel-beds of the Bristol Channel, noticed by Dr. Buckland as proofs of his Diluvial theory, are the accumulated glacial alluvia of all the rivers of the West, from the Severn to the Tone: they are the equivalents in age of the great accumulations of angular débris.

Over the whole of the West of England the remains of the great Pachyderm fauna occur abundantly in, more generally beneath, the old alluvia, as also beneath angular débris, at various elevations, about the Mendip, Quantock, and Exmoor ranges; but there is no evidence whatever that the great characteristic part of that fauna was in occupation of the area at more than one period. It became extinct, even over the area of the South of England, which was not submerged; indeed the extensive subaërial glaciation which that area has undergone from Cornwall to Kent and Sussex, is inconsistent with the existence of such a fauna.

Lastly, with reference to the age assigned to these later changes, subsequent to that of extreme cold, a relative date is arrived at for many of the so-called "Raised Beaches" occurring on our western coasts. The example nearest to Porlock in the West is that between Braunton and Baggy Point, long since so well described by Sir R. Murchison and Professor Sedgwick. At this place there is the evidence of the more recent changes at low levels, the older sea-bed, at an elevation of 60 feet for its higher portions, being covered up by an enormous accumulation of angular debris-bed *.

I have already called attention to the great thicknesses and other characters of the angular débris overlying old sea-bed (Quart. Journ. Geol. Soc. vol. vii. p. 118), and would also refer to the observations of Sir H. De la Beche (Report on Cornwall, &c., chap. 13).

In a modified sense these sea-beds or raised beaches are preglacial, or older than the period of deep surface disintegration. But just as the amount of northern depression increased from South Northwards, so the progress of that depression was in the contrary direction, or from North to South; the line of the Bristol Channel was nearly the limit of this submergence, and was the last reached.

The interval of time which separates these more recent changes of relative level from that of the great depression of the Northern Hemisphere, is possibly very great, not so their distance from the present. The distinctive features of the newer deposits are, that they belong to the time of our existing assemblage of animals and plants, that they indicate changes of small vertical amount, and are remarkably uniform.

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## 2. *On the* Marine Origin *of the* Parallel Roads *of* Glen Roy.

By the Rev. R. Boog Watson, F.R.S.E., F.G.S.

(Abstract.)

The Parallel Roads of Glen Roy have been described by several observers, who have also offered explanations of the manner of their formation. In the author's opinion, Mr. Robert Chambers has solved this problem in his 'Ancient Sea Margins,' and in this paper he supported the view there advocated, and offered some objections to the theory of an ice-dam, originally put forward by Prof. Agassiz, and recently illustrated by Mr. Jamieson†.

After noticing the strong points of the ice-dam theory, Mr. Watson remarks that, though Prof. Agassiz and Mr. Jamieson agree

* Bed *a* of Section. Geol. Trans. 2nd ser. vol. v. p. 279.
† Quart. Journ. Geol. Soc. vol. xix. p. 235.

in supporting it, yet they differ so much respecting details that they mutually weaken their cause*. He then considers the specific objections to the theory, especially the existence of terraces similar to the Parallel Roads, though less perfect, at all levels round our coasts, as well as inland, along every fjord in Norway, and across the whole of Sweden; these, he says, cannot be accounted for by the ice-dam theory, which therefore treats them as something distinct, whereas they are specifically the same, differing from the Glen Roy Roads only in being less perfectly preserved. Mr. Watson also remarks that, even in Lochaber, there are banks of water-sorted gravel at various heights and unconnected with any "col"—a fact which cannot be accounted for by the ice-dam theory; and he mentions particularly two short lines between the two highest roads in Glen Roy, and one in Glen Gluoy at 960 feet, which do not correspond with any "col," also several instances in and near Glen Collarig. He then describes an extraordinary series of terraces on Ben Clinaig, and draws attention to certain gigantic flat-topped heaps of water-sorted gravel, whose levels do not correspond with those of any of the terraces. Mr. Watson therefore asks, What can the ice-dam theory do with all these? He also states that if the cold was severe enough to supply the ice needed for such a dam, it was too cold in Lochaber for lakes, and *vice versâ*. Glaciers, he remarks, are mere tongues of ice projecting beyond the snow-line, and the area which these tongues occupy is minute compared with that occupied by the body—the snow-field which contains them; but the ice-dam theory reverses this relation, and makes the snow-body minute and the tongues gigantic. Mr. Watson also considers that it was impossible for the ice to be present at the places indicated, as no glacier from Ben Nevis could reach Glen Roy, and no independent glacier could be formed in Glen Spean. Another objection is, that no place can be found for the ice-dam theory between the glacial epoch and the present day—a consideration which the author discusses in detail, and he concludes his objections by urging that, as the sea has been all over the Lochaber district to a height of 2000 feet, there is no reason for seeking any other agency for the formation of the terraces, nor for introducing such a complex machinery as the ice-dam, where none is needed.

In supporting the "Marine" theory, on the grounds that the sea has been on the spot, and is capable of performing the work required, Mr. Watson gives the following sketch of the manner in which he conceives the "Parallel Roads" to have been formed:— "We have the land standing probably, in the first instance, rather higher than now, but gradually sinking, though perhaps with pauses. The climate resembled that of North Greenland. The land was swathed in thick ice, which was ever settling downwards to the sea, under that law of regelation which gives to ice its true viscid or plastic character. The whole surface of the rock was being moutonnéed and striated. The boulder-clay resulting from the destruction of the earlier soils and looser weathered rock-surfaces was

* See Reader 1864, p. 301 (September 3).

being shot out in heaps beneath the half-floating ice-foot. The finer clays and older shell-beds are the produce of the somewhat later and more land-sunken time, when the comparatively cleared surface of the rock and the shrunken glaciers no longer supplied the same mass of débris as before. The gales of spring from the S.W. came to break up the ice of winter where it lay on the level shallows, such as the long flat of Glen Spean, east of Loch Treig valley, and piled up the blocks of rock which the ice contained into those strange and monstrous sea-beaches (see Jamieson's map) which have been erroneously described as moraines. And, finally, dependent on the sheltered nature of the locality, on its exposure to the prevalent winds, on the character of the hill face, on the supply of débris from above, on the extent to which particular spots at the sea-level were already clothed with detritus under the influence of the varying currents pouring backwards and forwards over the cols at the glen heads—perhaps, too, to some extent, acted on by the ice-cake—subject to all these influences the terrace-lines were formed along the slopes. Sometimes they were swept away again almost before formed, or were spared only for later destruction; but, in the case of the sheltered fjord of Glen Roy, each terrace in turn was carried down with the subsiding land, and protected from injury below the sea in the quiet of the inland fjord, while the next terrace above it was being formed in its turn."

That there are some difficulties in the way of the "Marine theory" Mr. Watson does not deny, the greatest, perhaps, being, in his opinion, the marvellous perfection of the Glen Roy terraces when compared with anything similar there or elsewhere. He also discusses two other objections, being all that he thinks need consideration. The first of these is, that the horizontality of the "roads" is opposed to the idea of their having undergone subsidence and re-elevation; but Mr. Watson observes that there is no reason to suppose that any disturbance of relative levels should be exhibited when areas of thousands or hundreds of thousands of square miles are undergoing secular oscillations, and he cites in illustration the beach-lines along the Norwegian fjords. The other objection has been urged by Prof. Agassiz as his greatest difficulty in accepting the "Marine theory," namely, that the terraces present "no traces of organic life"*. Mr. Watson answers this by quoting several examples of Quaternary marine deposits which are also entirely barren of fossils; and he states that it would be surprising if fossils had been found in the Parallel Roads, as he has noticed that there is, from some cause or another, an extraordinary gap, utterly devoid of life, so far as we know, between the most recent of the *old* glacial beds and the very oldest of the *recent* deposits. The general character of the Scandinavian Quaternary beds he has found to correspond with that of the Scotch deposits, "and they also agree in this, that while true glacial shell-beds are to be found from the sea-level, and below it, up to 500 feet, or a little more, above it, there they cease altogether. The higher stratified

* Reader, Sept. 3, 1864, p. 301.

deposits are utterly devoid of a single organism, and it is not until we descend again to the height of 200 feet above the sea (in Scotland lower still) that we again begin to find fossils, in beds overlying the former; but in the shells of these later beds the glacial character has disappeared altogether." He holds, therefore, that the absence of organic remains from the terraces of Glen Roy simply accords with the character of similarly placed beds in every other locality, both in Scotland and in Scandinavia.

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November 22, 1865.

Robert Lightbody, Esq., Ludlow, Salop, was elected a Fellow.

The following communications were read:—

1. *On some* Spaces, *formerly occupied by* Selenite, *in the* Lower Eocene Clays *of the* London Basin; *with remarks on the* Origin *and* Disappearance *of the* Mineral. By P. Martin Duncan, M.B. Lond., Sec. G.S.

Contents.



1. *Position of the spaces and impressions in the Woolwich beds.*—Several sections of the Woolwich beds were made during the formation of the railroad from Lewisham to Dartford, and the *Ostrea*, *Cyrena*, and plant-beds were well shown. At one spot, between Mottingham and the Eltham road, the beds had a slight dip to the south-west, and cropped out on the side of a rounded hill which bounds a rivulet to the north. The lowest part of the section there exposed presented a thick layer of *Ostreæ*, and to this succeeded several feet of light-brown clay, sandy in places, in which *Cyrenæ* and *Melaniæ* were very abundant. A plant-bed followed being formed by remains of twigs, leaves, vegetable fibres, and long water-plants. The usual sequence was not then noticed, on the contrary, several small plant-beds were observed between the succeeding clays. Amidst the clay were some impressions which at first sight resembled the markings of verticillate leaves, but which were evidently parts of spaces once filled by stellate crystals of selenite.

Several lumps of clay were removed for examination, and presented, when cut into, numerous moulds of entire stellate groups, but all trace of the mineral which had produced them was gone.

2. *Description of the spaces and impressions.*—The spaces were from

$\frac{1}{4}$ inch to $\frac{3}{4}$ inch in diameter, were empty and moist, and were usually, but not invariably near a plant-bed. The impressions in the clay were very distinct, sharp, and permanent, and the flatness of the crystalline planes was perfectly represented, as was also the sharpness of the angles. The colour of the clay within and without the spaces was at first the same, but exposure to the air determined the deposit of sesquioxide of iron on the plane surfaces. Close to the exterior of the spaces were numerous spots resembling Entomostracous remains, but which were of a lighter colour than the clay, and which yielded to analysis alumina, silica, and sulphide of iron*. When permitted to dry, some of the hand-specimens showed much alteration near the selenite impressions, from the replacement of the protoxide by the peroxide of iron, but none elsewhere. No crystals or laminæ of selenite were found near the spaces. In one space there was a brilliant piece of carbon.

The clays were soft and not laminate; they contained variable quantities of sand, and graduated into a decided loam here and there. The section proved that the natural drainage through the deposit was in perfect operation.

3. *The mineral condition of the organic remains in the beds.*—The large *Ostreæ* were imperfectly silicified and very hard. The *Melaniæ* were generally very perfect, and were of all sizes: they were either empty, very fragile, and the carbonate of lime in the shell was tender in the extreme, or the shell was tough and its interior filled with crystalline carbonate of lime; or, in a few instances, an imperfect silicification had produced a cast.

The *Cyrenæ* were of various sizes, and were either very fragile and empty, or their interior was filled with dense carbonate of lime, the shell being here and there deficient.

The plant-remains were carbonized, and much of the surrounding clay was stained black, but in some places fibres existed of their usual colour.

4. *Discovery of the spaces in the London Clay.*—Shortly after these impressions were noticed in the Woolwich beds, several large moulds of selenite were discovered in the London Clay of the Tendring Hundred of Essex†. They were very numerous, and were larger than those from the Woolwich beds. The clay in which they were found was the usual dark blue-grey London Clay, and was unfossiliferous. The impressions were perfect, very complicated from the verticillate arrangement of the crystals, and the clay within the spaces was either perfectly like that without, or after a time became tinted with the sesquioxide of iron. Very small pieces of selenite were abundant close to the impressions.

5. *Considerations respecting the deposits.*—Selenite is very common

* The loam when washed with distilled water yielded less than 1 per cent. of soluble matters. They consisted of chloride of sodium, sulphate of magnesia, a trace of organic matter, and less than 1 per cent of sulphate of lime.

The finer particles of the loam took very long to settle, and the sediment consisted of silica, silicate of alumina, protoxide of iron, and salts of lime, soda, and magnesia.

† Mr. James Cooke, C.E., F.G.S., obtained the specimens.

in the London Clay, but comparatively rare in the Woolwich beds: moulds of it have not been hitherto recorded in the first deposit, but Messrs. Prestwich and De la Condamine noticed them many years ago in the latter at Counter Hill*.

However common these spaces may be, the facts still remain for consideration, that a rather insoluble mineral has been deposited in and removed from sedimentary marine and fluviatile deposits, and that the mineral has not hitherto been formed artificially. The crystalline nature, optical properties, and chemical composition of selenite are well known; but it is a species which has either been much neglected or has been treated as crystalline gypsum, being considered to be influenced identically with it by reagents.

The part of the Woolwich bed and that of the London Clay under consideration, were deposited under different circumstances. Mr. Prestwich's great essay has so exhausted the subject, that it simply remains to state that the one was accumulated during the physical changes incident to an estuary, and that the other is more or less a deep-sea deposit.

It is evident that neither the selenite nor the shells forming the bulk of the deposit near Mottingham were rolled, for the impressions are sharp, and the fragile shells are usually entire. The shells belonged to individuals of all ages, they were all jumbled together, and it is evident that the mollusca did not live quite on the same area in which their shells are preserved. If it could be allowed that these masses were washed together to die under some unusual circumstances, one of which must have been a sudden depression of the surface, an immense amount of decomposition must have ensued, and the decaying mass of mollusca, extending over a large area, would have produced well-marked changes in the lithology of the district. All the chemico-geologic facts, however, disprove such an amount of decomposition, and indicate a feeble amount of organic decay. The water-supply probably consisted of river-water, brackish water, and occasionally of pure sea-water. The river probably worked its way through the chalk, and its water was as well supplied with sulphate of lime as similar streams now are. More of this salt it could not have had, for the molluscous and plant-life was evidently abundant and vigorous. The quantity of clay and sand which now forms the matrix for the shells is but a small vestige of what was deposited contemporaneously with repeated quantities of shells, and it is most probable that during the slow depression of the surface of the land and estuarine bottom, the layers of shells were deposited with great quantities of silt and clay, which were more or less washed away from time to time. That is to say, the mollusca were gently washed into channels and formed a thin layer; they were covered up with silt and clay, and their decomposition was probably in progress when another layer was formed above; the greater part of the inorganic deposit was then washed away, and the layers gradually merged one into the other; or the succession of layers may have been numerous before the bulk of the sand and clay was removed. This explanation

* Prestwich, Quart. Journ. Geol. Soc. vol. x. p. 123.

meets the difficulty of accounting for the slight evidences of decomposition in the beds which are so crowded with shells.

It must be remembered, in considering the subsequent geologic chemistry of the beds, that as the depression of the estuarine deposit proceeded, it was covered with the marine London Clay, and that salt water percolated through its beds until all was elevated, and subaërial denudation commenced.

The London clay in the neighbourhood of the impressions is unfossiliferous, and contains no carbonate of lime, but doubtless the organisms common to all sea-bottoms were once present, and determined in a decided manner the mineral condition of the deposit. The small particles of selenite near the impressions were probably carbonate of lime at one period. River- and rain-waters had nothing to do with these clays at first, for they were washed and percolated by sea-water, until the elevation of the lower Eocene beds subjected them to the action of fluviatile and meteoric waters.

The slow rate of drainage through the London Clay is tolerably evident. It will be noticed that in one instance the evidences of the deposition and removal of selenite were found in beds which were shallow- and fresh- or brackish-water deposits, and that a prolonged exposure to percolation by sea-water was followed by a rapid perfect drainage by fresh water; whilst in the other instance the proofs were discovered in marine deposits which were not formed near the surface, and which have been finally slowly drained by fresh water. Moreover the selenite is common in the marine but rare in the estuarine deposit*, and in both it is scattered and is not in horizontal layers.

6. *Origin of Selenite.*—There are many instances of the formation of crystalline gypsum during the recent period, consequent on the evaporation of waters holding sulphate of lime and other salts, such as sulphate of soda and chloride of sodium, in solution. Darwin found large crystals in the banks of a South American salina which deposited large amounts of sulphate of soda; Bischof† and others notice the formation of laminar crystals on the faggots placed for retarding the percolation of certain saline waters, and there are some fine specimens of recent crystalline gypsum impregnated with sand in the museum of the Society. The deposition of small crystals and of the amorphous mineral occurs very constantly‡.

Now all these deposits occur under somewhat identical conditions, and often have a relation to the comparative solubilities of the chloride of sodium and sulphate of soda which are more or less present in the waters. The excess of sulphate of lime is rarely observed, and it is pernicious to molluscous life; and as it is not advisable to travel out of the usual course of things in attempting to account for difficult natural problems, it may be conceded that no more than an average amount of the salt is, in the first instance, present in the great ma-

* Mr. Prestwich notices the absence of selenite in the mottled clays of the Woolwich beds (*op. cit.*).

† Chem. and Phys. Geol. Cavendish Society, vol. i. p. 426.

‡ *Ibid.* vol. i. p. 154.

jority of instances where it is ultimately deposited by evaporation. It is very evident that the selenite of the London Clay could not have been the result of surface-evaporation, for it is found throughout the thickness of the deposit, which, moreover, is of deep-sea origin.

In the Woolwich beds the spaces were found, not in layers, but scattered and at various depths. It is possible that the facilities for evaporation were occasionally considerable in this deposit, but there are many reasons to be adduced against this idea.

There are no evidences of either the Woolwich or London Clay beds having been percolated by an intensely gypseous water. There is a difficulty in this part of the inquiry in consequence of the difference between selenite and the other forms of crystalline gypsum.

All the specimens which have resulted from evaporation which I have seen, cannot be called selenite, they are more fibrous, less laminar, and not so regularly crystalline. The distinction between the two forms is acknowledged by some, but ignored by other mineralogists, and Bischof must be classed amongst those who consider all the forms, except *Anhydrite*, to be identical in the chemico-geologic sense. But although burnt selenite acts chemically like burnt gypsum, still in its crystalline form it is infinitely more durable, less soluble, and less influenced by heat, cold, and moisture. The structure of selenite infers long periods of time for the perfection of its large laminate crystals; and if this be the case, it is, especially when the extra amount of water of composition is considered, a strong argument against its origin by simple and immediate deposit.

As there is some doubt whether selenite is ever the result of simple deposition, the examples now and then presented of selenite crystals developing in masses of amorphous gypsum, become very important. In fact the only definite knowledge of the origin of the mineral is derived from them, and all other explanations are hypothetical.

Gypsum may have been deposited in the clays from either the percolating river- or sea-water; but still this is less probable than its secondary and chemical* origin by the changes induced in carbonate of lime by decomposing organic matter. Although carbonate of lime does not now usually exist *per se* in the clays, still masses of it are found here and there, although they have been exposed to great water-washing. During the earlier years of the London and Woolwich beds, large amounts of carbonate of lime must have been formed from the detritus of shells, and in many places they must have been exposed to the influence of sulphuretted hydrogen, and its associated gases—the result of the decomposition of organisms.

If it be admitted that water containing sulphate of lime will produce an evolution of sulphuretted hydrogen, carbonic oxide, and carbonic acid gases from dead organic matter, it simply remains to account for a sufficiency of oxygen to develope small quantities of sulphuric acid, before gypsum can be produced from the carbonate of lime. The constant presence of organisms between the layers of

* See "Remarks on the Production of Crystals," by John Morris, Mag. Nat. Hist., November 1837.

selenite and amidst gypsum is remarkable, as is also the frequent neighbourhood of plant-beds or lignites.

It is by no means improbable that the deoxidation of the vegetable remains before their complete transformation into lignite, may have been produced by the gases resulting from decomposing contiguous organic substances in contact with water containing usual amounts of sulphate of lime in solution. The sulphuretted hydrogen, deriving oxygen from the vegetable matters undergoing their transformation into more or less pure hydrocarbons, yielded the sulphuric acid requisite for the formation of the gypsum.

How constantly peat, coal, and several forms of gypsum are associated is well known, and the theory should hold good in all instances.

It would appear then most consistent to assert that the selenite of the London and Woolwich clays was formed in amorphous gypsum, the result of the decomposition of carbonate of lime by sulphuric acid in minute quantities, probably in percolating water.

The solution of the gypsum around the crystals of selenite and the closing in of the clay are inferred to have then taken place.

7. *How selenite may have been removed from the deposits.*—The selenite must have been removed from the spaces in one of the following manners:—

1. By being washed out mechanically.
2. By being simply dissolved by percolating waters.
3. By being decomposed.

1. The spaces were all closed, and the clay was not laminated until it became dry. The impressions of the planes and angles were perfect. These facts militate against the removal mechanically.

2. The improbability of the solution of the selenite may be gathered from the following considerations.

In the same London Clay, in more exposed situations, where constant moisture and sea-spray act in all seasons, selenite is still found in great abundance. If selenite be not dissolved on the Walton cliffs, why should it be dissolved inland, where the only moisture is that of very slowly percolating meteoric waters? Small particles of selenite remain undissolved close to the spaces, and there is an abundance of soluble matter around them. The hardness and perfection of the planes and angles of the impressions could not have been expected after so prolonged a percolation as that required to dissolve out the selenite.

3. The production of a salt which would entail a gradual destruction of the lamellar structure of the selenite, and would bring the mineral down to the level of solubility witnessed in gypsum, might account for the empty spaces. The theory which appears to be most reasonable is partly that by which Bischof accounts for the decomposition of beds of gypsum, and the consequent formation of other beds of gypsum out of strata of carbonate of lime. Bischof may be thus quoted*:—"If gypsum is impregnated with organic substances (bitumen) and comes in contact with water, it will be gradually de-

* *Op. cit.* vol. i. p. 419.

composed into sulphuret of calcium, while carbonic acid will at the same time be formed. Should the carbonic acid pass from deeper to higher strata, which are likewise undergoing decomposition, it gives rise, in the presence of water, to a disengagement of sulphuretted hydrogen, while the gypsum is converted into carbonate of lime. If these exhalations of sulphuretted hydrogen become converted by attraction of atmospheric oxygen into sulphuric acid, and this comes in contact with the younger strata of limestone, gypsum will again be formed."

It may be noticed in support of the adaptation of this theory to the cases under consideration, that the organic substances, some of them even bituminous, were at hand, and that the clays were doubtless always wet.

The former soluble condition of portions of the plant-beds may be estimated from the blackening of the clay and loam immediately around them; and it is probable that this solubility increased after the deoxidation of the vegetable matter had been completed.

It is remarkable that the only trace of a sulphide in the portion of the Woolwich beds under consideration, was found close to the selenite impressions; and it is equally interesting in reference to the theory I have adopted, that particles of selenite should have been found close to the large moulds in the London Clay.

If sulphide of calcium was formed, as already noticed, and the interlaminar spaces of the selenite were gradually the seat of its formation, thus offering a large surface for its development and for the action of percolating water, the gradual disappearance of the crystals was but a matter of time. If these theories of the origin and removal of selenite are correct, the decomposition of the plant-remains in one case, and of other organisms in the other, were of equal importance; and it is from the abundance of the evidences of such decomposition in the London Clay that the operation of solutions of organic matter is inferred.

8. *Conclusion.*—The preservation of the impressions of selenite is doubtless exceptional, and it is very probable that this mineral, like many others, is formed, decomposed, and removed without any trace being left of the complicated chemical operations which determined its existence and decay. The existence of soluble salts in the Woolwich clay is remarkable, for they cannot be all derived from the percolating surface-water, but from the original constituents of the bed. It is a proof of the great lapse of time required, even with the assistance of alterations in the level and dip which determine increased drainage, before such beds can be reduced to the mineralogical simplicity illustrated by clay-slate.

The formation of gypsum, and of its more durable replacing crystalline form selenite, suggests the decomposition and destruction of organic remains, and the disappearance of these minerals is equivalent to the destruction of the evidence of the former existence of organisms.

How organisms are preserved and destroyed in sedimentary strata, are questions constantly before the geologist; and these observations have been made with the intention of correlating the disappearance of selenite with that of the organisms to whose former existence it owed its origin. It is clear that if organisms deposited in sediment contribute at the commencement to the formation of such minerals as selenite, which are removeable in their turn, after a while the sediment may become free from all trace of former organic matters. In other words, there is no reason why the purest clay-slate may not have been formed from a fossiliferous clay.

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## 2. *On the* Relation *of the* Norwich *or* Fluvio-marine Crag *to the* Chillesford Clay *or* Loam. By the Rev. O. Fisher, M.A., F.G.S.

During the month of August last, in company with Professor Liveing, I visited Orford and Aldborough, and we made some observations which may tend to clear up the uncertainty which hangs over the relations of the Red Crag, Chillesford beds, and Fluvio-marine or Norwich Crag. We took with us the paper by Mr. Prestwich on the Chillesford Beds, in vol. v. of the Society's Journal, that by Mr. S. V. Wood, jun., "On the Red Crag and its Relation to the Fluvio-marine Crag, and on the Drift of the Eastern Counties" (Annals and Mag. of Nat. Hist., March 1864), and the same author's "Map of the Upper Tertiaries of the Eastern Counties, with remarks thereon," privately printed, 1865. After having begun to digest the materials we had collected, I visited the same neighbourhood again in the beginning of September.

Mr. Prestwich has left it open as to "whether the Chillesford deposit may not be identical with the Mammaliferous Crag of Norwich"*, or whether it "may not belong to a period one stage more recent than the Mammaliferous Crag; whether in fact it may not be the marine representative of that thin marine, freshwater, and land series, which, on the north-eastern coast of Norfolk, is spread over the patches of the Norwich Crag, and immediately underlies the great northern clay drift," *i. e.*, I conclude, Mr. Gunn's "laminated beds." Sir Charles Lyell, however, in his work on the Antiquity of Man, decidedly adopts the former view, saying that "the most southern point to which the marine beds of the Norwich Crag have been traced is Chillesford, near Woodbridge in Suffolk"†.

Mr. Wood, jun., on the other hand, considers the Chillesford beds to be a local member of the division of the glacial series, which in his last-mentioned paper he terms "the middle drift." He says, p. 4, "The Chillesford beds described by Mr. Prestwich in 1849 as overlying the Red and Coralline Crags, pass up without the least break into the middle drift, and are evidently part of that division." And with respect to the Fluvio-marine Crag and its relation to the Chillesford beds, he says, "The conclusion I have formed is that the Fluvio-marine Crag of Thorpe is inferior to the fifth stage Red Crag" (that is, the phosphatic nodule bed), while in another place he states

* Quart. Journ. Geol. Soc. vol. v. p. 351. † Ed. 1863, p. 211.

that "this horizontal Crag" (*i. e.* the phosphatic nodule bed) "passes up into the Chillesford beds at Chillesford."

In short, Mr. Wood's views, as he informs me, are these, "That the Red and Fluvio-marine Crag are coeval; while the Chillesford beds are but a fossiliferous (and that only local) horizon of the "middle drift," at about one-third to one-half of the distance from the base of that deposit, the horizontal crag being only the very base of the 'middle drift' over parts of the Red Crag area."

I feel that any contribution towards the solution of this interesting though limited problem is worth recording, and I can assure the Society that my companion and I made our first examination with no previous bias towards one view rather than another.

The section at Chillesford loam-pit close to the chancel of the church gives—

| | ft. | in. |
|---|---|---|
| Drift from the Boulder-clay | 5 | |
| Brown laminated loam with crushed shells | 2 | |
| Micaceous brown sand | 7 | |
| Light-brown sand with Myæ in their natural burrows | 0 | 6 |
| Coarse sands, less micaceous, and not laminated. | | |

In the adjoining pit of Red Crag, distant about fifty-eight yards, there is a difference in character between the upper and lower half of the section. The lower has the ordinary aspect of Red Crag, but the upper appears to be a continuation of the sands of the loam-pit.

There is in the upper part a bed of shells horizontally stratified, a foot thick at about 5 feet below the level of the Mya-bed in the loam-pit. Then succeed 5 feet more of horizontally drifted shelly sand, which rests on the ordinary obliquely laminated Red Crag.

Proceeding to Chillesford brick-pit, the loamy clay is dug for 15 feet, down to a shelly sand, but I did not meet with Myæ in it. In other respects the deposit agrees very closely in character with that in the pit behind the church. In these two pits the grey colour so characteristic of this bed at some points is only observable in a few thin layers, the prevailing colour here being a light brown.

The same clay, of a greyish-brown colour, and resting on yellowish sands, is met with in a clay-pit at the western corner of Sudbourn Park. The porous character of the sands is shown by the fact that a field-drain, yielding a continuous stream of water, is turned into the pit, and sinks away without forming any pool. The substratum at this place must be Coralline Crag, which comes to the surface just inside the park.

Thus far these Chillesford beds appear to consist of laminated micaceous clays, sometimes brown and sometimes grey, having at their base a sandy band, at some spots containing *Myæ truncatæ* in their natural burrows, the whole resting on a loose yellowish-brown sand. These beds indiscriminately overlie the Red and Coralline Crags. We found these beds again more or less modified between Aldborough and the pit at Thorpe, near Aldborough, where the Fluvio-marine Crag appears. There were indications at that spot which appeared to us to show that the Chillesford beds pass under this Crag, and I commenced the present paper upon the data we had so far gathered; but not being satisfied with my proofs, I determined to make a careful section from Orford to the Thorpe pit, and at my second visit walked over the ground for this purpose.

To some extent the section will explain itself, but I desire to advert to a few particulars of it.

The chief difficulty in the geology of this neighbourhood arises from the repeated erosions which the surface has undergone, the newer beds being thrown down upon the eroded surfaces of the older.

One consequence of this is that we ordinarily find the succession incomplete. Another is that any given deposit does not continue of a uniform thickness, but while its upper surface, where it has escaped erosion, is nearly horizontal, the lower follows the contour of the surfaces of the rocks on which it rests.

Another difficulty arises from the sandy beds of the district being so similar to one another, that it is difficult to distinguish them by their lithological features.

As far as my notice extended I did not see any indication of faulting, and the dip of the beds appeared very regular, being very slightly towards the north.

The section commences at the Orford windmill, which is marked on the Ordnance Map as being 54 feet above the sea-level. Here the beds are capped by a drift gravel 7 feet thick. It contains large flints and quartz boulders, eight or ten pounds in weight. It rests on the Chillesford Clay.

The clay or loam is seen in a small pit beyond Queen Esther Grove. It is exposed for 10 feet, and rests on reddish-yellow shelly sand. At the interval of one field the shelly sand is seen beneath the hedge. A quarter of a mile further on, at Sudbourn Church Walks, is a shallow pit in brown micaceous loam. The shelly sand, always more or less noticeable below the Chillesford loam, is well exposed in the bottom of this pit. A small excavation which I made disclosed the Mya-bed in great perfection. It was about 2 feet thick, with three or four tiers of the united bivalves. They lay so close together that it was impossible to remove one without breaking

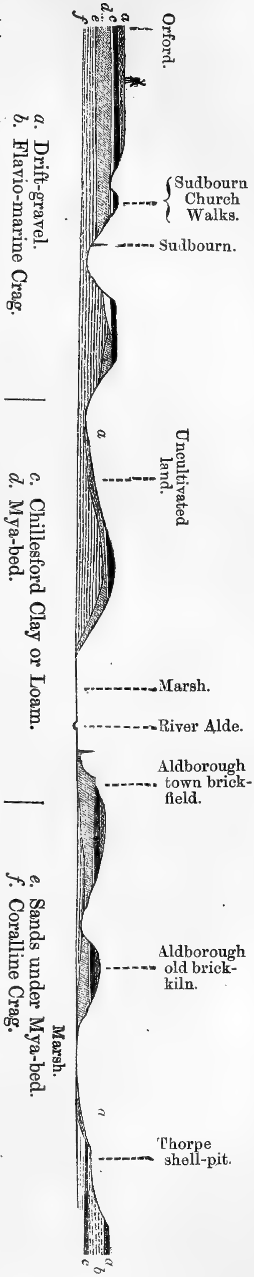


Fig. 1.—*Section from Orford to Thorpe, near Aldborough.*

others; but, from the fact of the matrix in which they were imbedded being harder than the sand which filled the shells, I found it impossible to obtain perfect specimens. The upper part of this fossil bed abounded in *Mactra ovalis,* a few having the valves united, while the lower part yielded great numbers of *Tellina obliqua,* many of which also had their valves united. The species which I collected here were—

| | |
|---|---|
| Trophon antiquum. | Mactra ovalis (abundant). |
| Turritella communis. | Tellina obliqua (abundant). |
| Mytilus edulis. | Mya truncata (abundant). |
| Modiola modiolus. | |

Between this pit and Sudbourn Church loose sands occur. These appear to crop out from beneath the Mya-bed.

At the bottom of the valley the Coralline Crag may be seen in a pond, and several pits have been worked in that stratum on the side of the adjoining hill. But there is one remarkable pit near the top of the hill, due north of *x* in O*x* Covert, which is referred to by Mr. Prestwich in his list as consisting of Coralline Crag capped with the Red Crag, and which appears to deserve description.

The overlying deposit, 15 feet thick, I believe to be not Red Crag, but a shoal-deposit derived from the Mya-bed. The appearance of the deposit differs considerably in colour and texture from the undoubted Red Crag of Butley and Chillesford, the nearest points at which I saw it; and while many of the commoner shells of the Red Crag are at this place rare or altogether absent, those of the Mya-bed are in profusion; above all *Mactra ovalis*, the common shell hereabouts of the upper part of the Mya-bed, forms its chief ingredient. The Coralline Crag at this spot attains a higher level than usual, which I doubt not was the cause of this remarkable accumulation of dead shells, washed together during the formation of the Mya-bed. The species which I noticed in this crag were—

| | |
|---|---|
| Mactra ovalis (in extreme profusion). | Mya truncata (equally abundant). |
| Tellina obliqua (extremely abundant). | Mytilus edulis (common). |
| —— prætenuis (abundant). | Trophon antiquum (rare). |

There is a resemblance between the species of this bed and of that already described as occurring in the upper part of the Chillesford Red-Crag pit, at a level a little below the Mya-bed.

Crossing the hill, the Chillesford loam is seen near a farm-house, and the sands beneath it in the side of a lane near the bottom of the hill. The Coralline Crag is dug in an adjoining pit.

Crossing the valley, I met with a bed of sand covering Coralline Crag, the surface of which was eroded into hummocks. The place is on the same line of country as the pit mentioned by Mr. Prestwich on the north of Ferry Farm-house, where he saw the surface of the Crag "strongly indented by drift sands and gravel."

This sand appeared to differ from that which I had hitherto noticed as underlying the Mya-bed, and which I had just seen on the opposite side of the valley. It contained a few flints of considerable size, and the herbage which covered it was chiefly heath.

I have coloured it on my section as belonging to the sands between the Boulder-clay and the Crag, whose geological position appears as yet not well made out.

The line of section here crosses the hill obliquely. The Chillesford Clay was seen near the top of it, by the side of the road. At the extreme end of the hill, where it sinks beneath the marsh, sands were seen which I believe to be those underlying the Chillesford Clay.

Crossing the marsh, the section enters a low cliff towards the River Alde, close to the Aldborough Gas-works. This cliff is composed of drifted sands containing frequent small patches of shells. There is one rather constant band of shells about 11 feet from the base of the cliff. It is best seen in a pit by the side of a lane opposite the Gas-works. The shells found in the cliff were—

| | |
|---|---|
| Tellina prætenuis (very abundant). | Cyprina Islandica. |
| —— obliqua (abundant). | Mactra ovalis. |
| Mytilus edulis. | Cardium edule. |
| Mya truncata. | |

At 5 or 6 feet above this band of shells, at the top of the low cliff, the Chillesford Clay commences. It is extensively worked at a brick-pit between the cliff and Aldborough Church. The clay is capped by brown sands.

The Mya-bed is not seen at this spot, but close to the first milestone from Aldborough it appears in the roadside-cutting. The species collected there with scarcely any searching were—

| | |
|---|---|
| Tellina obliqua (valves united) | Turritella communis. |
| Mya truncata. | Natica. |
| Mactra ovalis. | Calyptræa. |
| Buccinum undatum. | |

The lower ground hereabouts is occupied by the Coralline Crag, which is exposed in a large pit just on the west side of the line of section. Mr. Wood noticed in the heading of this pit at one place traces of a shelly crag, and at another a patch of phosphatic nodules. We saw also both these. They appeared to have been drifted; and I have little doubt that the Crag had been derived from the Mya-bed, and I think it very possible that the nodules may have come from the Coralline Crag itself. We found such in the Coralline Crag at Sudbourn Park, which renders it not unlikely that an old water-washed surface of that rock might yield them.

The Chillesford Clay is again met with in the Old Aldborough brick-kiln on the rising ground above the Crag-pit. This is the brick-kiln mentioned by Mr. Wood.

The clay is here overlain unconformably by brown sands.

A tract of low marshy land is now crossed, upon which we saw traces of Coralline Crag, as we thought, dug out of a deep hole.

The rising ground beyond the marsh, on which to the east stands the hamlet of Thorpe, consists of brown sands. They are rather coarse, and contain ferruginous layers. These sands are exposed in a railway-cutting on the edge of the marsh. A little further on, about a furlong and a half beyond a crossing over the railway, there is a small sand-pit. Its position may be found on the Ordnance Map on the side of the hill opposite the last *h* in "Aldringham Churc*h*." Here we met with an abundance of impressions of shells in the more clayey layers. The most common species was *Mytilus edulis*. The shells (as well as I can distinguish them) appear to be—

Mytilus edulis (abundant). Pecten. Cardium.

Two furlongs further to the north is an old pit overgrown with herbage. It is in brown sand. Near it is another of similar material with water in it; and a few yards further to the north the Thorpe "shell-pit" is reached. This has been considered, I believe rightly, to be an exposure of the Fluvio-marine or Norwich Crag *. Its thickness is very considerable, but owing to the state of the pit it is not possible to estimate it exactly †. It must, however, attain ten or twelve feet in the pit. There is also a trace of the same bed in the bank on the western side at the end of the lane near the *n* in "Aldringham Common." This must be 30 feet or more above the bottom of the pit, though it does not necessarily follow that the deposit was that thickness; nor am I positive that it is *in situ*.

At the bottom of the "shell-pit" is a small pool of water, and digging at its edge I soon reached the bottom of the bed of Crag. In its lowest layer were numerous pebbles of indurated brown micaceous sandy clay, and beneath it the brown sandy clay itself, from which they had evidently been derived.

A strong spring rose from the junction as I dug, and I have no doubt it is the same spring which supplies the small pond resting on brown sandy loam, already mentioned as being close at hand.

We were impressed with the opinion that we here had the Fluvio-marine, or Norwich Crag, resting upon the Chillesford Clay. Before my second visit to the place it occurred to me that this Crag might be a drifted condition of the Mya-bed, as I believe the fifteen feet of shelly Crag resting on Coralline Crag near Ferry-farm to be. But on examining the evidence again I was confirmed in my former opinion.

I have mentioned brown sands as covering the Chillesford Clay at both the Aldborough brick-pits, and as appearing again between the marsh (through which flows the Hundred River) and the shell-pit. These sands are, as I have stated, fossiliferous in the latter place. They may be seen, emerging from beneath the Boulder-clay, at Aldringham Green, and they are again capped by it just north of the

* Woodward, Phil. Mag. 1835, p. 354. Gunn's Geology of Norfolk, p. 12. Wood on Red Crag. Ann. & Mag. Nat. Hist. March 1864, p. 9.

† The species I found here were—

| | |
|---|---|
| Buccinum undatum (abundant). | Tellina obliqua. |
| Purpura lapillus. | —— lata ? |
| Litorina litorea (abundant). | —— prætenuis. |
| Conovulus pyramidalis. | Mactra solida. |
| Cerithium tricinctum. | Cardium edule. |
| Turritella communis. | Cyprina Islandica. |
| Pecten opercularis. | Mya arenaria ? |
| Mytilus edulis. | |

village of Thorpe. The spread of these sands generally obscures the subjacent rocks, but by a valley-denudation the Norwich Crag is exposed at the one spot described; and I believe the top of the Chillesford Clay to be also exposed for a short distance. To the presence of this clay I attribute the water which is found in the pit close by the shell-pit. The sands would not support water.

The stratification of the district strongly favours the view I have taken of the superposition of the Norwich Crag upon the Chillesford Clay. On the other hand, it would be quite possible to conceive that the Mya-bed might be here expanded into a thick bed of Crag, and this is what has been generally assumed to be the case. I think, however, that the evidence rather supports my suggestion.

In the first place, the assemblage of species as seen at the shell-pit differs from that of the Mya-bed. As strongly as I felt convinced on the spot that the Crag above Ferry-farm was derived from the Mya-bed, so strongly did I feel that the Crag at Thorpe was not derived from it.

In the second place, the pebbles of indurated clay found at the bottom of the shell-pit exactly correspond in composition and colour with the Chillesford Clay, wherever it is weathered brown, as, for instance, at Chillesford itself.

In the third place, I have always noticed a porous sand underlying the Mya-bed, which would not support water. Indeed, in the clay pit near Sudbourn Park I have mentioned that a run of water from a field-drain is conducted to this sand and immediately lost in it. If, therefore, the Thorpe Crag were on the horizon of the Mya-bed, I do not think that we should have a spring at its base, nor a pond close by in the subjacent stratum.

The conclusion then appears to be correct, that the Fluvio-marine Crag at Thorpe near Aldborough rests on the Chillesford Clay, and that the descending sequence in that district is—

1. Fluvio-marine or Norwich Crag.
2. Chillesford Clay.
3. Mya-bed resting on sands, which, as at Aldborough Gas-works, are occasionally fossiliferous.
4. Red Crag.

Let us now see whether this sequence is borne out by other exposures of these beds.

It has long been known that a formation containing, as Sir Charles Lyell tells us, "lamellibranchiate shells with their valves united, mixed with land and freshwater Testacea, and with the bones and teeth of Elephant, Rhinoceros, Horse, and Deer" *, occurs

* Elements, 1855, p. 156. Since this paper was read I have been favoured with the sight of a letter written in 1864 by Col. Alexander to Mr. Searles V. Wood. Putting the contents of this letter by the side of the information I have received from Mr. Ewen, I gather that four Mastodon teeth have been obtained on this coast. That which is figured by Professor Owen in his 'Fossil Mammals' was found on the beach at Sizewell Gap, near Thorpe. Another, which Mr. Ewen now possesses, was found under the cliff after a fall at Easton Bavent. A third, with part of the jaw attached, was seen by Col. Alexander in the talus

at Easton Bavent Cliff near Southwold. I visited this spot in October, and was at once convinced, by the identity of the lithological character, that we here have the Chillesford Clay underlain by the Mya-bed.

Yet at this spot, as at Chillesford Brick-pit, I found no Myas *in situ*, though single valves occur. *Tellina lata*, with its valves united, is extremely common, as is also *Tellina prætenuis*.

Immediately beneath the Chillesford Clay we come upon a band of drifted shells, two or three inches thick, containing flints and fragments of bone imbedded in a coarse sand, and, beneath this, sand with *Tellinæ* as they lived. The bed occurs, where I saw it, at the very bottom of the second cliff north of the farm-house, and was only visible for a few feet, the rest being obscured by talus.

The following species occur at this spot:—

| | |
|---|---|
| Tellina lata. | Mactra ovalis. |
| —— obliqua. | Pecten opercularis. |
| —— prætenuis. | Cyprina Islandica. |
| Mya truncata. | Litorina litorea. |
| Leda myalis. | Paludina lenta. |

Mr. Ewen of Southwold, a friend of the late Col. Alexander, informed me that this band used to occur twenty-five years ago higher up in the cliff, and to the south of the spot where I found it, but that it had, through the wasting of the cliff, descended beneath the beach at the old locality, owing to the dip of the bed. This is important for my theory, as will appear in the sequel.

On examining other spots in the neighbourhood of Southwold, I found a pit at a place called Yarn Hill, near Potter's Bridge. Here is a bed of shells, chiefly *Tellinæ* in sand. It is covered by a brown loam, which I believe to be weathered Chillesford Clay, a band of flints in sand intervening; I have no doubt of its being a continuation of the Mya-bed seen in the cliff.

The species found at Yarn Hill were:—

| | |
|---|---|
| Tellina obliqua (common). | Litorina litorea. |
| —— lata (common). | Buccinum undatum. |
| —— prætenuis (common). | Natica catena. |
| Mactra subtruncata (common). | —— Guillemini. |
| —— ovalis (not common). | Ringicula buccinea. |
| Cardium edule (common). | Paludina lenta. |
| Cyprina Islandica (fragments). | Succinea oblonga. |
| Mytilus edulis. | |

On the hills above this pit are pits of Chillesford loam and clay, extensive brick-works being carried on in the latter at Manor House, Frostenden, and other places. At Frostenden brick-kiln the sand is dry beneath the clay, but the Mya-bed appears to be absent. Draw-

of the same cliff, and appears to have come from some position above the Mya-bed. It fell to pieces. A fourth, now in the possession of Mr. Ewen, was taken from the Mya-bed. It is the tooth of a very young animal.

Col. Alexander speaks of the occurrence of Crag shells in the talus of Easton Cliff to the south of the outcrop of the Mya-bed. The impression left on my mind is that some patches of Norwich Crag were then existing in the cliff in the position I have assigned to it above the Chillesford Clay, but hidden by talus.

ing a line from the spot where the Mya-bed occurs on the beach to the pit at Yarn Hill, which is scarcely raised above the sea-level, and bearing in mind that the outcrop on the coast has been carried beneath the beach towards the south by the encroachment of the sea, we obtain a dip towards the south-west.

Proceeding to Wangford, we meet with pits in the true Norwich Crag, exactly resembling the deposit at Thorpe, near Aldborough, and at the pits about Norwich. It is a gravelly deposit of considerable thickness; how thick the section does not show, because the upper part is denuded, but about 9 feet remains. The shells are not grouped as in the Mya-bed, the proportion of univalves being greater. None of the bivalves are in pairs. Here I found an antler of a deer, but too much decayed for removal.

I dug in the floor of this pit and found the Crag to rest on a laminated sandy loam, closely agreeing with the upper part of the Chillesford Clay at Easton Bavent Cliff. The dip of the beds to the south-west, as determined above, agrees well with this identification.

There is another pit, which I had not time to visit, at Bulcham Workhouse. I am told by Mr. Wood, jun., that it is in the Norwich Crag. Its position would agree very well with the view I take of its superposition on the Chillesford Clay.

Thus the observations I was enabled to make in the neighbourhood of Southwold confirm my former view, that the descending order of sequence is—

1. Norwich Crag,
2. Chillesford Clay,
3. Mya-bed;

while they give the additional fact that the Mastodon and other Mammalia have been procured from the Mya-bed at Easton Cliff. We cannot, then, hesitate to include the Chillesford Clay in the Norwich Crag series.

I am not aware whether the Chillesford Clay occurs in the Norfolk district of the Crag, where it rests immediately upon the Chalk.

There can be no doubt about the Chillesford Clay being a marine deposit, for I found in it a lenticular patch of sand containing shells similar to those of the Mya-bed; and Mr. Prestwich and Mr. Wood found marine shells in it at Chillesford. The character of the deposit might otherwise have led one to suppose that it was lacustrine.

There are still some problems of considerable complexity to be solved respecting the sequence between the Mya-bed and the Red Crag, and again from the Norwich Crag upwards.

It is well known that in the district of the Red Crag there are thick beds of reddish-brown sand overlying the fossiliferous Red Crag. These have been called "the unproductive sands of the Crag"*. Mr. Wood, jun., considers them to belong to his "middle drift," and thinks that the Chillesford beds are a local modification of them. I am not prepared to deny that the Chillesford beds, and therefore also the Norwich Crag, may be a local modification of these sands; but I

* Prestwich, Quart. Journ. Geol. Soc. vol. x. p. 93, note.

question their bearing any relation to the sands which usually underlie the Boulder-clay, and which Mr. Wood has called "middle drift." Indeed, I believe that he feels that difficulty himself, for he is unable to make a separation between these unproductive sands and the phosphatic nodule-band, and yet he evidently shrinks from dissociating that peculiar band from the general deposit of the Red Crag. He says, "I incline strongly to a belief that this horizontal Crag is merely the redeposit of the material of the Red Crag beach, washed up on the submergence of the Crag beneath the middle-drift sea;" though further on he adds, "but in the case of the horizontal Crag or nodule-band, this dissociation"—of the nodule-band from the Red Crag—"seems difficult to arrive at"*.

My own impression is that the mass of sands met with between the Boulder-clay and the Red Crag belongs to several deposits of different ages. The unproductive sands of the Crag, which are of a peculiar unctuous character, are one deposit. The laminated brown and yellow sands seen, for instance, about Aldringham Common, in which I found *Mytili* abundant, are another, and I suspect belong to the "laminated beds" of Mr. Gunn, which underlie the Norfolk Till. We have still a third deposit of sand in the "middle drift," overlying these, and containing those beds of rounded pebbles which have contributed chiefly to form the beach of the Suffolk coast.

I believe that all these sands may be seen emerging from beneath the Boulder-clay in the interval between Westerfield and Bealings stations on the East Suffolk railway.

* Remarks, &c., pp. 5 & 6.

# PROCEEDINGS

### OF

# THE GEOLOGICAL SOCIETY.

## POSTPONED PAPER.

*On the* CARBONIFEROUS ROCKS *of the* VALLEY *of* KASHMERE. By Capt. H. GODWIN-AUSTEN. *With* NOTES *on the* BRACHIOPODA *collected by* Capt. GODWIN-AUSTEN *in* THIBET *and* KASHMERE, by T. DAVIDSON, Esq., F.R.S., F.G.S.

[Communicated by R. A. C. Godwin-Austen, Esq., F.R.S., For. Sec. G.S.]

(Read partly on May 25, 1864, and partly on June 21, 1865*.)

THE district or Pergunah of Vihi is situated on the right bank of the Jhelum, above Srinagar, and is bounded on the N.W. by Zebanwan (8813 feet), on the S.E. by Wasterwan.

The rough panoramic sketch (fig. 2) of the hills which surround this valley, as seen from the line of the river looking east, indicate the positions of the several places at which the following sections were taken. The distance from Zéwan to Reshpur is about 8 miles. The level plain consists of the lacustrine and alluvial deposits of the Kashmere valley, through which the streams from the hills have cut deep courses. The Jhelum flows between high banks of the same formation.

Everywhere, both in Kashmere and Thibet, a Palæozoic series underlies the Mesozoic formations. The age of the Palæozoic rocks is that of the Carboniferous series of Europe, but as yet fossils have not occurred to enable me to distinguish any formations of older date. As, however, Lower Silurian fossils from the Khyber Hills were found by Dr. Falconer in the gravel of the Cabul River, as also by Colonel Strachey on the Niti Pass, the great masses of slaty and metamorphosed rocks, which in this part of the Himalayan chain underlie the Carboniferous beds, may be referred to a Lower Palæozoic series.

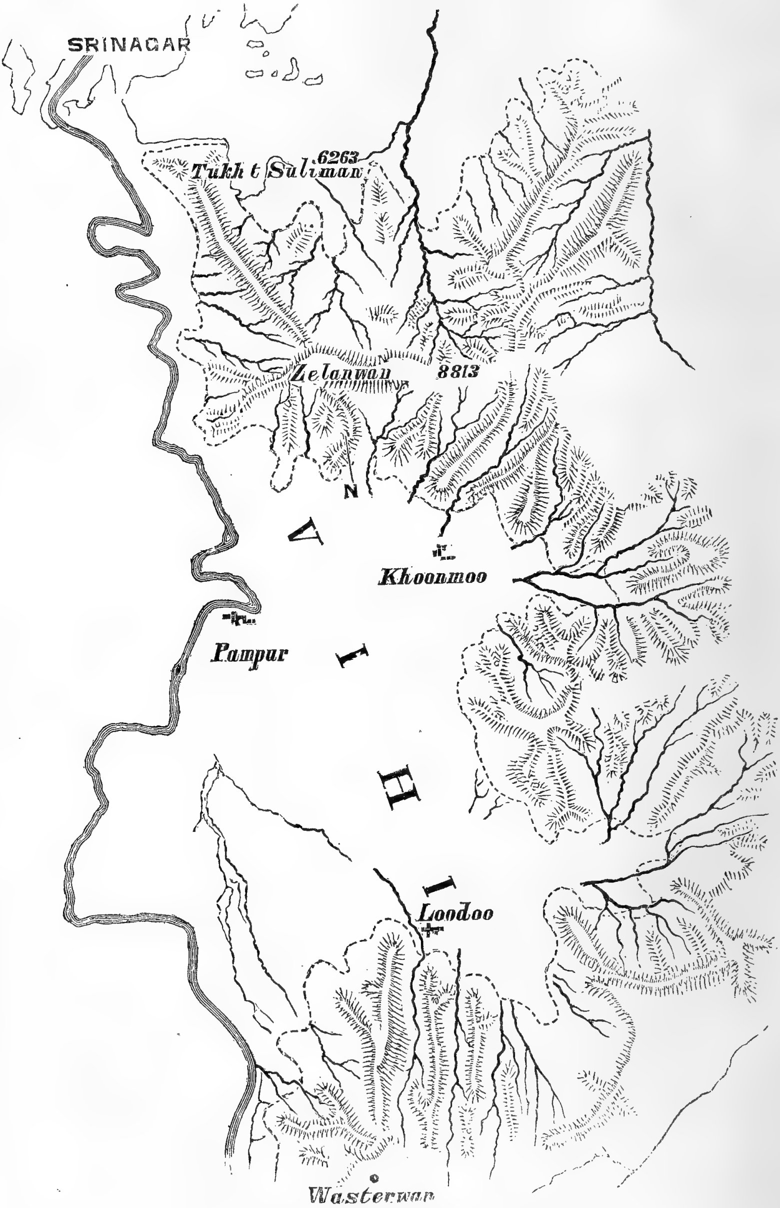
The Carboniferous formation may be traced all along the range of mountains on the north side of the Kashmere valley, where, in conjunction with Dr. Vercher, I met with its characteristic fossils in great abundance.

Fig. 3 is a section along a spur from Wasterwan, between Barus and Reshpur, in a direction from S. to N. At the base are the metamorphosed hornblende-slates of Wasterwan Peak. Next comes the quartz-rock, followed by beds of limestone (fig. 3, p. 31).

Beyond Zéwan, to the east, near Khoonmoo, is an outlying or projecting spur of limestone(fig. 4); the strike is S.W. N.E., and the dip. 30° S.E.

* For the abstracts of these communications already published, and for the other communications read at these evening-meetings, see Quart. Journ. Geol. Soc. vol. xx. p. 383, and vol. xxi. p. 492.

Fig. 1.—*Sketch-map of the District of Vihi.*




The dotted line at the base of the hills indicates the boundary of the lacustrine formation.

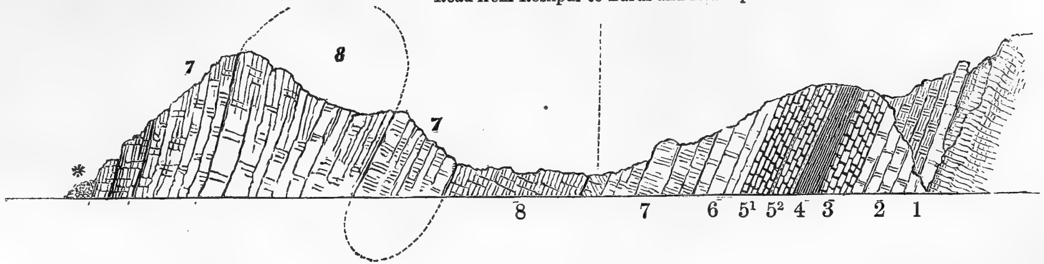
Fig. 2.—*Rough Panoramic Sketch of the Hills around the Vihi Valley, Kashmere.*


1. Zéwan or Zebanwan. 2. Khoonmoo. 3. Waiyan. 4. Loodoo. 5. Reshpur. 6. Barus.

The dotted line at the base of the hills indicates the boundary of the lacustrine formation.

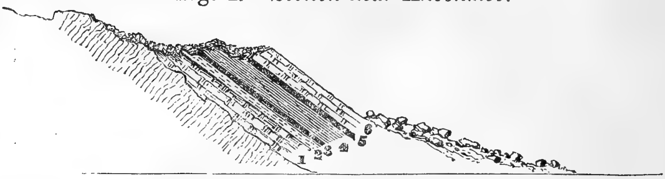
Fig. 3.—*Section along a spur from Wasterwan, between Barus and Reshpur.*

Road from Reshpur to Barus and Avantipoor.




| | | feet. |
|---|---|---|
| 1. | White quartz rock | 15 |
| 2. | Hard fossiliferous limestone; less so towards lower beds | 80 |
| 3. | Shaly limestone, weathering green, full of fossils (Zéwan beds) (Bed 3, fig. 7, and bed 4, fig. 10.) | 40 |
| 4. | Slaty band | 15 |
| 5. | Micaceous sandy limestone. | |
| | $5^1$. Band full of well-preserved shells—*Spirifera Rajah.* | |
| | $5^2$. Ditto, with *Productus semireticulatus.* | |
| | About 35 feet between these beds—in all | 60 |
| 6. | Grey limestone, weathered rocks, light brown | 200 |
| 7. | Hard compact limestone—no fossils | 410 |
| 8. | Hard compact limestone, weathering light ochre | 100 |
| 9. | Alluvial clay of the Kashmere valley. | |
| * | Talus of limestone. | |
| | | 920 |

Fig. 4.—*Section near Khoonmoo.*




The upper part of the bed next above the Hornblendic rocks and slates is

| | | feet. |
|---|---|---|
| 1. | Fine compact rock—calcareous | 10 |
| 2. | Light purple sandstone, with particles of hornblende | 5 |
| 3. | Hard dark-blue slates, alternating with | 2 |
| 4. | Brown shales and hard sandstone | 15 |
| 5. | Black limestone (like the marble pillars of the Shalimar Summer-house) | 4 |
| 6. | Shaly limestone. | |

No fossils were found in any of these beds.

Fig. 5 is a section across an outlier of limestone at the foot of a ridge from Zebanwan to the S.E. The strike here is S.W. N.E., dip 30° S.E.

Fig. 5.—*Section at the foot of a ridge, from Zebanwan, to the* S.E.

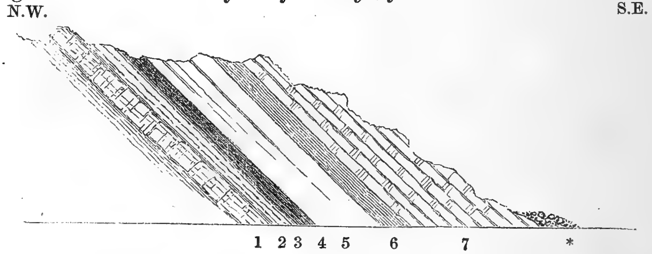
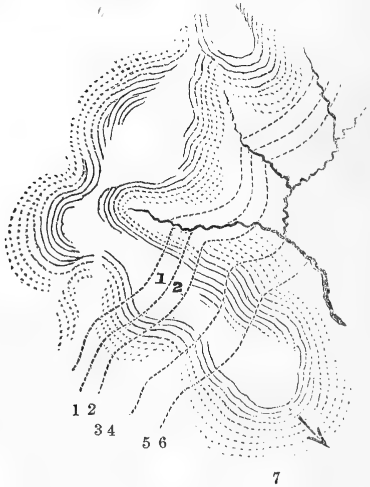



Fig. 6.—*Plan of the ridge near Zebanwan.*



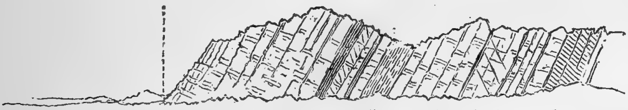
On the hornblendic slaty rock, which here everywhere underlies the Carboniferous series, there is in ascending order—

| | feet. |
|---|---|
| 1. White flinty quartzite | 12 |
| Passing up into | |
| 2. Altered sandstone and shaly beds, very hard and splintery | 15 |
| 3. A bed of water-worn pebbles and shingle, of quartz and hornblendic rock, imbedded in a sandy crumbling matrix | 4 |
| The shingle at the bottom is much the coarsest. | |
| 4. Sandstone, also containing water-worn pebbles | 2 |
| 5. Alternations of shaly slate and sands | 30 |
| 6. Calcareous shales | 20 |
| Passing up into | |
| 7. Hard compact crystalline limestone, of a dark-blue grey, interstratified with grey shales, which weather to a green tint. | |

Both the limestones and shales are extremely fossiliferous, containing many Bráchiopoda. I have given this part of the series (Nos. 6 & 7) the name of the Zèwan beds, from the village near.

The section (fig. 7) near Barus, on the right bank of the Jhelum River, Kashmere, under Wasterwan Peak, exhibits the following strata, having a dip of 50° W.

Fig. 7.—*Section on the right bank of the Jhelum River, near Barus.*



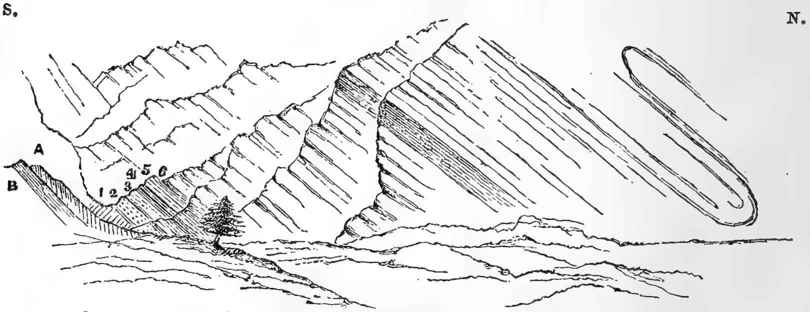

| | feet. |
|---|---|
| 1. Quartzite | 20 |
| 2. Hard compact limestone, *Productus scabriculus*, *Ter. sacculus*, *Athyris subtilita* | 40 |
| 3. Shaly limestone, full of *Fenestella*, *Streptorhynchus crenistria*. Zéwan beds | 50 |
| *Spirifer Moosakailensis*, Dav., and *Productus semireticulatus*. | |
| 4. Compact limestone, with few and obscure fossils | 100 |
| 5. Calcareous slate or shale | 30 |
| 6. Micaceous sandy calcareous beds—in all | 60 |
| 6*a*. *Spirifera Rajah.* | |
| 6*b*. *Productus semireticulatus*, *P. scabriculus* (large form), *Chonetes lævis*, *C. Austeniana*, in great number. | |
| 30 feet between. Beds 5, fig. 3. | |
| 7. Hard compact grey limestones. No fossils seen, about | 150 |

*Section across the Entrance of Ravine.**—Above the village of Khoonmoo there is a very interesting section, as a great thickness of the Carboniferous series is exhibited. On the left, and overlying the Hornblende-slate series, are the beds represented in Sect. B, dipping in the same direction as all the other beds at this place.

* A large Chunar tree stands at the entrance into the ravine.

Fig. 8.—*Plan of part of the district on the right bank of the Jhelum River, near Barus.*

Fig. 9.—*Section across the entrance of the Ravine above the Village of Khoonmoo.*




On the right (looking upwards) the lowest bed is

| | | feet. |
|---|---|---|
| 1. | Compact quartzite | 12 |
| 2. | Sandy calcareous beds, with a few shells | 10 |
| 3. | Hard limestone, with Orthoceras | 10 |
| 4. | Limestone, with small *Productus scabriculus*, *Spirifera Kashmiriana*, *S. Vihiana* | 3 |
| 5. | Grey limestone | 6 |
| 6. | Bed with shells, &c., well preserved, *Athyris subtilita* | 2 |
| | 6*a*. Compact unfossiliferous limestone beds | 1200 |
| | 6*b*. Bed made up of broken Brachiopods | 20 |
| 7. | Limestone up to the great fold of the beds, extending to the ridge full 3500 feet above the valley, and including a bed containing Bryozoa at the horizon indicated by the figure | 1200? |

The valley above the Shalimar Garden lies over on the other side

[*To face* p. 35.

CORRIGENDA *to the* ABSTRACT *of* Capt. GODWIN-AUSTEN'S Paper—"GEOLOGICAL NOTES *on* PART *of the* NORTH-WESTERN HIMALAYAS," published in Quart. Journ. Geol. Soc. vol. xx. p. 383–387.

Page 385, line 29, *erase the paragraph commencing* As these limestones, *and ending* Ladak and Little Thibet.

The Nummulitic series occurs, as has been stated at the commencement of § 3, p. 385, line 27, on the southern face of the Pir-Pinjal range and close to the older Siwalik rocks, but I have nowhere seen it in the Kashmir valley, and I think it very probable that in ancient days the Nummulitic sea conformed to the base of the present line of Himalayahs, more or less, and did not extend to the north at all. The limestone near the Wuller Lake, and at the base of the hills on the northern side of the Kashmir valley is undoubtedly Carboniferous.

Page 385, line 12 from bottom, *the paragraph commencing* On the southern slopes *up to* showing the palates very well, p. 386, line 2, should have come into § 2. *The Siwalik Series*; it not being Nummulitic, but the next formation in the series above.

5. *The Carboniferous Series*, p. 386, line 14.—It is a little ambiguous, and might lead the reader to suppose that the genera mentioned occurred indiscriminately through the whole mass of the beds up to that and together with the bed containing Goniatites. These, I may mention, contained no other shells that I could find.

I see it also stated—"*These also occur in superposition.*" Now I should say hardly ever, and never in the Kashmir valley itself. Further east, in Zauskar, Spiti, &c., the Palæozoic and Mesozoic may do, but not in the mountains to the south, south-east, and east of the valley.

In Mr. Davidson's note on the fossils, p. 387, line 20, it is stated:—"*From this rock, at Shigar, near Skardo, Capt. Godwin-Austen obtained six or seven*, &c." Now the fossils mentioned were all found in the Carboniferous limestones of the Kashmere valley and have no connexion with the very imperfect specimens, said to be Palæozoic, obtained near Skardo. I am afraid the labels on the fossils must have come off, or that by some means they got mixed together. The same must have occurred to the land and freshwater shells sent home; for *Helix hispida* was obtained in the lacustrine clay of the Kashmere valley, and not from Kuardo near Skardo. Some of the other shells are from other localities, but as I have no duplicates I cannot remember whence they came.

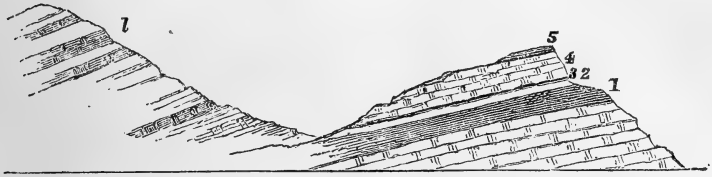
H. GODWIN-AUSTEN.

Deyrah Dhoon,
7th December, 1865.

of the ridge, at the head of the ravine, in which valley I think that the lowest beds will be found.

The section given in fig. 10 was taken on the south side of the Vihi valley, near the village of Loodoo, across a ravine beneath Wasterwan Peak.

Fig. 10.—*Section on the south side of the Vihi Valley, near the Village of Loodoo.*




Above the usual basement-rocks, consisting of the Hornblendic slate, of which a considerable thickness may here be seen, are

| | | feet |
|---|---|---|
| 1. | Dark splintery slate and quartz-rock, with badly-defined lamination .. | 20 |
| 2. | Light olive-green splintery rock, very compact, fracture cuboidal, like 2 in fig. 5 ........ | 2 |
| 3. | Beautiful white or light-grey quartz, like flint ........ | 1 |
| 4. | Blue limestone, with beds which weather light-green ........ This is bed 3 of fig. 3; contains the same species in great numbers. The lower beds contain, or may be said to be made up of Fenestellæ. | 30 |
| 5. | Dark-blue shales. These shales occur in the opposite side of the ravine, and are surmounted by a great mass of hard compact limestone (*l*), weathering to a red tint, and containing Goniatites. | |

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## *Note on some* Carboniferous, Jurassic, *and* Cretaceous (?) Brachiopoda, *collected by* Captain Godwin-Austen *in the* Mustakh Hills, *in* Thibet. By Thomas Davidson, Esq., F.R.S., F.G.S.

(Plate I.)

### § 1. Carboniferous Species.

The Carboniferous series in Thibet is stated by Capt. Godwin-Austen to consist of:—(1) quartzites; (2) limestones full of fossils of all kinds; (3) an argillaceous series; (4) compact limestone with fewer fossils, surmounted by a succession of beds full of *Goniatites*.

The impure limestone (no. 2) is of a darkish grey colour, and appears in some parts to be a mass of organic remains; it bears much resemblance, both in the character of the rock and in its fossils, to deposits of a similar age in Great Britain. From this rock at Shigar, near Skardo, Capt. Godwin-Austen has procured six or seven species of Brachiopoda, of which four only are determinable, the remaining two or three being too imperfect to admit of a satisfactory determination.

1. Terebratula Austeniana, spec. nov. Pl. I. fig. 1.

Shell almost circular, nearly equally and moderately convex; surface smooth. Beak moderately produced, and truncated by a small foraminal aperture; marginal line slightly curved in front, but not affecting the regular convexity of the dorsal valve, while it produces a small depression or sinus near the front of the ventral. Only one specimen of this shell was found by Capt. Godwin-Austen in Thibet; it measures 1 inch in length and breadth, by $\frac{1}{2}$ inch in depth.

2. SPIRIFER, sp. Pl. I. fig. 4.

Of this *Spirifer*, two fragments of the dorsal valve have been collected; when perfect it was semicircular, moderately convex, with a smooth wide slightly raised mesial fold, each valve being ornamented by some twenty-eight or thirty flattened ribs. The ventral valve being unknown, it would be unsafe to venture upon a specific determination, especially as several Devonian and Carboniferous species present characters very similar to those displayed by the fragment under description.

3. RHYNCHONELLA PLEURODON, var. DAVREUXIANA, De Koninck. Pl. I. figs. 2 & 3.

Several specimens agreeing with British and Belgian examples of *R. Davreuxiana*, De Koninck, have been found by Capt. Godwin-Austen (see Davidson, 'Mon. British Carb. Brachiopoda,' pl. 23. figs. 19–21).

4. ORTHIS, sp. Pl. I. fig. 5.

Two fragments of one valve only were collected by Capt. Godwin-Austen. In shape this valve is semicircular, with rounded cardinal angles, 1 inch in length, by 1 inch 2 lines in breadth. It is moderately convex and ornamented by numerous fine radiating striæ, which increase in number by the interpolation of ribs at various distances from the beak. The surface is likewise crossed by numerous concentric lines. These fragments are not, however, sufficiently complete to warrant a specific determination.

5. PRODUCTUS SEMIRETICULATUS, Martin. Pl. I. fig. 6.

Specimens of this characteristic Carboniferous shell do not appear rare in the Thibet limestone.

6. CHONETES HARDRENSIS, var. THIBETENSIS. Pl. I. fig. 7.

This small species occurs by millions in the Carboniferous limestone and shale of Thibet, where it does not appear to have much exceeded $4\frac{1}{2}$ lines in length and 7 in width. Prof. De Koninck agrees with me in considering it to be a variety of *C. Hardrensis*. The shell is semicircular, concavo-convex, with a straight hinge-line, each valve being provided with a narrow subparallel area. The surface of each valve is ornamented with from thirty-five to fifty rounded ribs, of which a small proportion are due to interpolation. The surface is also traversed by fine contiguous striæ. As I have elsewhere observed, *C. Hardrensis* is a very variable species, and this has, no doubt, induced palæontologists to consider some of its local variations in shape as distinct species. The striæ vary much in number and strength; in some British examples they are exceedingly numerous and fine, while in other specimens they are much less numerous and coarser, the shell differing in size much according to age and locality. *C. variolata*, D'Orb., is, I believe, only a different name for the same shell.

## § 2. Jurassic Species.

According to Capt. Godwin-Austen, rocks of the Jurassic period are largely developed at Kato, in Ladak, in the Suru Country of Thibet. In a limestone rock of a yellowish colour, which Capt. Godwin-Austen refers to the Oxfordian period, the two following species of Brachiopoda have been met with.

1. Terebratula Thibetensis, spec. nov. Pl. I. figs. 11–14.

Shell longer than wide, sometimes oval and rounded in front, but more often truncated or indented at the front, and even biplicated. Ventral valve regularly convex and rather deeper than the opposite one; beak incurved and truncated by a circular foramen; dorsal valve evenly convex or biplicated near the front. Dimensions variable. Length 1 inch 8 lines, width 1 inch 1 line, depth 11 lines.

This species is extremely variable in its external shape, so much so, indeed, that were I not provided with thirty-five or thirty-six examples, showing every intermediate form, I should hardly venture to consider them all as variations in shape of a single species. Some examples are of an elongated oval form (fig. 12), such specimens being nearly uniformly convex with hardly any apparent biplication in the dorsal valve, under which aspect it resembles some examples of *T. punctata*, and other closely related forms. Other specimens have a straight or slightly indented hinge-line, with a greater or less tendency to biplication, as in fig. 11, under which condition they approach in shape some examples of Mr. E. E. Deslongchamps's *T. dorsoplicata* and even *T. perovalis*, while others, again, are decidedly biplicated, as in figs. 13 and 14, and are not unlike some Cretaceous specimens of *T. biplicata* and the Jurassic *T. indentata*.

The same kind of variation in form, with almost similar shapes, has been shown to occur in *T. biplicata* and in *T. dorsoplicata*, &c.; and, indeed, so similar and perplexing are the resemblances of the shell under description to several congeneric forms already described, that it is with much uncertainty that I have ventured to apply to the Thibet shell a distinct specific denomination.

2. Rhynchonella Katonensis, spec. nov. Pl. I. figs. 15 & 16.

Shell variable in shape, almost circular and globular, nearly as wide as long. Valves about equally convex and deep, ornamented with from thirteen to fourteen angular ribs, of which from three to six occupy a slightly elevated fold in the dorsal valve, and sinus in the ventral; beak incurved, of moderate projection. Proportions variable. About 13 lines in length and breath, by 10 in depth.

Of this shell two varieties appear to occur at Kato, which may be distinguished by the number and projection of their ribs.

## § 3. Cretaceous (?) Species.

A compact light grey limestone near Lacholung La, north side, in the Suru Country in Thibet, contains in abundance two species of Brachiopoda. The exact age of this rock does not appear to have been hitherto satisfactorily determined; but as these two Brachiopods have a very Cretaceous aspect, and as Capt. Godwin-Austen informs me that a rock at a place called Kalatys in the Upper Indus, not above fifty miles from where the Jurassic fossils were found, contains *Hippurites*, it may not perhaps be impossible that the light compact limestone in question may belong to the Cretaceous period. This point, however, cannot well be determined from the examination of the two species of Brachiopoda therein found, as somewhat similarly shaped shells do also occur in rocks of the Jurassic period.

1. Waldheimia Blanfordi, spec. nov. Pl. I. fig. 8.

Shell obscurely pentagonal, straight or slightly indented in front. Valves gently convex and smooth, no mesial fold in the dorsal valve, but a gentle depression or sinus occurs near the front of the ventral; beak small, truncated by a foraminal aperture. Length $8\frac{1}{2}$, width 8, depth 4 lines.

2. Rhynchonella, sp. Pl. I. figs. 9 & 10.

Shell transversely oval, wider than long. Valves equally deep and convex; when well-shaped there exists in the dorsal valve a wide very slightly elevated mesial fold, a sinus being present in the opposite one. The surface of each of the valves is ornamented with about twenty-four angular ribs, of which five or eight occupy the fold and sinus. These last are, however, very often shifted more to the one or to the other side, giving the shell an unsymmetrical appearance. Beak angular; foramen small, contiguous to the umbone. Proportions variable. Length 10, width 12, depth 5 lines.

This irregularity in the position of the fold and sinus may be occasionally noticed in many species of the genus *Rhynchonella*, but is particularly prevalent in certain Jurassic forms, such as *R. inconstans*, *R. sulcata*, *R. dimidiata*, &c.; indeed so closely do some of the specimens under description approximate in shape to some specimens of Parkinson's *R. sulcata*, and to another species to which Sowerby had given the name of *R. dimidiata*, that I would not venture for the present to indentify the Thibet fossil by any definite specific denomination.

## EXPLANATION OF PLATE I.

*Illustrative of Carboniferous, Jurassic, and Cretaceous (?) Brachiopoda from Thibet.*

(The figures are all of the natural size.)

CARBONIFEROUS SPECIES, FROM SHIGAR, NEAR SKARDO.

Fig. 1. *Terebratula Austeniana*, spec. nov.
2 & 3. *Rhynchonella pleurodon*, var. *Davreuxiana*, De Koninck.
4. *Spirifer*, sp.
5. *Orthis*, sp.
6. *Productus semireticulatus*, Martin.
7. —— *Hardrensis*, var. *Thibetensis.*

CRETACEOUS (?) SPECIES, FROM NEAR LACHOLUNG LA, IN THE SURU.

8. *Waldheimia Blanfordi*, spec. nov.
9 & 10. *Rhynchonella*, sp.

JURASSIC SPECIES, FROM KATO, LADAK, IN THE SURU.

11–14. *Terebratula Thibetensis*, spec. nov.
15 & 16. *Rhynchonella Katonensis*, spec. nov.

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## *Notes on the* CARBONIFEROUS BRACHIOPODA *collected by* CAPTAIN GODWIN-AUSTEN *in the* VALLEY OF KASHMERE. By T. DAVIDSON, Esq., F.R.S., F.G.S., &c.

(PLATE II.)

IN 1864 I was requested by Mr. Godwin-Austen to examine a series of Carboniferons Brachiopoda which his son had obtained from limestone and shales near Shigar and Skardo, in Thibet (see p. 35), and which I found to consist of the following species:—

1. Terebratula Austeniana, *n. sp.*
2. Spirifer ? Not sufficiently complete to be satisfactorily determined.
3. Rhynchonella pleurodon, *var.* Davreuxiana.
4. Orthis, *sp.* (approaching in form to *O. Micheleni*).
5. Productus semireticulatus.
6. Chonetes Hardrensis, *var.*

The species were few in number, but bear great resemblance to those found in rocks of a similar age in Europe and America, and there is every reason to believe that when the Carboniferous series of Thibet shall have been further searched that a larger number of species will be discovered.

This year I have again had under examination a much larger series of Brachiopoda which Captain Godwin-Austen had procured from the Carboniferous limestone and shales which form the hills around Vihi, in the Valley of Kashmere. The Brachiopoda abound in a bed of limestone near the entrance of the ravine above the village of Khoonmoo; but the lowest portion, or Zèwan bed, is stated by Captain Godwin-Austen to contain the larger number of Brachiopoda; and a higher stage, still near the base of the formation, is said to contain abundant remains of *Productus*. Barus may likewise be named as one of the most fossiliferous localities. These Brachiopoda are, however, but rarely in a good state of preservation, and most of the specimens occur only in the condition of more or less mutilated and worn fragments. Here again we find many of our common and widely spread European and American species, along with a few that had not yet been noticed from other parts of the world, and which indicate that the Carboniferous rocks of Thibet, Kashmere, and the Punjab belong to one great formation.

1. Terebratula sacculus, Martin, sp.? Pl. II. fig 1.

*Anomites sacculus*, Martin, Petref. Derb., tab. xlvi. fig. 1.

Two ventral valves of a shell having much the appearance of some of our British examples of *T. sacculus* occur in a grey-coloured limestone from Barus.

2. Athyris subtilita, Hall, var. Pl. II. fig. 2.

*Terebratula subtilita*, Hall, in Howard Stansbury's Exploration of the Valley of the Great Salt Lake of Utah, p. 409, pl. 2. figs. 1 & 2.

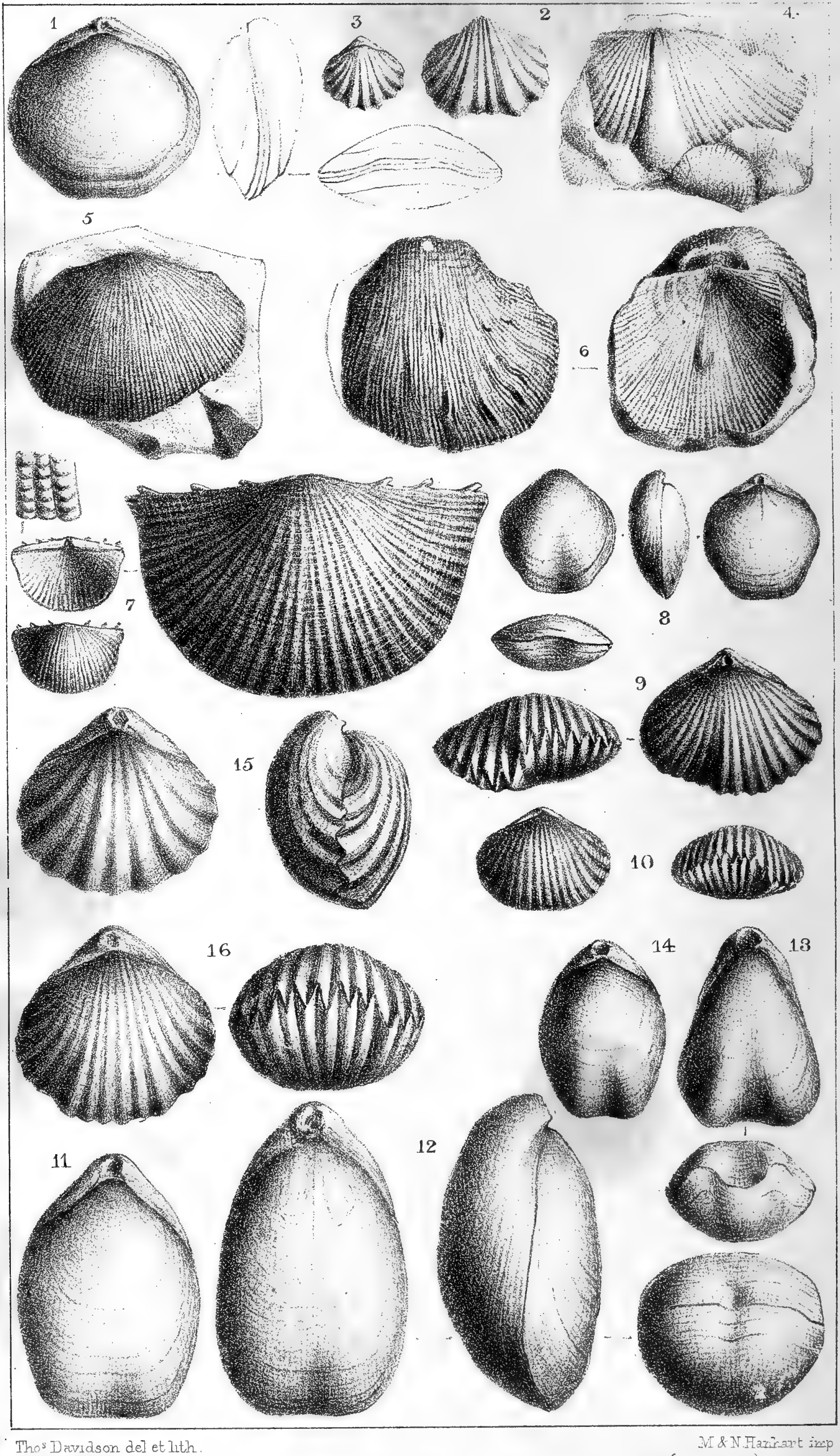
This appears to be a common shell in a grey limestone at Khoonmoo, but has also been found at Barus, and is very abundant in the Punjab.

3. Spirifera Rajah, Salter. Pl. II. fig. 3.

*Spirifera Rajah*, Salter, Palæontology of Niti in the Northern Himalaya, pp. 59 & 111. Calcutta, 1865.

Shell marginally longitudinally oval; hinge-line slightly shorter than the greater width of the shell. Ventral valve convex, with a narrow sinus or groove extending from the extremity of the beak to the front, and along the centre of which there exists a narrow thread-like rib. The surface of this valve is ornamented with from sixteen to twenty rounded ribs, of which the two central ones are the largest as well as the most prominent, each rib being again furrowed by three, four, or five smaller ones, while the whole surface is also finely longitudinally striated. Beak prominent and incurved; area of moderate width and divided in the middle by a triangular fissure. Dorsal valve convex, but less deep than the ventral. The mesial fold is well defined and composed of a single rib at its origin, and continues so to some distance, when a smaller lateral rib is produced on either side, and extends to the front; the remaining portion of the valve is covered with a similar succession of smaller rounded ribs, simple at their origin, but soon producing a small one on each of its lateral portions, the whole surface being also marked with fine longitudinal striæ, as well as by numerous fine concentric lines of growth. The largest specimen I have seen, if complete, would measure in length 23, in width 22 lines.

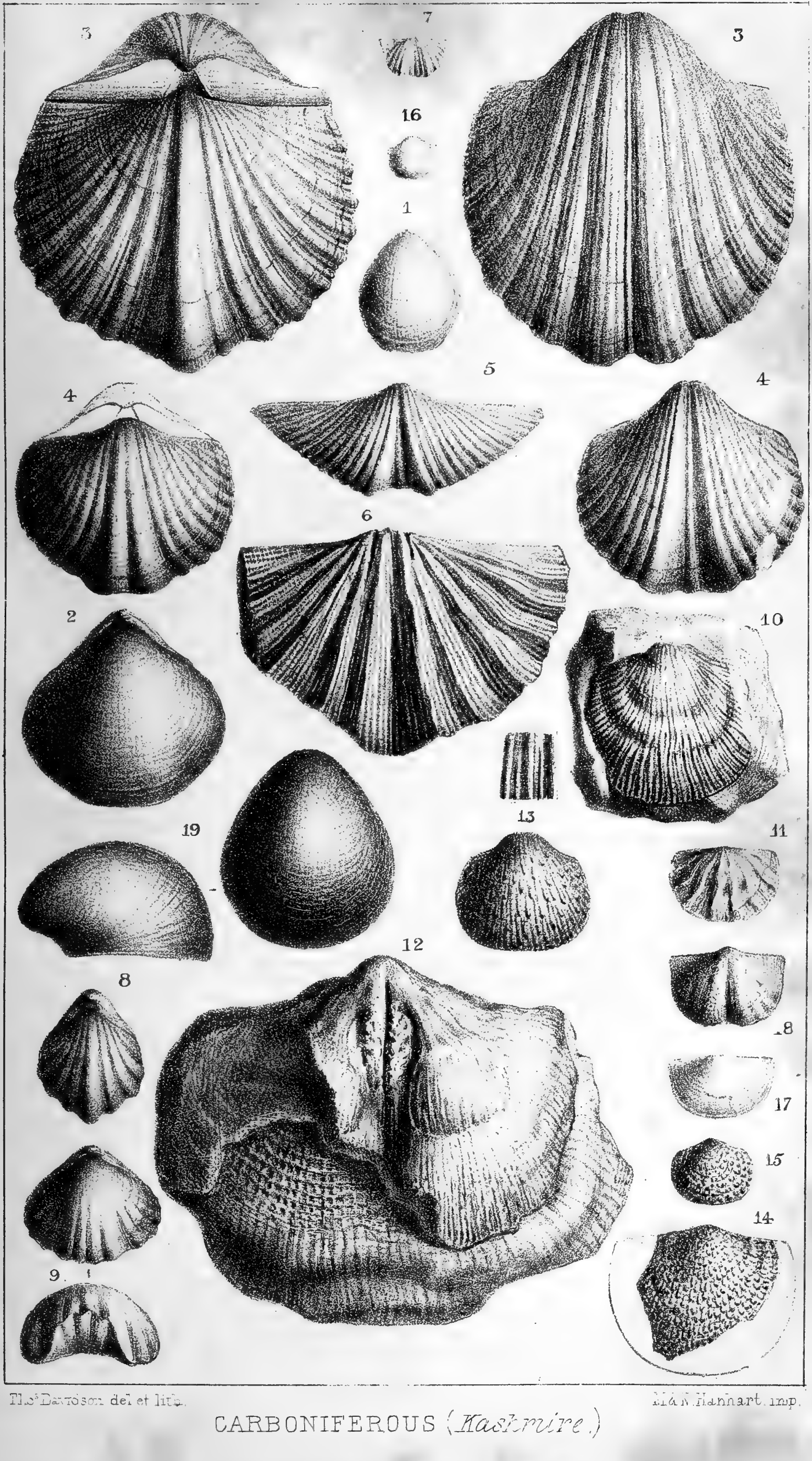
Of this beautifully sculptured Spirifer a great many imperfect specimens were found by Captain Godwin-Austen at Barus, in beds of the Carboniferous age. At p. 59 of Colonel R. Strachey's 'Palæontology of Niti,' this species is described and figured by Mr. Salter, who observes that "the peculiar square shape, not very convex valves, acute ribs, are all characters in which *Spirifera Rajah* approaches very near




Thos Davidson del et lith.

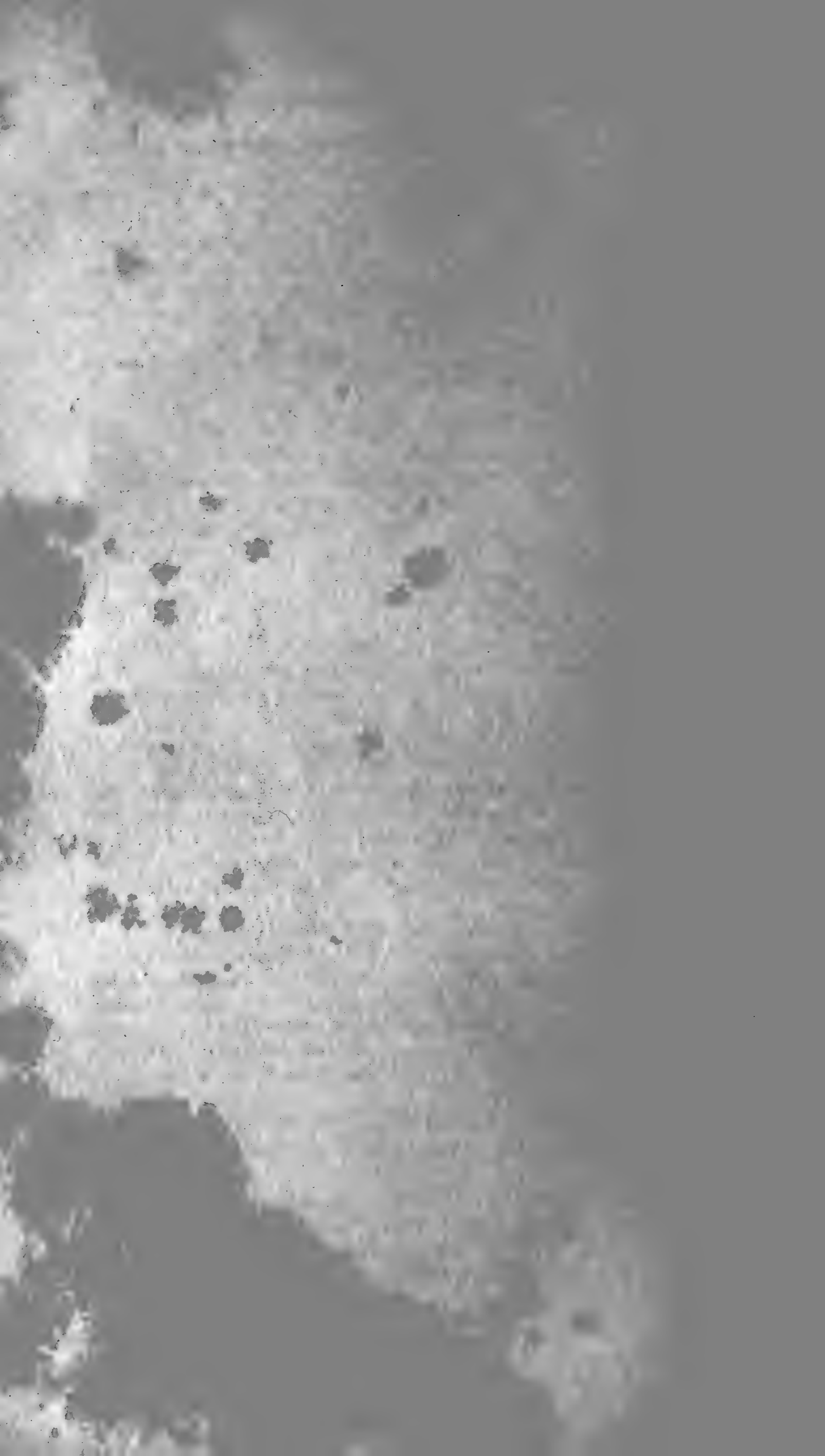
M & N. Hanhart imp

CARBONIFEROUS, JURASSIC & CRETACEOUS (*Thibet*)




Thos Davidson del et lith. M & N Hanhart imp.

CARBONIFEROUS (*Kashmire.*)



the *Spirifera Keilhavii.* But the fasciculate secondary ribs are stronger, while the costæ themselves are less deep." At page 59 of the work above named this shell is stated to have been derived "from the Trias beds of Spiti Pass"; but at page 111 of the same work Mr. H. F. Blanford observes that the *Spirifera Rajah* (of Salter) does not occur in the same bed with Triassic Ammonites, but in beds decidedly below them—beds which other evidence combines to show must be referred to the same general relative age (in the sense of *homotaxis*) as the Carboniferous of Europe. This last view would be confirmed by Captain Godwin-Austen's observations in Kashmere, where the species is Carboniferous.

4. Spirifera Vihiana, spec. nov. Pl. II. fig. 4.

Shell longitudinally oval, longer than wide; hinge-line rather shorter than the greatest width of the shell. Both valves are convex, the ventral being the deeper; and each is ornamented with from eighteen to twenty simple ribs. In the dorsal valve the mesial fold is divided by a longitudinal groove, while in the middle of the sinus of the ventral there exists a small median rib. Beak incurved; area of moderate dimensions. One specimen measured 15 lines in width by about 14 in length.

Three valves of this Spirifer were found embedded in a single specimen of limestone from Barus, in the Valley of Kashmere. It is distinguishable from *S. pinguis* by its constant well-marked median rib in the sinus of the ventral valve.

5. Spirifera Kashmeriensis, spec. nov. Pl. II. fig. 5.

Shell transversely fusiform; hinge-line long and straight, the lateral margins becoming gradually attenuated. Ventral valve ornamented with about twenty simple ribs; the sinus deep and divided along the middle by a small median slightly projecting rib, which, commencing at a short distance from the beak, extends to the front. Length 7, width 18 lines.

Of this Spirifer I have seen two or three ventral valves only, one of them occurred in the same block of limestone along with *S. Vihiana* obtained from the neighbourhood of Barus, the other specimens were labelled Khoonmoo. It may be distinguished from the preceding species by its very transverse spindle shape, and it is not very unlike in form some examples of *S. macropterus*, Goldf., but may be distinguished by the presence of the small median rib in the sinus.

6. Spirifera Moosakhailensis, Dav. Pl. II. fig. 6.

*Spirifera Moosakhailensis*, Dav. Quart. Journ. Geol. Soc. vol. xviii. p. 28, pl. 2. fig. 2.

Two or three specimens, agreeing in character with those I have already described from the Carboniferous limestone of Moosakhail and Kafir Kote, in the Punjab, were found at Barus. Prof. E. Beyrich informs us also that this shell was found in the Carboniferous limestone of the Island of Timor.

7. Spirifera Barusiensis, spec. nov. Pl. II. fig. 7.

Shell subrhomboidal; hinge-line straight and as long as the width of the shell; cardinal extremities angular and projecting; sinus wide. Surface ornamented with about fifteen ribs, those in the sinus being much smaller than those on the lateral portions of the valve. Length 2½, width 5 lines.

Of this small Spirifer a single ventral valve was found in the Carboniferous shales or Zéwan beds of the Valley of Kashmere. It is quite different in shape and character from the other three species, and remarkable on account of the great comparative width of its sinus. The description of this shell and that of *S. Kashmeriensis* are necessarily very incomplete, since our material consists of ventral valves only.

8. Rhynchonella Barumensis, spec. nov. Pl. II. fig. 8.

Shell elongated, subtrigonal; dorsal valve convex, the mesial fold being very wide and composed of three ribs, of which the central is the most elevated; three smaller ribs occupy each of the lateral portions of the valve. Ventral valve rather deeper than the opposite one, the wide sinus having two ribs, while three or four smaller ones occupy each of the lateral portions of the valve. Beak much produced and incurved at its angular extremity. The lateral portions of the ventral valve at and near the beak are much depressed and form a convex curve, which indents to a considerable extent the corresponding portion of the dorsal.

Of this species two longitudinal halves only were found in the Zéwan beds, Valley of Kashmere; but they were sufficiently perfect to enable me to accurately restore the wanting portions. The largest example measured, when perfect, 9 lines in length, by 7 in width, and 4 in depth. It bears a certain resemblance to some examples of *Rhynchonella angulata*, Linn., with which, however, it cannot with certainty be identified.

9. Rhynchonella Kasmeriensis, spec. nov. Pl. II. fig. 9.

Shell oblato-deltoidal, wider than long. Ventral valve convex, with a wide deep sinus possessing four or five rounded ribs of unequal width, namely, a small central one intervening between two larger ones. Three or four ribs occupy also each of the lateral portions of the valve. Beak small, incurved. Dorsal valve convex, smooth at the umbone; mesial fold wide, evenly convex, and ornamented with four ribs, three others occupying each of the lateral portions of the valve in the contiguity of the margin.

Of this shell a single specimen was found in the Zéwan beds, Valley of Kashmere; in form it approaches some examples of *R. pugnus*, but differs by the shape of the ribs in the sinus. The study of more specimens would be desirable.

10. Streptorhynchus crenistria, Phillips. Pl. II. fig. 10.

*Spirifera crenistria*, Phillips, Geol. of Yorkshire, vol. ii. pl. ix. fig. 6.

Several examples agreeing with those found in Europe have been obtained at Barus and in the Zéwan beds, in the valley of Kashmere. The species occurs also in the Punjab.

11. Streptorhynchus, ? sp. Pl. II. fig. 11.

One imperfect valve appears referable to another species of this subgenus, but the specimen was not sufficiently complete to admit of its specific distinctions or characters being satisfactorily determined. The valve is about 5 lines in length by 7 in width, moderately convex, and ornamented with about eight rounded ribs, three or four smaller longitudinal ones occupying the wide interspace left between the larger. From the Zéwan beds, in the Valley of Kashmere.

12. Productus semireticulatus, Martin, sp. Pl. II. fig. 12.

*Anomites semireticulatus*, Martin, Petrif. Derb. pl. xxxii. figs. 1 & 2, and pl. xxxiii. fig. 4.

A large variety of this well-known and far spread species is exceedingly abundant at Barus, and is indeed (along with *Spirifera Austeniana* and *Athyris subtilita*) the Brachiopod most commonly found, but unfortunately apparently always in a very bad or indifferent state of preservation; it occurs also near Loodoo west of Wasterwan A smaller variety has been found in the Punjab and also in Thibet.

13. Productus cora, D'Orbigny.

*Productus cora*, D'Orbigny, Paléontologie du Voyage dans l'Amérique Méridionale, pl. v. figs. 8, 9, & 10.

Three or four specimens referable to this species have been found at Barus; it occurs also in the Punjab, and is very common in Europe.

14. Productus scabriculus, Martin. Pl. II. fig. 13.

*Anomites scabriculus*, Martin, Petrif. Derb. p. 8, pl. xxxi. fig. 5.

Of this well-known species some examples were found at Barus and Khoonmoo.

15. Productus Humboldtii, D'Orb. Pl. II. fig. 14.

*Productus Humboldtii*, D'Orb. Paléont. du Voy. dans l'Amérique Méridionale, pl. 5, figs. 4–7.

Two fragments referable to this species were found at Khoonmoo, and in the Zéwan beds, Valley of Kashmere; it is also common in the Punjab.

16. Productus longispinus, Sow. ?

*Productus longispinus*, Sow. Min. Conch. vol. i. p. 154, pl. lxviii. fig. 1.

Of this species an imperfect example was obtained from the grey limestone at Khoonmoo. It is exactly like some specimens found in the Punjab.

17. Productus striatus, Fischer?

*Mytilus striatus,* Fischer, Oryct. du Gouv. de Moscow, p. 181, pl. xix. fig. 4.

A fragment, having much the appearance of having belonged to this well-known species, was found at Barus, in the Valley of Kashmere, but the specimen was not sufficiently complete to warrant a certain identification. The shell is not rare in the Punjab.

18. Productus spinulosus?, Sow. Pl. II. fig. 15.

Two specimens, bearing much resemblance to some of our European examples, were obtained from the grey limestone of Khoonmoo. The shell is small, transversely semicircular; the ventral valve regularly convex, without sinus; surface covered with numerous subregular small tubercles, somewhat quincuncially arranged (each tubercle having given rise in the perfect shell to a slender spine); the concentric wrinkles are also slightly marked, and on one specimen somewhat as we find to be the case in *P. Keyserlingiana,* or even *P. Deshayesiana,* De Koninck, to which these Kashmere shells bear some resemblance.

19. Productus lævis, spec. nov. Pl. II. fig. 16.

Shell small, nearly circular; hinge-line slightly shorter than the greatest width of the shell; ventral valve evenly convex; ears small; surface smooth? Length 3 lines, the width slightly exceeding that of the length.

Of this small species a single ventral valve has been discovered, but it was so distinct, both by its shape and surface, from other known species of the genus that I have ventured to apply to it a distinctive designation. It occurs in a coarse limestone in the Zéwan beds, Valley of Kashmere, but less compact and of a lighter grey than the bed from which most of the species found at Khoonmoo were obtained.

20. Productus, sp.?

A fragment of internal cast indicates the presence of another species, but not specifically determinable from the material in our possession. Barus.

21. Chonetes lævis, spec. nov. Pl. II. fig. 17.

Shell marginally semicircular, concavo-convex; hinge-line straight, about as wide as the width of the shell; each valve is provided with a subparallel area, which is widest in the ventral valve; ventral valve moderately convex, flattened towards the ears; surface smooth? Length 4, width 6 lines. Of this *Chonetes* two or three more or less complete specimens occur on a fragment of limestone from Barus, in the Valley of Kashmere.

22. Chonetes? Austeniana, spec. nov. Pl. II. fig. 18.

Shell marginally transversely semicircular; hinge-line straight, as wide as the shell; ventral valve moderately convex, with a narrow median concave groove commencing at the extremity of the beak and extending to the front; four obscure rounded ribs of very small elevation may be traced on the lateral portions of the valve in contiguity as to the central groove. I have seen but a single incomplete specimen of this species, which occurs in the same coarse light-grey limestone which contains *Productus lævis.* From the Zéwan beds, Valley of Kashmere.

23. Discina Kashmeriensis, spec. nov. Pl. II. fig. 19.

Shell marginally ovate or longitudinally oval, the posterior portion being narrower than the anterior. The imperforate valve is convex, and most elevated towards the middle, the rounded apex sometimes projecting beyond the level of the posterior margin. Surface smooth. Length 13, width 11 lines.

Of this curious species two specimens were found at Khoonmoo, in the Valley of Kashmere.

## EXPLANATION OF PLATE II.

*Illustrative of Carboniferous Brachiopoda from Kashmere.*

(The figures are all of the natural size.)

Fig. 1. *Terebratula sacculus*, Martin. Barus.
2. *Athyris subtilita*, Hall, var. Barus and Khoonmoo.
3. *Spirifera Rajah*, Salter (partly restored). Barus.
4. —— *Vihiana*, spec. nov. Barus.
5. —— *Kashmeriensis*, spec. nov. Barus and Khoonmoo.
6. —— *Moosakhailensis*, Dav. Barus.
7. —— *Barusiensis*, spec. nov. Zéwan beds.
8. *Rhynchonella Barumensis*, spec. nov. Zéwan beds.
9. —— *Kashmeriensis*, spec. nov. Zéwan beds.
10. *Streptorhynchus crenistria*, Phillips. Barus and Zéwan beds.
11. ——, sp. Zéwan Beds.
12. *Productus semireticulatus*, Martin. Barus,
13. —— *scabriculus*, Martin. Barus and Khoonmoo.
14. —— *Humboldtii*, D'Orb. Khoonmoo and Zéwan beds.
15. —— *spinulosus*?, Sow. Khoonmoo.
16. —— *lævis*, spec. nov. Zéwan beds.
17. *Chonetes lævis*, spec. nov. Barus.
18. ——? *Austeniana*, spec. nov. Zéwan beds.
19. *Discina Kashmeriensis*, spec. nov. Khoonmoo.

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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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December 6, 1865.

W. Phipson Beale, Esq., 27 Victoria Street, S.W.; Henry Braddon, Esq., 5 Danes' Inn, Strand; Captain Robert Clipperton, H.B.M. Consul at Kertch; Tellef Dahll, Esq., Kragere, Norway; R. A. Eskrigge, Esq., 24 The Albany, Old Hall Street, Liverpool; Hugh Frederick Hall, Esq., Liverpool; Hedworth Hylton Joliffe, Esq., Merstham, Surrey; Edward Myers, Esq., 29 Summer Hill Terrace, Birmingham; George Pycroft, Esq., M.R.C.S.E., Kenton, Exeter; Ferdinand Stoliczka, Ph.D., of the Geological Survey of India, Calcutta; Erwin Harvey Wadge, Esq., Stradbrook Hall, Blackrock, co. Dublin, Ireland; Henry Augustus Ward, Esq., Professor of Natural Sciences in the University of Rochester, New York; and Frederick M. Williams, Esq., M.P., Goonvrae, near Truro, were elected Fellows.

The following communications were read:—

1. *On the* Western Limit *of the* Rhætic Beds *in* South Wales, *and on the* Position *of the* "Sutton Stone." By E. B. Tawney, Esq., F.G.S. *With a note on the* Corals, by P. Martin Duncan, M.B., Sec.G.S.

[Plates III. & IV.]

Contents.



1. *Introduction.*—The object of the present paper is to notice some

peculiarities of the *Avicula-contorta* series at their most westerly boundary in Great Britain; to discuss the "Sutton Stone" as to its stratigraphical, lithological, and palæontological relations; to show from organic remains that its affinities are with the Triassic formation, and not with the Lias as commonly supposed, and then to claim it as Rhætic, and in so doing to extend, for the first time in England, the range of Ammonites down into the Rhætic series.

At the Bath Meeting of the British Association for 1864, Sir R. I. Murchison announced the presence of the argillaceous limestones and shales of the Rhætic series in a small outlier of Lias (as mapped) close to Pyle Station (west of Bridgend); and having in this way had my attention directed to the subject, I found that the *Avicula-contorta* strata were widely extended in this district; and as they show some peculiarities here, I will begin by a few remarks on these beds.

2. *Pyle district.*—The above-mentioned patch, sufficiently described by Mr. Bristow*, consists of buff-coloured marls and greyish-brown shales and limestones, which last, from their appearance and conchoidal fracture, remind one of the Cotham marble: these are probably high in the series; they are mapped as lying on the Keuper.

A few hundred yards south of this we reach the southern limit of the Keuper in this district. It consists of red marls with buff and green marls resting upon them; the same conditions occur at the base of the Rhætic series at Wenvoe, Barry Island: and besides this, there is very little of the New Red series in this district; what has been hitherto called Keuper is much of it Rhætic.

I am obliged to dissent from the opinion expressed by Sir H. De la Beche in his comprehensive and admirable memoir on the "Formation of Rocks in South Wales"†, that the sandstones near Pyle church are inferior to the red marl lately spoken of: the district is more broken by faults than is expressed in the map of the Geological Survey; and this may have caused some ambiguity.

The sandstones at the base (10–12 feet thick) are in places much weathered, the iron being changed to peroxide, and the mass crumbling to rusty sand under the hammer; others are unoxidized and harder, namely the pale-green or yellow thick sandstones, affording when dry a good building-stone: some of these beds are very similar to the white Keuper sandstones near Bridgend. Above these are hard, green-and-white mottled and purple marls. These belong to the *Avicula-contorta* series, and not to the Keuper. The search for fossils is frequently unsuccessful here, from the oxidation of the beds, due to exposure to moisture and air. On the quarry-refuse heaps are found great numbers of a small species of *Natica* crowded together by hundreds; *Anatina præcursor* also is abundant. The fossils of these sandstones, which are exceedingly fossiliferous on Stormy Down and near Laleston are

| | | |
|---|---|---|
| Myophoria postera, | Saurichthys apicalis, | Axinus elongatus, |
| Natica Pylensis, | Acrodus minimus, | —— depressus, |
| Anatina præcursor, | Avicula contorta, | —— cloacinus. |
| Modiola minima, | | |

* Report Brit. Assoc. Bath, 1864, Trans. Sections, p. 50.
† Memoirs of the Geological Survey, vol. i. p. 252.

Since commencing this paper, a pit sunk for sand on Stormy Down revealed the following section (this excavation has since been again partly filled up):—At the base were seen 6 feet of the pale-green and white sandstones; these were extremely fossiliferous (a specimen from these beds is presented to the Society): above were green laminated marls containing *Avicula contorta*, and then yellow sands and sandstones (about 6 feet).

3. *Bridgend district.*—Though fossils were perfectly conclusive as to the true nature of the above beds, yet the following section is of great interest as showing their relation to the Rhætic shales and bone-bed. This section is on the south side of the South Wales Railway-cutting at Cwrt-y-Coleman, about a mile and a half west of Bridgend.

At the base are seen 8 or 10 feet of white or yellowish massive sandstone with a few small rounded quartz pebbles. I have not found fossils in this bed, except coprolites at the top of it, but I believe it may be of Rhætic age; and it is probable that it will be found to be fossiliferous, as it contains brown stains and marks of organic matter, and in this and general structure is like some of the beds at the top of the section. It may probably be of these sandstones that Sir H. De la Beche notices travelled blocks on the western part of Newton Down*; he describes it as a quartz rock (between Pyle and Bridgend), with the grains of white quartz firmly bound together by nearly colourless silica.

Above this are about 3 feet of shales, including a curious marly limestone, grey and green in colour, the grey part of which is very full of shells and shell-fragments: the fracture of this bed is conchoidal, so that the shells are nearly always broken across. Above this is a siliceo-micaceous limestone from 2 to 3 inches thick, with irregular marly surfaces: this is the true representative of the Aust bone-bed. On splitting off the exterior laminæ of this bed a multitude of teeth of *Acrodus* and *Hybodus* and fish-scales are seen. I have also found a reptilian bone. The remains I have noticed in this bed are

| | | |
|---|---|---|
| Saurichthys apicalis, | Gyrolepis tenuistriatus, | Hybodus cuspidatus (*Ag.*), |
| —— acuminatus, | —— alberti, | —— orthoconus (*Plien.*), |
| Acrodus minimus, | Hybodus minor (*Ag.*), | —— plicatilis (*Ag.*), |
| —— acutus, | | and scales of other species. |

This bed is not conglomeratic, beyond an occasional rolled quartz pebble, but is a fine-grained tough micaceous limestone.

I was ignorant at the time of this discovery that the bone-bed had been found so far west as St. Hilary, nine miles east of Bridgend.

Above the bone-bed come dark shales, 3 feet; then a chocolate-coloured soft sandstone-bed (1 inch) containing *Avicula contorta*, *Pecten Valoniensis*; then shales, 3 inches; then three beds of siliceous limestones with fish-scales, *Anomia*, &c.; these beds change their conditions somewhat at different parts of the section, being more sandy in places or again thin out into shale; above are 9 feet of shales, marls, and sandstones; and then 17 feet of white and pale-green and yellow sandstones and sands.

* *Loc. cit.* p. 252.

These beds represent the black shales and argillaceous limestones above the bone-bed at Penarth, &c.

The abundance of silica and comparative scarcity of calcareous and aluminous matter here, as compared with the sections of Penarth or the west of England, is noticeable; the explanation no doubt lies in the proximity of this series to or upon the Palæozoic rocks of Carmarthenshire, Brecknockshire, Cardiganshire, and North Wales, with their sandstones and grits.

Though a fault is now the boundary of the Rhætic series northwards, it perhaps nearly corresponded with the shore of the Rhætic sea, the rivers running into which drained large Palæozoic areas. That the water was shallow is probable from the varied conditions of the bedded sandstone in a small area round this district; moreover the abundance of sand and not mud shows the probable deposition near a shore. That it coincided with some shore and system of islands at the close of the Bunter period we know from the disposition of the Magnesian Conglomerate in this area.

We may suppose that there has been no great extension either of the Rhætic or Keuper series northward on the Coal-measures; or more cases similar to that described by Sir H. de la Beche near Bridgend, of Trias resting on Coal, would have occurred. The great denudation of the Coal-measures took place before the deposition of the secondary rocks here; and perhaps denuding forces have been *comparatively* passive since.

4. *Keuper near Bridgend.*—North of Bridgend, one mile and a half on either side of the river Ogmore, are white Keuper sandstones showing very similar characters to some of the *Avicula-contorta* sandstones: these yield a stone well fitted for architectural purposes, being soft but durable. At the quarry here there are 25 feet of pale-green or white Keuper sandstones capped by 6 feet of green sandy marls (Rhætic?). These sandstones must be at the base of the Keuper.

5. *Sutton Stone.*—I come now to the consideration of the Sutton Stone. This is spoken of by Sir H. De la Beche * as a "whitish variety of the Lias." He notices that it commences with a white conglomerate enclosing pebbles of Carboniferous Limestone, upon which formation the Sutton Stone is seen to lie, and particularly well on the coast between Sutton and West farmhouses, and again at Dunraven Point. He notices the grey Lias above these beds, and draws attention to the conglomeratic character of the Lias around Langan.

These beds I now claim as Rhætic, and would unquestionably separate from the Lias. As developed on the coast, they are between 80 and 90 feet in thickness: to the lower half of this the term "Sutton Series" may apply; and for the upper half I propose the name of "Southerndown series," as they are best seen in the fine cliff-exposure under the hamlet of Southerndown.

6. *Sutton Series.*—The term "Sutton Stone" is generally applied to the white and softer beds or freestones which are used for architec-

* *Loc. cit.* p. 272.

tural purposes. The beds differ much in texture: some are fine-grained white limestones, others are softer and very shelly; some are yellowish-white, and at the upper part are pale-grey and become gradually harder. All these, together with the white conglomerate at the base, I include in the Sutton series: the characters of whiteness and softness are only gradually lost, the pale-grey beds being equally fossiliferous, and in fact the top beds differ only by being darker and harder.

The Sutton series is seen lying on the Carboniferous Limestone along the coast from the mouth of the river Ogmore to the Southerndown cliffs, and is again brought up by a fault at Dunraven, where it forms the Point arching over the Carboniferous Limestone. Between Sutton and West the Carboniferous Limestone is approximately horizontal; and there is apparent conformability between it and the white conglomerate which begins the Sutton series; further on towards Southerndown the Carboniferous Limestone dips at about an angle of 45°, while the Sutton series is still nearly horizontal: this is also the relation of the beds at Dunraven Point; immediately after this the Sutton and Southerndown series disappear beneath the Lias and the sea.

The conglomerate at the base consists of rolled pebbles of Carboniferous Limestone very numerously imbedded with occasional pieces of chert in a soft, fossiliferous, white matrix. The fossils most abundant in this bed are

| | |
|---|---|
| Lima tuberculata, | Ostrea lævis, |
| Plicatula intusstriata, | Cardita rhomboidalis, |
| —— acuminata, | Corals. |

The included fragments of Carboniferous Limestone are seen to contain *Spiriferæ*, *Productæ*, &c.

Some of the corals may be derived from the Carboniferous Limestone, for that formation here is seen to be full of corals weathered out on the surfaces of the beds by the action of the sea and atmosphere; the other species are not derived. This conglomerate is 4 feet thick.

Above this come the white and pale-yellow freestones; many of these beds contain shattered fragments of black chert, frequently collected together in bands. The source of these abundant chert-masses is probably the Carboniferous Limestone. At Dunraven Point the Carboniferous Limestone is seen to contain bands of this black chert as well as large ramifying spongiform masses. Another noticeable character of the series is the curious sutural junction of many of the beds, the appearance being of miniature basalt-like columns, proceeding from a few inches deep in one bed upwards for the same height into that immediately above; this is, doubtless, of stalactitic origin; the structure may sometimes be seen passing through a fossil and distorting it more or less.

The presence and dissemination of Galena through these beds is also to be noticed. Sir H. De la Beche notices it as occurring in the plants of the Lower Lias (*sic*) here *; this may probably be in

* *Loc. cit.* p. 273, in note.

the lignite associated occasionally with the Sutton and Southerndown series, as I believe the Galena is confined almost entirely to these beds; it occurs in disseminated crystals and small strings, but not in workable veins.

It is plentifully scattered at Sutton and along the coast, and has before been noticed at Candleston *, where an attempt was made to work it. A more recent failure is that of Langan: a shaft was sunk and buildings half erected before the attempt was abandoned; this shaft passes through parts of the grey series, showing the rock to be a fine conglomeratic mixture of small flint-fragments with calcareous matter, and it reaches to the white series.

These beds are very fossiliferous; I have obtained from them some species new to Britain, and others, which are described in the sequel. Owing to the porous nature of the rock, the original shell-substance of the fossils is often dissolved away; this has added much difficulty to the determination of the species.

The most characteristic and common fossils are *Pecten Suttonensis*, *Ostrea multicostata*, a Muschelkalk species, *Lima tuberculata*, a coral, *Patella Suttonensis*, *Plicatula intusstriata*, and *P. acuminata*.

The Sutton Stone was formerly apparently more appreciated as a building-stone than it is now; it was used in several Norman castles in the county, having been conveyed considerable distances by land: it was also used in Neath Abbey (the characteristic fossils may be seen in stones lying about the ruins), and, I am told, in Swansea Castle; to these it was, no doubt, taken by water.

Besides the Sutton quarries, which are still worked, there is a good quarry east of Tythingstone church which has not been used for a long time, but from which much good stone has been taken.

7. *Southerndown Series.*—As the term Sutton Stone is applied only to the building-stones, I have divided off the rest of the series which intervenes before the commencement of the Lias here; and, for convenience of reference, I call it the Southerndown series; this has hitherto been regarded as Lias.

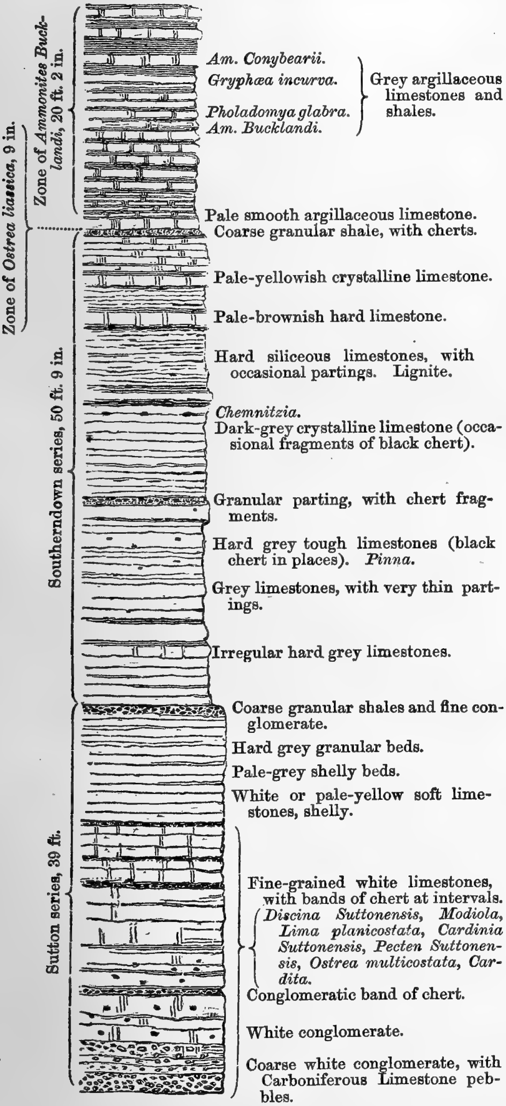
At the base we have a bed of chert-gravel, or rough shale full of small fragments of chert, together with larger pieces; it is 9 inches thick. This physical line may be also said to separate the softer, more fossiliferous, and whiter beds below, from the harder, darker, and perhaps less fossiliferous beds above.

As this series is not worked at all on the coast, nor much quarried inland, our knowledge of its fossils is much less full; however, *Plicatula intusstriata* occurs throughout it.

This series differs lithologically from the Sutton Stone in the beds being much harder and more irregularly bedded, and they are frequently subcrystalline and separated by thin arenaceous partings; again, the fragments of black chert are more sparingly scattered. On the other hand, it differs from the Lower Lias beds—which are earthy limestones separated generally by argillaceous shales, having no fragments of black chert, and not being conglomeratic. The two series differ also entirely in their fossils.

* *Loc. cit.* p. 273, in note.

Fig. 1.—*Vertical Section of Southerndown Cliff.*



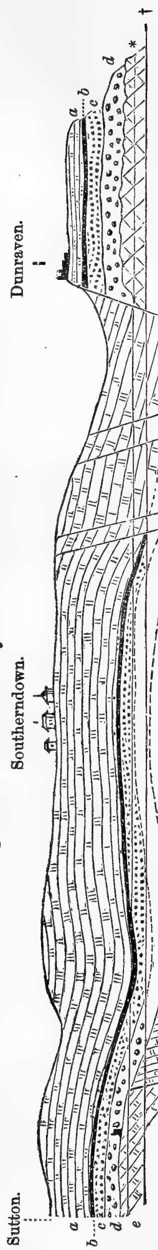




Fig. 2.—*Coast-section from Sutton to Dunraven.*

*a.* Zone of *Ammonites Bucklandi.* | *c.* Southerndown series. | *d.* Sutton series. | * High-water level.
*b.* Zone of *Ostrea liassica.* | | *e.* Carboniferous limestone. | † Low-water level.

Sometimes among the beds of this series may be seen a paler, softer, and shelly bed, showing a sort of return to the conditions of the lower beds.

This series I have estimated as 50 feet thick, having measured it bed by bed along the coast west of Dunraven; it extends here a distance of about one mile and a half, forming low anticlinals, but dipping on the whole east of south. There is some uncertainty in this estimate, from the presence of three small faults, for which I have allowed $4\frac{1}{2}$, $4\frac{1}{2}$, and $8\frac{1}{2}$ feet respectively, the downthrow being to the east.

About 16 feet down occurs a bed with a great number of large *Chemnitziæ*; the wearing action of the sea has formed sections through the columellæ of many, as they lie horizontally imbedded in the limestone terrace below high-water mark. Owing to the hardness and toughness of the beds, I have been unable to obtain specimens.

The uppermost bed of the series, which I take as the line of demarcation from the Lias, is a bed of conglomerate composed of chert-gravel with arenaceous matter, 4 to 8 inches thick, loosely held together; the fossils of this bed are

Plicatula intusstriata (abundantly),
Modiola minima,
Ostrea lævis,
Ostrea liassica,
Pentacrinus,
Cidaris-spines.

Above this boundary-parting is a bed of smooth, pale-grey, conchoidal limestone, containing

Ostrea liassica,
Pholadomya glabra,
Modiola minima.

Above this begins the *Ammonites-Bucklandi* series (the Planorbis-beds being absent) with shale and argillaceous limestone containing *Gryphæa incurva*, *Myacites unionides*, *Cidaris* (the same as that occurring at the top of the Rhætic series, and probably *Cidaris Edwardsii*).

Then, about 3 feet up, *Gryphæa incurva* occurs socially in dozens, with *Ammonites Conybeari*, *A. rotiformis*, *A. Bucklandi*, *Lima*, *Pholadomya ambigua*, &c.

At Dunraven Point the Carboniferous Limestone dips at an angle of 43°, while the Sutton series lies in a gently curved arch upon it. The Sutton series here is 40 feet thick, the same thickness as near West, but the grey or Southerndown series is scarcely one quarter of its former thickness; there is a small fault here also.

The chief fossils which I have found in the Southerndown beds are

Plicatula intusstriata,
—— acuminata,
Ostrea multicostata,
Ostrea lævis,
Pecten Suttonensis,
Lima Dunravenensis,
Pinna papyracea,
Inoceramus Ramsayi.

These are enumerated in a tabular list as they occur in some of the chief localities of this district (see *infrà*, p. 79).

8. *The position of the Sutton Stone.*—Having been struck by the presence of *Plicatula intusstriata* in the Sutton stone, a shell acknowledged to be characteristic of the Rhætic series, and never, I believe, really found out of it*, I convinced myself by diligent search that the usual Liassic species of Ammonites, &c., were absent from these beds, while those fossils that were present had many of them either been noticed in the Rhætic beds of the Continent or showed strong affinities to the Upper Triassic fauna. This part of the series was therefore no longer to be considered Liassic.

It now became necessary to find the boundary between the Rhætic and Liassic series. By examining the range of the characteristic species, *Ostrea multicostata* and *Pecten Suttonensis,* I observed that they ceased vertically at a line generally marked by lithological characters.

The Southerndown series as here restricted must therefore be taken from the Lias. The sections seen in the valley between Bridgend and Pyle, and through which the South Wales Railway runs, are perfectly conclusive as to the non-Liassic nature of the white or Sutton series.

Near Cwrt-y-Coleman, &c., we find 7 feet of white shelly limestones covered by 4 feet of mottled green and yellow marls, and 2 feet of purple-red marls. In the Sutton limestone here, *Myophoria postera* is found with *Turritella* and other shells, of which I have only bad specimens. The marls are Rhætic, and are very similar to those noticed near Pyle church; they may be, perhaps, the same as occur at the base of the "Stormy Lime and Cement Works," on the South Wales Railway.

At the base of these works are 9 feet of dark and pale-green marls; above are the *Avicula-contorta* shales ($1\frac{1}{2}$ feet), with *Pecten Valoniensis,* &c.; above this are pale-grey, smooth limestones, separated by dark brown-grey shales, which are the equivalents of the White Lias of the West of England. The fossils here are fish-scales and the following shells:—

| | |
|---|---|
| Monotis decussata, | Plicatula intusstriata, |
| Modiola minima, | Ostrea liassica, |

and a *Cardinia,* which also occurs in the White Lias of Saltford.

Above are argillaceous limestones, with *Ostrea liassica* and *Modiola minima.* The Ostrea-series is well developed in the neighbourhood.

Another interesting section is seen half a mile north of the last, at French Quarry. The Rhætic series here consists of white shelly limestones and green marly bands. *Monotis decussata* and *Axinus cloacinus* are very abundant; and *Ostrea liassica* is seen to begin here in the Rhætic beds, and gradually increase in numbers until it reaches its climax in the "Ostrea-beds" (Lower Lias).

Again, in Laleston-churchyard Quarry part of the Sutton lime-

* I have lately heard that *Plicatula intusstriata* has been found attached to *Gryphæa incurva* from the *Ammonites-Bucklandi* beds. I have not, however, seen the specimen.

stones are seen beneath the Monotis-beds, *Monotis decussata* being characteristic in the West of England of a zone near the top of these beds.

In the shales here occur the spines and portions of the test of an Echinoderm (*Hemipedina?*): the same species occurs at Stormy. The presence of cubic crystals of Galena in the shales is also noteworthy. This same section may be seen also north of Bridgend, on the Tondu road.

It will be seen from the foregoing sections how varied are the conditions of the Rhætic series within a small area. The Pyle valley, enclosed between the two east and west faults mentioned by Sir H. De la Beche *, is much broken by lesser faults; and to these is, no doubt, due the fragmentary nature of the evidence as to the sequence of the beds. I am unacquainted with any section which shows the position of the *Avicula-contorta* sandstones in relation to the Sutton and Southerndown series.

We have seen that some of the Sutton limestone appears to be below the Monotis-beds, which contain also *Axinus elongatus*; they are also below green and purple marls (page 77 *suprà*). If the green marls in the Stormy cement-works' section be the same as those mentioned near Cwrt-y-Coleman, &c., we have a key to the position of the Sutton limestones; they would be below shales containing *Avicula contorta*. We still, however, require the exact relation of the Southerndown to the *Avicula-contorta* series.

We have yet to consider the evidence of fossils. And, first, the absence of *Avicula contorta* from the Sutton series (a shell which is found everywhere, in sandstones, limestones, and shales) would seem to point to more than a mere change in the sea-bottom—namely, to a different horizon in time. Moreover we can scarcely consider the Sutton and *Avicula-contorta* series contemporaneous, as they are found in close proximity. I believe it probable that the Sutton series was, at any rate, slightly anterior in time to the *Avicula-contorta* series. This seems likely from its physical aspect and the abundance in the former of *Ostrea multicostata*, a characteristic Muschelkalk species, but which has been noticed from the Infralias of Luxembourg by Terquem; while, on the other hand, the abundance of *Plicatula intusstriata*, the affinities of the Pectines, Limæ, and Cardiniæ, show that it must be included in the Rhætic series. The presence of Ammonites is very remarkable: there seem to be two species present, at any rate. My specimens, however, are very imperfect. The great paucity, if not entire absence, of Brachiopoda, as compared with the foreign beds, is also remarkable. The Sutton beds cannot be regarded as equivalents of the White Lias of the West of England.

The Southerndown series seems to have been formed under much the same circumstances as that of Sutton, but in deeper water in an area of depression upon the Carboniferous Limestone of this area. The same is the case also with the analogous beds on Broadfield Down, near Bristol, whose similarity of condition was noticed by

* *Loc. cit.* p. 238.

Sir H. De la Beche*. I have no doubt that these beds are also Rhætic; they are conglomeratic in places, enclosing Carboniferous-limestone fossils; and they are precisely similar to the Sutton conglomerate. I have found in them *Plicatula intusstriata*, a *Cardinia* like the one at Stormy (page 77 *suprà*), and an *Arca* abundantly as casts. Except *Ostrea liassica* (?) and *Modiola minima* (?), the Lias fossils seem absent.

I am greatly indebted to my friend Mr. W. Saunders, F.R.S., of Bristol, for the inspection of his collection from the curious white and siliceous modifications of Lias (spoken of by Buckland and Conybeare†) at Chewton Mendip, East Harptree, Shepton Mallet, &c.

An examination of these fossils leaves no doubt on my mind that they are for the most part Rhætic; some of them were—

| | | | |
|---|---|---|---|
| From Chewton, Mendip, and East Harptree. | Ostrea multicostata,<br>Monotis decussata,<br>Axinus elongatus. | From Shepton Mallet. | Pecten Suttonensis,<br>Lima tuberculata. |

9. *Middle Lias.*—As it is not expressed on the map, I may remark that the upper part of the Bridgend Railway-section is *Middle* and not *Lower* Lias. This is shown by the presence of *Ammonites spinatus, Gryphæa cymbium, Avicula inæquivalvis, Pecten sublævis,* and *P. dentatus, Belemnites,* &c.

10. *Table showing the range of the Fossils of the Rhætic Beds of South Wales.*

| Species. | Sutton series. | | | | | | | Southern-down series. | | | | *Avicula-contorta* series. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wetsh St. Donats. | Laleston. | Sutton. | Southerndown. | Dunraven. | St. Mary Hill. | Langan. | Southerndown. | Dunraven. | Ewenny. | Langan. | Laleston. | Cwrt-y-Coleman | Stormy-down. | Pyle. |
| Equisetites | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | | |
| Avicula contorta, *Portl.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * | * | * |
| Axinus elongatus, *Moore* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * | * | |
| —— depressus, *Moore* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * |
| —— cloacinus, *Moore* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | * | * |
| Myophoria postera, *Qu.* | ... | * | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | * | |
| Modiola minima | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * | * | * |
| Anatina præcursor, *Qu.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | * | * |
| Natica Pylensis, *Tawn.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * |
| Monotis decussata | ... | ... | * | ... | ... | ... | ... | ... | ... | ... | ... | * | ... | * | |
| Pecten Valoniensis, *Portl.* | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | * | * | |

* These beds were coloured as Rhætic by Mr. Bristow on the map of the Geological Survey laid before the Bath Meeting of the British Association by Sir R. I. Murchison in 1864.

† "Buckland and Conybeare on the South-west district of England," Trans. Geol. Soc. 2nd series, vol. i. p. 294.

*Table* (continued).

| Species. | Sutton Series. | | | | | | | Southern-down series. | | | | *Avicula-contorta* series. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wetsh St. Donats. | Laleston. | Sutton. | Southerndown. | Dunraven. | St. Mary Hill. | Langan. | Southerndown. | Dunraven. | Ewenny. | Langan. | Laleston. | Cwrt-y-Coleman. | Stormy-down. | Pyle. |
| Pleurophorus elongatus, *Moore* | | | | | | | | | | | | | * | | |
| Ostrea liassica, *Strickl.* | | | | | | | | | | | | * | | * | |
| Hemipedina, sp. | | | | | | | | | | | | * | | * | |
| Acrodus acutus, *Ag.* | | | | | | | | | | | | | * | | * |
| —— minimus, *Ag.* | | | | | | | | | | | | | * | | * |
| Saurichthys acuminatus, *Ag.* | | | | | | | | | | | | | * | | |
| —— apicalis, *Ag.* | | | | | | | | | | | | | * | * | |
| Hybodus raricostatus, *Ag.* | | | | | | | | * | | | | | | | |
| —— minor, *Ag.* | | | | | | | | | | | | | * | | |
| —— plicatilis, *Ag.* | | | | | | | | | | | | | * | | |
| —— cuspidatus, *Ag.* | | | | | | | | | | | | | * | | |
| —— orthoconus, *Plien.* | | | | | | | | | | | | | * | | |
| Gyrolepis tenuistriatus, *Ag.* | | | | | | | | | | | | | * | * | |
| —— Alberti, *Ag.* | | * | | | | | | | | | | | * | * | |
| Plicatula intusstriata, *Emm.* | * | | * | * | * | * | * | * | | * | * | | | * | |
| —— acuminata, *Terq. & Piette* | | | * | | | | | | | | | | | | |
| Ostrea multicostata, *Münst.* | * | | * | * | * | * | * | * | * | | | | | | |
| —— lævis, *Tawn.* | | | * | | | | * | * | | | | | | | |
| Anomia socialis, *Tawn.* | | | | | | * | | | | | | | | | |
| Pecten Suttonensis, *Tawn.* | * | | * | * | * | * | | * | * | | * | | | | |
| —— Etheridgii, *Tawn.* | | | * | * | | | | * | | | | | | | |
| Lima tuberculata, *Terq.* | * | | * | | | * | | | * | | | | | | |
| —— planicostata, *Tawn.* | | * | * | | * | | | | | | | | | | |
| —— angusta, *Tawn.* | | | * | | | | | | | | | | | | |
| —— subduplicata, *Tawn.* | | | * | | | | * | | * | | | | | | |
| —— Dunravenensis, *Tawn.* | | | * | | | | | | * | | | | | | |
| Pinna insignis, *Tawn.* | | | * | | | | | | * | | | | | | |
| Perna Ramsayi, *Tawn.* | | | | | | | | * | | | | | | | |
| Cardinia Suttonensis, *Tawn.* | | | * | | | | | | | | | | | | |
| —— ingens, *Tawn.* | | | | | | | * | | | | | | | | |
| Cardita rhomboidalis, *Tawn.* | | | * | | | | | | | | | | | | |
| Modiola imbricatoradiata, *Tawn.* | | | * | | | | | | | | | | | | |
| Astarte Duncani, *Tawn.* | | | * | | | | | | | | | | | | |
| Cyprina normalis, *Tawn.* | | | * | | | | | | | | | | | | |
| Patella Suttonensis, *Tawn.* | | | * | | | | | | | | | | | | |
| Chemnitzia (new species) | | | * | | | | | * | | | | | | | |
| Turritella, sp. | | | * | | | | | | | | | | | | |
| Trochotoma, sp. | | | | * | | | | | | | | | | | |
| Ammonites Dunravenensis, *Tawn.* | | | | * | * | | | | | | | | | | |
| Ammonites Suttonensis, *Tawn.* | | | | | * | | | | | | | | | | |
| Rhabdophyllia recondita, *Laube* | | | | | * | | | | | | | | | | |
| Thecosmilia rugosa, *Laube* | | | | | * | | | | | | | | | | |
| Elyastræa Fischeri, *Laube.* | | | | | * | | | | | | | | | | |
| Astrocœnia Oppeli, *Laube.* | | | | | * | | | | | | | | | | |
| Montlivaltia, sp. | | | | | * | | | | | | | | | | |

## 11. *Descriptions of the Species.*

1. Ammonites Suttonensis, spec. nov.

I am unable to describe this Ammonite, the characters of the back and keel not being sufficiently preserved in my specimens. In a side view it resembles *A. Hettangiensis*, Terquem, but it does not seem to have a square and slightly keeled back like that species. It is allied to *A. Johnstoni* or some of the ribbed "Planorbes." Diameter $1\frac{1}{2}$ inch.

*Locality and position.*—I have found this species about 20 ft. above the base of the Sutton series, both at Dunraven and at the Sutton quarries.

2. Ammonites Dunravenensis, spec. nov. Pl. IV. fig. 1.

This fragment of an Ammonite differs entirely from the preceding, being more involute, and it is more elongated.

*Locality.*—Found 30 ft. above the base of the Sutton series at Dunraven.

In form this species is allied to *A. Hagenovi* (Dunker), a shell which, though from the Angulatus-zone, by the disposition of its lobes and saddles is entirely allied to *Ceratites* (*vide* Terquem, "Infralias de l'est de France," in Mém. Soc. Géol. de France, 2nd series, vol. viii. pl. x. figs. 3–5).

3. Pecten Etheridgii, spec. nov. Pl. III. fig. 4.

Shell thin, suborbicular, equilateral, slightly convex. Surface with numerous shallow or flat, not very closely set, radiating ribs, with very fine concentric striæ. Ears large, unequal, concentrically and radiatingly striated; anterior ear slightly hollowed out. Length $1\frac{1}{8}$ inch; breadth $\frac{5}{6}$ths of length; umbonal angle 70°–75°.

*Locality and position.*—Sutton and Southerndown series at Sutton.

*Affinities.*—This shell differs from *P. calvus* (Goldf.) in the ears being less unequal and comparatively larger. It has much resemblance to *P. Schneideri*, Giebel, from the Muschelkalk, but is less circular in form.

I have named this shell after my friend Mr. Etheridge, F.R.S.E., who has afforded me much help in the discrimination of the species.

4. Pecten Suttonensis, spec. nov. Pl. III. fig. 3.

Shell circular, convex, inequivalve, inequilateral. Left valve more convex than the right; at the anterior side in both valves the ribs bend forwards, producing the inequilateral form. Ribs alternately larger and smaller; about twenty principal ones, between each primary rib a smaller, and between many of the secondaries occurs a still smaller rib or carina. Ribs crossed by fine, concentric, raised lines of growth, which curve downwards in crossing. In the auricular regions, beyond the last rib, are broad lateral areas, crossed by numerous, slightly wavy, oblique lines; posterior area the wider; there is a steep fall from the areas by the last rib, down to the ears, particularly in the more convex valve. Ears large, unequal, posterior ear largest; in the right valve the anterior ear is hollowed out below; both ears have radiating costæ and transverse striæ. Umbonal angle 110°–115°; length $2\frac{3}{4}$ inches; breadth equals length.

*Locality and position.*—Sutton and Southerndown series at Sutton. Very abundant.

The exterior structure of the shell is frequently badly preserved; the concentric striations are then lost, and many of the smaller ribs, but their alternate character remains generally more or less plain.

*Affinities.*—This shell is most nearly allied to *P. Valoniensis* (or *Lugdunensis*, Michelin); it agrees with it and *P. Bavaricus*, Winkl., and *P. Favrii* *, Stopp. (all Rhætic species), in the characters of the lateral areas, but with neither of them in the character of the ribs. In general form and alternate arrangement of ribs it resembles *P. Schrœteri*, Giebel, from the Muschelkalk; but that species has not the obliquely marked areas.

Some specimens of *P. Valoniensis* show a much greater resemblance than others to this species.

5. Pecten, sp.

Another orbicular *Pecten* I am unable to describe, having only one imperfect specimen, the umbo being wanting. It is distinguished by elevated strong concentric striæ in the interspaces between the ribs. It has a slight resemblance to *P. æquivalvis*; but the ribs are more numerous, narrower, and less regular than in that species; this shell is also much smaller.

6. Lima tuberculata, Terquem.

Shell moderately convex, suboval, slightly inequilateral. Ribs 11–12, narrow, radiating, bearing occasionally tubercles or remains of spines; the ribs slope away gradually into the interspaces, which are broad. Surface with concentric, more or less rugose laminæ. Posterior ear larger; anterior ear gaping below, somewhat plicated. Hinge-line straight. No lunule. Length $2\frac{1}{4}$ inches; breadth $\frac{4}{5}$ths of length.

*Locality and position.*—Sutton and Southerndown series and Lias at Bridgend.

This species is most nearly allied to *L. pectiniformis* of the Inferior Oolite, but is much smaller and less rugose. It corresponds entirely with the description of Terquem's species *L. tuberculata* (Mém. de la Soc. Géol. de France, vol. v. 2nd series, 1855). I have not hesitated, therefore, to identify it with that species. It was described from the Infralias (Planorbis- and Angulatus-beds) of Luxembourg, and has been noticed by Renevier from the Rhætic beds of the Canton de Vaud (Bull. de la Soc. Vaudoise des Sciences Nat. vol. viii. p. 34); from the Infralias of the Department of Côte d'Or by Martin (Mém. de la Soc. Geol. de France, 2nd series, vol. vii.); and I have also found it in the Planorbis-beds near Bridgend.

* This name seems preoccupied, having been given to another shell by M. d'Archiac (1854); Stoppani's name must therefore be cancelled, and I propose to substitute for it the specific name of *Renevieri*.

7. Lima planicostata, spec. nov. Pl. III. fig. 7.

Shell ovate, oblique, moderately convex, considerably longer than broad. Surface of shell with distinct concentric lines of growth and very faint radiating striæ, which are most marked on the posterior part of the shell. Ears unequal, the posterior largest. Length $\frac{3}{4}$ to $1\frac{1}{2}$ inch; breadth $\frac{4}{5}$ths of length.

*Locality and position.*—Sutton series at Laleston and Sutton &c.

This shell differs from *L. præcursor* in form, and by the absence of depressions in the interspaces between the ribs. It has some resemblance to *L. compressa*, Terquem, and to *L. acuta*, Stopp.; but the sculpturing of those species renders them very distinct.

8. Lima angusta, spec. nov. Pl. III. fig. 6.

Shell moderately convex, elongated, obliquely oval, inequilateral, most arched in the centre. Anterior side straight for five-sixths of its length and nearly parallel to the longer axis of the shell. Posterior margin swollen in the centre and slightly concave below the ear. Surface with regular, not very close or deep, radiating lines, concentric striæ, and lines of growth, which cross over the flat ribs. Auricular areas sloping gradually into the umbo. Hinge-line straight. No lunule. Length $2\frac{1}{2}$–3 inches; breadth $\frac{3}{5}$ths of length.

*Locality and position.*—Sutton series at Sutton and Dunraven.

My examples of this shell are rather weathered, so that the surface-markings are not so well preserved as could be wished.

The form of this shell is characteristic. The shell that approaches nearest to it is *L. prælonga*, Martin, from the Angulatus-zone of the Department of Côte d'Or.

9. Lima subduplicata, spec. nov. Pl. III. fig. 8.

Shell ovate, slightly oblique, narrow at the hinge-line, convex. Ribs about 25, elevated, not sharp; on the anterior and posterior sides they become narrower and sharper, and the interspaces wider; interspaces with a fine costa between each of the ribs. Length $\frac{1}{2}$ to 1 inch; breadth $\frac{2}{3}$rds of length.

*Locality and position.*—Sutton and Southerndown series at Sutton &c. Common.

The exterior of the shell is frequently lost, and the costæ are then invisible.

Closely allied to *L. duplicata* (Great Oolite): it corresponds exactly in form, but the line on the ribs is apparently absent. In its mature state it is much smaller than *L. pectinoides*, neither are the ribs so sharp, and the interspaces are broader than in that species. It resembles an unnamed species figured by Quenstedt (Jura, p. 47, pl. iv.).

10. Lima Dunravenensis, spec. nov. Pl. III. fig. 9.

Shell moderately convex, obliquely oval. Anterior side straight for four-fifths of its length, and curving round suddenly into the inferior margin, which is strongly convex. Surface with numerous fine, slightly wavy radiating lines, crossed by a few concentric lines of growth. Length $3\frac{1}{2}$ inches; breadth $\frac{5}{6}$ths of length.

*Locality and Position.*—Sutton and Southerndown series at Dunraven &c. Common.

From the imperfect state of my specimens, I am unable to say whether the interspaces between the ribs are punctated.

This shell is distinguished from *L. punctata* by its straight anterior side; the size of the ribs brings it nearest in character to *Lima Valoniensis*, Def., cited by Dumortier (Dépôts Jurassiques du Bassin du Rhône, p. 54) as occurring associated with *Pecten Valoniensis*, Def. In form it bears much resemblance to *L. exaltata*, Terquem, from the Infralias of the province of Luxembourg; but the ribs are a little wider than in that species. In the absence, therefore, of the characters of the whole shell I cannot identify it with either of these species.

11. Lima, sp.

I have the hinge-area of a remarkable *Lima* which bears a great resemblance to the hinge of *Lima cometes*, Dumortier, 'Bassin du Rhône,' pl. xxiii. figs. 1 and 2; but in the absence of the rib-characters I cannot identify it, as by its form it is also allied to *L. tuberculosa* (Terquem). The hinge-line is not straight, but forms an obtuse angle with the ears; the ears are strongly plicated. No lunule. The shell is very thick around the ligamental pit, but is abruptly hollowed out below.

12. Ostrea lævis, spec. nov. Pl. III. fig. 2.

Shell extremely convex, elongate, and ovate. Surface with concentric, somewhat irregular, fine, imbricated folds of growth or delicate wavy lamellæ. Margin thick and entire. Length $1\frac{1}{2}$ inch; breadth $\frac{2}{3}$rds of length.

*Locality and position.*—Sutton series at Sutton and Langan. Common.

This shell varies in different localities, being sometimes very narrow; it is readily distinguished from *Ost. liassica* by its convexity, and does not occur in such numbers together as that species.

13. Ostrea multicostata, Münst. Pl. III. fig. 1.

Shell elliptical, frequently nearly equilateral, thick. Umbo near the hinge, from which strongly elevated straight or slightly wavy ribs diverge; ribs acutely rounded, crossed by fine concentric lines of growth, equally visible in the interspaces; interspaces the same size as the ribs. Ribs extend to the margin, causing it to be undulated; margin thick, rounded. Length 3 inches; breadth $\frac{6}{7}$ths of length.

*Locality and position.*—Sutton and Southerndown series at Sutton &c. Common and characteristic species.

The area of attachment is devoid of ribs and frequently occupies a large portion of the shell.

This shell is variable, affecting at different times the appearance of *O. spondyloides*, *O. multicostata*, and *O. difformis*. Terquem, in describing the *Ostreæ* of the Province of Luxembourg, proposed to unite these three Muschelkalk species, as there is little apparent difference between them; but subsequently (" Infralias de l'est de France," in Mém. Soc. Géol. de France, 2nd series, vol. viii.) he deemed it unadvisable to refer his species to them or the genus *Ostrea*, and it stands as *Carpenteria Heberti*. As the Sutton fossil bears considerable resemblance to Terquem's figures, it is with much diffidence that I continue to refer it to the Muschelkalk type; the examination, however, of several specimens having the same character of the umbonal region leaves no doubt in my mind of its being an *Ostrea*; and the description of *O. multicostata* corresponds entirely with our shell.

In some of my specimens the ribs are not so elevated and regular, but more lamellar; but these differences may be ascribed, I think, to a young state; others show a likeness in external characters to *Plicatula Baylii* (Terquem), but as I have not seen the hinge, I must leave it to future researches to settle this point.

*Affinities.*—This shell bears some resemblance to *Ostrea arietis* of the Angulatus- and Bucklandi-beds), but is still more nearly allied to *O. Rhodani*, Dumortier, from his Planorbis-zone *. He figures also a fragment, which may be allied to this species, as passing up into the Angulatus-zone; he considers it to be allied to the Muschelkalk species, *Ostrea complicata* (Dumortier, Bass. du Rhône, pl. xxiii. fig. 6).

14. Anomia socialis, spec. nov. Pl. III. fig. 10.

Provisionally I call this shell *Anomia*, from its shell-structure; there are not, however, in my possession data enough to safely determine or describe the specific characters. Its abundance, however, in some localities where it occurs in groups, renders it a most noticeable shell; I therefore name it as above. Length $1\frac{1}{4}$ inch.

*Locality and position.*—Sutton series at St. Mary Hill. Common.

This shell has a great resemblance to *Ostrea subanomia* (Münst.) from the Muschelkalk, but I cannot with any surety refer it to that species.

15. Pinna insignis, spec. nov. Pl. III. fig. 5.

Shell thin, acute at the umbo, broadly wedge-shaped; posterior extremity gaping, strongly rounded, and truncated. Dorsal edge thickened and well defined. Surface smooth, with broad, wavy, concentric folds. Length 7 to 8 inches; breadth 4 to 5 inches.

*Position and locality.*—Sutton and Southerndown series at Sutton and Dunraven.

This shell is most usually found in quite a fragmentary condition; it attained a large size, and was a widely gaping form.

Notwithstanding the imperfect state of my examples, I am obliged to create a new species. It differs considerably from *Pinna semistriata*, Terquem (Pal. de Lux. pl. xxii. fig. 1), being comparatively wider, and the concentric folds do not show the same disposition. It is also more pyramidal than *Pinna papyracea*, Stopp., and the shell is not so extremely thin as in that species.

* Dumortier includes in the Planorbis-zone- beds containing *Pecten Valoniensis* and *Plicatula intusstriata* abundantly.

16. PERNA? RAMSAYI, spec. nov.

Shell oblique, elongated, moderately convex, thin. Surface with rounded wavy concentric folds, which extend across the shell. Ear large, crossed by sigmoid folds or lines. Hinge unknown. Length 4 inches; breadth $\frac{3}{4}$ths of length.

*Locality and position.*—Southerndown series near Sutton.

My specimen only shows the interior of the shell, which is, however, very thin. The hinge-line also is broken off, so that the genus is uncertain. It bears some slight resemblance to *Perna infraliasina* Quenst., but it is considerably larger than that shell. Until the external shell is known, it cannot be referred to that species. I dedicate it, therefore, provisionally, to Prof. A. C. Ramsay, F.R.S., Professor of Geology at the Royal School of Mines.

17. PLICATULA ACUMINATA, Terq. et Piette.

I have specimens corresponding to the description given of this shell by Terquem and Piette (Mém. Soc. Géol. de France, 2nd series, vol. viii. p. 107, pl. xiii. figs. 20, 21), the distinguishing character being the acute hinge with transverse folds and radiating ribs. They cite it as a rare shell, in beds containing *Belemnites acutus.*

18. PLICATULA INTUSSTRIATA, Emm.

This is one of the most characteristic species. In England it is a characteristic Rhætic species; but on the continent it passes up into the Planorbis-zone, if not higher. The species *P. Lotharingiæ,* Terq. et Piette, evidently belongs to Emmerich's type; it is cited from the Planorbis-zone. Dumortier says (Infralias, p. 76) that it is characteristic of the Planorbis-zone, never being found *below* or above; it is probable, therefore, that his Planorbis-zone corresponds to the upper part of our Rhætic series, including the White Lias.

19. CARDINIA SUTTONENSIS, spec. nov. Pl. IV. fig. 3.

Shell transversely oblong, obovate; ventral margin gently rounded; anterior end broadest, obtuse; posterior end subacutely rounded. Surface with deep, concentric, distant lines of growth, and smaller, elevated, intervening striæ, which become less distinct at the posterior end. Umbones somewhat acute, placed about one-fourth of the length from the anterior end. Length $2\frac{1}{4}$ inches; breadth $\frac{2}{3}$rds of length.

*Locality and position.*—Sutton quarries, Sutton series.

This shell is nearest in form to *C. regularis,* Terquem; but the posterior end is more acute than in that species; the size is also larger, and the shell thicker. It is less cuneiform than *C. acuminata,* Martin, to which it bears some resemblance.

20. CARDINIA INGENS, spec. nov. Pl. IV. fig. 2.

This large cast of the interior is from the Sutton series near Langan. My specimens do not show the outside of the shell. All that I saw with the outside shell were in an earthy condition and crumbled on being moved. The concentric folds of growth were distinct and strong.

It approaches nearest to *C. crassissima*, Ag.; but the pallial line does not quite agree with that species.

21. Cardita ? rhomboidalis, spec. nov. Pl. IV. fig. 6.

Shell convex, rhomboidal; a rounded ridge extends from the umbo to the posterior margin. Dorsal and ventral margins nearly parallel; posterior end of shell widest. Umbones placed far forwards, somewhat recurved. Hinge-line straight. Interior margin of the shell delicately crenate. Surface with regular, elevated, concentric lines, which cross over the rounded ridge, and, by a sharp curve, reach the dorsal margin. Length 1 inch; breadth $\frac{2}{3}$rds of length.

*Locality and position.*—Sutton quarries, Sutton series. Common near the base.

The shell-substance is rarely found. The mould of the inside drops out of the cast, leaving the impression of the exterior surface: from this gutta-percha casts may easily be obtained.

Not having seen the hinge-teeth, I am uncertain of the genus.

It somewhat resembles *Cardita tetragona*, Terquem; I therefore refer it provisionally to that genus.

22. Modiola imbricato-radiata, spec. nov. Pl. IV. fig. 8.

Shell small, convex, transversely oblong, comparatively thick. A rounded elevated dorsal ridge extends from the umbo to the posterior margin. Posterior margin rounded; ventral slightly concave. Surface of shell ornamented with numerous radiating rounded ribs, which are slightly wavy and sometimes forked, crossed by a few growth-lamellæ. Umbones obtuse, placed far forwards. Length 0·6 inch; breadth $\frac{2}{3}$rds of length.

*Locality and position.*—Sutton quarries, Sutton series. Common near the base.

The ornamentation is like that of the Oolitic species *M. pulcherrima*; it reminds us also of *Mytilus furcatus*, but is very much smaller, the margin not so concave, &c.

23. Astarte Duncani, spec. nov. Pl. IV. fig. 4.

Shell convex, rhomboidal, inequilateral, widest at the posterior end; posterior margin rounded and forming rather less than a right angle with the ventral margin. Surface of shell with strong concentric lines of growth wider apart posteriorly, and intervening finer ones. Umbones placed far forwards. Length $\frac{3}{4}$ inch; breadth $\frac{3}{4}$ths of length.

*Locality and position.*—Sutton quarries, Sutton series.

The genus of this shell is not quite certain, my specimen not showing the hinge-line.

It is named after our Secretary, who has kindly undertaken the description of the corals from the Sutton Stone.

24. Cyprina normalis, spec. nov. Pl. IV. fig. 7.

Shell suborbicular, convex, inequilateral, thick. Umbones slightly anterior, acute. Surface concentrically marked by numerous lines of growth. Anterior side well rounded; posterior subacute. Length $\frac{3}{4}$ to $1\frac{1}{2}$ inch; breadth $\frac{4}{5}$ths of length.

*Locality and position.*—Sutton quarries, Sutton series.

The form of this shell renders it probable that it is a *Cyprina*. I have not seen the hinge, owing to the unfavourable state of the matrix.

25. Anatina præcursor, Quenst., var. Pylensis. Pl. IV. fig. 5.

Shell flatly convex, transverse, inequilateral. Anterior end rounded; posterior end slightly produced, narrower, and somewhat depressed. Lines of growth consisting of from six to ten concentric rounded folds, which extend along the shell, being nearly as distinct posteriorly as anteriorly. A slight ridge proceeds from the umbo to the postero-ventral margin. Ventral margin rounded. Umbones subcentral, depressed posteriorly. Length $1\frac{1}{2}$ inch; breadth half of length.

*Locality and position.*—*Avicula-contorta* sandstones at Pyle, Stormy Down, &c.

This shell differs from the description given by Oppel and Suess in being considerably shorter posteriorly. It approaches thus more to the form of *A. Suessii*, but it lacks the median depression which hollows out the ventral margin of that species. It differs from Oppel's figure of *A. præcursor* by the extension of the folds along the posterior part of the shell as they curve round to meet the dorsal margin.

These differences are perhaps enough to constitute a new variety, but do not, I believe, necessitate the formation of a new species.

26. Patella Suttonensis, spec. nov. Pl. IV. figs. 9 *a*, 9 *b*.

Shell convex, oval. Apex not quite central, but nearest the posterior margin, and the highest point of the shell. Surface covered with regular, elevated, slightly imbricated, concentric lines, which become a little fainter near the apex. Length $\frac{3}{4}$ inch; breadth $\frac{3}{4}$ths of length.

*Locality and position.*—Sutton quarries, Sutton series.

This shell has much the aspect of a *Discina*; but as it is not horny in texture (neither have I found a lower valve), I refer it to this genus.

It resembles *Patella elliptica*, from the Muschelkalk, and also *P. Hettangiensis*, from the Angulatus-beds of Hettange; it clearly differs, however, from these species. The form differs from *P. Hettangiensis* in the region of the apex especially.

27. Chemnitzia, sp.

There is a large univalve shell, $4\frac{1}{2}$ inches long, common in a bed near the middle of the Southerndown series; natural sections of the shell, showing the columella, may sometimes be seen on the beds, which have been slightly polished by the sea. I have no specimens, owing to the difficulty of breaking up the beds at this place.

28. Turritella, sp.

I have some small species from the Sutton Stone which may belong to this genus and to *Chemnitzia*, but which it is impossible to recognize specifically.

29. Trochotoma, sp.

A very flat form from the Sutton Stone may probably be referred to this genus. Its imperfect state prevents a description.

30. Natica Pylensis, spec. nov. Pl. IV. fig. 10.

Shell ovate. Body-whorl large. Spire depressed, of two volutions. Suture deeply impressed. Apex blunt. Aperture semicircular. Length 0·1 to 0·3 inch.

*Locality and position.*—*Avicula-contorta* sandstones at Pyle and Stormy Down.

This shell never exceeds the above small dimensions; it generally occurs in the form of casts. It is both gregarious in great numbers, and occurs singly.

## *Note on the* Madreporaria *from the* "Sutton Stone."

By P. Martin Duncan, M.B. Lond., Sec. G.S.

The collection of Madreporaria from the base of the Sutton Stone contains a considerable number of specimens, some of which are derived fossils, and the others, generally in a very fair state of preservation, indicate a lower coralliferous horizon than has been hitherto noticed in the British Secondary rocks.

A fine-grained white limestone with much calc-spar is the matrix of the Secondary corals; and the Palæozoic are contained in a rougher stone, more or less conglomeratic. The neighbourhood of the Carboniferous Limestone accounts for the presence of its fossils at the base of the Sutton Stone; and the derived species therein contained are well known and characteristic.

The species are:—

1. Lithostrotion irregulare.
2. Amplexus coralloides.

These forms do not require any notice; they are unlike any from Mesozoic sources, and are very common in the Carboniferous strata. The specimens of the fine-grained limestone which contain undoubted Secondary corals are numerous, and the fossils are either well preserved or are in the form of casts.

Four species can be determined satisfactorily, or rather three species and three varieties of a fourth, whose Alpine type is not present. The subgenus of one other form can be recognized; and in all probability the numerous casts must be referred to it. The species are unlike any hitherto discovered in North-western Europe, and, with certain reservations, indicate a zone of Madreporaria which in the Alpine Trias would be deemed St. Cassian.

The great 'Monograph of the British Fossil Corals,' by MM. Edwards and Haime, does not contain a description of any species from the Lower Lias, and there still remains a great gap in our knowledge of the Madreporaria, between the Permian and the Liassic strata yielding *Isastræa Murchisoni*, Wright, and *Thecocyathus Moorei*, Ed. & H.

Lately, large series of Middle and Lower Liassic corals have passed through my hands, and MM. Chapuis and Dewalque in Belgium, De Fromentel in France, and Stoppani in Italy have described species which have enabled me to mark out the characteristic species in our Middle and Lower Lias. The species from the Sutton Stone have nothing in common with any species from the Liassic strata.

The White Lias of Somerset has yielded two species of Corals*. Unfortunately the condition of these fossils prevents their specific determination; but they belong to the genus *Montlivaltia*. One is a broad flat form, and is probably allied to the *Montlivaltiæ* of the Lower Lias, which are usually more or less discoid. The other specimen is a small tall and conical form, with well-marked transverse ridges on its epitheca. This peculiarity is to a certain extent Liassic; but the stunted growth and the apparently multiseptate arrangement ally the form to the Triassic *Montlivaltiæ*. Neither of the White-Lias forms are contained in the collection from the base of the Sutton Stone. A *Montlivaltia* was discovered in the *Avicula-contorta* series at Beer Crowcombe, by Mr. Chas. Moore†.

In the late researches of Reuss upon the Madreporaria of the Kössen strata, numerous species were determined; some ascend into the Lias, according to Stoppani; and all have a good Secondary facies, there being no traces of Palæozoic genera.

The corals of the Dachstein series are still in a very unsatisfactory state, as regards their description; but it will suffice to assert that they are not of the Palæozoic genera *Lithodendron* and *Cyathophyllum*; on the contrary, the species belong to the genera which dominated during the Jurassic epoch.

It is now tolerably evident that all the St. Cassian corals formerly associated with Palæozoic generic names are Mesozoic forms, and that only two new species, carefully determined by Reuss, belong to as many genera, one being Palæozoic, and the other closely allied to a Palæozoic genus.

Recently Gustav Laube ‡ has concluded the examination of Münster and Klipstein's St. Cassian Sponges, Corals, Crinoids, and Echinoderms: he has not distinguished a single Palæozoic genus amongst the Corals, but he has determined the great distinction between the Liassic and Triassic coral faunæ.

It is the defective information respecting the corals of the Dachstein series, and of the relation of the St. Cassian corals to those of the Dachstein and of the Kössen strata, which causes me to make a reservation in my opinion about the age of the Sutton-Stone species. In other words, there is insufficient information concerning the vertical range of the St. Cassian species of Corals; and the discovery of some of

* Boyd Dawkins, Quart. Journ. Geol. Soc. vol. xx. p. 406.
† Quart. Journ. Geol. Soc. vol. xvii. p. 511.
‡ Die Faune der Schichten von St. Cassian, 1. Abtheil.

them in South Wales adds to the probability of their having a greater vertical range than has hitherto been supposed, from their following the law that the widely wandering in space are persistent in time.

There are some considerations respecting the range of some Rhætic and Liassic mollusca, both in England, France, and Switerland, and concerning the alternations of the *Avicula-contorta* and Dachstein-bivalve and the coralliferous strata in the Kössen and Dachstein divisions of the Alpine Trias, which strengthen the necessity for caution in correlating distant Triassic strata possessing species in common.

Moreover it cannot be admitted that the coral fauna of the period is fairly represented in the Alpine Trias, great as its number of genera may be. It is also remarkable that the *Avicula-contorta* series should be very uncoralliferous: doubtless the *Aviculæ* with their associated bivalves and generally puny Gasteropods were dwellers in a muddy area, where only stunted and simple Madreporaria can live.

The alternations of the strata just mentioned, and the great vertical range of some species, indicate that although the succession of the Upper Triassic, Rhætic, and Lower Liassic strata is to be traced in ascending order, still this succession may have a very doubtful chronological meaning. The species which form the little coral fauna of the Sutton series do not indicate a vigorous condition of the polypelife of the period: their affinity with the Alpine St. Cassian species is beyond doubt; and whatever their age may be, they are still the oldest amongst the Mesozoic forms in this country.

This is a conclusion which was determined irrespectively of Mr. Tawney's researches, and it is strengthened by them. The absence of the usual species of the mollusca of the *Avicula-contorta* beds, the close proximity of these beds, the existence of a number of local species, and the localization of the Sutton Stone in the west indicate that the series resting on the Mountain-limestone is older than the "*contorta*"-bearing strata. How much older, is of course subject to the application of the remarks already made.

*List of the Species.*

1. Rhabdophyllia recondita, *Laube*.
2. Thecosmilia rugosa, *Laube*.
3. Elyastræa Fischeri, *Laube*.
4. Astrocœnia Oppeli, *Laube*, 3 vars.
5. Montlivaltia, sp.

*Remarks on the species.*—The three species at the head of the list are described and admirably delineated in Gustav Laube's work. *Rhabdophyllia* is a well-known Jurassic genus, and was doubtless one of those misnamed *Lithodendron* in the Alpine Trias. The species *recondita* is a very well-marked one, and the singular disposition of the smaller septa to bend towards the larger is very distinctive. The genus is unknown in the British Lias, and the species is only remotely related to the Oolitic forms.

The *Thecosmilia rugosa* is a compound coral, stunted in growth, and given to fissiparous division of its calices; the rugose transverse markings of the epitheca are well shown, both in Laube's drawing and in the Sutton species. So alike are the drawing and the specimen that it might be asserted the one was taken from the other.

The genus *Elyastræa* described by Laube is new, and not known out of the St. Cassian strata; it is allied to the Mesozoic genera *Heliastræa, Isastræa,* and *Prionastræa,* and it has some faint trace of the double-wall arrangement of many Palæozoic genera. *Heliastræa* and *Prionastræa* flourished in the Oolitic and Cretaceous periods, and are still represented in the existing coral fauna, but *Isastræa* was a St. Cassian genus, and lasted until the Falunian epoch. The discovery of the genus which unites all these sufficiently to make their generic distinction doubtful, is very important, and that it should occur so low in the Mesozoic series is very suggestive. The species *Fischeri* is a bulky form, with very irregular calices, and is represented in the Sutton Stone by a large specimen partly polished.

The most common coral in the collection is one which has a broad base and an undulating gibbous surface, covered with small geometrical calices. This is the commonest form; but another is equally large as regards its base, and has a flat upper surface covered with calices, like the gibbous form. There is not a specific difference.

A third form covers, like a parasite, part of the surface of the *Rhabdophyllia recondita*; the calices are smaller than in the other forms; but they are all essentially alike. It is remarkable that the *Rhabdophyllia* in its St. Cassian habitat is covered by a parasitic sponge.

The three varieties of *Astrocœnia Oppeli* are judged to be such because the minute anatomy of the calices is alike in all cases, and that the habit of growth of the type is not sufficient to enable it to assume a specific difference. It is a pity that Laube had not the larger Sutton variety for the type; but he has the right to have the three forms referred to his by priority of description. I have named the varieties—

1. Gibbosa, | 2. Plana,
3. Parasitica.

The genus is well known in the Lower Cretaceous, Eocene, and Miocene coral faunæ, but has not been found hitherto in Jurassic deposits.

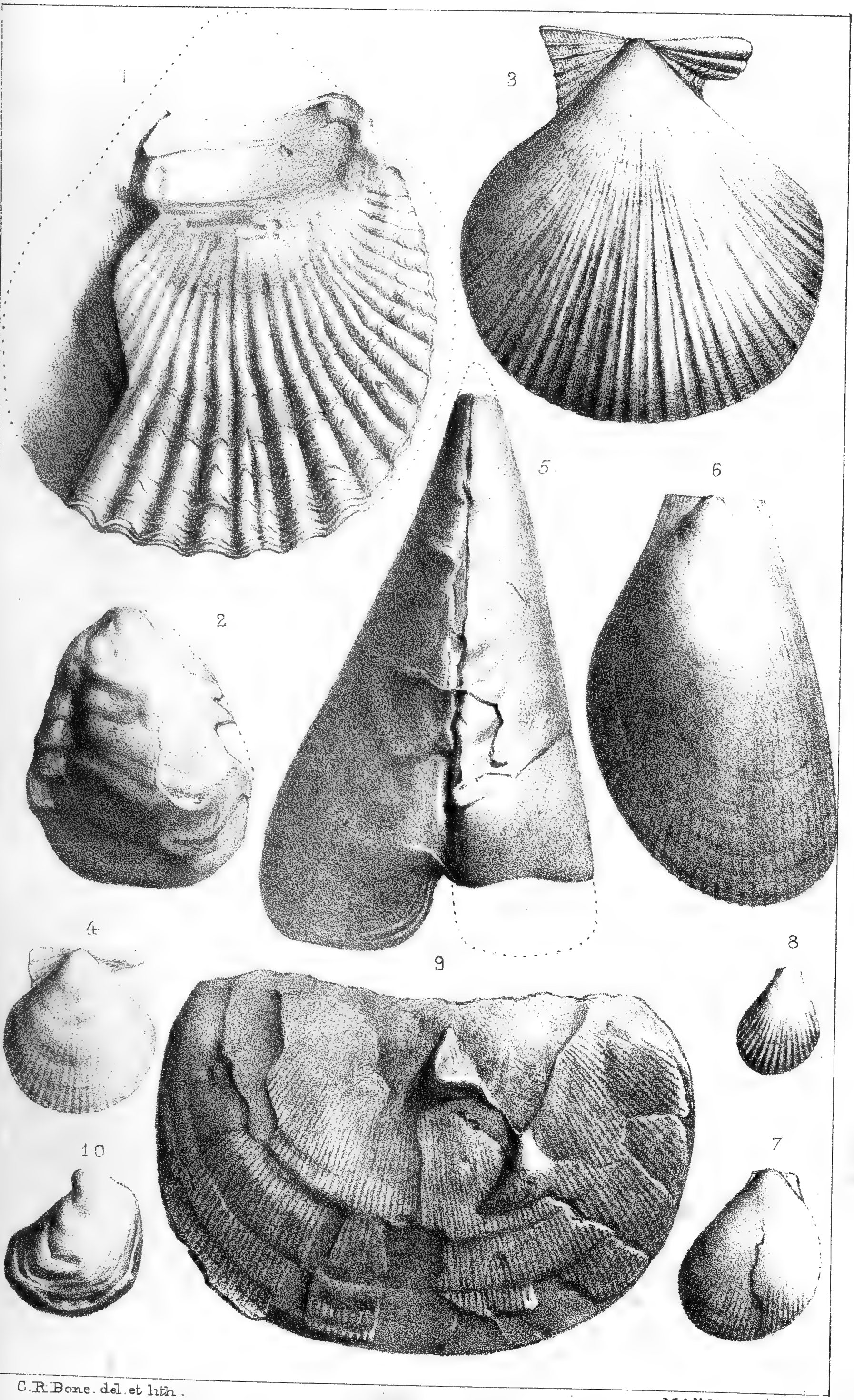
The *Montlivaltia* from the Sutton Stone is a stunted, multiseptate form, with a ridged epitheca; it resembles the general type of that section of the genus which is almost peculiar to the St. Cassian coral fauna. The casts of it are common, but the specific determination is impossible.

## EXPLANATION OF PLATES III. & IV.

*Illustrative of the Rhætic Fossils of South Wales.*

### Plate III.

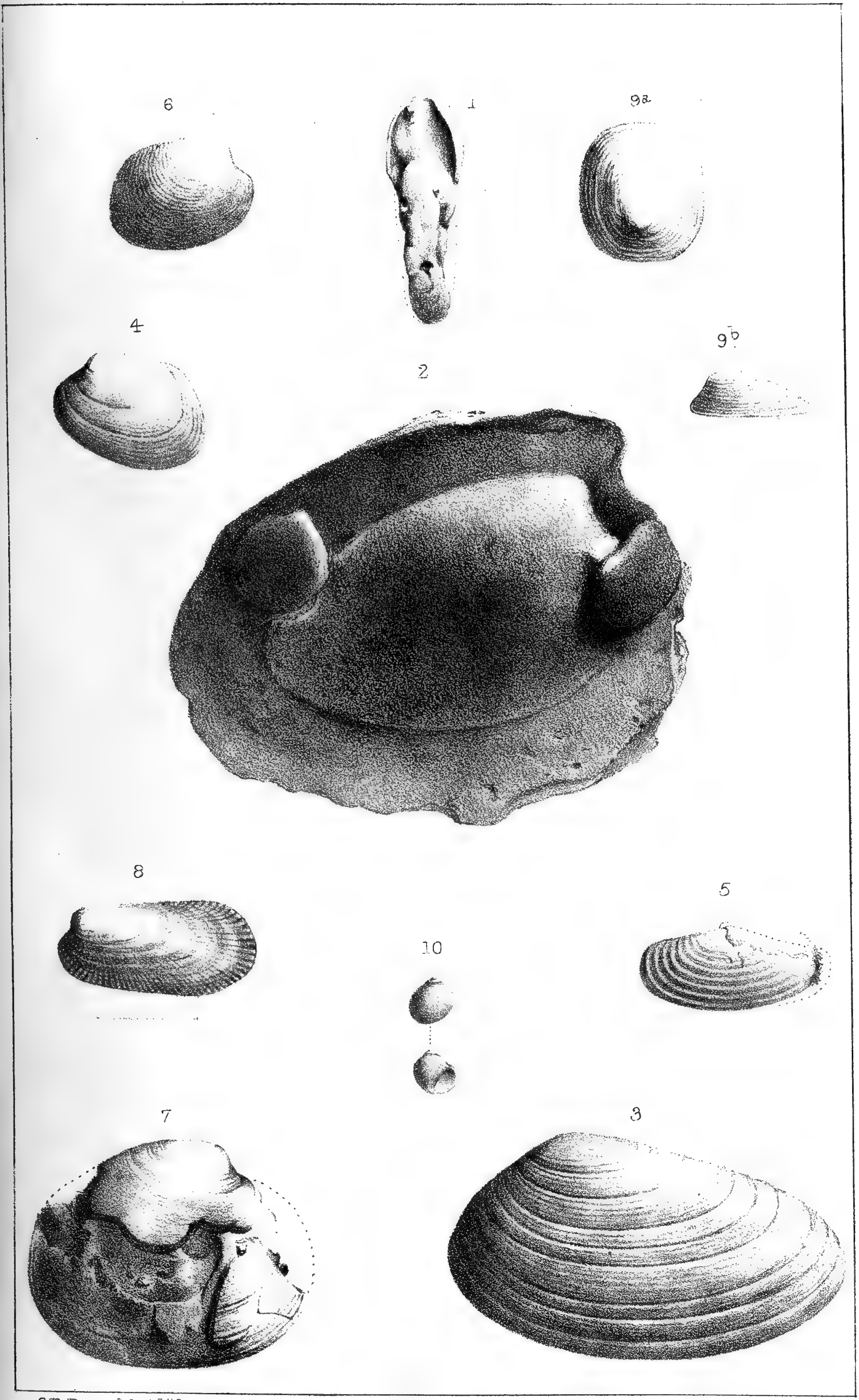
Fig. 1. *Ostrea multicostata,* Münst. Sutton and Southerndown series.
2. —— *lævis,* Tawn. Sutton series.




C. R. Bone. del. et lith.

M & N. Hanhart imp.

RHÆTIC FOSSILS FROM SOUTH WALES




C R Bone del et lith.

M & N Hanhart imp

RHÆTIC FOSSILS FROM SOUTH WALES.

Fig. 3. *Pecten Suttonensis*, Tawn. Sutton and Southerndown series.
4. —— *Etheridgii*, Tawn. Sutton and Southerndown series.
5. *Pinna insignis*, Tawn. Sutton and Southerndown series.
6. *Lima angusta*, Tawn. Sutton series.
7. —— *planicostata*, Tawn. Sutton series.
8. —— *subduplicata*, Tawn. Sutton and Southerndown series.
9. —— *Dunravenensis*, Tawn. Sutton and Southerndown series.
10. *Anomia socialis*, Tawn. Sutton series.

Plate IV.

Fig. 1. *Ammonites Dunravenensis*, Tawn. Sutton series.
2. *Cardinia ingens*, Tawn. Sutton series.
3. —— *Suttonensis*, Tawn. Sutton series.
4. *Astarte Duncani*, Tawn. Sutton series.
5. *Anatina præcursor*, Quenst. *Avicula-contorta* sandstones.
6. *Cardita rhomboidalis*, Tawn. Sutton series.
7. *Cyprina normalis*, Tawn. Sutton series.
8. *Modiola imbricato-radiata*, Tawn. Sutton series.
9*a*, 9*b*. *Patella Suttonensis*, Tawn. Sutton series.
10. *Natica Pylensis*, Tawn. *Avicula-contorta* sandstones.

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## 2. *Notes on a* Section *of* Lower Lias *and* Rhætic Beds, *near* Wells, Somerset. By the Rev. P. B. Brodie, M.A., F.G.S.

The accidental lowering of a road at Milton Lane, one mile and a half north of Wells, exposed a very interesting section of Lias and Rhætic beds, which has not been referred to by Mr. Dawkins in his paper "On the Relations of the Liassic and Rhætic Series in Somersetshire." This section is the more deserving of notice because, as a general rule, the sections in the immediate neighbourhood only exhibit the White Lias and Rhætic beds, and these have not hitherto been recorded so near the city in a northerly direction, nor so close to the Mendips; and in this case we have the "Lima-beds" the highest seen, passing into and overlying the White Lias and the *Avicula-contorta* zone. The nearest section to Wells described by Mr. Dawkins, showing the White Lias and Rhætic series, though very obscure, is at Pen Knowle, about five miles west of the town. The Milton-Lane section gives a clearer view of the succession of the "Lima-beds" downwards, and I can confirm Mr. Dawkins's* statement that the "White Lias" rests immediately upon the Rhætic beds†; for whether the strata below No. 4 in the annexed section, down to the "White Lias," belong to the "Lima series," which is most probable, and to which I have referred them, or form a reduced equivalent of the "Insect and Saurian beds," it is evident that the latter do not here or elsewhere underlie the "White Lias." The following is the section‡ at Milton Lane, in descending order:—

* This was also pointed out by Mr. Bristow in his paper communicated to the Bath Meeting of the British Association.

† At Harbury, in Warwickshire, the Lima-beds rest immediately on the White Lias.

‡ This section was taken conjointly with my friend Mr. James Parker.

*Section at Milton Lane.*

| | | | feet. | inches. |
|---|---|---|---|---|
| Lima-beds. | 1. | Thick blue limestones, compact, containing *Lima gigantea*, *L. duplicata* and another species, *Hemicardium cardioides*, *Pinna*, *Myacites*, *Pecten*, *Pholadomya*, and *Waldheimia perforata* (same species as in No. 4), *Ammonites Bucklandi*, *A. Conybeari*, and *Nautilus striatus* ........ | 5 | 0 |
| | 2. | Clay and bands of indurated rubbly limestone, often nodular, with many fossils, especially *Lima gigantea* ...... | 6 | 0 |
| | 3. | Thicker beds of sandy limestone, divided by sand, from 4 to 8 inches thick; very fossiliferous .................... | 4 | 0 |
| | 4. | Sandy limestones and intercalated shale, numerous fossils—*Lima duplicata*, *Lima*?, small *Avicula*, *Trochus* (same species as in No. 5), and *Waldheimia perforata** | 7 | 0 |
| | 5. | Hard sandy shelly limestone, very fossiliferous, with particles of quartz, and shaly partings 2 or 3 inches each, yielding *Ammonites* (very imperfect) and casts of *Astarte* and *Trochus*...... .................................... | 5 | 0 |
| White Lias. | 6. | White Lias limestone, hard, close-grained, containing the usual fossils, especially *Cardium Rhæticum*, *Modiola Hillana*, *Lima*, and *Pecten*. I did not observe *Ostrea intusstriata*, nor any corals .............................. | 7 | 4 |
| | 7. | Soft marly shale (base of White Lias), with *Modiola minima*, *M. Hillana*, *Cardium Rhæticum*, *Lima*, and spiny *Plicatula* ............................................ | 3 | 0 |
| Rhætic Series. | 8. | A peculiar bed, with much quartz, broken and rubbly ... | 1 | 6 |
| | 9. | Black shales, with thin layers of selenite in some parts, and frequent traces of peroxide of iron, from 6 inches to ½ inch thick. Contains *Cardium Rhæticum* and *Avicula contorta* unusually well preserved, and casts of other small bivalves and apparently some minute seed-vessels of some plant. The shells were tolerably abundant, but the genera few ............................................ | 8 | 0 |
| | 10. | Grey marl; with the exception of traces of small plants, no fossils were observed .................................... | 2 | 6 |
| | 11. | Alternations of clay and marl, rather variable, about 3 or 4 inches thick ............................................ | 2 | 6 |
| | 12. | Hard grey marl, similar to No. 15, becoming harder as it ascends ........................................................ | 2 | 6 |
| | 13. | Soft green marl and shale ....................................... | 1 | 4 |
| | 14. | Series of grey and yellow marls, with layers of marl near the top, where it is more indurated ........................ | 0 | 2 |
| Trias. | 15. | Marly parting ..................................................... | 0 | 6 |
| | 16. | Red and white marls. | | |

The Lima-series here amounts to 27 feet, the White Lias to 10 feet 4 inches. The Rhætic (including the grey marls) to 18 feet 6 inches. I could see no trace of *Ammonites planorbis*, nor any of the peculiar limestones indicating the "Insect and Saurian" zones, which seem to be entirely wanting, the Lima-beds resting immediately upon the "White Lias." There is certainly a greater thickness of Lias at this spot than might have been at first sight expected, considering that, as a whole, it thins out towards the Mendips, with which it here comes into almost immediate contact. The direction of the lane is nearly at right angles to the strike of the beds, which dip about ten degrees, but somewhat irregularly, being much disturbed to the north-east. I found one piece of bone-bed lying loose at the lower end of the lane, near the bed No. 14, full of bones, teeth,

* Most of the shells in nos. 1 & 4 were too imperfect for determination of the species.

and scales of fish (*Hybodus*), &c.; but after a careful search on several occasions, neither Mr. Parker, myself, nor the workmen could find any more, or discover its exact position *in situ*. The lithological character of this "bone-bed" was rather different from that which it usually presents, the bones and teeth being imbedded in a hard mass of limestone-conglomerate, made up of lighter-coloured angular fragments of limestone forming a kind of coarse breccia. On another visit to Milton Lane, after I had left Wells, Mr. Parker informed me that a further excavation nearer to the Mendips exhibited a slight difference in the stratum No. 8, which was much faulted and broken up, one side being let down, with an intervening band of dark shale belonging, I suppose, to the "*Avicula-contorta* zone."

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## December 20, 1865.

Hugh Leonard, Esq., C.E., Calcutta; William Lyon, Esq., J.P., Wellington, New Zealand; Moses Pullen, Esq., Painswick, Gloucestershire; and Charles Stavely Rooke, M.I.C.E., 12 Blenham Terrace, Leeds, were elected fellows.

The following communication was read:—

## *On the* Conditions *of the* Deposition *of* Coal, *more especially as illustrated by the* Coal-formation *of* Nova Scotia *and* New Brunswick. By J. W. Dawson, LL.D., F.R.S., F.G.S., Principal of McGill College, Montreal.

[Plates V–XII.]

Contents.

## § I. Introduction.

In several former papers presented to this Society, I have endeavoured to illustrate the arrangement of the Carboniferous rocks of Nova Scotia, and to direct attention to their organic remains, the structures found in their coals, and the evidence which they afford as to the mode of accumulation of that mineral. The present paper is intended as the summing up and completion of these researches, with the addition of the new facts resulting from a careful study of the microscopic structure of more than seventy beds of coal occurring in the South-Joggins section, and of the fossil plants associated with them. These results will, I hope, throw much additional light on some of the more difficult problems connected with the theory of the accumulation of vegetable matter in the Carboniferous period, and its conversion into coal.

The subjects to which I propose to direct attention may be conveniently arranged under the following heads:—

(1) General considerations relating to the physical conditions of the Carboniferous period in Nova Scotia.

(2) Details of the character and contents of the several beds of coal in the Joggins section, arranged in the order of Logan's Sectional List.

(3) Remarks on the genera of animals and plants whose remains occur in the coal, and on their connexion with its accumulation.

## § II. General Considerations relating to Physical Conditions.

1. *Physical Characters of the several Coal-formations.*—The total vertical thickness of the immense mass of sediment constituting the Carboniferous system in Nova Scotia may be estimated from the fact that Sir W. E. Logan has ascertained by actual measurement at the Joggins a thickness of 14,570 feet; and this does not include the lowest member of the series, which, if developed and exposed in that locality, would raise the aggregate to at least 16,000 feet. It is certain, however, that the thickness is very variable, and that in some districts particular members of the series are wanting, or are only slenderly developed. Still the section at the Joggins is by no means an exceptional one, since I have been obliged to assign to the Carboniferous deposits of Pictou, on the evidence of the sections exposed in that district, a thickness of about 16,000* feet; and Mr. Brown has estimated the Coal-formation of Cape Breton, exclusive of the Lower Carboniferous, at 10,000 feet in thickness†.

When fully developed, the whole Carboniferous series may be arranged in the following subordinate groups or formations, the limits of which are, however, in most cases not clearly defined:—

a. *The Upper Coal-formation.*—It consists of sandstones, shales, and conglomerates, with a few thin beds of limestone and coal. *Calamites Suckovii*, *Annularia galioides*, *Cordaites simplex*, *Alethopteris nervosa*, *Pecopteris arborescens*, *Dadoxylon materiarium*, *Lepidophloios parvus*, and *Sigillaria scutellata*, are among its characteristic vegetable fossils.

* Quart. Journ. Geol. Soc. vol. i. p. 329.

† *Ibid.* vol. vi. p. 116.

b. *The Middle Coal-formation, or Coal-measures proper.*—This series includes the productive beds of coal, and is destitute of properly marine limestones. Beds tinged with peroxide of iron are less common in this formation than in any of the others. Dark-coloured shales and grey sandstones prevail, and there are no conglomerates. *Sigillariæ* and *Stigmariæ* of many species are the most conspicuous and abundant fossils, but Ferns, *Cordaites*, and *Calamites* are also extremely abundant, and all the genera of Carboniferous plants are represented. Many beds, especially those in the vicinity of layers of coal, contain minute *Entomostraca*, shells of the genus *Anthracomya* (*Naiadites*), *Spirorbis carbonarius*, and remains of ganoid and placoid fishes.

c. *The "Millstone-grit" Formation.*—This name, though not in all cases lithologically appropriate, has been borrowed from English geology to designate the group of sandstones, shales, and conglomerates, destitute of coal, or nearly so, and with few fossil plants, which underlies the Coal-measures. In its upper and middle part it includes thick beds of coarse grey sandstone holding prostrate trunks of coniferous trees (*Dadoxylon Acadianum*). In its lower part red and comparatively soft beds prevail.

d. *The Lower Carboniferous Marine Formation.*—The essential features of this formation are thick beds of marine limestone, characterized principally by numerous Brachiopods, especially *Productus Cora*, *P. semireticulatus*, *Athyris subtilita*, and *Terebratula sufflata**, with other marine invertebrates. Associated with these limestones are beds of gypsum, and they are enclosed in thick deposits of sandstone, clay, and marl, of prevailing red colours.

e. *The Lower Carboniferous Coal-measures, or Lower Coal-measures.*—In some localities these resemble in mineral character the true Coal-measures. In others they present a great thickness of peculiar bituminous and calcareous shales. They usually contain in their lower part thick beds of conglomerate, and coarse sandstone which in some places prevail to the exclusion of the finer beds. The characteristic plants of these beds are *Lepidodendron corrugatum*, and *Cyclopteris Acadica*, with *Dadoxylon antiquius*, and *Alethopteris heterophylla*†. They also contain locally great quantities of remains of fishes, and many Entomostracans, among which are *Leaia Leidyi* and an *Estheria*, also *Leperditia subrecta*, Portlock, *Beyrichia colliculus*, Eichw., and a *Cythere*‡, probably new.

The last two groups are equivalent to the "Sub-carboniferous" of some American geologists; but independently of the objection to the use of a term which would seem to imply a formation under, and distinct from, the Carboniferous, and of undetermined age, I find in Nova Scotia no reason, either palæontological or stratigraphical, for any greater distinction than that implied in the term Lower

* See Davidson "On Lower Carboniferous Brachiopoda from Nova Scotia," Quart. Journ. Geol. Soc. vol. xix. p. 158.

† Dawson, "On the Lower Coal-measures," &c., Quart. Journ. Geol. Soc. vol. xv. p. 62.

‡ Prof. Jones has kindly determined these species.

Carboniferous. The Lower Coal-measures are, it is true, more distinct in their flora from the Middle Coal-measures than the latter from the Upper Coal-formation; but still many species are common to the two former, and the difference is small as compared with that between the Lower Carboniferous and the Upper Devonian. The Devonian rocks are also in this region unconformable to the Carboniferous, having been disturbed and altered prior to the deposition of the latter; while no want of conformity, except of the local character hereafter to be noticed, occurs in the Carboniferous.

2. *Physical Conditions attending the Deposition of the Coal-formations.*—The conditions of deposit implied in the mineral character of the several formations above described, would appear to be of three leading kinds:—(1) The deposition of coarse sediment in shallow water, with local changes leading to the alternation of clay, sand, and gravel. This predominates at the beginning of the period, recurs after the deposition of the marine limestones in the formation of the "Millstone-grit," and again prevails in the Upper Coal-formation. (2) The growth of corals and shellfish in deep clear water, along with the precipitation of crystalline limestone and gypsum. These conditions occurred during the formation of the Lower Carboniferous Limestone and its associated gypsum. (3) The deposition of fine sediment, and the accumulation of vegetable matter in beds of coal and carbonaceous and bituminous shale, and of mixed vegetable and animal matters in the beds of bituminous limestone and calcareo-bituminous shale. These conditions were those of the Middle Coal-formation.

Within the limits of Nova Scotia, these conditions of deposition applied, not to a wide and uninterrupted space, but to an area limited and traversed by bands of Silurian and Devonian rocks, already partially metamorphosed and elevated above the sea, and along the margins of which igneous action still continued, as evidenced by the beds of trap intercalated in the Lower Carboniferous*; while about the close of the Devonian period still more important injections and intrusions of igneous matter had occurred, as shown by the granitic dykes and masses which traverse the Devonian beds, but have not penetrated the Carboniferous†. There is evidence, however, in the Carboniferous rocks of the Magdalen Islands and of Newfoundland, and in the fringes of such rocks on parts of the coast of Nova Scotia‡ and New England, that the area in question was only a part of a far more extensive region of Carboniferous deposition, the greater part of which is still under the waters of the Atlantic and of the Gulf of St. Lawrence.

There is ample proof that most of the coarser matter of the Carboniferous rocks was derived from the neighbouring metamorphic ridges; but much of the finer material was probably drifted from more distant sources. There seems no good reason to doubt that in the Carboniferous period, and especially in those portions of it in

* Dawson, Quart. Journ. Geol. Soc. vol. i. p. 329.
† Dawson, Canadian Naturalist, 1860, p. 142.
‡ Jukes's 'Newfoundland;' 'Acad. Geology,' p. 274.

which the areas now under consideration were in the condition of shallow seas or swampy flats, the greater part of the Laurentian and Silurian districts of North America existed as land; while the great number of Coal-formation plants common to Europe and America may indicate the existence of intermediate lands now submerged. From such lands, undergoing waste during the long Carboniferous time, the materials of the shales and finer sandstones may have been derived.

Taking this view of the source of the sediment, we should infer that the time of the formation of the marine limestones was that of greatest depression of the land, when the local ridges of older rock were mere reefs and islets, and when sediment from more distant lands was deposited only at intervals. We should also infer that the time of the formation of the coal-beds was that of greatest elevation, when the former sea-bottoms had become land-surfaces or flats, exposed only to occasional inundation, and when rivers were bearing downward from large continental regions great quantities of fine silt. Further, the conditions of the Millstone-grit and of the Newer Coal-formation must have been of an intermediate character, requiring wide sea-areas receiving great quantities of sediment, and on this account, as well as because of their shallowness, unfavourable to marine life, while the areas of vegetable growth were also of limited extent.

It would also follow that when the Lower Coal-measures and conglomerates were formed, the land was slowly subsiding; that in the time of the marine limestones it attained to its greatest depression, and long remained nearly stationary; that in the Millstone-grit period there was re-elevation, and that in the period of the Middle Coal-formation and Newer Coal-formation there was again subsidence, slow and interrupted at first, but subsequently of greater amount. From the absence of Permian deposits it may be inferred that elevation again took place at the close of the Carboniferous period, to such an extent as to preclude further deposition in the area in question; while the red sandstone and trap of Mesozoic age indicate the recurrence at that time of conditions somewhat similar to those of the beginning of the Carboniferous period.

The general phenomena of deposition above indicated apply to all the Carboniferous areas of Nova Scotia and New Brunswick, and, so far as known, to those of the Magdalen Islands and of Newfoundland. But, as I have pointed out in 'Acadian Geology,' numerous local diversities occur, in consequence of the interference of the older elevated ridges with the regularity of deposition. In some places the entire Lower Carboniferous series seems to be represented by conglomerates and coarse sandstones. In others, the Lower Coal-measures, or the Marine Limestones, or both, are extensively developed. These local differences are, on a small scale, of the same character with those which occur on a large scale in the Northern and Southern Appalachian districts and Western districts of the United States, and in the different coal-areas of Great Britain and Ireland, as compared with each other and with the Carboniferous districts of

America. On the whole, however, it is apparent that certain grand features of similarity can be traced in the distribution of the Carboniferous rocks throughout the northern hemisphere.

It is further to be observed that in Nova Scotia and New Brunswick, as well as in Eastern Canada, disturbances occurred at the close of the Devonian period which have caused the Carboniferous rocks to lie unconformably on those of the former; and that in like manner the Carboniferous period was followed by similar disturbances, which have thrown the Carboniferous beds into synclinal and anticlinal bends, often very abrupt, before the deposition of the Triassic Red Sandstones. These disturbances were of a different character from the oscillations of level which occurred within the Carboniferous period. They were accompanied by volcanic action, and were most intense along certain lines, and especially near the junction of the Carboniferous with the older formations.

I have noticed an apparent case of unconformability between members of the Carboniferous system near Antigonish*. In the county of Pictou the arrangement of the beds suggests a possible unconformability of the Upper Coal-formation and the Coal-measures†. In New Brunswick Prof. Bailey‡ has observed indications of local unconformability of the Coal-formation with the Lower Carboniferous. But the strict conformability of all the members of the Carboniferous series in the great majority of cases, shows that these instances of unconformability are exceptional. In the section at the Joggins, more especially, the whole series presents a regular dip, diminishing gradually from the margin to the middle line of the trough, where the beds become horizontal.

The most gradual and uniform oscillations of level must, however, be accompanied with irregularities of deposition and local denudation; and phenomena of this kind are abundantly manifest in the Carboniferous strata of Nova Scotia. I have described in 'Acadian Geology' a bed in the Pictou coal-field which seems to be an ancient shingle-beach, extending across a bay or indentation in the coast-line of the Carboniferous period§. At the Joggins many instances occur of the sudden running out and cutting off of beds ||, and Mr. Brown has figured a number of instances of this kind in the Coal-formation of Sydney¶. They are of such a character as to indicate the cutting action of tidal or fluviatile currents on the muddy or sandy bottom of shallow water. In some instances the layers of sand and drift-plants filling such cuts suggest the idea of tidal channels in an estuary filled with matter carried down by river-inundations. Even the beds of coal are by no means uniform when traced for considerable distances. The beds which have been mined at Pictou and the Joggins show material differences in quality and associations; and small beds may be observed to change in a remarkable manner, in

* Quart. Journ. Geol. Soc. vol. i. p. 32.
† *Ibid.* vol. x. p. 42; Acadian Geology, p. 249.
‡ Report on Geology of Southern New Brunswick, p. 118.
§ Quart. Journ. Geol. Soc. vol. x. p. 45.
|| *Ibid.* vol. x. p. 12.
¶ *Ibid.* vol. vi. p. 125 *et seq.*

their thickness and in the materials associated with them, in tracing them a few hundreds of feet from the top of the cliff to low-water mark on the beach. I have no doubt that, could we trace them over sufficiently large areas, they would all be found to give place to sandstones, or to run out into bituminous shales and limestones, according to the undulations of the surfaces on which they were deposited, just as the peaty matter in modern swamps thins out toward banks of sand, or passes into the muck or mud of inundated flats or ponds.

3. *Geological Cycles.*—The foregoing considerations bring, in a very distinct manner, before us two different, and at first sight irreconcileable, general views which we may take of any given geological period. *First,* we must regard every such period as presenting during its whole continuance the diversified conditions of land and water with their appropriate inhabitants; and *secondly,* we must consider each such period as forming a geological cycle, in which such conditions to a certain extent were successive. As we give prominence to one or the other of these views, our conclusions as to the character of geological chronology must vary in their character; and in order to arrive at a true picture of any given time, it is necessary to have both before us in their due proportion.

We know that the marine animals of the Lower Carboniferous seas continued to exist in the time of the Coal-formation, and that some of them survived until the Permian period, proving to us the existence of deep seas even in that age which we regard as specially characterized by swampy flats supporting land-plants. In like manner we know that some of the species of land-plants found in the lowest Coal-measures continued to exist in the time of the Upper Coal-formation, proving that there was some land suitable for them throughout the epoch of the deep-sea limestones. Regarded from this point of view, any exceptional beds with land-plants in the marine parts of the formation, or beds with sea-shells in the parts where land-conditions predominate, acquire a special interest; and so likewise do regions in which, as in some parts of the Appalachian Coal-field, the marine limestones are absent, and those in which, as in some parts of the Western States, marine conditions seem to have continued throughout the whole period. In Nova Scotia, so far as my present knowledge extends, the marine limestones of the Lower Carboniferous cut off the flora of the Lower Coal-measures, apparently by a long interval of time, from that of the Middle Coal-formation; and in like manner the fossils of the marine limestones cease at the time of the Millstone-grit, and only in one instance, that of a small bed of limestone near Wallace Harbour, partially reappear in the Upper Coal-formation*. I have, however, ascertained that the Marine Limestones may be divided into an upper and a lower member, and that there is some reason to suppose that in some parts of Nova Scotia, where the true Coal-measures are not developed, the upper member may in part, at least, represent them†.

* Acad. Geol. p. 183; Quart. Journ. Geol. Soc. vol. ii. p. 133.

† Quart. Journ. Geol. Soc. vol. xv. pp. 63 *et seq.* My friend Mr. C. F. Hartt, who

On the other hand, I have not as yet been able to bridge over the gulf which separates the flora of the Lower Carboniferous Coal-measures from that of the Middle Coal-formation, an interval which may include much of the "Lower Coal-measures" of Rogers in the Pennsylvania Coal-field.

Turning to that broader view which takes the prevalent conditions of each portion of the period as characteristic, notwithstanding the local existence of dissimilar conditions, we not only find, as already stated, that the sequence in Nova Scotia coincides generally with that in other parts of America and in Europe, but that, viewed in this aspect, the Carboniferous period constitutes one of four great physical cycles, which make up the Palæozoic age in Eastern America—and each of which was characterized by a great subsidence and partial re-elevation, succeeded by a second and very gradual subsidence. Viewed in this way, the Lower Carboniferous conglomerate and Lower Coal-measures correspond analogically with the Oriskany Sandstone, the Oneida and Medina Sandstones, and the Potsdam and Calciferous. The Carboniferous Limestone corresponds with the Corniferous Limestone, the Niagara Limestone, and the Trenton group of limestones. The Coal-measures correspond with the Hamilton group, the Salina group, and the Utica Shale. The Upper Coal-formation corresponds with the Chemung, the Lower Helderberg, and the Hudson-River groups. The Permian is not represented in Eastern America; but as developed in Europe it clearly constitutes a similar cycle. These parallelisms, which deserve more attention from geologists than they have yet received, may be tabulated thus*:—

*Tabular View of Cycles in the Palæozoic Age in Eastern America.*
(The several formations are arranged in descending order.)

| Character of group. | Lower Silurian. | Upper Silurian. | Devonian. | Carboniferous. |
|---|---|---|---|---|
| Shallow, subsiding marine area, filling up with sediment | Hudson-River group. | Lower Helderberg group. | Chemung gr. | Upper Coal-formation. |
| Elevation, followed by slow subsidence, land-surfaces, &c. | Utica shale | Salina group | Hamilton gr. | Coal-measures. |
| Marine conditions; formation of limestones, &c. | Trenton, Black R. and Chazy limestones. | Niagara and Clinton limestones. | Corniferous limestone. | Lower Carboniferous limestone. |
| Subsidence; disturbances; deposition of coarse sediment | Potsdam and Calciferous sandstones. | Oneida and Medina sandstones. | Oriskany sandstone. | Lower Coal-measures and conglomerate. |

In the Permian of Europe, the Stinkstein, the Rauchwacke, the Zechstein, and the Rothliegendes might form a fifth parallel column.

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has more recently studied the Marine Limestones, has obtained facts which seem to indicate the possibility of a more minute subdivision than any hitherto attempted of these beds.

* Dr. Sterry Hunt has directed attention to them in a paper "On Bitumens," 'Silliman's Journal' [2], xxxv. p. 166, and in the 'Geology of Canada,' 1863, p. 627; and Dana refers to them in his 'Manual of Geology.' Eaton and Hall had previously noticed these parallelisms.

Of course such parallelism might be variously expressed by reckoning a smaller or larger number of groups. Independently of these different modes of statement, however, I believe that the basis of such comparisons exists in nature, and that it will prove possible to subdivide geological time into determinate natural cycles, the parts of which are analogous to those of similar cycles. A further question to be solved is, whether such cycles corresponded in all parts of the world, or whether, as is more likely, the earth might be divided into areas in which in each cycle elevation and subsidence were contemporaneous. So far as the present subject is concerned, I merely desire to show that the Carboniferous rocks of Nova Scotia represent a complete cycle of the earth's history, and correspond in time with the Carboniferous of Europe, and in value with the other great divisions of the Palæozoic age.

4. *Summary of facts relating to the mode of accumulation of Coal.*—With regard to the more special subject of this paper, I would rather invite attention to the details to be presented under the next head, than make any preliminary general statements. It is, however, necessary to notice here the several views which have prevailed as to the probable accumulation of coal by driftage or growth *in situ*, in water or on land. I have already, in previous publications*, stated very fully the conclusions at which I have arrived on some portions of this subject, and I would now sum up the more important general truths as follows:—(1) The occurrence of *Stigmaria* under nearly every bed of coal, proves beyond question that the material was accumulated by growth *in situ*, while the character of the sediments intervening between the beds of coal proves with equal certainty the abundant transport of mud and sand by water. In other words, conditions similar to those of the swampy deltas of great rivers are implied. (2) The true coal consists principally of the flattened bark of Sigillarioid and other trees, intermixed with leaves of ferns and *Cordaites*, and other herbaceous débris, and with fragments of decayed wood constituting "mineral charcoal," all these materials having manifestly alike grown and accumulated where we find them. (3) The microscopical structure and chemical composition of the beds of Cannel-coal and earthy bitumen, and of the more highly bituminous and carbonaceous shales, show them to have been of the nature of the fine vegetable mud which accumulates in the ponds and shallow lakes of modern swamps. When such fine vegetable sediment is mixed, as is often the case, with shales, it becomes similar to the bituminous limestone and calcareo-bituminous shales of the Coal-measures. (4) A few of the underclays which support beds of coal are of the nature of the vegetable mud above referred to; but the greater part are argillo-arenaceous in composition, with little vegetable matter, and bleached by the drainage from them of water containing the products of vegetable decay. They are, in short, loamy or clay soils, and must have been sufficiently above water to admit of drainage. The absence of sul-

* "On the Structures of Coal," Quart. Journ. Geol. Soc. vol. xv. Air-breathers of the Coal Period, Montreal, 1863, p. 18.

phurets, and the occurrence of carbonate of iron in connexion with them, prove that, when they existed as soils, rain-water, and not sea-water, percolated them. (5) The coal and the fossil forests present many evidences of subaërial conditions. Most of the erect and prostrate trees had become hollow shells of bark before they were finally imbedded, and their wood had broken into cubical pieces of mineral charcoal. Land-snails and galley-worms (*Xylobius*) crept into them, and they became dens or traps for reptiles. Large quantities of mineral charcoal occur on the surfaces of all the larger beds of coal. None of these appearances could have been produced by subaqueous action. (6) Though the roots of *Sigillaria* bear some resemblance to the rhizomes of certain aquatic plants, yet structurally they are absolutely identical with the roots of Cycads, which the stems also resemble. Further, the *Sigillariæ* grew on the same soils which supported Conifers, *Lepidodendra*, *Cordaites*, and Ferns, plants which could not have grown in water. Again, with the exception, perhaps, of some *Pinnulariæ* and *Asterophyllites*, there is a remarkable absence from the Coal-measures of any form of properly aquatic vegetation. (7) The occurrence of marine or brackish-water animals in the roofs of coal-beds, or even in the coal itself, affords no evidence of subaqueous accumulation, since the same thing occurs in the case of modern submarine forests. For these and other reasons, some of which are more fully stated in the papers already referred to, while I admit that the areas of coal-accumulation were frequently submerged, I must maintain that the true coal is a subaërial accumulation by vegetable growth on soils wet and swampy, it is true, but not submerged. I would add the further consideration, already urged elsewhere, that, in the case of the fossil forests associated with the coal, the conditions of submergence and silting-up which have preserved the trees as fossils must have been precisely those which were fatal to their existence as living plants—a fact sufficiently evident to us in the case of modern submarine forests, but often overlooked by the framers of theories of the accumulation of coal.

It seems strange that the occasional inequalities of the floors of the coal-beds, the sand or gravel ridges which traverse them, the channels cut through the coal, the occurrence of patches of sand, and the insertion of wedges of such material splitting the beds, have been regarded by some able geologists as evidences of the aqueous origin of coal. In truth, these appearances are of constant occurrence in modern swamps and marshes, more especially near their margins, or where they are exposed to the effects of ocean-storms or river-inundations. The lamination of the coal has also been adduced as a proof of aqueous deposition; but the microscope shows, as I have elsewhere pointed out, that this is entirely different from aqueous lamination, and depends on the superposition of successive generations of more or less decayed trunks of trees and beds of leaves. The lamination in the truly aqueous cannels and carbonaceous shales is of a very different character.

It is scarcely necessary to remark that in the above summary I have had reference principally to the appearances presented by the Coal-formation of Nova Scotia, and that I have no wish to undervalue the admirable researches on this subject of Brongniart, Goeppert, Hawkshaw, Beaumont, Binney, Rogers, Lesquereux, and others, whose publications on this subject I have read with interest, and have tested in their application to the phenomena presented to me in the coal-fields of Nova Scotia. I may add that in my opinion the phenomena of the Stigmaria-underclays, to which attention was first directed by Sir W. E. Logan, furnish the key to the whole question of the origin of coal, and that the comparisons of Coal-deposits, by Sir Charles Lyell, with the "Cypress-swamps" of the Mississippi perfectly explain all the more important appearances in the Coal-formation of Nova Scotia.

## § III. Details of the Character and Fossil Contents of the several Beds of Coal, as exposed in the South Joggins Section.

1. *Introduction.*—Under this heading I propose to state all the facts bearing on the origin and mode of formation of the several coals, obtained either by careful study of their outcrops on the ground, or by subsequent examination, with the aid of the microscope, of specimens collected from them. I shall follow the order of the detailed section published by Sir W. E. Logan in 1845*, including the additional points observed by Sir C. Lyell and myself in 1852, and by myself in several successive visits†, but giving in minute detail only the coals and their associated roof-beds and underclays. The sandstones and shales which constitute the mechanical filling-in between the beds of coal I shall group together in the shortest possible manner, referring to the published sections above-mentioned for details. I shall, however, mention every case of the occurrence of beds holding erect trees, and of Stigmarian underclays, as well as of beds of bituminous limestone and highly carbonaceous shale. I regard the former as being truly land-surfaces, as well as the coals, and the latter as accumulations of vegetable mud or muck which imply the contemporaneous existence in their vicinity of swamps and forests.

2. *Logan's Section* (order descending). a. *Division* 1.—This extends along the coast from Shoulie River to the vicinity of Ragged Reef, being nearly horizontal at the former place and gradually assuming a decided south-west dip towards the latter. It is 1617 feet in vertical thickness, and constitutes the upper part of the "Upper Coal-formation." It occupies the centre of the great synclinal of the western part of the Cumberland coal-area, and presents the newest beds of the Carboniferous system.

The rocks are thick-bedded white and grey sandstones, passing in some places into conglomerates with quartz pebbles, and interstratified with reddish and chocolate shales. The sandstones predominate.

Fossils are not numerous in these beds. Those found are *Dadoxy-*

* Report of Progress of Canadian Survey, 1845.
† Quart. Journ. Geol. Soc. vol. x.; also Acadian Geology, p. 128 *et seq.*

*lon materiarium*, of which there are many drifted trunks in the sandstones in a blackened and calcified condition, *Calamites Suckovii*, *C. Cistii*, *Calamodendron approximatum*, *Lepidodendron undulatum*, *Lepidophloios parvus*, and *Stigmaria ficoides*. As in the Upper Coal-formation of Pictou, trunks of Conifers and Calamites are the most abundant fossils.

b. *Division* 2.—This occurs at Ragged Reef and its vicinity. Its thickness is 650 feet. It constitutes the lower part of the Upper Coal-formation.

The rocks are white and grey sandstones with occasional reddish beds, and red and grey shales. The sandstones and shales are nearly in equal proportions. Underclays, or soils supporting erect plants, probably *Sigillariæ*, occur at two levels.

Fossils are not numerous. Those collected were *Sigillaria scutellata* and *Stigmaria ficoides*, *Calamites Suckovii*, *Sphenopteris hymenophylloides*, *Alethopteris lonchitica*, *Cyclopteris heterophylla* (?), *Beinertia Gœpperti*, and portions of the strobiles of two species of *Lepidophloios*, namely *Lepidophyllum lanceolatum* and *L. trinerve*.

c. *Division* 3.—This extends in descending order from the vicinity of Ragged Reef to M[c]Cairn's Brook. Its thickness is 2134 feet. It includes the upper part of the "Middle Coal-formation," and is perhaps equivalent, in part at least, to the Upper Coal-measures of Great Britain, and to the Upper Coal-formation of American authors.

It includes 1009 feet of sandstone, almost all of which is grey, and 912 feet of grey and reddish shale and clay. It contains 22 beds of coal, all of small thickness, and most of them of coarse quality. Below I give each bed of coal in detail, with its roof and floor and its fossils; and the intervening mechanical beds in brackets. The thickness of the roofs and floors is included in that stated for the intervening beds.

| | | ft. | in. |
|---|---|---|---|
| | (Carbonaceous shale, grey understone, with *Stigmaria* and grey shale) | 7 | 0 |
| Coal-group 1 ... | Grey argillaceous shale. | | |
| | *Coal* 1 inch | 0 | 1 |
| | Grey argillaceous underclay, *Stigmaria*. | | |

The roof holds abundance of *Alethopteris lonchitica*. The coal is coarse and earthy, with much epidermal and bast tissue*, vascular bundles of ferns, and impressions of *Sigillaria* and *Cordaites*. It is a compressed vegetable soil or dirt-bed, resting on an argillaceous subsoil with rootlets of *Stigmaria*.

| | | ft. | in. |
|---|---|---|---|
| | (Grey and reddish sandstones and grey and red shales with ironstone nodules) | 281 | 6 |
| Coal-group 2 ... | Reddish argillaceous shale. | | |
| | *Coal* 1 inch; Carbonaceous shale 4 inches; *Coal* 1 inch | 0 | 6 |
| | Reddish underclay, *Stigmaria*. | | |

* For explanation as to the nature of these and other structures in the coal, see under § IV., below.

The coal is coarse, earthy, and shaly. It contains *Cordaites,* fern stipes, and bast tissue.

| | | ft. | in. |
|---|---|---|---|
| | (Reddish shale and grey sandstone, the latter seen in the cliff to thin out and give place to reddish shale) | 53 | 9 |
| Coal-group 3 ... | Grey sandstone. | | |
| | *Coal* 1 inch.... | 0 | 1 |
| | Grey and reddish sandy understone, *Stigmaria.* | | |

The coal is coarse and shaly. No fossils were observed, except stumps and rootlets of *Stigmaria* in the underclay.

| | | | |
|---|---|---|---|
| | (Reddish grey shale and grey sandstone) | 6 | 0 |
| Coal-group 4 ... | Reddish grey shale. | | |
| | *Coal* 2 inches | 0 | 2 |
| | Grey and reddish argillaceous underclay, *Stigmaria.* | | |

The coal is coarse and earthy. No fossils were observed, except *Stigmaria* rootlets in the underclay. This and the last coal are to be regarded merely as fossil vegetable soils or dirt-beds.

| | | | |
|---|---|---|---|
| | (Grey sandstone and grey and reddish shale. One underclay, and erect *Calamites* in the lowest bed) | 239 | 6 |
| Coal-group 5 ... | Grey argillaceous shale. | | |
| | *Coal* 2 inches | 0 | 2 |
| | Grey argillo-arenaceous underclay, *Stigmaria.* | | |

The coal is filled with leaves of *Cordaites borassifolia,* dividing it into thin papery layers. The underclay has many large branching roots of *Stigmaria.*

| | | | |
|---|---|---|---|
| | (Grey shale and sandstone) | 19 | 0 |
| Coal-group 6 ... | Grey arenaceous shale. | | |
| | *Coal* 3 inches | 0 | 3 |
| | Grey argillo-arenaceous underclay, *Stigmaria.* | | |

This coal is composed of flattened bark of *Sigillaria,* of which there are many layers in the thickness of the bed. The species are not distinguishable.

| | | | |
|---|---|---|---|
| | (Grey sandstone and shale. One underclay with *Stigmaria*) | 12 | 6 |
| Coal-group 7 ... | Grey argillaceous shale. | | |
| | *Coal* 1 inch. | | |
| | Grey argillacous underclay, *Stigmaria,* 1 ft. 6 in. | | |
| | *Coal* 2 inches. | | |
| | Grey argillaceous underclay, *Stigmaria,* 4 inches. | | |
| | *Coal* 1 inch. | | |
| | Grey argillaceous underclay, *Stigmaria* | 2 | 2 |

This is an alternation of thin coarse coals or fossil vegetable soils with *Stigmaria* subsoils. The roof-shale contains erect *Calamites,* which seem to have been the last vegetation which grew on the surface of the upper coal.

| | | | |
|---|---|---|---|
| | (Grey and reddish sandstones and shales) | 73 | 0 |
| Coal-group 8 ... | Red and grey shale. | | |
| | *Coal* 1 inch | 0 | 1 |
| | Grey hard underclay, *Stigmaria.* | | |

This coal contains flattened trunks of *Sigillaria scutellata,* or an allied species, and of other *Sigillariæ,* also abundance of vascular bundles of ferns and portions of epidermal tissues of different plants.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and red and grey shales. *Stigmaria* in the upper bed, and prostrate *Sigillaria* and *Cordaites* in some of the sandstones and shales)... | 490 | 0 |
| Coal-group 9 ... | Grey argillaceous shale, ironstone nodules. | | |
| | *Coal* 3 inches ........................................ | 0 | 3 |
| | Argillo-arenaceous underclay, *Stigmaria*. | | |

The roof of this coal holds prostrate *Sigillariæ* of three species and *Cordaites borassifolia.* The coal is hard and shining, with impressions of flattened *Sigillariæ,* also of *Cordaites, Asterophyllites, Carpolites,* and vascular bundles of ferns.

| | | ft. | in. |
|---|---|---|---|
| | (Underclay and reddish grey shale) .................... | 6 | 0 |
| Coal-group 10... | Reddish grey shale. | | |
| | *Coal* and coaly shale 8 inches. | | |
| | Grey argillaceous underclay, nodules of ironstone, and *Stigmaria* 2 feet. | | |
| | *Coal,* stony and compact, 2 inches .................... | 2 | 10 |
| | Grey argillaceous underclay, *Stigmaria*. | | |

The roof-shale has obscure impressions of plants, apparently petioles of ferns. The upper coal is thinly laminated and full of leaves of *Cordaites* and ferns, among which is *Alethopteris lonchitica.* The lower coal is compact, resembling cannel, and has many vascular bundles of ferns. It seems to be composed of herbaceous matter macerated in water and mixed with mud.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and shale with nodules of ironstone) | 23 | 0 |
| Coal-group 11... | Grey argillaceous shale. | | |
| | *Coal,* shaly, 3 inches ........................................ | 0 | 3 |
| | Arenaceous underclay, *Stigmaria*. | | |

An erect ribbed *Sigillaria* appears in the roof-shale. The coal contains many flattened *Sigillariæ,* also *Trigonocarpa, Cordaites,* and vascular bundles of ferns.

| | | ft. | in. |
|---|---|---|---|
| | (Arenaceous understone with ironstone nodules and *Stigmaria,* and carbonaceous shale)................ | 7 | 9 |
| Coal-group 12... | Carbonaceous shale. | | |
| | *Coal* 2 inches ........................................ | 0 | 2 |
| | Argillaceous underclay, ironstone, and *Stigmaria*. | | |

This coal is hard and laminated, with many vascular bundles of ferns upon its surfaces.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and grey argillaceous shale)........... | 12 | 0 |
| Coal-group 13... | Grey argillaceous shale. | | |
| | *Coal* 7 inches ........................................ | 0 | 7 |
| | Grey argillaceous underclay, ironstone, and *Stigmaria*. | | |

The roof contains erect stumps, not distinctly marked. The coal has indications of bark of *Sigillaria,* and is hard and shining, with a coarse earthy layer in the middle.

| | | ft. | in. |
|---|---|---|---|
| | (Grey shale) ........................................ | 7 | 0 |
| Coal-group 14... | Grey shale, as above. | | |
| | *Coal* 4 inches ........................................ | 0 | 4 |

| | | ft. | in. |
|---|---|---|---|
| Coal-group 14... | Grey argillo-arenaceous underclay, ironstone, and *Stigmaria* ........................................ | 1 | 6 |
| | *Coal* 2 inches ........................................ | 0 | 2 |
| | Grey argillaceous underclay, ironstone, and *Stigmaria*. | | |

The upper coal has impressions of bark of trees and *Cordaites*, especially in its upper part.

| | | | |
|---|---|---|---|
| | (Grey and reddish shale and grey sandstone, with Stigmarian soils at two levels) ........................ | 52 | 0 |
| Coal-group 15... | Grey shale. | | |
| | *Carbonaceous shale* 2 inches. | | |
| | Argillaceous underclay, ironstone, and *Stigmaria*... | 1 | 0 |
| | *Coal* 1 inch........................................ | 0 | 3 |
| | Argillaceous underclay, ironstone, and *Stigmaria*.... | | |

The upper shaly bed is a coal interlaminated with shale, which enables the nature of the coaly matter to be ascertained. It contains flattened *Sigillariæ* of several species, *Calamites*, *Cordaites*, *Cyperites*, leaves of *Sigillaria*, and *Lepidophylla*. The clay parting is the roof of the lower coal, and contains *Cyperites* and *Cordaites*. It has been converted into an underclay by the growth of *Sigillaria* upon it in the formation of the upper bed of coaly shale. The lower coal is compact, but showed an impression of a Calamite.

| | | | |
|---|---|---|---|
| | (Grey sandstone and grey and reddish shale, ironstone nodules)........................................ | 16 | 0 |
| Coal-group 16... | Grey argillaceous shale. | | |
| | *Coal* and carbonaceous shale 2 inches.................. | 0 | 2 |
| | Reddish argillaceous underclay, ironstone, and *Stigmaria*. | | |

The roof supports an erect tree, a *Sigillaria* 8 feet high and 1 foot in diameter. It is also rich in *Cyperites**, *Cordaites*, and *Calamites*. The coal contains *Calamites* and and also discigerous tissue of Conifers or *Sigillaria*.

| | | | |
|---|---|---|---|
| | (Grey sandstones and reddish and grey shales, with several Stigmarian underclays and coaly films or thin vegetable soils. One of the underclays supports large stumps of *Sigillaria*, with *Cyperites*, *Cordaites*, and *Lepidodendron* in the bed around their bases)........................................ | 38 | 6 |
| Coal-group 17... | Red and grey argillaceous shale. | | |
| | *Coal* 1 inch. | | |
| | Gray argillo-arenaceous underclay, *Stigmaria*, 4 ft. | | |
| | *Coal* 4 inches. | | |
| | Carbonaceous shale 4 inches. | | |
| | *Coal* 1 inch........................................ | 4 | 10 |
| | Grey arenaceous underclay, *Stigmaria*. | | |

The upper layer of coal consists in part of leaves of *Cordaites*. The middle layer has much *Cordaites* and *Cyperites*.

| | | | |
|---|---|---|---|
| | (Underclay and grey shale)........................................ | 2 | 3 |
| Coal-group 18... | Grey shale, as above. | | |
| | *Coal* 3 inches ........................................ | 0 | 3 |
| | Grey arenaceous underclay, *Stigmaria*. | | |

* By this term I continue, for convenience, to designate the leaves of *Sigillariæ*.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone, and red and grey shale. Stigmarian soils at two levels) | 26 | 0 |
| Coal-group 19... | Reddish shale. | | |
| | *Coal* 1 inch | 0 | 1 |
| | Red argillaceous underclay, *Stigmaria.* | | |

The roof contains an erect *Sigillaria.* The coal and that of the previous bed were not well seen.

| | | | |
|---|---|---|---|
| | (Grey sandstone and red and grey shales, with many drift-trunks and erect *Sigillariæ* at four levels)... | 222 | 0 |
| Coal-group 20... | Grey shale. | | |
| | *Coal* 1 inch | 0 | 1 |
| | Red and grey underclay, *Stigmaria* | 36 | 0 |

This coal contains much *Cordaites.*

| | | | |
|---|---|---|---|
| | (Grey and red shales and grey sandstone. One Stigmarian soil, and resting on it carbonaceous shale with *Cyperites*) | 16 | 3 |
| Coal-group 20*a** | Grey shale. | | |
| | *Coal* 2 inches. | | |
| | Underclay, *Stigmaria,* 2 inches. | | |
| | *Coal* 1 inch. | | |
| | Underclay 1 inch, *Stigmaria.* | | |
| | *Coal* 3 inches | 0 | 9 |
| | Argillaceous underclay, ironstone, and *Stigmaria.* | | |

These coals contain mineral charcoal, showing scalariform and epidermal tissues. The coals are impure, and were probably concealed at the time of Sir W. E. Logan's visit.

| | | | |
|---|---|---|---|
| | (Sandstone and red and grey shale, with one Stigmarian soil) | 93 | 3 |
| Coal-group 21... | Red shale. | | |
| | *Coal* and carbonaceous shale, 2 inches | 0 | 2 |
| | Grey argillaceous underclay, *Stigmaria.* | | |

In the bed above the roof-shale are erect *Calamites.* The coal is an uneven or irregular bed, and consists of flattened *Sigillariæ, Cyperites, Cordaites,* and ferns.

| | | | |
|---|---|---|---|
| | (Grey and reddish sandstones and shales, with drift-trunks of *Dadoxylon materiarium, Sigillaria,* and *Calamites*) | 334 | 0 |
| Coal-group 22... | Grey and red shale, nodules of ironstone. | | |
| | *Coal* and carbonaceous shale, 2 inches | 0 | 2 |
| | Grey argillo-arenaceous underclay, *Stigmaria.* | | |

This coal consists of flattened bark of *Sigillaria* with *Cordaites,* and vascular bundles of ferns. It contains also remains of fishes. Among these was found a tooth of *Ctenoptychius.* The underclay includes stumps of *Stigmaria,* as well as rootlets.

| | | | |
|---|---|---|---|
| | (Grey sandstone and shale with one Stigmarian soil supporting erect stumps of *Sigillaria*) | 68 | 0 |
| Total thickness of Division 3, according to Logan's measurements | | 2159 | 8 |

d. *Division* 4.—This division of the section extends from McCairn's Cove to the end of the high cliff beyond "Coal-mine Point." It

* I designate in this way coal-groups not noticed in Logan's section.

corresponds to the lower part of the Middle Coal-formation, and probably to the Lower Coal-formation of some American authors. Its thickness, according to the measurements of Sir William E. Logan, is 2539 feet. It is remarkable for the prevalence of grey sandstones and grey and dark-coloured shales. It constitutes the part of the section re-examined by Sir C. Lyell and myself in 1852; and in the memoir which I subsequently published it is divided into 27 groups or subdivisions. For facility of reference these groups are indicated by the Roman numerals in the following pages, beginning with the highest group, XXVII.

XXVII.

| | | ft. | in. |
|---|---|---|---|
| Coal-group 1 ... | Bituminous limestone and calcareo-bituminous shale 4 feet.<br>*Coal* 1 foot ........................................<br>Grey argillo-arenaceous underclay, *Stigmaria*. | 5 | 0 |

The roof has *Naiadites carbonarius* and *N. elongatus*, *Spirorbis carbonarius*, scales of *Rhizodus*, and obscure vegetable fragments. The coal contains flattened *Sigillariæ*, *Cordaites*, *Alethopteris lonchitica*, *Cyperites*, *Calamites Nova-scotica*, and many vascular bundles of ferns.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and shale with six underclays and erect *Sigillaria* at two levels; also a thin shale with *Naiadites*, *Cythere*, *Calamites*, and *Cordaites*. One of the sandstones has scales and teeth of a large fish (? *Rhizodus*) and plants covered with *Spirorbis*) ........................................ | 50 | 0 |
| Coal-group 2 ... | Grey argillaceous shale.<br>*Coal* 1 inch.<br>Clay 3 inches.<br>*Coal* 1 inch.<br>Clay 1 inch.<br>*Coal* 1 inch.<br>Shale 4 inches.<br>*Coal* 3 inches ........................................<br>Grey argillo-arenaceous underclay, *Stigmaria*. | 1 | 2 |

The roof has numerous vegetable fragments and flattened *Sigillariæ* and *Calamites*. One of the coals contains mineral charcoal, showing bast tissue, scalariform tissue, and fragments of epidermis. The lower coal has bark of *Sigillaria*, *Stigmaria*, and *Cyperites*, also numerous *Trigonocarpa* and vascular bundles of ferns. The clay partings and the underclay have obscure rootlets, probably of *Stigmaria*.

| | | ft. | in. |
|---|---|---|---|
| | (Arenaceous underclay and shale with remains of *Stigmaria*.) | | |
| Coal-group 3 ... | Grey argillaceous shale.<br>*Coal* 3 inches ........................................<br>Hard argillo-arenaceous underclay, *Stigmaria*. | 0 | 3 |

The roof has stumps of *Sigillariæ*, erect and with roots of *Stigmaria* descending among them from the bed above. The coal, which is coarse and earthy, has vascular bundles of ferns, scalariform vessels, bast tissue, and scales and spines of fishes (*Palæoniscus*, &c.), with coprolitic matter. The underclay shows abundant Stigmarian rootlets.

| | | ft. | in. |
|---|---|---|---|
| | (Underclay and grey arenaceous shale) | 6 | 0 |
| Coal-group 4 ... | Grey argillaceous shale.<br>*Coal* 9 inches.<br>Carbonaceous shale 6 inches.<br>*Coal* 1 inch.<br>Carbonaceous shale 4 inches.<br>*Coal* 1 inch.<br>Carbonaceous shale 8 inches.<br>*Coal* 2 inches.<br>Grey shale 1 foot 7 inches.<br>*Coal* 8 inches | 4 | 10 |
| | Argillo-arenaceous underclay, *Stigmaria.* | | |

The roof contains obscure flattened plants. The coal is hard or shaly, with vascular bundles of ferns and bast tissue. The carbonaceous shales yield *Cordaites borassifolia, Alethopteris lonchitica, Calamites, Sigillaria,* and *Cyperites.* The grey shale parting has erect stumps, apparently of *Sigillaria.* The upper shales and coals are very pyritous, and decompose when exposed to the weather—an indication that sea-water had access to these beds while the vegetable matter was still recent.

XXVI.

| | | ft. | in. |
|---|---|---|---|
| | (Grey argillaceous sandstone and red and grey shale, with two Stigmarian soils. Footprints, probably of *Dendrerpeton*, and rain-marks occur in these beds; and it was in one of them that Mr. Marsh discovered the vertebræ of *Eosaurus Acadianus*) . | 82 | 0 |

XXV.

| | | ft. | in. |
|---|---|---|---|
| Coal-group 5 ... | Bituminous limestone 2 feet.<br>*Coal* ½ inch.<br>Argillo-arenaceous clay, *Stigmaria,* 6 inches.<br>*Coaly shale* ½ inch.<br>Grey argillo-arenaceous shale, ironstone nodules, *Stigmaria,* 1 foot 6 inches.<br>*Coaly shale* 1 inch.<br>Grey shale, ironstone nodules, *Stigmaria,* 2 ft. 6 in.<br>*Coal* 6 inches | 7 | 2 |
| | Argillo-arenaceous underclay, *Stigmaria.* | | |

The bituminous limestone of the roof contains *Naiadites carbonarius* and *N. elongatus*, fish-scales, and Cyprids. The upper layer of coal contains impressions of *Sigillaria* and *Lepidodendron,* on some of which are shells of *Spirorbis.* It has epidermal tissues, vascular bundles of ferns, and reticulated vessels. The coaly shales are of the nature of coarse coals, but with numerous thin layers of shaly matter. The lower coal contains petioles of ferns and *Cordaites* matted together, and numerous *Cardiocarpa.* The two thick clay partings and the underclay are Stigmarian soils.

XXIV.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and chocolate and grey shales, with two Stigmarian soils) | 147 | 0 |

XXIII.

| | | ft. | in. |
|---|---|---|---|
| Coal-group 6 ... | Carbonaceous shale, passing downward into bituminous limestone, 1 foot 10 inches. | | |
| | *Coal* 4 inches ........ | 2 | 2 |
| | Argillo-arenaceous underclay, *Stigmaria.* | | |

The roof contains *Naiadites carbonarius, Cythere, Spirorbis,* fish-scales, and coprolites. The coal is hard and laminated, and has on its surfaces leaves of *Cordaites* and vascular bundles of ferns. It is remarkable for containing scattered remains of a number of species of fishes, belonging to the genera *Ctenoptychius, Diplodus, Palæoniscus,* and *Rhizodus.* The underclay has rootlets of *Stigmaria,* and the bed below this has large roots of the same.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and shale, the latter with nodules of ironstone. Erect trees at one level) ........ | 30 | 0 |
| Coal-group 7 ... | Grey sandstone. | | |
| | *Coal* 10 inches. | | |
| | Carbonaceous shale 2 inches | | |
| | *Coal* 10 inches. | | |
| | Carbonaceous shale 2 inches. | | |
| | *Coal* and coaly shale 2 feet 6 inches........ | 4 | 6 |
| | Grey argillo-arenaceous underclay, *Stigmaria.* | | |

This is the bed worked at the Joggins as the "Main Seam;" and I believe that it improves somewhat in mining it inward from the shore. The roof has afforded *Sigillaria catenoides* and other species, *Alethopteris lonchitica, Cordaites borassifolia, Lepidodendron elegans, Trigonocarpa, Naiadites, Spirorbis, Cythere,* fragments of insects (?). The mineral charcoal contains bast tissue, scalariform, epidermal, and cellular tissues. In the compact part of the coal there is dense cellular and epidermal tissue. The roof is especially rich in *Cordaites,* sometimes with *Spirorbis* adherent.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and shale, with many ironstone nodules in the shale, and erect *Sigillaria* and underclays at five levels. One of the latter has large stumps of *Stigmaria* and a thin coaly layer resting on it) ........ | 68 | 0 |
| Coal-group 8 ... | Grey shale with nodules of ironstone. | | |
| | *Coal* 2 inches. | | |
| | Grey shale 4 inches. | | |
| | *Coal* 3 inches. | | |
| | Carbonaceous shale 1 foot 3 inches. | | |
| | *Coal* 1 inch. | | |
| | Argillaceous shale, ironstone nodules, 4 feet. | | |
| | *Coal* 1 foot........ | 7 | 1 |
| | Grey argillo-arenaceous underclay, ironstone nodules, and *Stigmaria.* | | |

The roofs of the first and second beds in this group are among the richest in fossils in the Joggins section. They have afforded *Pecopteris lonchitica, Cyclopteris, Cyperites, Cordaites borassifolia, Cardiocarpum fluitans, Sigillaria elegans, Lepidophloios Acadianus, Lepidodendron undulatum,* *Pinnularia*, *Trigonocarpa*, &c.; also *Diplostylus Dawsoni**, *Eurypterus*, *Cythere*, *Naiadites*, and *Spirorbis* attached to plants. The lower coal, called locally the "Queen's Vein," has in its mineral charcoal bast cells, uniporous, rariporous, and multiporous wood-cells, scalariform vessels, epidermal tissue, and vascular bundles of ferns, also stipes of ferns and bark of *Sigillaria*. The mineral charcoal occurs principally in a thick layer near the bottom of the bed. Its roof has trunks of *Lepidophloios*, *Lepidodendron*, and *Sigillaria*, fossilized by carbonate of iron. The upper part of the lowest underclay is dark and carbonaceous, with Stigmarian rootlets. ft. in.

XXII.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstones, grey and chocolate shales with ironstone nodules; three underclays and erect *Calamites* and *Sigillaria* in three beds) ........... | 110 | 0 |

XXI.

| | | ft. | in. |
|---|---|---|---|
| Coal-group 9 ... | Grey shale and ironstone nodules.<br>*Coal* and coaly shale 1 foot 3 inches .................<br>Argillaceous underclay, *Stigmaria*. | 1 | 3 |

The roof contains erect *Sigillariæ*, *Stigmaria*, *Calamites*, and *Cordaites*. The coaly shale has fern-stipes and *Cordaites*. The coal itself is coarse and shaly, and has a layer of mineral charcoal containing bast and epidermal tissue. There are also in the coal remains of *Calamites* and *Cordaites*, and fragments, possibly, of insects.

| | | ft. | in. |
|---|---|---|---|
| | (Grey and reddish shales with nodules of clay-ironstone, and grey and reddish sandstone. One underclay supporting a coaly film, and erect trees at two levels) ........................................... | 28 | 6 |
| Coal-group 10... | Chocolate shale.<br>*Coal* and coaly shale 2 inches.<br>Coaly shale 6 inches.<br>*Coal* 4 inches ...............................................<br>Argillo-arenaceous underclay, *Stigmaria*. | 1 | 0 |

The upper coal contains flattened *Sigillariæ* and *Stigmaria*. The lower bed is hard and unequal, with curved laminæ and obscure traces of petioles of ferns. The mineral charcoal has bast and scalariform tissues.

XX.

| | | ft. | in. |
|---|---|---|---|
| | (Red and grey shales and grey sandstones. Erect *Calamites* in one bed. Four underclays) ............ | 78 | 6 |

XIX.

| | | ft. | in. |
|---|---|---|---|
| Coal-group 11... | Chocolate shale.<br>*Coal* and coaly shale 8 inches ...........................<br>Argillaceous underclay, *Stigmaria*. | 0 | 8 |

The roof has *Cordaites*, *Calamites*, and rootlets. The coal contains much mineral charcoal with the structure of dense

* Salter, Quart. Journ. Geol. Soc. vol. xix. p. 77.

aporous bast tissue; it also contains *Cyperites* and many vascular bundles of ferns.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstones and argillaceous shale. Erect trees at two levels) | 37 | 0 |
| Coal-group 12... | Grey shale.<br>Coal and coaly shale 1 foot<br>Argillaceous underclay, ironstone, and *Stigmaria*. | 1 | 0 |

The roof contains erect *Sigillaria* and *Calamites*, also *Cordaites* with *Spirorbis* attached, and *Lepidodendron*. The coal has in one layer much *Cordaites*, in others it includes an immense number of specimens of *Sporangites papillata*; it has also bast tissue, epidermal tissue, and discigerous tissue.

| | | ft. | in. |
|---|---|---|---|
| | (Shale and sandstone, penetrated by Stigmarian rootlets, and containing in one of the shales *Lepidodendron*, *Sigillaria*, and *Carpolithes*) | 13 | 0 |
| Coal-group 13... | Grey shale.<br>*Coal* and coaly shale<br>Argillaceous underclay, *Stigmaria*. | 0 | 6 |

The roof has much *Cordaites*. The shaly portions of the coal contain *Sigillaria elegans*, *Alethopteris lonchitica*, *Cordaites borassifolia*, *Lepidodendron*, *Diplotegium*, *Trigonocarpum*, *Stigmaria*, and *Sporangites glabra*, also vascular bundles of ferns and bast tissue.

XVIII.

| | | ft. | in. |
|---|---|---|---|
| | (Grey and red shales and grey sandstone; one of the latter with erect *Calamites* and *Sigillariæ*. One underclay) | 69 | 4 |

XVII.

| | | ft. | in. |
|---|---|---|---|
| Coal-group 13*a*. | Grey shale.<br>*Coal* 8 inches<br>Argillaceous underclay, *Stigmaria*. | 0 | 8 |

The roof has *Cordaites* and many decayed stipes. The coal has *Cordaites* and vegetable fragments.

XVI.

| | | ft. | in. |
|---|---|---|---|
| | (A very thick sandstone with shales. Erect *Calamites*, footprints of reptiles, and rain-marks) | 57 | 0 |

XV.

| | | ft. | in. |
|---|---|---|---|
| Coal-group 14... | Grey shales with ironstone.<br>*Coal* 3 inches.<br>Coaly shale 2 inches.<br>*Coal* 3 inches.<br>Underclay, *Stigmaria*, 6 feet.<br>Coaly shale 4 inches.<br>Underclay, *Stigmaria*, 1 foot.<br>Coaly shale 8 inches.<br>Coal 2 inches<br>Argillo-arenaceous underclay, *Stigmaria*, and ironstone. | 8 | 10 |

On the roof of the upper coal is a fine-ribbed *Sigillaria* with Stigmarian roots. In the roof and shaly partings are *Sigillaria Brownii, S. Schlotheimiana,* and other species, *Stigmaria, Lepidodendron, Calamites, Cordaites, Sporangites glabra, Alethopteris lonchitica, Sphenopteris latifolia, Pinnularia,* and *Cyperites*; also *Cythere, Naiadites,* and fragments of reptilian (?) bones. The coal is pyritous, and exhibits impressions of the bark of *Sigillaria*; it contains also bast tissue, scalariform tissue of *Sigillaria,* and multiporous tissue of *Sigillaria* and *Calamodendron.*

| | | ft. | in. |
|---|---|---|---|
| | (Sandstone and shale, erect *Calamites* and *Sigillaria* with *Stigmaria.* The erect trees contain reptilian remains of the genera *Dendrerpeton, Hylonomus,* and *Hylerpeton*; also *Pupa vetusta, Xylobius Sigillariæ,* and remains of insects) ........ | 10 | 0 |
| Coal-group 15... | Coaly shale. | | |
| | *Coal* 6 inches ........ | 0 | 6 |
| | Arenaceous underclay, *Stigmaria.* | | |

The erect trees above mentioned are rooted in the roof of this coal. It contains *Cyperites, Lepidophylla, Trigonocarpa* of 2 species, *Sphenophyllum, Alethopteris lonchitica, Cordaites,* and *Asterophyllites.* There are shells of *Spirorbis* on some of the plants. The coal contains layers of bark of *Sigillaria* and leaves of *Cordaites,* and much bast tissue, with scalariform, uniporous, and reticulated tissues, probably of *Sigillaria.*

| | | ft. | in. |
|---|---|---|---|
| | (Sandstones and shales; erect *Calamites* and *Stigmaria*)........ | 21 | 0 |
| Coal-group 15*a*. | Grey shale. | | |
| | *Coal* 4 inches ........ | 0 | 4 |
| | Argillaceous underclay, *Stigmaria.* | | |

The roof contains *Calamites, Sigillaria, Alethopteris lonchitica, Pinnularia, Lepidodendron, Cyperites, Sporangites,* and *Spirorbis.* One *Sigillaria* extends 30 feet without branching. The roof supports an erect tree. The coal is filled with flattened stems of *Sigillaria* lying in different directions, also flattened *Lepidodendra*; and in its mineral charcoal it has beautiful porous and scalariform tissues.

XIV.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and grey and red shales. Many prostrate trunks of *Sigillaria* and *Lepidodendron,* one underclay, and erect trees at one level) ...... | 68 | 0 |
| Coal-group 16... | Shale with the aspect of underclay. | | |
| | *Coal* and coaly shale 6 inches ........ | 0 | 6 |
| | Argillo-arenaceous underclay, ironstone, and *Stigmaria.* | | |

This bed was not well exposed, and afforded no fossils.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and shale with one underclay)...... | 25 | 6 |
| Coal-group 17... | Grey shale. | | |
| | *Coal* and coaly shale 3 inches ........ | 0 | 3 |
| | Argillo-arenaceous underclay, *Stigmaria.* | | |

The roof has vegetable fragments and *Cordaites.* The

| | | ft. | in. |
|---|---|---|---|
| coal is hard and coarse, and contains flattened broad-ribbed *Sigillaria*, *Cordaites*, and vascular bundles of ferns. | | | |
| | (Shale and sandstone, erect trees at one level) ...... | 31 | 3 |

XIII.

| | | | |
|---|---|---|---|
| Coal-group 18... | Grey shale.<br>*Coal* 8 inches ........................................<br>Argillo-arenaceous underclay. | 0 | 8 |

The roof has an erect *Sigillaria*. The coal is shaly and laminated. It contains much *Cordaites*, also *Lepidodendron*, *Calamites*, and *Alethopteris lonchitica*. In one layer there are *Naiadites*, *Spirorbis*, and scales of fishes.

| | | | |
|---|---|---|---|
| | (Grey sandstone and shale in several beds, *Stigmaria*)........................................ | 29 | 0 |
| Coal-group 19... | Argillaceous shale.<br>Coaly shale 4 feet.<br>Bituminous limestone 2 feet 6 inches.<br>Coal 1 inch........................................ | 6 | 7 |

The roof has *Naiadites*, scales and teeth of fishes, *Cythere*, and *Spirorbis*. The coal is hard and coarse, with vascular bundles of ferns and prostrate *Sigillariæ*.

| | | | |
|---|---|---|---|
| | (Shale and sandstone) ........................................ | 20 | 6 |
| Coal-group 20... | Coaly shale 1 foot.<br>Bituminous limestone 1 foot 6 inches.<br>*Coal* and clay partings 2 feet 4 inches.................. | 4 | 10 |

The roof has *Naiadites*, *Spirorbis* attached to plants, and small rhombic fish-scales. The coal alternates with limestone at the top, and contains remains of *Sigillaria*, *Sporangites*, and vascular bundles of ferns.

| | | | |
|---|---|---|---|
| | (Sandstone, and grey and black shale with coaly layers)........................................ | 21 | 0 |
| Coal-group 21... | Grey shale and calcareo-bituminous shale.<br>*Coal* 10 inches ........................................<br>Argillaceous underclay, *Stigmaria*. | 0 | 10 |

The roof has obscure vegetable fragments and *Naiadites*. The coal contains vascular bundles of ferns, bast tissue, uniporous cells, and scalariform and reticulated vessels.

| | | | |
|---|---|---|---|
| | (Grey sandstone and shale. Two underclays)......... | 20 | 0 |
| Coal-group 22... | Grey shale.<br>Coal and coaly shale 2 inches ..........................<br>Argillaceous underclay, *Stigmaria*. | 0 | 2 |

This bed was not well exposed.

| | | | |
|---|---|---|---|
| | (Sandstone and shale, with one erect tree and two underclays)........................................ | 12 | 0 |
| Coal-group 23... | Coaly and grey shale.<br>*Coal* and coaly shale 4 inches.<br>Bituminous limestone 4 inches.<br>*Coal* and coaly shale 7 inches ..........................<br>Argillo-arenaceous underclay, *Stigmaria*. | 1 | 3 |

The roof has an erect tree, also *Cordaites* and *Spirorbis*. The shale and bituminous limestone contain *Sigillaria* and

*Lepidophloios*, also many large-furrowed trunks, probably old *Sigillariæ* or *Lepidodendra*.

XII.

| | | ft. | in. |
|---|---|---|---|
| | (Sandstone, shale, and calcareo-bituminous shale with three underclays) | 26 | 0 |
| Coal-group 24... | Calcareo-bituminous shale.<br>*Coal* and coaly shale 1 inch<br>Argillo-arenaceous underclay, *Stigmaria*. | 0 | 1 |

This bed was not exposed.

| | | ft. | in. |
|---|---|---|---|
| | (Underclay and shale) | 5 | 0 |
| Coal-group 25... | Grey shale.<br>*Coal* and coaly shale 8 inches<br>Argillo-arenaceous underclay, *Stigmaria*. | 0 | 8 |

The roof has *Alethopteris lonchitica*, *Cordaites*, and petioles of ferns. The coal shows bast tissue and remains of *Sigillaria* and *Calamites*.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and shale, with erect *Sigillariæ* at four or five levels, and two Stigmarian underclays) | 117 | 8 |
| Coal-group 26... | Grey shale.<br>*Coaly* shale 4 inches<br>Argillo-arenaceous underclay, *Stigmaria*. | 0 | 4 |

This bed was not exposed.

| | | ft. | in. |
|---|---|---|---|
| | (Shale and sandstone, with *Stigmaria*) | 13 | 0 |
| Coal-group 27... | Grey shale.<br>*Coal* 3 inches<br>Argillo-arenaceous underclay, *Stigmaria*. | 0 | 3 |

This bed was not well exposed.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone and shale, with bituminous shale and limestone, and erect *Calamites*) | 64 | 0 |

XI.

| | | ft. | in. |
|---|---|---|---|
| Coal-group 28... | Calcareo-bituminous shale.<br>*Coal* and coaly shale 7 feet.<br>Underclay, *Stigmaria*, 4 feet.<br>Coaly shale 1 foot.<br>*Coal* 6 inches<br>Arenaceous underclay, *Stigmaria*. | 12 | 6 |

This group is a series of thin coaly layers and underclays. The roof has *Naiadites carbonarius* and *N. elongatus*, also *Cythere* and scales of fishes. The coal contains bast tissue and different kinds of scalariform and epidermal tissues. In the lower bed is a coaly stump and an irregular layer of mineral charcoal, arising apparently from the decay of similar stumps.

| | | ft. | in. |
|---|---|---|---|
| | (Grey and carbonaceous shale and grey sandstone) | 29 | 0 |
| Coal-group 29... | Underclay, *Stigmaria*.<br>*Coal* and coaly shale 5 feet.<br>Underclay 6 feet.<br>Coal, coaly shale, and ironstone, 6 feet.<br>*Coal* 4 feet<br>Argillaceous underclay, *Stigmaria*. | 21 | 0 |

This is a group of unusually thick beds, indicating long quiescence. The roof includes laminæ of coal, some of them composed of the bark of *Sigillaria catenoides*, also an erect *Sigillaria* rooted in the coal below. The coal and coaly shale exhibit remains of *Sigillaria, Cordaites, Lepidophyllum*, and *Cyperites*; and one layer has many hard pyritized fragments of wood. The mineral charcoal has vascular bundles of ferns, coarse scalariform tissue, and porous tissue. The underclay rests on a bed with *Naiadites*.

| | | ft. | in. |
|---|---|---|---|
| | (Underclay, *Stigmaria*, and grey and carbonaceous shales) | 18 | 0 |
| Coal-group 29*a* | Shale and coaly layers. | | |
| | *Coal* 4 feet | 4 | 0 |
| | Argillaceous underclay, *Stigmaria*. | | |

The roof has obscure fragments of plants and stumps in the state of mineral charcoal. The coal shows impressions of flattened trunks, probably *Sigillariæ*. This coal contains a great variety of tissues, especially bast and scalariform of different kinds, and epidermal. My measurements in this part of the section differ somewhat from those of Sir W. E. Logan, who, I suppose, had not a good opportunity of examining the two last coals. The coal 29*a* is now mined by an adit from the shore, called the "new mine."

| | | ft. | in. |
|---|---|---|---|
| | (Sandstone and shale. One sandstone has many large erect *Sigillariæ*, some of them with rough and furrowed bark) | 35 | 0 |
| Coal-group 30 | Argillaceous shale and ironstone. | | |
| | *Coal* 4 inches. | | |
| | Underclay, dark-coloured, 2 feet. | | |
| | Coal and coaly shale 2 inches. | | |
| | *Coal* 3 inches. | | |
| | Coaly shale 2 inches. | | |
| | Coal 1 inch | 3 | 0 |
| | Soft argillaceous underclay, *Stigmaria*. | | |

The roof has bark of *Sigillaria* preserved in ironstone. The coal is pyritous, and consists of layers of mineral charcoal alternating with bright coal; it has obscure impressions of plants and bast tissue in the mineral charcoal.

## X.

| | | ft. | in. |
|---|---|---|---|
| | (Grey shale and sandstone. One underclay, and erect *Calamites* and *Sigillaria* at two levels) | 19 | 0 |
| Coal-group 31 | Grey sandstone. | | |
| | Coal and coaly shale 1 foot. | | |
| | Underclay, *Stigmaria*, 1 foot. | | |
| | Coaly shale 6 inches. | | |
| | *Coal* 2 inches | 2 | 8 |
| | Argillaceous underclay, *Stigmaria*. | | |

The roof contains *Sigillariæ*, and the coal has flattened impressions of the same. This coal is remarkable as having a roof of sandstone. Its underclay is also peculiar. It is about 9 feet in thickness, and contains *Stigmaria* and nodules of ironstone throughout. It rests on a bituminous limestone containing *Naiadites* and scales of fishes, and also large roots of *Stigmaria* evidently *in situ*. This bed gives more colour to the idea of *Stigmaria* having grown under water than any other bed at the Joggins. I believe, however, that it merely implies the drying-up of a pond or creek into a swamp, subsequently inundated at intervals with muddy water.

| | | ft. | in. |
|---|---|---|---|
| | (Underclay and bituminous limestone, succeeded by sandstone and shale) | 27 | 8 |
| Coal-group 32... | Grey shale.<br>*Coal* and coaly shale 2 feet 4 inches<br>Argillo-arenaceous underclay, *Stigmaria*. | 2 | 4 |

This is a series of thin coaly bands alternating with shales. The roof contains trunks of *Sigillaria, Cordaites, Alethopteris,* and *Cyperites*. The coal has numerous flattened trunks of *Sigillaria*.

| | | ft. | in. |
|---|---|---|---|
| | (Grey and reddish sandstone and shale. Five underclays, one with a film of coal and erect *Sigillariæ* at two levels) | 149 | 0 |
| Coal-group 33... | Coaly shale.<br>*Coal* 1 inch<br>Argillaceous underclay, *Stigmaria*. | 0 | 1 |

The roof has flattened trunks and vegetable fragments. The coal is a mere soil, with remains of *Sigillaria* and *Cordaites,* and vascular bundles of ferns.

| | | ft. | in. |
|---|---|---|---|
| | (Red and grey sandstone and shale) | 45 | 0 |
| Coal-group 33*a*. | Grey shale.<br>*Coal* and coaly and grey shale (underclay).<br>Argillaceous underclay, *Stigmaria*. | | |

These layers, though not of sufficient importance to be measured as coal-bands, are most interesting as furnishing examples of what may be termed rudimentary coal-beds. Each layer is plainly composed of prostrate trunks of *Sigillaria* resting on Stigmarian underclay, and mixed with *Cordaites, Alethopteris lonchitica,* and vascular bundles of ferns. In one layer is a stump in the state of mineral charcoal. In another there are coprolites, scales of fishes, *Spirorbis,* and fragments of Crustaceans. In a reddish shale above these beds there is a patch of grey sandstone interlaced with Stigmarian roots, as if the sand had been prevented from drifting away by a tree or stump.

| | | ft. | in. |
|---|---|---|---|
| | (Reddish and grey sandstones and shales, with three or more underclays, having their coaly layers holding *Sigillaria*. Erect *Sigillariæ* at two levels) | 246 | 0 |
| Coal-group 34... | Underclay, with ironstone and *Stigmaria*.<br>*Coal* and coaly shale 2 inches.<br>Underclay, with ironstone and *Stigmaria*, 4 feet.<br>*Coal* and coaly shale 2 inches<br>Argillo-arenaceous underclay, *Stigmaria*. | 4 | 4 |

Only obscure vegetable fragments were observed.

| | | ft. | in. |
|---|---|---|---|
| | (Grey and reddish sandstone and shale, with *Stigmaria*) | 13 | 10 |

| | | ft. | in. |
|---|---|---|---|
| Coal-group 35... | Underclay with *Stigmaria.* | | |
| | Coaly shale 3 inches | 0 | 3 |
| | Red and greenish underclay, a few rootlets. | | |

The coaly shale contains many leaves of *Cordaites borassifolia.*

| | | | |
|---|---|---|---|
| | (Red, grey, and dark shale, sandstone, and bituminous limestone. Three underclays and erect trees at one level) | 67 | 9 |

IX.

| | | | |
|---|---|---|---|
| Coal-group 36... | Bituminous limestone. | | |
| | Coaly shale and *coal* 3 inches. | | |
| | Reddish shale and ironstone, 2 feet 6 inches. | | |
| | *Coal* 3 inches | 3 | 0 |
| | Argillaceous underclay, *Stigmaria.* | | |

The roof has *Stigmaria* in situ, and has been a soil or underclay. It also contains *Cythere,* fish-scales, coprolites, and *Spirorbis.* In the upper coaly shale are prostrate carbonized trunks.

| | | | |
|---|---|---|---|
| | (Reddish and grey shale, sandstone, and bituminous limestone) | 21 | 6 |
| Coal-group 37... | Bituminous limestone and shale. | | |
| | *Coal* 4 inches. | | |
| | Underclay 1 foot 6 inches. | | |
| | *Coal* 6 inches. | | |
| | Underclay 1 foot. | | |
| | Bituminous limestone 3 inches. | | |
| | Shale 3 inches. | | |
| | Coal 1 inch | 3 | 11 |
| | Underclay with *Stigmaria.* | | |

The roof has *Stigmaria,* also fish-scales, *Naiadites,* and *Cythere.* The shales are pyritized. The coal shows only obscure fragments of plants; but *Sigillariæ* in the state of ironstone occur in some of the clays.

VIII.

| | | | |
|---|---|---|---|
| | (Red and grey sandstone and shale. Two underclays. Many shells of *Pupa vetusta* occur in one of these, about 12 feet below the last coal) | 83 | 0 |

VII.

| | | | |
|---|---|---|---|
| Coal-group 38... | Calcareo-bituminous shale. | | |
| | *Coal* 1 inch. | | |
| | Bituminous limestone 6 inches. | | |
| | *Coal* 2 inches. | | |
| | Underclay passing into chocolate shale, *Stigmaria.* | | |

The bituminous limestone and shale contain *Cythere, Naiadites elongatus* and *N. carbonarius,* coprolites, *Spirorbis,* and *Stigmaria.* The lower coal has *Sigillaria elegans, S. scutellata* (?), *S. Brownii, Alethopteris lonchitica, Cordaites borassifolia,* and vascular bundles of ferns.

| | | | |
|---|---|---|---|
| | (Red and grey shales and sandstones, and one grey limestone with *Cythere.* One underclay. Many drift trunks, among which are *Sigillaria* and *Lepidophloios*) | 123 | 6 |

V.

| | | ft. | in. |
|---|---|---|---|
| Coal-group 39... | Red and grey shale, with ironstone. | | |
| | *Coal* ½ inch .................................................. | 0 | 0½ |
| | Grey underclay, with *Stigmaria*, resting on bituminous limestone, with *Stigmaria* and *Cythere*. | | |

This thin coal consists of a layer of flattened trunks, probably of *Sigillaria*, with a quantity of mineral charcoal.

IV.

| | | ft. | in. |
|---|---|---|---|
| | (Red and grey shales. One bed with erect *Calamites*, another with erect *Sigillaria*) ........................ | 65 | 4 |

III.

| | | ft. | in. |
|---|---|---|---|
| Coal-group 40... | Grey shale and ironstone. | | |
| | Bituminous limestone and shale, with coaly films, 7 inches. | | |
| | Underclay 1 foot. | | |
| | *Coal* 1 inch. | | |
| | Coaly shale 3 inches. | | |
| | Underclay 1 foot. | | |
| | Bituminous limestone 6 inches. | | |
| | *Coal* and coaly shale 2 inches ........................... | 3 | 7 |
| | Argillaceous underclay, ironstone, and *Stigmaria*. | | |

The bituminous limestone and shale have *Naiadites*, *Cythere*, *Spirorbis*, scales of fishes, and coprolites, and a large spine of *Gyracanthus*, also roots of *Stigmaria*. The upper underclay holds carbonized erect trunks. The lower coal has vascular bundles of ferns and *Cordaites*. The roof supports erect stumps.

| | | ft. | in. |
|---|---|---|---|
| | (Underclay with ironstone nodules) ...................... | 5 | 0 |
| Coal-group 41... | Underclay as above. | | |
| | Calcareo-bituminous shale and films of *coal* ......... | 3 | 4 |
| | Argillaceous underclay, *Stigmaria*. | | |

The bituminous limestone has *Naiadites carbonarius*, *Cythere*, coprolites, and *Spirorbis*. The roof has prostrate *Sigillariæ* converted into coaly layers. The underclay has distinct stumps of *Stigmaria*.

| | | ft. | in. |
|---|---|---|---|
| | (Shales with *Stigmaria* and ironstone, sandstones, bituminous limestone, and carbonaceous shale at bottom) .................................................. | 14 | 4 |
| Coal-group 42... | Bituminous limestone. | | |
| | *Coal* 3 inches. | | |
| | Shale 1 foot. | | |
| | *Coal* 1 foot. | | |
| | Underclay, *Stigmaria*, 1 foot. | | |
| | *Coal* 2 inches .................................................. | 3 | 5 |
| | Dark argillaceous underclay, *Stigmaria*. | | |

The roof contains *Naiadites*, *Cythere*, and coprolites. The coal is coarse, pyritous, and shaly, and has bark of *Sigillaria*, *Calamites*, and vascular bundles of ferns. It seems to be the edge of a bed, as it thins rapidly in the direction of the bank, or to the east.

II.

| | | ft. | in. |
|---|---|---|---|
| | (Reddish shale and sandstone with one underclay | 35 | 0 |
| Coal-group 43... | Reddish underclay with *Stigmaria*. | | |
| | Coaly shale 1 inch ........................................ | 0 | 1 |
| | Reddish underclay, *Stigmaria*. | | |

This bed diminishes to a mere film towards the bank.

I.

| | | ft. | in. |
|---|---|---|---|
| | (Reddish, grey, and dark shales and sandstone, *Stigmaria* in some beds, and erect *Sigillariæ* and *Calamites* at one level) ........................................ | 63 | |
| Coal-group 44... | Grey shale with ironstone. | | |
| | Bituminous limestone and shale with ironstone, 10 ft. 1 in. | | |
| | *Coal* ½ inch. | | |
| | Bituminous limestone, *Stigmaria*, ½ inch. | | |
| | *Coal* 5 inches. | | |
| | Bituminous limestone, *Stigmaria*, 2 inches. | | |
| | *Coal* 1 inch. | | |
| | Bituminous limestone, *Stigmaria*, 2 inches. | | |
| | Coal ½ inch ........................................ | 11 | 0½ |
| | Argillo-arenaceous underclay, traces of rootlets. | | |

The bituminous limestone has scales of fishes, *Spirorbis*, and *Cythere*. The coal has *Cordaites* and vascular bundles of ferns.

| | | ft. | in. |
|---|---|---|---|
| | (Red and grey sandstone and shale. One underclay, and erect *Calamites* at one level) ........................ | 98 | 6 |
| Coal-group 45... | Reddish shale. | | |
| | Carbonaceous shale, 10 inches. | | |
| | Coaly matter ½ inch. | | |
| | Hard underclay, *Stigmaria*, 2 feet. | | |
| | Coaly matter ½ inch. | | |
| | Underclay, *Stigmaria*, 7 feet. | | |
| | Coal 3 inches ........................................ | 10 | 2 |
| | Arenaceous underclay, *Stigmaria*. | | |

In the roof of the lower coal is an erect tree. The coal has vascular bundles of ferns, remains of fern-leaves, and bast tissue. The underclay has many coaly films, apparently flattened bark of trees.

| | | ft. | in. |
|---|---|---|---|
| | Reddish and grey sandstone and shale .............. | 5 | 6 |
| Total thickness of Division 4, according to Logan's measurements...... | | 2539 | 1 |

e. *Division* 5.—This consists of reddish shales and red and grey sandstones. It contains no coal, and is poor in fossils, only a few drifted trunks appearing in the section. It corresponds to the upper part of the Millstone-grit series. Its thickness, according to the measurements of Sir William E. Logan, is 2082 feet.

f. *Division* 6.—This may be regarded as the middle of the Millstone-grit series. It constitutes a sort of false coal-formation, separated from the Middle Coal-formation by the barren beds of Division 5. It contains nine small or rudimentary coal-beds, which, however, are not well seen in the section, and have afforded few facts of interest. It has many thick and coarse sandstones and much red shale, with comparatively few dark-coloured beds. Its total thickness is stated by Sir W. E. Logan at 3240 feet.

Though this group contains little coal, it is to be observed that it has many underclays, indicating soils which supported forests of *Sigillaria*, and that erect *Sigillariæ* occur very near the base of the division. The absence of important beds of coal is therefore due to the local physical conditions, and not to the want of the necessary vegetation.

| | | ft. | in. |
|---|---|---|---|
| | (Sandstones and shales with many drifted trunks of *Dadoxylon*) | 539 | 7 |
| Coal-group 1 | Blackish grey shale.<br>Calcareous shale 1 foot.<br>Black shale 3 feet.<br>*Coaly shale* 2 inches<br>Argillo-arenaceous underclay, *Stigmaria*. | 4 | 2 |
| | (Red and grey sandstone and shale and concretionary limestone, trunks of *Dadoxylon* and other trees. One underclay) | 160 | 1 |
| Coal-group 2 | Grey shale.<br>*Coaly shale* 1 inch<br>Reddish and grey underclay, *Stigmaria*. | 0 | 1 |
| | (Series of underclays with *Stigmaria*. The beds are reddish or grey, and arenaceous) | 19 | 1 |
| Coal-group 3 | Reddish shale.<br>*Coaly shale* 1 inch.<br>Greenish shale 6 inches.<br>*Coaly shale* 1 inch.<br>Greenish shale 2 feet 6 inches.<br>*Coaly shale* 3 inches.<br>Greenish shale 1 inch.<br>*Coal* and coaly shale 3 inches<br>Argillo-arenaceous underclay, *Stigmaria*. | 3 | 9 |

The coal contains bast tissue and reticulated, porous, and scalariform tissues of *Sigillaria* and *Calamodendron*.

| | | ft. | in. |
|---|---|---|---|
| | (Series of underclays as before) | 12 | 0 |
| Coal-group 4 | Underclay, *Stigmaria*.<br>*Coal* and coaly shale 3 inches<br>Argillo-arenaceous underclay, *Stigmaria*. | 0 | 3 |
| | (Series of underclays as before) | 24 | 0 |
| Coal-group 5 | Grey shale.<br>*Coaly matter* ½ inch<br>Greenish underclay, *Stigmaria*. | 0 | ½ |
| | (Underclay and sandstone, the latter with an erect *Sigillaria*) | 10 | 0 |
| Coal-group 6 | Sandstone (erect *Sigillaria* as above),<br>*Coaly shale* 3 inches<br>Argillo-arenaceous underclay, *Stigmaria*. | 0 | 3 |
| | (Fifteen feet of underclay, under which a thick sandstone with great quantities of drifted trunks of *Dadoxylon* and *Sigillaria*. Below this alternations of grey and red sandstone and shale) | 210 | 10 |
| Coal-group 7 | Grey sandstone.<br>Bituminous limestone 3 inches.<br>Grey shale 3 feet.<br>Grey limestone 2 inches.<br>*Coaly shale* 6 inches.<br>Bituminous limestone 3 inches.<br>*Coaly shale* 1 foot.<br>*Coal* 1 inch<br>Argillo-arenaceous underclay, *Stigmaria*. | 5 | 3 |

The lower bituminous limestone contains *Naiadites ovalis*, *Cythere*, and scales of Lepidoid fishes. The lower coal has much *Cyperites* and bark of *Sigillaria*, also bast tissue in mineral charcoal.

| | | ft. | in. |
|---|---|---|---|
| | (Thick beds of grey sandstone and grey shale, with drifted trunks of *Dadoxydon*, *Sigillaria*, and *Calamites*, and leaves of *Cordaites*) | 532 | 0 |
| Coal-group 8 ... | Grey shale. | | |
| | *Coal* ½ inch | 0 | ½ |
| | Argillo-arenaceous underclay, *Stigmaria*. | | |

This coal is laminated, the laminæ being bark of *Sigillariæ*. The underclay is very rich in *Stigmaria*.

| | | ft. | in. |
|---|---|---|---|
| | (Grey sandstone with grey and red shale. Many drifted trunks of *Sigillaria* and *Calamites*, and an erect *Sigillaria* in the lowest bed of sandstone) | 1224 | 0 |
| Coal-group 9 ... | Grey shale. | | |
| | Coaly matter and carbonaceous shale | 0 | 2 |
| | Argillo-arenaceous underclay, *Stigmaria*, and ironstone. | | |
| | (Grey and red sandstone and shale and calcareous bands, some of them bituminous. Near the middle a thick band of laminated black shale with *Naiadites lævis*, *Cyperites*, and *Lepidostrobus*. Drifted *Calamites* in the sandstones) | 496 | 4 |
| Total thickness, according to Logan | | 3240 | 9 |

g. *Division* 7.—This division consists principally of red and chocolate shales with red and grey sandstone, arenaceous conglomerates, and thin beds of concretionary limestone. It may be regarded as the base of the Millstone-grit formation. Its thickness is stated by Sir W. E. Logan at 650 feet.

No fossils, other than carbonized fragments of plants, have been found in this division.

h. *Division* 8.—This division consists of reddish shales with greenish and red sandstone, grey shale, grey compact limestone, and gypsum. It may be regarded as the upper part of the Lower Carboniferous formation; and almost immediately under its lowest beds there are marine limestones with *Productus cora* and other characteristic Lower Carboniferous fossils.

Only fragments of plants, often replaced by sulphuret of copper, have been found in this division. Its thickness is stated by Logan at 1658 feet.

## § IV. Remarks on the Animals and Plants whose Remains occur in the Coal.

1. *Introduction.*—Under this heading I shall, in the first place, present a tabular view of the relative frequency of occurrence of the several genera in the beds of coal and their roof-shales, without reckoning the almost invariable occurrence of *Stigmaria* in the underclays, which is of course to be taken as an indication of the existence of Sigillarioid trees in connexion with the growth of the coal.

The number of coals reckoned may vary according to the manner in which the several layers are grouped; but as arranged in the above sectional list it amounts to eighty-one in all. Of these, 23 are found in Division 3 of Logan's section, being the upper member of the Middle Coal-formation; 49 are found in Division 4 of Logan's section, being the lower member of the Middle Coal-formation; 9 occur in Division 6 of Logan's section, or in the equivalent of the Millstone-grit. In the latter group few of the coals were sufficiently well exposed to enable a satisfactory examination to be made. I have grouped the remains under three heads—External Forms of Plants, Microscopic Structure of Plants, and Animal Remains—and have arranged the forms under each in the order of their relative frequency of occurrence.

*Table showing the Relative Frequency of Occurrence of Genera of Plants and Animals in the Coals of the South Joggins.*

| Names of Fossils. | | Division 3. 23 coals. | Division 4. 49 coals. | Division 6. 9 coals. | Total. 81 coals. |
|---|---|---|---|---|---|
| *Plants.* | | | | | |
| Sigillaria.............. | occurs in | 13 | 34 | 2 | 49 |
| Cordaites ........... | " | 15 | 26 | ... | 41 |
| Filices (mostly *Alethopteris lonchitica*) | " | 4 | 17 | 2 | 23 |
| Lepidodendron and Lepidophloios ... | " | 1 | 15 | ... | 16 |
| Calamites ........... | " | 4 | 12 | ... | 16 |
| Carpolites, &c. ...... | " | 2 | 9 | ... | 11 |
| Asterophyllites ...... | " | 1 | 2 | ... | 3 |
| Calamodendron ...... | " | ... | 1 | ... | 1 |
| *Structures.* | | | | | |
| Vascular bundles of ferns ............... | " | 8 | 22 | ... | 30 |
| Bast tissue (*Sigillaria*) | " | 2 | 16 | 2 | 20 |
| Epidermal tissue (*Cordaites*, &c.) ... | " | 6 | 6 | ... | 12 |
| Scalariform (*Sigil.*, *Stig.*, *Lepidod.*, &c.) | " | 1 | 9 | 1 | 11 |
| Discigerous (*Sigillaria* and *Dadoxylon*, &c.) | " | 1 | 8 | 1 | 10 |
| Reticulated (*Calamodendron*, Ferns, &c.) | " | ... | 2 | 1 | 3 |
| *Animals.* | | | | | |
| Fishes (*Palæoniscus*, *Rhizodus*, &c.) ... | " | 1 | 16 | 1 | 18 |
| Naiadites (*Anthracomya*, &c.)......... | " | ... | 16 | 1 | 17 |
| *Spirorbis carbonarius* | " | ... | 16 | ... | 16 |
| *Cythere* .............. | " | ... | 13 | 1 | 14 |
| Insects (?) ........... | " | ... | 3 | ... | 3 |
| Reptiles (*Dendrerpeton*, &c.) ......... | " | ... | 1 | ... | 1 |
| *Pupa vetusta* and *Xylobius sigillariæ*...... | " | ... | 1 | ... | 1 |

It will be observed that, whether we regard the external forms or the internal structures preserved, the predominant plants are *Sigillaria, Cordaites,* and Ferns, with *Lepidodendron* and *Calamites.* The substance of the coal itself, so far as its structure is preserved, may be said to be principally composed of bark of *Sigillaria* and leaves and stems of ferns and *Cordaites.* In regard to the proportions in different parts of the series, little difference exists, except that *Cordaites* and *Calamites* are rather more abundant in the upper coals, and *Lepidodendron* in the lower, while the middle of the series is the headquarters of *Sigillaria* and ferns. Remains of aquatic animals occur in connexion with a large proportion of the coals, more especially in the middle of the series. This may be explained in connexion with the theory of growth of the coal *in situ* by the following considerations:—(1) It was necessary to the preservation of the vegetable matter composing a bed of coal that it should be submerged and covered with sediment. (2) On the submergence of a swamp covered with standing trees and other vegetation, these would prevent the passage of strong currents carrying coarse detritus, and the area would be covered with fine sediment deposited in still water and under conditions favourable to certain kinds of aquatic animals. (3) When the currents carrying detritus were sufficiently powerful to uproot and sweep away the forests and the brakes of *Calamites,* they would also remove or disturb the vegetable soil. It follows that we should expect the more important coals to be covered with fine sediment containing animal as well as vegetable remains, and that beds roofed with sandstone or coarse shale must either have been of small area or sparsely covered with trees at the time of their submergence. This accounts for the otherwise anomalous circumstance that the evidences of aqueous conditions in association with the coal are proportionally more abundant in the middle than in the upper part of the Coal-measures. We may now proceed to consider the genera of plants and animals separately, in their relation to the growth of coal.

2. *Coniferous Trees.*—Four species of coniferous trees, referable to the genus *Dadoxylon,* have been found in the Coal-formation of Nova Scotia. They are known to me only by the microscopic structure of their wood; but on the evidence afforded by this I have named and described them as new species*. One of them, *D. antiquius,* is closely allied to *D. Withami* of Great Britain, and, like that species, belongs to the Lower Carboniferous Coal-measures. Its structure is of that character for which Brongniart proposed the generic name "*Palæoxylon.*" It has not yet been found at the Joggins. Another species, *D. Acadianum,* is found abundantly at the Joggins in the condition of drifted trunks imbedded in the sandstone of the lower part of the Coal-formation and the upper part of the Millstone-grit series. The third species, *D. materiarium,* is very near to *D. Brandlingii* of Great Britain, and may possibly be only a variety. It is especially abundant in the sandstone of the Upper Coal-formation, in

* Descriptions referred to here and in subsequent pages will be found in "Synopsis of the Flora of the Carboniferous Period," Can. Nat. vol. viii., and in the Appendix.

which vast numbers of drifted trunks of this species occur in some places. The fourth species, *D. annulatum*, presents a very peculiar structure, probably of generic value. It has alternate concentric rings of discigerous woody tissue, of the character of that of *Dadoxylon*, and of compact structureless coal, which either represents layers of very dense wood or, more likely, of corky cellular tissue. In the latter case the structure would have affinities with that of certain *Gnetaceæ* and of Cycads.

Though coniferous trees usually occur as decorticated and prostrate trunks, I have recorded the occurrence of one erect specimen, in a sandstone a little above the "Main Coal," at the Joggins. It probably belonged to the species last named. Tissues of coniferous trees are very rare in the coal itself. Most of the discigerous tissues found in the coal belong to *Sigillaria* and *Calamodendron*. From the abundance of coniferous trees in sandstones above and below the coal, and their comparative absence in the coal and coal-shales, it may be inferred that these trees belonged rather to the uplands than to the coal-swamps; and the great durability and small specific gravity of coniferous wood would allow it to be drifted, either by rivers or ocean-currents, to very great distances. I am not aware that the fruits of pine trees occur at the Joggins, unless some of the *Trigonocarpa* are of this character. Nor has any foliage of these trees been found; but at Tatmagonche, in the continuation of the Upper Coal-formation, there are leafy branchlets which I have named *Araucarites gracilis*, and which may possibly have belonged to *Dadoxylon materiarium*.

The casts of pith-cylinders known as *Sternbergiæ* are abundant in some of the sandstones, especially in the Upper Coal-formation. I have shown that in Nova Scotia, as in England, some of these singular casts belong to *Dadoxylon**; but as the pith-cylinder of *Sigillaria* and of *Lepidophloios* was of a similar character, those which are destitute of woody investment cannot be determined with certainty, though in general the transverse markings are more distant in the *Sternbergiæ* of *Sigillaria* and *Lepidophloios* than in those of *Dadoxylon*.

In Plate V., and in Plate VI. fig. 14, I have given illustrations of the coniferous plants above referred to.

3. *Sigillariæ*.—I have catalogued or described no less than twenty-one species belonging to this family, from the Coal-measures of Nova Scotia. They may be arranged under the following provisional genera:—

| | |
|---|---|
| (1.) Favularia, *Sternberg* .... | Sigillaria elegans, *Brongn.* |
| | —— tessellata, *Brongn.* |
| | —— Bretonensis, *Dawson.* |
| (2.) Rhytidolepis, *Sternberg* .. | —— scutellata, *Brongn.* |
| | —— Schlotheimiana, *Brongn.* |
| | —— Saullii, *Brongn.* |
| | —— Dournaisii, *Brongn.* |
| | —— Knorrii, *Brongn.* |

* Proceedings of the American Association, 1837, Canadian Naturalist, vol. ii. Paper on Structures of Coal, Quart. Journ. Geol. Soc. 1860.

| | |
|---|---|
| (2.) Rhytidolepis (*continued*) | Sigillaria pachyderma, *Brongn.* |
| | —— flexuosa, *L. & H.*? |
| | —— elongata, *Brongn.* |
| (3.) Sigillaria, *Brongn.* ...... | —— reniformis, *Brongn.* |
| | —— Brownii, *Dawson.* |
| | —— lævigata, *Brongn.* |
| | —— planicosta, *Dawson.* |
| | —— catenoides, *Dawson.* |
| | —— striata, *Dawson.* |
| | —— eminens, *Dawson.* |
| (4.) Clathraria, *Brongn.* .... | —— Menardi, *Brongn.* |
| (5.) Leioderma, *Goldenb.* .... (Asolanus, *Wood*). | —— Sydnensis, *Dawson.* |
| (6.) Syringodendron, *Sternb*... | —— organum, *L. & H.* |

Of these, seven are probably new species, and the remainder can be identified with reasonable certainty with European species. The differences in the markings in different parts of the same tree are, however, so great, that I regard the greater part of the recognized species of *Sigillariæ* as merely provisional. Even the generic limits may be overpassed when species are determined from hand specimens. A fragment of the base of an old trunk of *Sigillaria* proper would necessarily be placed in the genus *Leioderma*, and a young branch of *Favularia* has all the characters of the genus *Clathraria*. It is, however, absolutely necessary to make some attempt at generic distinction among the diverse forms included in the genus *Sigillaria*; otherwise it will be impossible to reconcile the conflicting statements of authors as to the dimensions, habit of growth, foliage, roots, and fructification of these singular plants;—such statements usually applying to one or more of the subordinate generic types. I shall therefore notice separately, and with especial reference to their function in the production of coal, the several generic or subgeneric forms, beginning with that which I regard as the most important—namely, *Sigillaria* proper, of which, in Nova Scotia, I regard the species which I have named *S. Brownii* (figs. 15 to 20, Pl. VI.) as the type. Other species are represented in figs. 21 to 28.

In the restricted genus *Sigillaria* the ribs are strongly developed, except at the base of the stem; they are usually much broader than the oval or elliptical tripunctate areoles, and are striated longitudinally. The woody axis has both discigerous and scalariform tissues, arranged in wedges, with medullary rays as in exogens*; the pith is transversely partitioned in themanner of *Sternbergia*; and the inner bark contains great quantities of long and apparently very durable fibres, which I have, in my descriptions of the structures in in the coal, named "bast tissue." The outer bark was usually thick, of dense and almost indestructible cellular tissue. The trunk when old lost its regular ribs and scars, owing to expansion, and became furrowed like that of an old exogenous tree. The roots were *Stigmariæ* of the type of the ordinary *S. ficoides*. I have not seen the

* Quart. Journ. Geol. Soc., paper on Structures of Coal.

leaves or fruits attached; but, from the associations observed, I believe that the former were long, narrow, rigid, and two- or three-nerved (*Cyperites*), and that the latter were *Trigonocarpa*, borne in racemes on the upper part of the stem. These trees attained to a great size. I have seen one trunk four feet in diameter, and specimens of two feet or more in diameter are common: some of these trunks have been traced for thirty or forty feet without branching. The greater number of the erect stumps preserved at the Joggins appear to belong to this genus, which also seems to have contributed very largely to the formation of coal. Judging from the paucity of their foliage, the density of their tissues, and the strong structural resemblance of their stems and roots to those of Cycads, I believe that their rate of growth must have been very slow.

The genus *Rhytidolepis*, in which the areoles are large, hexagonal, and tripunctate, and the ribs narrow and often transversely striate, ranks as a coal-producer next to *Sigillaria* proper, and is equally abundant in the Coal-measures. These trees seem to have been of smaller size and feebler structure than the last mentioned, and are less frequently found in the erect position; but they are very abundant on the roofs of the coal-beds. Judging from such specimens as I have seen, their roots were less distinctly Stigmarioid than in the last genus, though this appearance may arise from difference of preservation. Their leaves were of the same type as in the last genus; and their stems bear rings of irregular scars, which may mark stages of growth, or the production of slender racemes of fruit in a verticillate manner. The woody axis of the stems of this genus was composed of scalariform and coarsely porous tissues, much like those of modern Cycads. I figure, as an illustration of the genus, a fragment of *S. scutellata* showing one of the belts of abnormal scars.

The genus *Favularia* is represented in Nova Scotia principally by the typical species *S. elegans* of Brongniart. The admirable investigations of the structure of the stem of this species by Brongniart, with the further illustrations given by Corda, Hooker, and Goldenberg, still afford the best general views of the structure of *Sigillariæ* which we possess*. It is to be observed, however, that Brongniart's specimen was a young stem or a branch, and that it affords a very imperfect idea of the development of discigerous and bast tissues in the full-grown stems of *Sigillaria* proper. The trees of this genus appear to have been of small growth; and they branched in the manner of *Lepidodendron*, the smaller branches being quite destitute of ribs, and with the areoles elliptical and spirally disposed. The stems show joints or rings of peculiar scars at intervals, as in the last genus. The leaves differ from those of the other genera, being broad and with numerous slender parallel veins, almost in the manner of *Cordaites*. (Figs. 26 and 27, Plate VII.)

The genus *Clathraria* is evidently closely allied to the above, and is possibly founded on branches of trees of the genus *Favularia*. It is a rare form in Nova Scotia.

* See also Binney "On some Fossil Plants showing Structure, from the Lower Coal-measures of Lancashire," Quart. Journ. Geol. Soc. vol. xviii. p. 106.—Edit.

Of the genus *Leioderma* or *Asolanus* I know but one species, independently of those specimens of old trunks of the ordinary *Sigillaria* in which the ribs have disappeared. My species, *S. Sydnensis*, is founded on specimens collected by Mr. Brown at Sydney, Cape Breton, which are especially remarkable for the curious modification which they present of the Stigmarian root. The specimens described by Mr. Brown under the name of *S. alternans**, and which have been copied by Geinitz and Goldenberg, belong, I believe, to this species. (Fig. 28, Plate VII.)

On the genus *Syringodendron* of Sternberg I have no observations to make. I have seen only fragments of stems; and these seem to be very rare.

I include under *Sigillariæ* the remarkable fossils known as *Stigmaria*, being fully convinced that all the varieties of these plants known to me are merely roots of *Sigillaria*; I have verified this fact in a great many instances, in addition to those so well described by Mr. Binney and Mr. Brown. The different varieties or species of *Stigmaria* are no doubt characteristic of different species of *Sigillaria*, though in very few cases has it proved possible to ascertain the varieties proper to the particular species of stem. The old view, that the *Stigmariæ* were independent aquatic plants, still apparently maintained by Goldenberg and some other palæobotanists, evidently proceeds from imperfect information. Independently of their ascertained connexion with *Sigillaria*, the organs attached to the branches are not leaves, but rootlets. This was made evident long ago by the microscopic sections published by Goeppert, and I have ascertained that the structure is quite similar to that of the thick fleshy rootlets of *Cycas*. The lumps or tubercles on these roots have been mistaken for fructification; and the rounded tops of stumps, truncated by the falling in of the bark or the compression of the empty shell left by the decay of the wood, have been mistaken for the natural termination of the stem†. The only question remaining in regard to these organs is that of their precise morphological place. Their large pith and regular areoles render them unlike true roots; and hence Lesquereux has proposed to regard them as *rhizomes*. But they certainly radiate from a central stem, and are not known to produce any true buds or secondary stems. In short, while their function is that of roots, they may be regarded, in a morphological point of view, as a peculiar sort of underground branches. They all ramify very regularly in a dichotomous manner, and, as Mr. Brown has shown, in some species at least, give off conical tap-roots from their underside.

In all the *Stigmariæ* exhibiting structure which I have examined, the axis exhibits only scalariform vessels. Corda, however, figures a species with wood-cells, or vessels with numerous pores, quite like those found in the stems of *Sigillaria* proper; and, as Hooker has pointed out, the arrangement of the tissues in *Stigmaria* is similar to that in

* Quart. Journ. Geol. Soc. vol. v. p. 354 *et seq.*

† For examples of the manner in which a natural termination may be simulated by the collapse of bark or by constriction owing to lateral pressure, see my papers, Quart. Journ. Geol. Soc. vol. x. p. 35, and vol. vii. p. 194.

*Sigillaria*. After making due allowance for differences of preservation, I have been able to recognize eleven species or forms of *Stigmaria* in Nova Scotia, corresponding, as I believe, to as many species of *Sigillaria**. At the Joggins, *Stigmariæ* are more abundant than any other fossil plants. This arises from their preservation in the numerous fossil soils or *Stigmaria* underclays. Their bark, and mineral charcoal derived from their axes, also abound throughout the thickness of the coal-beds, indicating the continued growth of *Sigillaria* in the accumulation of the coal. (Figs. 83 to 87 Pl. XII.)

Our knowledge of the fructification of *Sigillaria* is as yet of a very uncertain character. I am aware that Goldenberg has assigned to these plants leafy strobiles containing spore-capsules: but I do not think the evidence which he adduces conclusive as to their connexion with *Sigillaria*; and the organs themselves are so precisely similar to the strobiles of *Lepidophloios*, that I suspect they must belong to that or some allied genus. The leaves, also, with which they are associated in one of Goldenberg's figures seem more like those of *Lepidophloios* than those of *Sigillaria*. If, however, these are really the organs of fructification of any species of *Sigillaria*, I think it will be found that we have included in this genus, as in the old genus *Calamites*, two distinct groups of plants, one cryptogamous, and the other phænogamous, or else that male strobiles bearing pollen have been mistaken for spore-bearing organs.

I cannot pretend that I have found the fruit of *Sigillaria* attached to the parent stem; but I think that a reasonable probability can be established that some at least of the fruits included, somewhat vaguely, by authors under the names of *Trigonocarpum* and *Rhabdocarpus* were really fruits of *Sigillaria*. These fruits are excessively abundant and of many species, and they occur not only in the sandstones but in the fine shales and coals and in the interior of erect trees, showing that they were produced in the coal-swamps. The structures of these fruits show that they are phænogamous and probably gymnospermous. Now the only plants known to us in the coal-formation, whose structures entitle them to this rank, are the *Conifers*, *Sigillariæ*, and *Calamodendra*. All the others were in structure allied to cryptogams, and the fructification of most of them is known. But the Conifers were too infrequent in the Carboniferous swamps to have afforded numerous species of *Carpolites*; and, as I shall presently show, the *Calamodendra* were very closely allied to *Sigillariæ*, if not members of that family. Unless, therefore, these fruits belonged to *Sigillaria*, they must have been produced by some other trees of the coal-swamps, which, though very abundant and of numerous species, are as yet quite unknown to us. Some of the *Trigonocarpa* have been claimed for Conifers, and their resemblance to the fruits of *Salisburya* gives countenance to this claim; but the Conifers of the Coal-period are much too few to afford more than a fraction of the species. One species of *Rhabdocarpus* has been attributed by Geinitz to the genus *Nœggerathia*; but the leaves which he assigns to it are very like those of *Sigillaria elegans*, and may belong to some allied species. With

* See Appendix.

regard to the mode of attachment of these fruits, I have shown that one species, *Trigonocarpum racemosum* of the Devonian strata*, was borne on a rhachis in the manner of a loose spike, and I am convinced that some of the groups of inflorescence named *Antholithes* are simply young *Rhabdocarpi* or *Trigonocarpa* borne in a pinnate manner on a broad rhachis and subtended by a few scales. Such spikes may be regarded as corresponding to a leaf with fruits borne on the edges, in the manner of the female flower of *Cycas*; and I believe with Goldenberg that these were borne in verticils at intervals on the stem. In this case it is possible that the strobiles described by that author may be male organs of fructification containing, not spores, but pollen. In conclusion, I would observe that I would not doubt the possibility that some of the fruits known as *Cardiocarpa* may have belonged to Sigillarioid trees. I am aware that some so-called *Cardiocarpa* are spore-cases of *Lepidodendron*; but there are others which are manifestly winged nutlets allied to *Trigonocarpum*, and which must have belonged to phænogams. It would perhaps be unwise to insist very strongly on deductions from what may be called circumstantial evidence, as to the nature of the fruit of *Sigillaria*; but the indications pointing to the conclusions above stated are so numerous that I have much confidence that they will be vindicated by complete specimens, should these be obtained. (Figs. 29 and 30, Pl. VII., and figs. 69 to 79, Pl. XII.)

All of the Joggins coals, except a few shaly beds, afford unequivocal evidence of *Stigmaria* in their underclays; and it was obviously the normal mode of growth of a coal-bed, that, a more or less damp soil being provided, a forest of *Sigillaria* should overspread this, and that the Stigmarian roots, the trunks of fallen *Sigillariæ*, their leaves and fruits, and the smaller plants which grew in their shade, should accumulate in a bed of vegetable matter to be subsequently converted into coal—the bark of *Sigillaria* and allied plants affording "bright coal," the wood and bast tissues mineral charcoal, and the herbaceous matter and mould dull coal. The evidence of this afforded by microscopic structure I have endeavoured to illustrate in a former paper†.

The process did not commence, as some have supposed, by the growth of *Stigmaria* in ponds or lakes. It was indeed precisely the reverse of this, the *Sigillaria* growing in a soil more or less swampy, but not submerged, and the formation of coal being at last arrested by submergence. I infer this from the circumstance that remains of Cyprids, Fishes, and other aquatic animals are rarely found in the underclays and lower parts of the coal-beds, but very frequently in the roofs, while it is not unusual to find mineral charcoal more abundant in the lower layers of the coal. For the formation of a bed of coal, the sinking and subsequent burial of an area previously dry seems to have been required. There are a few cases at the Joggins where *Calamites* and even *Sigillariæ* seem to have grown on areas liable to frequent inundation; but in these cases coal did not accumulate. The non-laminated, slickensided and bleached condition of most of the underclays indicates soils of considerable permanence.

* "Flora of the Devonian Period," Quart. Journ. Geol. Soc. vol. viii. p. 324.

† "On the Structures in Coal," Quart. Journ. Geol. Soc. 1859.

In regard to beds destitute of Stigmarian underclays, the very few cases of this kind apply only to shaly coals filled with drifted leaves, or to accumulations of vegetable mud capable of conversion into impure coal. The origin of these beds is the same with that of the carbonaceous shales and bituminous limestones already referred to. It will be observed in the section that in a few cases such beds have become sufficiently dry to constitute underclays, and that conditions of this kind have sometimes alternated with those favourable to the formation of true coal.

There are some beds at the Joggins, holding erect trees *in situ*, which show that *Sigillariæ* sometimes grew singly or in scattered clumps, either alone or amidst brakes of *Calamites*. In other instances they must have grown close together, and with a dense undergrowth of ferns and *Cordaites*, forming an almost impenetrable mass of vegetation.

From the structure of *Sigillariæ* I infer that, like Cycads, they accumulated large quantities of starch, to be expended at intervals in more rapid growth, or in the production of abundant fructification. I adhere to the belief expressed in previous papers that Brongniart is correct in regarding the *Sigillariæ* as botanically allied to the *Cycadaceæ*, and I have recently more fully satisfied myself on this point by comparisons of their tissues with those of *Cycas revoluta*. It is probable, however, that when better known they will be found to have a wider range of structure and affinities than we now suppose.

There are some reasons for believing that the trees described by Corda under the names of *Diploxylon*, *Myelopithys*, and *Heterangium*, and also the *Anabathra* of Witham, are *Sigillariæ*. Much of the tissue discribed by Goeppert as *Araucarites carbonarius* is probably also Sigillarian.

4. *Calamodendron*.—The plants of this genus are quite distinct from *Calamites* proper. A *Calamodendron* as usually seen is a striated cast with frequent cross lines or joints; but when the whole stem is preserved, it is seen that this cast represents merely an internal pith-cylinder, surrounded by a woody cylinder composed in part of scalariform or reticulated vessels, and in part of wood-cells with one row of large pores on each side. External to the wood was a cellular bark, and the outer surface seems to have been simply ribbed in the manner of *Sigillaria*. It so happens that the internal cast of the pith of *Calamodendron*, which is really of the nature of a *Sternbergia*, so closely resembles the external appearance of the true Calamites as to be constantly mistaken for them. Most of these pith-cylinders of *Calamodendron* have been grouped in the species *Calamites approximatus*; but that species, as understood by some authors, appears also to include true *Calamites**, which, however, when well preserved, can always be distinguished by the scars of the leaves or branchlets which were attached to the nodes.

*Calamodendron* would seem, from its structure, to have been closely allied to *Sigillaria*, though, according to Unger, the tissues were dif-

* See Geinitz, "Steinkohlenformation in Sachsen."

ferently arranged, and the woody cylinder must have been much thicker in proportion.

The tissues of *Calamodendron* are by no means infrequent in the coal, and casts of the pith are common in the sandstones; but its foliage and fruit are unknown. (Fig. 31, Pl. VII., *a* to *c*.)

5. *Calamites*.—Nine species of true *Calamites* have been recognized in Nova Scotia, of which seven occur at the Joggins, the most abundant being *C. Suckovii* and *C. Cistii*. The Calamites grew in dense brakes on sandy and muddy flats. They were unquestionably allied to *Equisetaceæ*, and produced at their nodes either verticillate simple linear leaves, as in *C. Cistii*, or verticillate branchlets with pinnate or verticillate leaflets, as in *C. Suckovii* and *C. nodosus*. The Calamites do not seem to have contributed much to the growth of coal, though their remains are not infrequent in it. The soils in which they most frequently grew were apparently too wet and liable to inundation and silting up to be favourable to coal-accumulation. I have elsewhere shown that some of the species of *Calamites* gave off numerous adventitious roots from the lower parts of their stems, and also multiplied by budding at their bases*.

Of the genus *Equisetites* one species has been found in Cape Breton; but it has not as yet been recognized at the Joggins. (Fig. 88, Pl. XII.)

6. *Asterophyllites*, &c.—Five species of *Asterophyllites*, one of *Annularia*, five of *Sphenophyllum*, and three of *Pinnularia*, have been found in Nova Scotia. I place these together as probably allied plants. The *Pinnulariæ* were apparently slender roots, with thin epidermis, cellular bark, and a central axis. The others were probably low plants growing in wet places. I am not aware that they contributed to any great extent to the accumulation of coal; but as their tissues were scalariform, similar to those of ferns, it would not be easy to recognize them. A beautiful specimen of *Sphenophyllum emarginatum* from New Brunswick, in the collection of Sir W. E. Logan, has enabled me to ascertain that its stem had a simple axis of one bundle of reticulato-scalariform vessels, like those of *Tmesipteris* as figured by Brongniart. These curious plants were no doubt cryptogamous, having a habit of growth like that of *Equisetaceæ*, leaves like those of ferns or *Marsiliaceæ*, and fructification and structure like those of *Lycopodiaceæ*. They were closely allied to *Asterophyllites* and *Annularia*.

7. *Filices*.—Of the numerous species of ferns in the Carboniferous rocks of Nova Scotia, only a very few have been recognized at the Joggins. This may in part be due to the soft and crumbling character of the shales; but after much examination I am inclined to believe that the flora of the Joggins was originally poor in ferns. While the coal-field of Sydney, Cape Breton, has afforded forty-six species, the Joggins and its vicinity have as yet yielded only six or seven. Of these by far the most abundant is *Alethopteris lonchitica*, which appears throughout the Middle Coal-formation under a great number of varietal forms. It is also found abundantly at Springhill. At

* Quart. Journ. Geol. Soc. vol. x. p. 34

Sydney, on the contrary, *Pecopteris abbreviata* and *Alethopteris nervosa* are the most common ferns. But though fronds of ferns are comparatively rare at the Joggins, except in a few beds, and these holding principally the species *Alethopteris lonchitica*, bundles of scalariform vessels referable to ferns occur very plentifully in the coarser parts of the coal-beds, and would seem to indicate that vast quantities of stipes and fronds have been resolved into coal. It is to be observed, however, that it is not in all cases possible to distinguish the vascular bundles of ferns from those of the leaves of Sigillarioid and Lycopodiaceous plants. (Fig. 67, Pl. XII.)

Trunks of two species of tree ferns of the genus *Palæopteris* have been found in Nova Scotia and New Brunswick, and also obscure fragments, probably of *Caulopteris* and *Psaronius*. (Figs. 35 & 36, Pl. VIII.)

8. *Megaphyton*.—These are perhaps the most curious and puzzling plants of the coal. Their thick stems, marked by linear scars and having two rows of large depressed areoles on the sides, suggest no affinities to any known plants. They are usually ranked with *Lepidodendron* and *Ulodendron*, but sometimes, and probably with greater reason, are regarded as allied to tree ferns. At the Joggins a very fine species (*M. magnificum*) has been found, and at Sydney a smaller species (*M. humile*) ; but both are rare and not well preserved. If the large scars supported cones and the smaller leaves, then, as Brongniart remarks, the plant would much resemble *Lepidophloios*, in which the cone-scars are thus sometimes distichous. But the scars are not round and marked with radiating scales as in *Lepidophloios*; they are reniform or oval, and resemble those of tree ferns, for which reason they may be regarded as more probably leaf-scars*; and in that case the smaller linear scars would indicate ramenta, or small aërial roots. Further, the plant described by Corda as *Zippea disticha* is evidently a *Megaphyton*, and the structure of that species is plainly that of a tree fern of somewhat peculiar type. On these grounds I incline to the opinion of Geinitz, that these curious trees were allied to ferns, and bore two rows of large fronds, the trunks being covered with coarse hairs or small aërial roots. At one time I was disposed to suspect that they may have crept along the ground; but a specimen from Sydney shows the leaf-stalks proceeding from the stem at an angle so acute that the stem must, I think, have been erect. From the appearance of the scars it is probable that only a pair of fronds were borne at one time at the top of the stem; and if these were broad and spreading, it would be a very graceful plant. To what extent plants of this type contributed to the accumulation of coal I have no means of ascertaining, their tissues in the state of coal not being distinguishable from those of ferns and Lycopodiaceæ.

The species *Megaphyton humile* had, like Corda's *Zippea disticha*, a thick central axis striated longitudinally, and giving off very thick bundles of fibres, and probably scalariform vessels, to the bases of the leaves. (Figs. 33 & 34, Pl. VIII.)

* This is the view of Lindley, 'Fossil Flora,' p. 116.

9. *Lepidodendron.*—Of this genus nineteen species have been recorded as occurring in the Carboniferous rocks of Nova Scotia. Of these, six occur at the Joggins, where specimens of this genus are very much less abundant than those of *Sigillaria*. In the newer Coal-formation *Lepidodendra* are particularly rare, and *L. undulatum* is the most common species. In the Middle Coal-formation *L. rimosum*, *L. dichotomum*, *L. elegans*, and *L. Pictoense* are probably the most common species; and *L. corrugatum* is the characteristic *Lepidodendron* of the Lower Carboniferous, in which plants of this species seem to be more abundant than any other vegetable remains whatever.

To the natural history of this well-known genus I have little to add, except in relation to the changes which take place in its trunk in the process of growth, and the study of which is important in order to prevent the undue multiplication of species. These are of three kinds. In some species the areoles, at first close together, become, in the process of the expansion of the stem, separated by intervening spaces of bark in a perfectly regular manner; so that in old stems, while widely separated, they still retain their arrangement, while in young stems they are quite close to one another. This is the case in *L. corrugatum* (Pl. XI.). In other species the leaf-scars or areoles increase in size in the old stems, still retaining their forms and their contiguity to each other. This is the case in *L. undulatum*, and generally in those *Lepidodendra* which have very large areoles. In these species the continued vitality of the bark is shown by the occasional production of lateral strobiles on large branches, in the manner of the modern Red Pine of America. In other species the areoles neither increase in size nor become regularly separated by growth of the intervening bark; but in old stems the bark splits into deep furrows, between which may be seen portions of bark still retaining the areoles in their original dimensions and arrangement. This is the case with *L. Pictoense*. This cracking of the bark no doubt occurs in very old trunks of the first two types, but not at all to the same extent. I figure three examples of these peculiarities in mode of growth:—

*Lepidodendron corrugatum*, Dawson.—I quote in the Appendix my description of this species, and may refer to the figures in Plate XI. for further illustration. I do not know any other species in Nova Scotia which has the same habit of growth; but *L. oculatum* and *L. distans* of Lesquereux show a tendency to it. The present species is exclusively Lower Carboniferous, and occurs on that horizon in New Brunswick, in Pennsylvania, and, I believe, also in Ohio; though the beds holding it in the latter State have been by some regarded as Devonian.

*L. undulatum*, Sternberg.—I think it not improbable that several closely allied species are included under this name. On the other hand, all the large-areoled *Lepidodendra* figured in the books must have branches with small scars, which, in the present state of knowledge, it is impossible to identify with this species. I suppose that *L. elegans* resembles the present species in its mode of growth, at least if the large-scarred specimens attributed to it are really of the same species. *L. dichotomum* (=*L. Sternbergii*) also resembles it to some extent. (Fig. 41, Pl. IX.)

*L. Pictoense*, Dawson.—This species I described as follows, from young stems, in my "Synopsis of the Coal-Plants of Nova Scotia:"—"Areoles contiguous, prominent, separated in young stems by a narrow line, long-oval, acuminate; breadth to length as 1 to 3 or less; lower half obliquely wrinkled, especially at one side. Middle line indistinct. Leaf-scar at upper end of areole, small, triangular, with traces of three vascular points, nearly confluent. Length of areole about 0·5 inch."

Additional specimens from Sydney show that in old trunks of this species the areoles do not enlarge, but the bark becomes split into strips. I have reason to think that a new species from Nova Scotia which I have described in the Appendix, *L. personatum*, agrees with it in this respect. (Figs. 37, 38, and 39, Pl. IX.)

The *Lepidodendra* resemble each other too closely to admit of good subgeneric distinction. The grounds on which the distinction of *Sagenaria* and *Aspidiaria* is founded are quite worthless, the apparent position of the vascular scars in the areoles depending on accidents of preservation much more than on original differences. The genus *Knorria* includes many peculiar conditions of decorticated *Lepidodendra*.

In regard to the accumulation of coal, *Lepidodendra*, when present, appear under the same conditions with *Sigillariæ*, the outer bark being converted into shining coal, and the scalariform axis appearing as mineral charcoal of a more loose and powdery quality than that derived from *Sigillaria*. On the planes of lamination of the coal the furrowed bark of old trunks can scarcely be distinguished from that of old *Sigillariæ*.

10. *Lepidophloios.*—Under this generic name, established by Sternberg, I propose to include those Lycopodiaceous trees of the Coal-measures which have thick branches, transversely elongated leaf-scars, each with three vascular points and placed on elevated or scale-like protuberances, long one-nerved leaves, and large lateral strobiles in vertical rows or spirally disposed. Their structure resembles that of *Lepidodendron*, consisting of a *Sternbergia* pith, a slender axis of large scalariform vessels, giving off from its surface bundles of smaller vessels to the leaves, a very thick cellular bark, and a thin dense outer bark, having some elongated cells or bast tissue on its inner side.

Regarding *L. laricinum* of Sternberg as the type of the genus, and taking in connexion with this the species described by Goldenberg, and my own observations on numerous specimens found in Nova Scotia, I have no doubt that *Lomatophloios crassicaulis* of Corda, and other species of that genus described by Goldenberg, *Ulodendron* and *Bothrodendron* of Lindley, *Lepidodendron ornatissimum* of Brongniart, and *Halonia punctata* of Geinitz all belong to this genus, and differ from each other only in conditions of growth and preservation. Several of the species of *Lepidostrobus* and *Lepidophyllum* also belong to *Lepidophloios*.

The species of *Lepidophloios* are readily distinguished from *Lepidodendron* by the form of the areoles, and by the round scars on the stem, which usually mark the insertion of the strobiles, though in barren stems they may also have produced branches; still the fact of my finding the strobiles *in situ* in one instance, the accurate resemblance which the scars bear to those left by the cones of the Red Pine when borne on thick branches, and the actual impressions of the radiating scales in some specimens, leave no doubt in my mind that they are usually the marks of cones; and the great size of the cones of *Lepidophloios* accords with this conclusion.

The species of *Lepidophloios* are numerous, and individuals are quite abundant in the Coal-formation, especially toward its upper part. Their flattened bark is frequent in the coal-beds and their roofs, affording a thin layer of pure coal, which sometimes shows the peculiar laminated or scaly character of the bark when other characters are almost entirely obliterated. The leaves also are nearly as abundant as those of *Sigillaria* in the coal-shales. They can readily be distinguished by their strong angular midrib.

I figure, in illustration of the genus, all the parts known to me of *L. Acadianus*, and characteristic specimens of other species. One of these, *L. parvus*, is characteristic of the Upper Coal-formation. (*Vide* Plate X. & Plate XI. fig. 51.)

11. *Cordaites* or *Pychnophyllum*.—This plant is represented in the Coal-formation chiefly by its broad striated leaves, which are extremely abundant in the coal and its associated shales. Some thin coals are indeed almost entirely composed of them. The most common species is *C. borassifolia*, a plant which Corda has shown to have a simple stem with a slender axis of scalariform vessels resembling that of *Lepidophloios*; for this reason, notwithstanding the broad and parallel-veined leaves, I regard this genus as belonging to *Lycopodiaceæ* or some allied family. It must have been extremely abundant in the Carboniferous swamps; and, from the frequency of its being covered with *Spirorbis*, I think it must either have been of more aquatic habit than most of the other plants of the Coal-formation, or that its leaves must have been very durable. While the leaves are abundant, the stems are very rare. I infer that they were usually low and succulent. Much of the tissue found in the coal, which I have called "epidermal," probably belongs to leaves of *Cordaites*.

In the Upper Coal-formation there is a second species, distinguished by its simple and uniform venation. This I have named *C. simplex*.

12. *Sporangites*.—To avoid the confusion which envelopes the classification of Carpolites, I have used the above name for rounded spore-cases of *Lepidodendron* and allied plants, which are very frequent in the coal. A smooth round species like a mustard-seed, is excessively abundant in the Lower Carboniferous at Horton, and probably belongs to *Lepidodendron corrugatum*, with which it is associated. A species covered with papillæ, *S. papillata*, constitutes nearly the whole of some layers in coal 12, group xix. of the preceding Section.

I have no indication as to the plant to which it may belong, except that it is associated with *Cordaites*. (Figs. 80 & 81, Pl. XII.)*

13. *Tissues in the Mineral Charcoal.*—On these I have little to add to the statements in my paper of 1859, "On the Vegetable Structures in Coal"†. These tissues may be arranged as follows:—

a. *Bast tissue, or elongated cells from the liber or inner bark of* Sigillariæ *and* Lepidodendron, *but especially of the former.*—This kind of tissue is abundant in a calcified state in the shales associated with the coals, and also as mineral charcoal in the coals themselves, and in the interior of erect *Sigillariæ*. It is the kind of tissue figured by Brongniart as the inner layer of bark in *Sigillaria elegans*, and very well described by Binney (Quart. Journ. Geol. Soc. vol. xviii.) as "elongated tissue or utricles." Under the microscope many specimens of it closely resemble the imperfect bast tissue of the inner bark of *Pinus strobus* and *Thuja occidentalis*; and like this it seems to have been at once tough and durable, remaining in fibrous strips after the woody tissues had decayed. It is extremely abundant at the Joggins in the mineral charcoal of the smaller coal-seams. It is often associated with films of structureless coal, which represent the dense cellular outer bark which, in the trunk of *Sigillaria*, not only surrounded this tissue, but was intermixed with it. (Fig. 62, Pl. XII.)

b. *Vascular bundles of Ferns.*—These may be noticed by all close observers of the surfaces of coal, as slender hair-like fibres, sometimes lying separately, in other cases grouped in bands half an inch or more in diameter, and imbedded in a loose sort of mineral charcoal. When treated with nitric acid, each bundle resolves itself into a few scalariform vessels surrounded with a sheath of woody fibres, often minutely porous. This structure is precisely that of macerated fern-stipes; but, as already stated, there may have been some other coal-plants whose leaves presented similar bundles. As stated in my former paper "On the Vegetable Structures in Coal," this kind of tissue is especially abundant in the coarse and laminated portions of the coal, which we know on other evidence to have been made up, not of trunks of trees, but of mixed herbaceous matters. (Pl. XII. fig. 67.)

c. *Scalariform vessels.*—These are very abundant in the mineral charcoal, though the coarser kinds have been crushed and broken in such a manner that they usually appear as mere débris. The scalariform vessels of *Lepidodendron*, *Lepidophloios*, and *Stigmaria* are very coarse and much resemble each other. Those of ferns are finer, and sometimes have a reticulated structure. Those of *Sigillaria* are much finer and often have the aspect of wood-cells with transversely elongated pores like those of *Cycas*. Good examples of these are figured in the paper already referred to. (See also Plate XI. figs. 54, &c.)

d. *Discigerous wood-cells.*—These are the true bordered pores

* It much resembles the spore-cases of *Flemingites gracilis*, as figured by Carruthers, 'Geol. Mag.' vol. ii. I suppose this to be a strobile of *Lepidophloios*.

† Quart. Journ. Geol. Soc. February 1860.

characteristic of *Sigillaria, Calamodendron,* and *Dadoxylon.* In the two former genera the disks or pores are large and irregularly arranged, either in one row or several rows. In the latter case they are sometimes regularly alternate and contiguous. In the genus *Dadoxylon* they are of smaller size and always regularly contiguous in two or more rows, so as to present an hexagonal areolation. Discigerous structures of *Sigillaria* and *Calamodendron* are very abundant in the coal, and numerous examples were figured in my former paper. I have indicated by the name *Reticulated Tissue* certain cells or vessels which may either be reticulated scalariform vessels, or an imperfect form of discigerous tissue. I believe them to belong to *Stigmaria* or *Calamodendron.* (Figs. 57 & 68, Pl. XII.)

e. *Epidermal tissue.*—This is a dense cellular tissue representing the outer integuments of various leaves, herbaceous stems, and fruits. I have ascertained that the structures in question occur in the leaves and stipes of *Cordaites* and ferns, and in the outer coat of *Carpolites* and *Sporangites.* With this I may include the obscure and thick-walled cellular tissue of the outer bark of *Sigillaria* and *Lepidodendron* and other trees, which, though usually consolidated into compact coal, sometimes exhibits its structure.

I would here emphatically state that all my observations at the Joggins confirm the conclusion, which I arrived at many years ago from the study of the coals of Pictou and Sydney, that the layers of clear shining coal (pitch or cherry coal) are composed of flattened trunks of trees, and that of these usually the bark alone remains; further that the lamination of the coal is due to the superposition of layers of such flattened trunks alternating with the accumulations of vegetable matter of successive years, and occasionally with fine vegetable muck or mud spread over the surface by rains or by inundations. In connexion with this, it is to be observed that the density and *impermeability* of cortical tissues not only enable them to endure after wood has perished or been resolved into bits of charcoal, but render them less liable than the wood to mineral *infiltration.*

14. *Rate of Growth of Carboniferous Plants.*—Very vague statements are often made as to the supposed rapid rate of growth of plants in the Carboniferous period. Perhaps the most trustworthy facts in relation to this subject are those which may be obtained from the coniferous trees. In some of these (for instance, *Dadoxylon materiarium, D. annulatum,* and *D. antiquius*) the rings of growth, which were no doubt annual, are distinctly marked. On measuring these in a number of specimens, and comparing them with modern species, I find that they are about equal in dimensions to those of the Balsam-Fir or the Yellow Pine of America. Assuming, therefore, similarity in habit of growth and extent of foliage to these species, we may infer that, in regard to coniferous trees, the ordinary conditions of growth were not dissimilar from those of Eastern America in its temperate regions at present. When, however, we compare the ferns and *Lycopodiaceæ* of the Coal-formation with those now growing in Eastern America, we see, in the much greater dimensions and luxuriance of the former, evidence of a much

more moist and equable climate than that which now subsists; so that we may suppose the growth of such plants to have been more rapid than it is at present. These plants would thus lead us to infer a warm and insular climate, perhaps influenced by that supposed excess of carbonic acid in the atmosphere, which, as Tyndall and Hunt inform us, would promote warmth and moisture by impeding terrestrial radiation. With this would also agree the fact that the Conifers have woody tissues resembling those of the pine trees of the milder climates of the southern hemisphere at present.

If we apply these considerations to *Sigillaria*, we may infer that the conditions of moisture and uniformity of temperature favourable to ferns and *Lycopodiaceæ* were also favourable to these curious plants. They must have been perennial; and the resemblance of their trunks to those of Cycads, together with their hard and narrow leaves, would lead us to infer that their growth must have been very slow. A similar inference may be drawn from the evidences of very slow and regular expansion presented by the lower parts of their stems. On the other hand, the distance, of a foot or more, which often intervenes between the transverse rows of scars, marking probably annual fructification, would indicate a more rapid rate of growth. Further, it may be inferred, from the structure of their roots and of their thick inner bark, that these, as in Cycads, were receptacles for great quantities of starch, and that the lives of these plants presented alternations of starch-accumulation and of expenditure of this in the production of leaves, wood, and abundant inflorescence. They would thus, perhaps for several years, grow very slowly, and then put forth a great mass of fructification, after which perhaps many of the individuals would die, or again remain for a long time in an inactive state. This view would, I think, very well harmonize with the structure of these plants, and also with the mode of their entombment in the coal.

From the manner of the association of Calamites with erect *Sigillariæ*, I infer that the former were, of all the plants of the Coal-formation, those of most rapid dissemination and growth. They appear to have first taken possession of emerging banks of sand and mud, to have promoted the accumulation of sediment on inundated areas, and to have protected the exposed margins of the forests of *Sigillariæ*.

In applying any conclusions as to the rate of growth of Carboniferous plants to the accumulation of coal, we must take into account the probable rate of decay of vegetable matter. When we consider the probable wetness of the soils on which the plants which produced the coal grew, the density of the forests, and the possible excess of carbonic acid in the atmosphere of these swamps, we must be prepared to admit that, notwithstanding the warmth and humidity, the conditions must have been favourable to the preservation of vegetable matter. Still the hollow cylinders of bark, the little fragments of decayed wood in the form of mineral charcoal, and the detached vascular bundles of ferns, testify to an enormous amount of decay, and show that, however great the accumulation of coal, it represents only a fraction of the vegetable matter which was actually produced. It has been estimated that it would require eight feet of compact vegetable matter to produce one foot of coal*; but if we reckon the whole vegetable matter actually produced in the process, I should suppose that five times that amount would be far below the truth, even in the most favourable cases; while there is evidence that in the Carboniferous period many forests may have flourished for centuries without producing an inch of coaly matter.

15. *Bivalve Shells.*—All the Lamellibranchiate shells, which are so numerous in some of the shales and bituminous limestones of the Joggins that some of the beds may be regarded as composed of them, belong to one generic or family group. They are the so-called Modiolas, Unios, or Anodons of authors. I proposed for them some years ago the generic name of *Naiadites,* and described six species from the Coal-measures of Nova Scotia, stating my belief that they are allied to *Unionidæ,* and that their nearest analogue may be the genus *Bysso-anodonta* of D'Orbigny, found in the River Papana†. Mr. Salter, however, to whom I sent specimens, regards these shells as belonging to his new genera *Anthracomya* and *Anthracoptera,* the former being supposed to be allied to *Myadæ*‡. More recently Gümbel and Geinitz have described similar shells from Thuringia as belonging to the genera *Unio* and *Anodon,* and regard my *Naiadites carbonarius* (*Anthracoptera carbonaria* of Salter) as a *Dreissena*§. As these shells swarmed in the waters of the Coal-formation estuaries or lagoons, facts tending to the elucidation of their habits and affinities are important with reference to the coal; I would therefore make the following remarks in relation to them:—

(1) Under the microscope, the shells of the thicker species, as *Naiadites carbonarius,* present an internal lamellar and subnacreous layer, a thin layer of vertical prismatic shell, and an epidermis—these structures being entirely similar to those of *Unionidæ.* In the thinner species, as in *N. lævis,* only the prismatic coat appears, and in this the prisms are in some instances placed obliquely. These thin shells, however, show evidence of an epidermis. (2) The ligament was external, there seem to have been no teeth, the shell was closed posteriorly; but there are indications of a byssal sinus. Mr. Salter describes the epidermis as wrinkled posteriorly; but this, with the exception of the rings of growth, appears to me to result from pressure. The shells are equivalve, and have the external aspect of *Unionidæ* or *Mytilidæ.* (3) I know of no instance in Nova Scotia of the occurrence of these shells in the strictly marine limestones, nor have any properly marine forms of Mollusca been found with *Naiadites* in the Coal-measures. (4) The mode of their occurrence precludes the idea that they were burrowers, but favours the belief that they were attached by a byssus to sunken or floating timber. On the whole I think that the balance of probability is in

* Dana's Manual, p. 367.
† Supplement to Acadian Geology, 1860.
‡ Quart. Journ. Geol. Soc. vol. xix. p. 79.
§ Neues Jahrbach, 1864. Geological Magazine, May 1865.

favour of the conclusion that they were brackish-water or fresh-water shells, allied to *Mytilidæ* or to embryonic *Unionidæ*.

16. *Spirorbis carbonarius.*—This little shell, which I described as a *Spirorbis* as long ago as 1845*, is apparently not specifically distinct from *Microconchus carbonarius* of the British coal-fields. Its microscopic structure is identical with that of modern *Spirorbes*, and shows that it is a true worm-shell. It is found throughout the Coal-formation, attached to plants and to shells of *Naiadites*, and must have been an inhabitant of enclosed lagoons and estuaries. Its occurrence on *Sigillariæ* has been used as an argument in favour of the opinion that these trees grew in sea-water; but, unfortunately for that conclusion, the *Spirorbis* is often found on the inside of *Sigillaria*-bark, showing that this had become dead and hollow. Beside this, the same kind of evidence would prove that *Lepidodendra*, *Cordaites*, and Ferns were marine plants. *Spirorbes* multiply fast and grow very rapidly; and these little shells no doubt took immediate possession of submerged vegetation, just as their modern allies cover fronds of *Laminaria* and *Fucus*.

As I have not met with a description of this little shell, I may state that it is dextral, with $2\frac{1}{2}$ to 3 turns. It is attached throughout its length, and when not compressed presents a somewhat deep umbilicus. It is closely marked with beaded or unequal transverse ridges. It has when young a close resemblance to *Sp. caperatus*, M'Coy, from the Carboniferous Limestone of Ireland; but this species has only two turns, and is sinistral.

17. *Crustacea.*—It appears in the table above that as many as fourteen beds of coal exhibit in their roofs shells of minute Entomostraca of the genera *Cythere* and *Bairdia*; and these occur in such quantities that considerable beds of shale and bituminous limestone are filled with their valves. Professor Jones regards the species as marine or brackish-water; and the same remark will, I presume, apply to the crustacean *Diplostylus Dawsoni*, and a fragment of *Eurypterus* described by Mr. Salter from Coal no. 8 of Division 4 of the Section. Of the small Entomostracans there are several species, which Professor Jones has now in his hands for determination. No Estherians have yet been found in the Coal-formation of Nova Scotia; but I have specimens of *Leaia Leidyi* from the Lower Carboniferous of Plaister Cove, and an undetermined *Estheria* from the same horizon at Horton Bluff.

It is to be observed that *Naiadites*, *Spirorbis*, and *Cythere* constantly occur associated in the same beds; and the conclusions as to habitat applicable to any one of these genera must apply to all.

18. *Fishes.*—Remains of fishes occur in connexion with eighteen of the coal-beds at the Joggins, usually in the roof-shales, though detached scales, teeth, spines, or coprolites are of occasional though rare occurrence in the coal itself, especially where the latter passes into coarse coal or carbonaceous shale. One thin bed, no. 6 of Division 4 of the Section, is full of remains of small fishes. It is hard and laminated, and roofed with a calcareous bed full of remains

* Quart. Journ. Geol. Soc. vol. i. p. 326.

of aquatic animals. It has a true Stigmarian underclay. I suppose it to have been a swamp or forest submerged and occupied by fishes while its vegetation was still standing. It contains remains of fishes of the genera *Ctenoptychius, Diplodus, Rhizodus,* and *Palæoniscus.* It also contains *Cythere, Naiadites,* and *Spirorbis.* In the other beds which contain fish-remains, most of these consist of small Lepidoganoids, but there are occasional teeth and scales of large species of *Rhizodus,* and also teeth and scales of Selachian fishes of considerable size.

19. *Land-animals.*—The Coal-formation of Nova Scotia has afforded the remains of eight species of Reptiles or Batrachians, belonging to the genera *Hylonomus, Baphetes, Dendrerpeton, Hylerpeton,* and *Eosaurus*; of one Myriapod, *Xylobius sigillariæ*; of one land snail, *Pupa vetusta*; and of one insect. All of these, except one of the reptiles, have been found at the Joggins. I have nothing in regard to them to add to what I have already published in my Memoir on 'Air-breathers of the Coal Period.'

## V. Appendix.

### *Descriptive List of Carboniferous Plants found in Nova Scotia and New Brunswick.*

[Abridged and corrected from "Synopsis of the Carboniferous Flora of Nova Scotia," Can. Nat. vol. viii.] *

### Dadoxylon, Unger.

1. Dadoxylon Acadianum, spec. nov. Pl. V. figs. 4–6.

Large trees, usually silicified or calcified, with very wide wood-cells, having three or more rows of small hexagonal areoles, each enclosing an oval pore; cells of medullary rays one-third of breadth of wood-cells, and consisting of twenty or more rows of cells superimposed in two series. Rings of growth indistinct.

M. C.†, Joggins, Port Hood, Dorchester (*J. W. D.*).

2. D. materiarium, spec. nov. Pl. V. figs. 7–9.

Wood-cells less wide than those of the last; two to rarely four rows of hexagonal disks. Medullary rays very numerous, with twenty or more rows of cells superimposed in one series. Rings of growth slightly marked. Approaches in the character of its woody fibre to *D. Brandlingii*; but the medullary rays are much longer. Some specimens show a large Sternbergian pith, with transverse partitions‡. Vast numbers of trunks of this species occur in some sandstones of the Upper Coal-formation.

M. and U. C., Joggins, Malagash, Pictou, &c. (*J. W. D.*); Glace Bay (*H. Poole*); Miramichi (*G. F. Matthew*).

* The illustrations are principally from photographs by my son George M. Dawson, and for the sake of economy have been confined to small and characteristic portions of the specimens.

† U. C., M. C., and L. C., indicate the Upper, Middle, and Lower Coal-formations.

‡ Canadian Naturalist, 1857.

3. D. ANTIQUIUS, spec. nov. Pl. V. figs. 1–3.

Wood-cells narrow, thick-walled, two to three rows of pores. Medullary rays of three or four series of cells with twenty or more superimposed, nearly as wide as the wood-cells. Rings of growth visible. This species would belong to the genus *Palæoxylon* of Brongniart, and is closely allied to *D. Withami*, L. and H., which, like it, occurs in the Lower Coal-measures.

L. C., Horton (*Dr. Harding*).

4. D. ANNULATUM, spec. nov. Pl. V. figs. 10–13.

Wood-cells with two or three rows of hexagonal disks. Medullary rays of twenty or more rows of cells superimposed, in two series. Wood divided into distinct concentric circles, alternating with layers of structureless coal representing cellular tissue or very dense wood. A stem 6 inches in diameter has fourteen to sixteen of these rings, and a pyritized pith about 1 inch in diameter. This is probably generically distinct from the preceding species.

M. C., Joggins (*Sir W. E. Logan*; *J. W. D.*).

ARAUCARITES, Unger.

ARAUCARITES GRACILIS, spec. nov. Pl. VI. fig. 14.

Branches slender, 0·2 inch in diameter, with scaly, broad leaf-bases. Branchlets pinnate, numerous, very slender, with small, acute, spirally disposed leaves.

U. C., Tatamagouche (*J. W. D.*).

SIGILLARIA, Brongn.

1. SIGILLARIA (FAVULARIA) ELEGANS, Brongn. Pl. VII. fig. 26.

Abundant, especially in the roofs of coal-seams. *S. hexagona* includes old trunks of this species. Young branches have scars of an elliptical form like those of *S. Serlii*.

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*).

2. S. (FAV.) TESSELLATA, Brongn.

M. C., Joggins and Pictou (*J. W. D.*); Sydney (*R. Brown*).

3. S. (RHYTIDOLEPIS) SCUTELLATA, Brongn. Pl. VI. fig. 25.

M. and U. C., Joggins (*Lyell*; *J. W. D.*).

4. S. (RH.) SCHLOTHEIMIANA, Brongn.

M. C., Joggins (*Lyell*; *J. W. D.*).

5. S. (RH.) SAULLII, Brongn.

M. C., Sydney (*R. Brown*); Joggins (*Lyell*; *J. W. D.*).

6. S. BROWNII, Dawson (Quart. Journ. Geol. Soc. vol. x.). Pl. VI. figs. 15–19.

M. C., Joggins (*J. W. D.*).

7. S. RENIFORMIS, Brongn.

M. C., Joggins (*Lyell*; *J. W. D.*); Sydney (*R. Brown*).

8. S. LÆVIGATA, Brongn.

M. C., Sydney (*R. Brown*); Joggins (*J. W. D.*).

9. S. PLANICOSTA, spec. nov. Pl. VI. fig. 21.

Scars half hexagonal above, rounded below; lateral vascular impressions elongate; central small, punctiform. Ribs 1·1 inch broad, smooth externally, longitudinally striated on the ligneous surface. Slight transverse wrinkles between the scars, which are distant from each other about an inch. Allied to *S. lævigata*, but with very thin bark.

M. C., Sydney (*R. Brown*).

10. S. CATENOIDES, spec. nov. Pl. VI. fig. 22.

Cortical surface unknown; ligneous surface with puncto-striate ribs 1·1 inch in breadth, and with single oval scars half an inch long, and an inch distant from centre to centre. A very large tree. Perhaps, if its cortical surface were known, it might prove to be a large *Syringodendron*.

M. C., Joggins (*J. Smith*); Sydney (*R. Brown*).

11. S. STRIATA, spec. nov. Pl. VI. fig. 23.

Ribs prominent, coarsely striate, 0·35 inch wide. Scars nearly as wide as the ribs, rounded, hexagonal, 1 inch distant; lateral vascular marks narrow, central large. On the ligneous surface scars single, round, oblong; bark very thin.

M. C., Joggins (*J. W. D.*).

12. S. ——?

A small erect stem, somewhat like *S. flexuosa*.

M. C., Joggins (*J. W. D.*).

13. S. (CLATHRARIA) MENARDI, Brongn.

M. C., Sydney (*R. Brown*); U. C., Pictou (*J. W. D.*).

14. S. (ASOLANUS) SYDNENSIS, spec. nov. Pl. VII. fig. 28.

Ribs obsolete; cortical and ligneous surfaces striate; vascular scars two, elongate longitudinally, and alike on cortical and ligneous surfaces; scars 1·1 inch distant, in rows 0·6 inch distant. Stigmarian roots, same with variety *h* of *Stigmaria*, as described below.

M. C., Sydney (*R. Brown*).

15. S. ORGANUM, L. & H.

M. C., Sydney (*R. Brown*).

16. S. ELONGATA, Brongn.

M. C., Sydney (*R. Brown*).

17. S. FLEXUOSA, L. & H.

M. C., Sydney (*R. Brown's list in 'Acadian Geology'*).

18. S. PACHYDERMA, L. & H.

M. C., Sydney (*R. Brown's list*).

19. S. (Fav.) Bretonensis, spec. nov. Pl. VII. fig. 27.

Like *S. tessellata*, but areoles more hexagonal, bark thin and smooth on both sides, and furrow above the scars arcuate and with a central punctiform elevation.

M. C., Sydney (*R. Brown*).

20. S. eminens, spec. nov. Pl. VI. fig. 24.

Like *S. obovata*, Lesqx., but with narrower ribs, and larger and less distant areoles, each with a slight groove above.

M. C., Sydney (*R. Brown*).

21. S. Dournansii, Brongn.

M. C., Joggins (*J. W. D.*).

22. S. Knorrii, Brongn.

M. C., Sydney (*R. Brown*).

### Syringodendron, Brongn.

Obscure specimens, referable to a narrow-ribbed species of this genus, occur in the Lower Carboniferous beds at Horton and Onslow.

### Stigmaria, Brongn.

Stigmaria ficoides, Brongn. Pl. XII. fig. 83–87.

Under this name I place all the roots of *Sigillariæ* occurring in the Carboniferous rocks of Nova Scotia. They belong, without doubt, to the different species of Sigillarioid trees; but it is at present impossible to determine to which; and the specific characters of the *Stigmariæ* themselves are, as might be anticipated, evanescent and unsatisfactory. The varieties which occur in Nova Scotia, discarding mere difference of preservation, may be arranged as follows:—

Var. *a*. Areoles large, distant; bark more or less smooth. This is the most common variety, and extends throughout the Coal-formation.

Var. *b*. Areoles large, separated by waving grooves of the bark.

Var. *c*. Similar, but ridges as well as furrows between the areoles; var. *undulata* of Goeppert.

Var. *d*. Areoles small, separated by waving grooves.

Var. *e*. Areoles moderate, in vertical or diagonal furrows separated by ridges; var. *sigillarioides* of Goeppert.

Var. *f*. Areoles small; bark finely netted with wrinkles or striæ.

Var. *g*. Areoles surrounded by radiating marks, giving a star-like form; var. *stellata* of Goeppert. The only specimen I have seen was found by Dr. Harding in the Lower Carboniferous Coal-measures of Horton.

Var. *h*. Areoles small, or obscure and infrequent. Surface covered with fine uneven striæ. My specimens were collected by Mr. Brown in the Middle Coal-measures at Sydney.

Var. *i*. Areoles narrow, elongate, bark smooth or striate.

Var. *k*. *alternans*, with areoles in double rows on broad ribs separated by deep furrows. Probably old furrowed roots.

Var. *l. Knorroides.* Prominent bosses or ridges instead of areoles. These are imperfectly preserved specimens.

The varieties *a, b, c, e, i,* have been seen attached to trunks of *Sigillariæ* of the group distinguished by broad and prominent ribs—*Sigillaria* proper of the above arrangement. *Stigmariæ,* like *Sigillariæ,* are exceedingly abundant in the Middle Coal-measures, and are comparatively rare in the Lower Carboniferous and newer Coal-formations.

### Calamodendron, Brongn.

1. Calamodendron approximatum, Brongn. Pl. VII. fig. 31.

This plant is evidently quite distinct from *Calamites* proper. The Calamite-like cast is a pith or internal cavity, surrounded by a thick cylinder of woody tissue consisting of scalariform vessels and woody fibres with one row of round pores; external to this is a bark of cellular and bast tissue. The structure appears to be allied to that of *Sigillaria,* and is one of the most common in the beds of bituminous coal.

M. C., Sydney (*R. Brown*); M. C., Joggins, Pictou (*J. W. D.*); Coal Creek (*C. B. Matthew*).

2. C. obscurum, spec. nov. Pl. VII. fig. 31 *d.*

This is a Calamite-like fragment found in a block of Sydney coal, in the state of mineral charcoal. The external markings are obscure, but the structure is well preserved. It differs from the last in having large ducts with many rows of pores, or reticulated instead of scalariform vessels. This is perhaps a Calamite.

M. C., Sydney (*J. W. D.*).

### Cyperites, L. & H.

Cyperites —— ?

These elongate linear leaves have two or three ribs, and the central band between the ribs raised above the margin; one species has been seen attached to *Sigillaria Schlotheimiana.*

The leaves of *Sigillaria elegans* are different, being as broad as the areoles of the stem, and with several parallel veins.

Middle and upper coals, everywhere.

### Antholithes, Brongn.

1. Antholithes Rhabdocarpi, spec. nov. Pl. VII. fig. 30.

Stem short, interruptedly striate, with two rows of crowded ovate fruits, and traces of floral leaves. Fruits half an inch long, striated longitudinally, attached by short peduncles.

M. C., Grand Lake (*C. F. Hartt*).

2. A. pygmæa, spec. nov. Pl. VII. fig. 30 *c.*

Rhachis 1 inch thick, rugose; two rows of opposite flowers, each showing four lanceolate striate floral leaves, two outer and two inner.

M. C., Joggins (*J. W. D.*).

3. A. SQUAMOSA, spec. nov. Pl. VII. fig. 29.

Rhachis thick, coarsely rugose, with two rows of closely placed cones or scaly fruits.

U. C., Pictou (*J. W. D.*).

4. A. ——?, spec. nov.

Indistinct, but apparently different from those above described.

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*).

TRIGONOCARPUM, Brongn.

1. TRIGONOCARPUM HOOKERI, Dawson, Quart. Journ. Geol. Soc. vol. xvii.

M. C., Mabou (*J. W. D.*).

2. T. SIGILLARIÆ, spec. nov. Pl. XII. fig. 76.

Ovate, $\frac{1}{4}$ inch long; testa smooth, or rugose longitudinally, acuminate, two-edged. Found in erect trunks of *Sigillariæ* in large numbers.

M. C., Joggins (*J. W. D.*).

3. T. INTERMEDIUM, spec. nov. Pl. XII. fig. 78.

Allied to *T. olivæformis*, but larger and more elongated.

M. C., Joggins, (*J. W. D.*).

4. T. AVELLANUM, spec. nov. Pl. XII. fig. 77.

Allied to *T. ovatum*, L. & H.; three-ribbed, size and form of a filbert.

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*).

5. T. MINUS, spec. nov. Pl. XII. fig. 75.

Half the size of *T. Hookeri*, and similar in form.

M. C., Joggins (*J. W. D.*).

6. T. ROTUNDUM, spec. nov.

Small, round-ovate, slightly pointed.

M. C., Joggins (*J. W. D.*).

7. T. NŒGGERATHI, Brongn.

Newer Coal-formation, Pictou (*J. W. D.*).

RHABDOCARPUS, Goepp. and Bergm.

1. RHABDOCARPUS ——?, spec. nov.

Ovate acuminate, less than half an inch long.

M. C., Joggins (*J. W. D.*).

2. R. INSIGNIS, spec. nov. Pl. XII. fig. 69.

1·5 inch long, ovate, smooth, with about seven ribs on one side, and the intervening surface obscurely striate. The nature of this fossil is perhaps doubtful; but if a fruit, it is the largest I have seen in the Coal-formation.

U. C., Pictou (*J. W. D.*).

### Calamites, Suckow.

1. Calamites Suckovii, Brongn.

This species is one of the most common in an erect position. It has verticillate branchlets, with pinnate linear leaflets.

M. C., Sydney (*R. Brown*); Joggins (*Lyell; J. W. D.*); Grand Lake (*C. F. Hartt*); U. C., Pictou (*J. W. D.*); Coal Creek (*C. B. Matthew*).

2. C. Cistii, Brongn.

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*); Bay de Chaleur (*Logan*); Coal Creek (*C. B. Matthew*).

Often found erect. Its leaves are verticillate, simple, linear, striate, apparently one-nerved, and 3 inches long.

3. C. cannæformis, Brongn.

M. C., Joggins (*Lyell; J. W. D.*); Sydney (*R. Brown*).

4. C. ramosus, Artis.

Possibly a variety of *C. Suckovii.*

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*).

5. C. Voltzii, Brongn. (*C. irregularis*, L. & H.)

M. C., Joggins (*J. W. D.*).

Often erect; has large irregular adventitious roots. This species is regarded by Brongniart as probably belonging to *Calamodendron*.

6. C. dubius, Artis.

M. C., Sydney (*R. Brown*); Joggins (*J. W. D.; Logan*); U. C., Pictou (*J. W. D.*).

7. C. Nova-scotica, spec. nov. Pl. XII. fig. 89.

M. C., Joggins (*J. W. D.*).

Ribs equal, less than a line wide, striated longitudinally. Joints obscurely marked, and with circular areoles separated by the breadth of three to four ribs. Bark of moderate thickness.

8. C. nodosus, Schloth.

This species has long slender branchlets, with close whorls of short rigid leaves.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*).

9. C. arenaceus (?), Jäger.

This species is mentioned with doubt in Lyell's list.

### Equisetites, Sternberg.

Equisetites curta, spec. nov. Pl. XII. fig. 88.

Short thick stems, enlarging upward, and truncate above; joints numerous; sheaths as long as the joints, with unequal acuminate keeled points. Lateral branches or fruit with longer leaf-like points. Has the characters of *Equisetites*; but its affinities are quite uncertain.

M. C., Sydney (*R. Brown*).

### ASTEROPHYLLITES, Brongn.

1. ASTEROPHYLLITES FOLIOSA, L. & H.

M. C., Joggins (*J. W. D.*); Sydney (*R. Brown*).

2. A. EQUISETIFORMIS, L. & H.

M. C., Sydney (*R. Brown*); Pictou (*J. W. D.*).

3. A. GRANDIS, Sternberg?

The specimens resemble this species, but are not certainly the same. Logan's specimens have terminal spikes of fructification.

M. C., Grand Lake (*C. F. Hartt*); Bay de Chaleur (*Logan*); Sydney (*Bunbury*).

4. ASTEROPHYLLITES, sp.

A species with tubercles (fruit) in the axils is mentioned in Lyell's list as from Sydney. I have not seen it, but have a specimen from Mr. Brown similar to *A. tuberculata*, Sternberg, which may be the same.

5. A. TRINERVIS, spec. nov. Pl. XIII. fig. 90.

Main stem smooth, delicately striate, with leaves at the nodes. Branches delicately striate, with numerous whorls of linear nearly straight leaves, 0·5 inch long, twenty or more in a whorl, and showing two lateral nerves in addition to the median nerve. This and *A. equisetiformis* would be placed by some authors in *Annularia*.

M. C., Sydney (*R. Brown*).

### ANNULARIA, Sternberg.

ANNULARIA GALIOIDES, Zenker.

M. C., Grand Lake (*C. F. Hartt*); U. C., Pictou (*J. W. D.*); Bay de Chaleur (*Logan*); Sydney (*R. Brown*).

### SPHENOPHYLLUM, Brongn.

1. SPHENOPHYLLUM EMARGINATUM, Brongn.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*); Bay de Chaleur (*Logan*); Pictou (*J. W. D.*).

2. S. LONGIFOLIUM, Germar.

U. C., Pictou (*J. W. D.*); M. C., Sydney (*R. Brown*).

3. S. SAXIFRAGIFOLIUM, Sternberg.

Elongate much-forked variety, closely allied to *S. bifurcatum*, Lesquereux.

Bay de Chaleur (*Logan*).

4. S. SCHLOTHEIMII, Brongn.

M. C., Sydney (*Bunbury*).

5. S. EROSUM, L. and H.

M. C., Sydney (*Bunbury*).

The last two species are regarded by Geinitz as varieties of *S. emarginatum*. A specimen of the last-named species in Sir William

Logan's collection shows a woody jointed stem like that of *Asterophyllites*, giving off branches at the joints; these again branch and bear whorls of leaves. The stem shows under the microscope a single bundle of reticulated or scalariform vessels like those of some ferns, and also like those of *Tmesipteris*, as figured by Brongniart. This settles the affinities of these plants as being with ferns or with *Lycopodiaceæ*.

PINNULARIA, L. & H.

1. PINNULARIA CAPILLACEA, L. & H.
   M. C., Sydney (*R. Brown*).

2. P. RAMOSISSIMA, spec. nov.
   More slender and ramose than the last.
   M. C., Joggins (*J. W. D.*).

3. P. CRASSA, spec. nov.
   Branching like *P. capillacea*, but much stronger and coarser.
   L. C., Horton (*C. F. Hartt*).

All these are apparently branching fibrous roots, of soft cellular tissue with a thin epidermis and slender vascular axis. Perhaps they are roots of *Asterophyllites*.

Genus NŒGGERATHIA, Sternberg.

1. NŒGGERATHIA DISPAR, spec. nov. Pl. XIII. fig. 91.

A remarkable fragment of a leaf, with a petiole nearly 3 inches long, and a fourth of an inch wide, spreading abruptly into a lamina, one side of which is much broader than the other, and with parallel veins running up directly from the margin as from a marginal rib. It appears to be doubled in at both edges, and is abruptly broken off. It seems to be a new species; but of what affinities, it is impossible to decide.
Bay de Chaleur (*Sir W. E. Logan*).

2. N. FLABELLATA, L. & H.
   M. C., Sydney (*R. Brown*).

CYCLOPTERIS, Brongn.

(including *Cyclopteris* proper, and subgenera *Aneimites*, Daws., and *Neuropteris*, Brongn.).

1. CYCLOPTERIS HETEROPHYLLA, Goeppert.
   M. C. and U. C., Joggins (*J. W. D.*).

2. C. (ANEIMITES) ACADICA, Dawson, Quart. Journ. Geol. Soc. vol. xvii. p. 5. Pl. VIII. fig. 32.

Stipe large, striate, branching dichotomously several times. Pinnæ with several broadly obovate pinnules grouped at the end of a slender petiolule, and with dichotomous radiating veins. Fertile pinnæ with recurved petiolules, and borne on the divisions of the main petiole near their origin. This plant might be placed in the genus *Adiantites*, Brongn., but for the fructification, which allies it with such ferns as *Aneimia*. It has a very large frond, the main petiole being sometimes 3 inches in diameter, and 2 feet long before branching. Flattened petioles have sometimes been mistaken for *Cordaites* and *Schizopteris*. It is a characteristic plant of the Lower Coal-measures.

L. C., Horton (*C. F. Hartt*); Norton Creek, N.B. (*G. F. Matthew*).

3. C. oblongifolia, Goeppert.

A little larger and coarser than Goeppert's figure.

U. C., Pictou (*J. W. D.*).

4. C. (Neuropteris) obliqua, Brongn.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*).

5. C. (?Neuropteris) ingens, L. & H.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*).

6. C. oblata, L. & H.

M. C., Sydney (*R. Brown*).

7. C. fimbriata, Lesquereux.

M. C., Sydney (*R. Brown*).

8. C. hispida, spec. nov. Pl. XIII. fig. 92.

Pinnate; pinnules obovate, diminishing in size towards the point, decurrent on the petiole; veins slender, distant, forking several times; under surface covered with stiff hairs.

M. C., Sydney (*R. Brown*).

9. C. antiqua, spec. nov. Pl. XIII. fig. 95.

L. C., ? Hebert River (*J. W. D.*).

Tripinnate; petioles slender; pinnules oblong, obtuse, decurrent on the petiole, not contiguous. Terminal pinnules much elongated; venation simple, divergent. This plant approaches more nearly to the peculiar species of *Cyclopteris* found in the Devonian, than any of the others I have seen in the Carboniferous.

Neuropteris, Brongn.

1. Neuropteris rarinervis, Bunbury.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*); Bay de Chaleur (*Logan*).

2. N. perelegans, spec. nov. Pl. XIII. fig. 93.

M. C., Sydney (*R. Brown*).

Resembles *N. elegans*, Brongn., but has narrower pinnules, and nerves less oblique to the midrib. The pinnules were thick and leathery, rough or cellular-netted above, and showing the venation only on the underside.

3. N. cordata, Brongn. (and var. *angustifolia*).

The ferns referred to this species are identical with *N. hirsuta* of Lesquereux. They abound in the Middle and Upper Coal-formations, and have larger pinnules than any of the other ferns. A single terminal pinnule in my collection is 5 inches long. The surface is always more or less hairy.

M. C., Sydney (*R. Brown*); U. C., Pictou (*J. W. D.*).

4. N. Voltzii, Brongn.

A single imperfect specimen like this species, but uncertain.

M. C., Pictou (*J. W. D.*).

5. N. gigantea, Sternb.

M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*); U. C., Pictou (*J. W. D.*).

6. N. flexuosa, Sternb.

M. C., Sydney (*R. Brown*); Joggins (*J. W. D.*).

7. N. heterophylla, Brongn.

M. C., Sydney (*R. Brown*); U. C., Pictou (*J. W. D.*).

9. N. Loshii, Brongn.

Bay de Chaleur (*Logan*).

10. N. acutifolia, Brongn.

M. C., Sydney (*Lyell's list*).

11. N. conjugata, Goepp.

M. C., Sydney (*Brown's list, Acad. Geol.*).

12. N. attenuata, L. & H.

M. C., Sydney (*l. c.*).

13. N. dentata, Lesq.

M. C., Sydney (*R. Brown*).

14. N. Soretii (Brongn.).

M. C., Sydney (*R. Brown*).

15. N. auriculata, Brongn.

M. C., Sydney (*R. Brown*).

16. N. cyclopteroides, spec. nov. Pl. XIII. fig. 94.

Pinnate; pinnules contiguous or overlapping, obliquely round-ovate, attached at the lower third of the base; nerves numerous, spreading from the point of attachment. Allied to *N. Villiersi*, Brongn.

M. C., Sydney (*R. Brown*).

### Odontopteris, Brongn.

1. Odontopteris Schlotheimii, Brongn.

M. C., Sydney (*R. Brown*); Bay de Chaleur (*Logan*); U. C., Pictou (*J. W. D.*).

2. O. subcuneata, Bunbury.

M. C., Sydney (*R. Brown*).

Dictyopteris, Gutb.

Dictyopteris obliqua, Bunbury.
M. C., Sydney (*R. Brown*).

Lonchopteris, Brongn.

Lonchopteris tenuis, spec. nov. Pl. XIII. fig. 103.

Pinnate or bipinnate; pinnules contiguous at the base, nearly at right angles to petiole, oblong elongate, obtuse. Network of veins very delicate. Allied to *L. Bricii*, Brongn., but with smaller, more elongate pinnules and finer veins. I suspect this to be a thick-leaved *Pecopteris*, showing a coarse cellular reticulation on the upper surface.
M. C., Sydney (*R. Brown*).

Sphenopteris, Brongn.

1. Sphenopteris munda, spec. nov. Pl. XIII. fig. 97.

Like *S. Dubuissonii*, Brongn., or *S. irregularis*, Sternberg, in habit; but the pinnules are obovate, decurrent, and few-veined.
M. C., Grand Lake (*C. F. Hartt*).

2. S. hymenophylloides, Brongn.
M. C., Sydney (*R. Brown*); U. C., Joggins (*J. W. D.*).

3. S. latior, spec. nov. Pl. XIII. fig. 98.

Petiole forking at an obtuse angle, slender, tortuous; divisions bipinnate; pinnæ with broad, rounded, confluent pinnules; veins twice forked, with sori in the forks of the veins. In habit like *S. latifolia*, Brongn., *S. Newberryi*, and *S. squamosa*, Lesq.
M. C., Grand Lake (*C. F. Hartt*); U. C., Pictou (*J. W. D.*).

4. S. decipiens, Lesquereux.
M. C., Sydney (*R. Brown*).

5. S. gracilis, Brongn.
M. C., Joggins (*J. W. D.*); Grand Lake (*C. F. Hartt*).

6. S. artemisiæfolia, Brongn.
M. C., Grand Lake (*C. F. Hartt*); Sydney (*R. Brown*).

7. S. Canadensis, spec. nov. Pl. XIII. fig. 99.

General aspect like *S. Hœninghausi*, but secondary pinnules with a margined petiole, and oblong pinnules divided into three to five obtuse points. It is not unlike *S. marginata*, from the Devonian of St. John.
Bay de Chaleur (*Logan*); Sydney? (*R. Brown*).

8. S. Lesquereuxii, Newberry.
M. C., Sydney (*R. Brown*).

9. S. microloba, Guttbier.
M. C., Sydney (*R. Brown*).

10. S. obtusiloba (?), Brongn.
M. C., Bay de Chaleur (*Logan*).

PHYLLOPTERIS, Brongn.

PHYLLOPTERIS ANTIQUA, spec. nov. Pl. XIII. fig. 96

Pinnate; petiole thick, woody; pinnules oblong, pointed, attached by the middle of the base; midrib strong, extending to the point, giving off very oblique nerves, which have obliquely pinnate nervules not anastomosing. A remarkable frond, which, if not the type of a new genus, must belong to that above named.

M. C., Sydney (*R. Brown*).

ALETHOPTERIS, Sternberg.

1. ALETHOPTERIS LONCHITICA, Sternberg.

M. and U. C., Joggins (*J. W. D.*); M. C., Sydney (*R. Brown*); Grand Lake (*C. F. Hartt*).

Very abundant throughout the Middle and Upper Coal-formations, and so variable that several species might easily be founded on detached specimens.

2. A. HETEROPHYLLA, L. & H.

L. C., Parrsborough (*A. Gesner*).

3. A. GRANDINI, Brongn.

M. C., Sydney (*R. Brown*).

4. A. NERVOSA, Brongn.

M. C., Sydney (*R. Brown*); Bay de Chaleur (*Logan*); U. C., Pictou (*J. W. D.*).

5. A. MURICATA, Brongn.

M. C., Joggins, Bathurst (*Lyell*); U. C., Pictou (*J. W. D.*).

6. A. PTEROIDES, Brongn. (*A. Brongnartii*, Goeppert).

L. or M. C., Bathurst (*Lyell's list*).

7. A. SERLII, Brongn.

M. C., Sydney (*R. Brown*); Bay de Chaleur (*Logan*).

8. A. GRANDIS, spec. nov. Pl. XIII. fig. 100.

Bipinnate; pinnæ broad, contiguous, united at the base; veins numerous, once forked, not quite at right angles to the midrib. Upper pinnæ having the pinnules confluent so as to give crenate edges. Still higher the apex of the frond shows distant decurrent long pinnules with waved margins. A very large and fine species of the type of *A. Serlii* and *A. Grandini*, but much larger and different in details. Its texture seems to have been membranaceous; and fragments from that part of the frond where the long simple pinnules are passing into the compound ones might be mistaken for an *Odontopteris*.

Bay de Chaleur (*Logan*).

PECOPTERIS, Brongn.

1. PECOPTERIS ARBORESCENS, Schloth.

Seems to have been an herbaceous species with a very strong petiole. It occurs in an erect position in a sandstone on Wallace River.

M. C., Sydney (*R. Brown*); U. C., Pictou (*J. W. D.*); Wallace River (*Dr. Creed*).

2. P. ABBREVIATA, Brongn.

M. C., Sydney (*R. Brown*); Salmon River, U. C., Pictou (*J. W. D.*). Very common both in the Upper and Middle Coal-formations.

3. P. RIGIDA, spec. nov.

Similar to *P. arborescens*, but much smaller, and with finer nerves. U. C., Pictou (*J. W. D.*).

4. P. UNITA, Brongn.

Certain pinnules of a frond are sometimes swollen as if covered with fructification below; and in this state they resemble *P. arguta*, Brongn. The sori are seen in other specimens, and are large, round, and covered with an indusium as in *Aspidium*.

M. C., Sydney (*R. Brown*); U. C., Pictou (*J. W. D.*).

5. P. PLUMOSA, Brongn.

M. C., Sydney (*R. Brown*).

6. P. POLYMORPHA, Brongn.

M. C., Sydney (*R. Brown*).

7. P. ACUTA, Brongn.

M. C., Pictou (*J. W. D.*).

8. P. LONGIFOLIA, Brongn.

*In Bunbury's list*, from Sydney.

9. P. TÆNIOPTEROIDES, Bunbury.

M. C., Sydney (*R. Brown*).

10. P. CYATHEA, Brongn.

M. C., Sydney (*R. Brown*).

11. P. ÆQUALIS, Brongn.

M. C., Sydney (*R. Brown*).

12. P. SILLIMANI?, Brongn.

*In Lyell's list*, from Sydney.

13. P. VILLOSA, Brongn.

M. C., Pictou (*Lyell's list*).

14. P. BUCKLANDI, Brongn.

M. C., Sydney (*Brown's list*).

15. P. OREOPTEROIDES, Brongn.

M. C., Sydney (*Brown's list*).

16. P. DECURRENS, Lesq.

Has pinnules more crowded, decreasing towards the apex, but may be a variety.

M. C., Sydney (*R. Brown*).

17. P. PLUCKENETII, Sternb.

M. C., Sydney (*R. Brown*).

BEINERTIA, Goeppert.

BEINERTIA GŒPPERTI, spec. nov. Pl. XIII. fig. 101.

Bipinnate; pinnæ broad, contiguous, obtuse, with thick pinnules. Pinnules rounded above, obovate below. Midrib thick, oblique, dividing above into a tuft of irregular hair-like veins.

M. C., Grand Lake (*C. F. Hartt*); Bay de Chaleur (*Logan*); U. C., Joggins (*J. W. D.*).

HYMENOPHYLLITES, Goeppert.

HYMENOPHYLLITES PENTADACTYLA, spec. nov.

In general habit like *Sphenopteris microloba*, Goepp., but with pinnules divided into from four to seven obtuse cuneate lobes, each with one vein.

M. C., Sydney (*R. Brown*).

PALÆOPTERIS, Geinitz.

1. PALÆOPTERIS HARTII, spec. nov. Pl. VIII. fig. 35.

Stem or leaf-bases transversely wrinkled with delicate lines; scars transversely oval, slightly appendaged below; vascular scars confluent. Breadth 1·4 in.; length 0·6 in.

M. C., Grand Lake (*C. F. Hartt*).

2. P. ACADICA, spec. nov. Pl. VIII. fig. 36.

Stem or leaf-bases longitudinally striated; scars transverse, flat above, rounded and bluntly appendaged below; vascular scars in a transverse row. Breadth of scars 0·7 inch; length 0·5 inch.

U. C., Pictou (*J. W. D.*).

CAULOPTERIS, L. & H.

Several small erect stems at the Joggins seem to be trunks of ferns, but are too obscure for description.

PSARONIUS, Cotta.

Trunks of this kind must be rare in the Nova Scotian coal-fields A few obscure stems surrounded by cord-like aërial roots have been found, and probably are remains of plants of this genus.

MEGAPHYTON, Artis.

1. MEGAPHYTON MAGNIFICUM, spec. nov. Pl. VIII. fig. 34.

Stems large, roughly striated longitudinally; scars contiguous, orbicular, deeply sunk, nearly 3 inches in diameter, and each with a bilobate vascular impression 2 inches broad and an inch high.

M. C., Joggins (*J. W. D.*).

2. M. HUMILE, spec. nov. Pl. VIII. fig. 33.

Stem 2·5 inches in diameter; leaf-scars prominent, flattened, and broken at the ends, 1 inch wide. Surface of the stem marked with irregular furrows, and invested with a carbonaceous coating. An internal axis, nearly 2 inches in diameter, with a coaly coating, sends off obliquely thick branches to the leaf-scars. This is a very remarkable specimen, and throws much light on the structure of *Megaphyton*. Unfortunately the minute structures are not preserved.

M. C., Sydney (*R. Brown*).

Genus LEPIDODENDRON, Sternberg.

1. LEPIDODENDRON CORRUGATUM, Dawson, Quart. Journ. Geol. Soc. vol. xv. Pl. XI. fig. 53.

Areoles elongate ovate, acute at both ends, with a ridge along the middle, terminating in a single elevated vascular scar at the upper end. In certain states the vascular mark appears in the middle of the areole. In young branches the areoles are contiguous and resemble those of *L. elegans*. In old stems they become separated by spaces of longitudinally wrinkled bark; in very old stems these spaces are much wider than the areoles. Leaves linear, 1 inch or more in length, usually reflected, one-nerved. Cones (*Lepidostrobi*) terminal, short, cylindric, with numerous short, acute-triangular scales. Structure of stem:—a central pith with a slender cylinder of scalariform vessels, exterior to which is a thick cylinder of cellular tissue and bast fibres, and a dense outer bark.

Var. *verticillatum* has the areoles arranged in regular decussate whorls instead of spirally. This difference, which might at first sight seem to warrant even a generic distinction, is proved by specimens in my possession to be merely a variety of *phyllotaxis*.

This species is eminently characteristic of the Lower Carboniferous Coal-measures, and has not yet been found in the Middle Coal-formation. Fragments of bark resembling that of this species, occur in the Coal-formation of Bay de Chaleur, along with leafy branches of *Lepidodendron*, which resemble those of this species, though, I believe, distinct.

L. C., Horton, &c. (*C. F. Hartt; J. W. D.*); Norton Creek, &c., New Brunswick (*G. F. Matthew*).

2. L. PICTOENSE, spec. nov. Pl. IX. fig. 37.

Areoles contiguous, prominent, long oval, acuminate, separated in young stems by a narrow line; breadth to length as 1 to 3, or less; lower half obliquely wrinkled, especially at one side. Middle line indistinct. Leaf-scar at upper end of areole, small, triangular, with traces of three vascular points, nearly confluent. Length of areole about 0·5 inch. Leaves contracted at the base, widening slightly, and gradually contracting to a point; ribs three, central distinct, lateral obscure; length 1 inch. Cones borne at the extremities of the smaller branches, oblong, obscurely scaly.

In habit of growth this species resembles *L. elegans*, for which imperfect specimens might be mistaken. It is also near to *L. binerve* and *L. patulum*, Bunbury*. It abounds in the Middle Coal-measures.

M. C., Sydney (*R. Brown*); Pictou (*H. Poole and J. W. D.*); Grand Lake (*C. F. Hartt*).

3. L. RIMOSUM, Sternberg.

M. C., Sydney (*R. Brown*); Joggins (*J. W. D.*).

4. L. DICHOTOMUM, Sternberg (*L. Sternbergii*, L. & H.).

M. C., Sydney (*R. Brown*); Joggins (*J. W. D.*); L. C., Horton, (*J. W. D.*).

5. L. DECURTATUM, spec. nov. Pl. IX. fig. 40.

Areoles approximate or separated by a shallow furrow, rhombic ovate, obliquely acuminate below, nearly as broad as long, wrinkled transversely, especially on the middle line, which appears tuberculated; vascular scar rhombic, twice as broad as long, with three approximate vascular points. In some flattened specimens the line separating the areoles is indistinct, and the scars appear on a transversely wrinkled surface without distinct areoles.

M. C., Pictou (*J. W. D.*).

6. L. UNDULATUM, Sternberg. Pl. IX. fig. 41.

Possibly several species are included under this name; but they cannot be separated at present.

M. C., Sydney (*R. Brown*); Joggins and Pictou (*J. W. D.*); U. C., Joggins (*J. W. D.*).

7. L. DILATATUM, Lindley & Hutton.

M. C., Joggins (*J. W. D.*).

8. L., sp. like TETRAGONUM, Goepp.

Obscurely marked, but a distinct species, unless an imperfectly preserved variety of *L. tetragonum*. The areoles are square, with a rhombic scar at the upper corner of each.

L. C., Horton (*J. W. D.*).

9. L. BINERVE, Bunbury.

M. C., Sydney (*R. Brown*).

10. L. TUMIDUM, Bunbury.

I think it probable that this species belongs to the genus *Lepidophloios*; but I have not seen a specimen.

M. C., Sydney (*R. Brown*).

11. L. GRACILE, Brongn.

In Brown's list in 'Ac. Geology.' Probably a variety of the next.

M. C., Sydney (*R. Brown*).

12. L. ELEGANS, Brongn.

In Bunbury and Brown's lists.

M. C., Sydney (*R. Brown*).

* In certain states of preservation, the lateral ribs of the leaves become obsolete; and in others the central disappears, in which state the resemblance to *L. binerve* is very close.

13. L. PLUMARIUM, L. & H.
M. C., Sydney (*in Brown's list*).

14. L. SELAGINOIDES, Sternb.
M. C., Sydney (*in Brown's list*).

15. L. HARCOURTII (Witham).
M. C., Sydney (*in Brown's list*).

16. L. CLYPEATUM (?), Lesqx.
M. C., Sydney (*R. Brown*); U. C., Joggins (*J. W. D.*).

17. L. ACULEATUM, Sternberg.
M. C., Sydney (*R. Brown*).

18. L. PLICATUM, spec. nov. Pl. IX. fig. 38.
Leaf-areoles much elongated; breadth to length as 1 to 5 or 6, transversely rugose; central line indistinct. Leaf-scar rhombic, with three vascular points; scars in old stems separated by rugose bark, and somewhat elongate.
M. C., Pictou (*J. W. D.*).

19. L. PERSONATUM, spec. nov. Pl. IX. fig. 39.
Areoles ovate acuminate; breadth to length as 1 to 3 or 4, contiguous in young stems; central lines distinct; lower part of areole with transverse lines. Leaf-scars ovate, with two marks above and two below; leaves slender, 1 inch long, one-nerved.
M. C., Sydney (*R. Brown*).

HALONIA, sp. HALONIA, L. & H.
A specimen probably referable to this genus from Grand Lake, in the collection of C. F. Hartt.

LEPIDOSTROBUS, Brongn.

1. LEPIDOSTROBUS VARIABILIS, L. & H.
The most common species.
M. C., Sydney (*R. Brown*); Pictou and Joggins (*J. W. D.*).

2. L. SQUAMOSUS, spec. nov. Pl. 10. fig. 46.
2 to 3 inches long, 1 inch thick; scales large, broadly trigonal, acute. Allied to *L. trigonolepis*, but larger. Probably a cone of *Lepidophloios*.
M. C., Grand Lake (*C. F. Hartt*).

3. L. LONGIFOLIUS, spec. nov.
Long-leaved, like *Lepidodendron longifolium*, L. & H.
M. C., Joggins (*J. W. D.*).

4. LEPIDOSTROBUS, sp.
Acute trigonal leaves, small.
M. C., Joggins (*J. W. D.*).

5. LEPIDOSTROBUS, sp.
Round, with obscure scales and remains of long leaves.
L. C., Horton (*J. W. D.*).

6. L. TRIGONOLEPIS, Bunbury.
M. C., Sydney (*R. Brown*).

LEPIDOPHYLLUM, Brongn.

1. LEPIDOPHYLLUM LANCEOLATUM, L. & H.
M. C., Joggins; U. C., Pictou (*J. W. D.*).

2. L. TRINERVE (?), L. & H.
Two-nerved or three-nerved, like *L. trinerve*, L. & H., but narrower. Both the above are parts of *Lepidostrobi*.
U. C., Joggins (*J. W. D.*).

3. L. MAJUS (?), Brongn.
M. C., Sydney (*R. Brown*).

4. LEPIDOPHYLLUM, sp.
Broad ovate, short, pointed, one-nerved, half an inch long.
U. C., Pictou.

5. L. INTERMEDIUM, L. & H.
M. C., Sydney (*R. Brown's list*).
*Halonia*, *Lepidostrobus* and *Lepidophyllum*, including only parts of *Lepidodendron* and *Lepidophloios*, are to be regarded as merely provisional genera.

LEPIDOPHLOIOS, Sternberg.

1. LEPIDOPHLOIOS ACADIANUS, spec. nov. Pl. X. fig. 45, Pl. XI. fig. 51.
Leaf-bases broadly rhombic, or in old stems regularly rhombic, prominent, ascending, terminated by very broad rhombic scars having a central point and two lateral obscure points. Outer bark laminated or scaly. Surface of inner bark with single points or depressions. Leaves long, linear, with a strong keel on one side, 5 inches or more in length. Cone-scars sparsely scattered on thick branches, either in two rows or spirally, both modes being sometimes seen on the same branch. Scalariform axis scarcely an inch in diameter in a stem 5 inches thick. Fruit, an ovate strobile with numerous acute scales covering small globular spore-cases. This species is closely allied to *Ulodendron majus* and *Lepidophloios laricinus*, and presents numerous varieties of marking.
M. C., Joggins, Salmon River, Pictou (*J. W. D.*); Sydney (*R. Brown*).

2. L. PROMINULUS, spec. nov. Pl. XI. fig. 52.
Leaf-bases rhombic pyramidal, somewhat wrinkled at the sides, truncated by regularly rhombic scars, each with three approximate vascular points.
M. C., Joggins (*J. W. D.*).

3. L. PARVUS, spec. nov. Pl. XI. fig. 50.
Leaf-bases rhombic, small, with rhombic scars broader than long;

vascular points obscure; leaves linear, acute, 3 inches or more in length, with a keel and two faint lateral ribs. Cones large, sessile.
U. C., Pictou; M. C., Joggins (*J. W. D.*); M. C., Sydney (*R. Brown*).

4. L. PLATYSTIGMA, spec. nov. Pl. X. figs. 47 & 48.

Leaf-bases rhombic, broader than long, little prominent; scars rhombic, oval, acuminate, slightly emarginate above; vascular points two, approximate or confluent.
M. C., Sydney (*R. Brown*); Joggins (*J. W. D.*).

5. L. TETRAGONUS, spec. nov. Pl. X. fig. 49.

Leaf-bases square, furrowed on the sides; leaf-scar central, with apparently a single central vascular point.
M. C., Joggins (*J. W. D.*).

### DIPLOTEGIUM, Corda.

DIPLOTEGIUM RETUSUM, spec. nov. Pl. XIII. fig. 102.

The fragments referable to plants of this genus are imperfect and obscure. The most distinct show leaf-bases ascending obliquely, and terminating by a retuse end with a papilla in the notch. Some less distinct fragments may possibly be imperfectly preserved specimens of *Lepidodendron* or *Lepidophloios*.
M. C., Joggins (*J. W. D.*).

### KNORRIA.

Nearly all the plants referred to this genus in the Carboniferous rocks are, as Goeppert has shown, imperfectly preserved stems of *Lepidodendron*. In the Lower Coal-formation many such *Knorria* forms are afforded by *L. corrugatum*.

KNORRIA SELLONII, Sternberg.

This appears different from the ordinary *Knorriæ*; its supposed leaves may be aërial roots. It has a large pith-cylinder with very distant tabular floors, like *Sternbergia*.
M. C., Sydney (*R. Brown*).

### CORDAITES, Unger. (PYCHNOPHYLLUM, Brongn.)

1. CORDAITES BORASSIFOLIA, Corda.

M. C., Pictou (*H. Poole*); Grand Lake (*C. F. Hartt*); Sydney (*R. Brown*); Joggins, Onslow (*J. W. D.*); Bay de Chaleur (*Logan*).
Very abundant in the Middle Coal-formation.

2. C. SIMPLEX, spec. nov.

Leaves similar to the last in size and form, but with simple, equal, parallel nerves. It may be a variety, but is characteristic of the Upper Coal-formation.
M. C., Grand River (*C. F. Hartt*); U. C., Pictou (*J. W. D.*).

CARDIOCARPUM, Brongn.

1. CARDIOCARPUM FLUITANS, spec. nov. Pl. XII. fig. 74.

Oval; apex entire or notched; surface slightly rugose; nucleus round ovate, acuminate, pitted on the surface, with a raised mesial line.

M. C., Joggins (*J. W. D.*).

2. C. BISECTUM, spec. nov. Pl. XII. fig. 73.

Nucleus as in the last species, but striate; margin widely notched at apex, and more narrowly notched below.

M. C., Grand Lake (*C. F. Hartt*).

3. CARDIOCARPUM, sp. like *C. marginatum*.

M. C., Joggins (*J. W. D.*).

4. CARDIOCARPUM, sp. allied to *C. latum*, Newberry.

M. C., Pictou (*H. Poole*).

These *Cardiocarpa* are excessively abundant in the roofs of some coal-seams; and the typical ones must have been samaras or winged nutlets. They must have belonged to phænogamous plants, and certainly are not the fruits of *Lepidodendron*, though some of the spore-cases of this genus have been described as *Cardiocarpa*. These I propose to place under the provisional genus *Sporangites*.

SPORANGITES, Dawson.

1. SPORANGITES PAPILLATA, spec. nov. Pl. XII. fig. 80.

I propose the provisional generic name of *Sporangites* for spores or spore-cases of *Lepidodendron, Calamites,* and similar plants, not referred to the species to which they belong. The present species is round, about 1 inch in diameter, and covered with minute raised papillæ or spines. It abounds in the roof of several of the shaly coals in the Joggins section, and especially in one in group 19 of that section.

M. C., Joggins (*J. W. D.*).

2. S. GLABRA, spec. nov. Pl. XII. fig. 81.

About the size of a mustard-seed, round and smooth. Exceedingly abundant in the Lower Carboniferous Coal-measures of Horton Bluff, with *Lepidodendron corrugatum,* to which it possibly belongs. A similar spore-case, possibly of another species of *Lepidodendron,* occurs rarely in the Middle Coal-formation at the Joggins.

STERNBERGIA, Artis.

This provisional genus includes the piths of *Dadoxylon, Sigillaria,* and other plants, usually preserved as casts in sandstone, retaining more or less perfectly the transverse partitions into which the pith-cylinders of many coal-formation trees became divided in the process of growth. These fossils are most abundant in the Upper Coal-formation, but occur also in the Middle Coal-formation. The following varieties may be distinguished:—

(*a*) Var. *approximata,* with fine uniform transverse wrinkles. This is usually invested with a thin coating of structureless coal.

(*b*) Var. *angularis*, with coarser and more angular transverse wrinkles. This is the character of the pith of *Dadoxylon*.

(*c*) Var. *distans*, usually of small size, and with distant and irregular wrinkles. This is sometimes invested with wood having the structure of *Calamodendron*, and perhaps is not generically distinct from *C. approximatum*.

(*d*) Var. *obscura*, with distinct and distant transverse wrinkles, but not strongly marked on the surface. This is the character of the pith-cylinders of *Sigillaria* and *Lepidophloios*.

### Endogenites, L. & H.

Many sandstone-casts, answering to the character of the plants described under this name by Lindley, occur in the Upper Coal-formation. They are sometimes 3 inches in diameter, and several feet in length, irregularly striated longitudinally, and invested with coaly matter. Sometimes they show transverse striation in parts of their length. I believe they are casts of pith-cylinders of the nature of *Sternbergia*, and probably of Sigillarioid trees.

### Solenites, L. & H.

Plants of this kind are found in the sandstones of the Upper Coal-formation of the Joggins.

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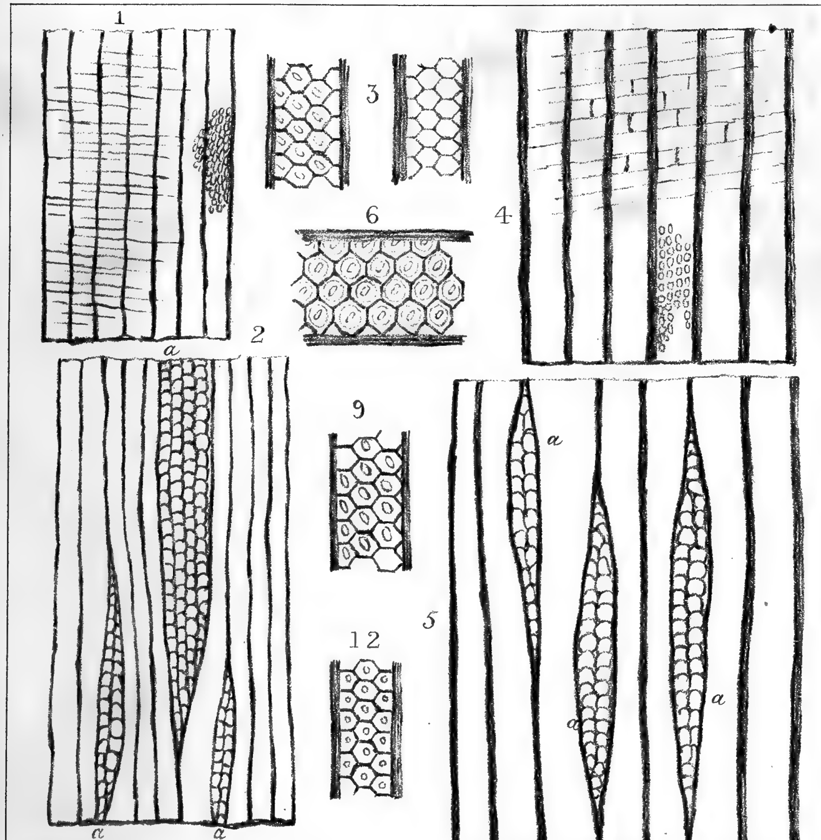
For all the specimens noticed in the above list as collected by Sir W. E. Logan, Richard Brown, Esq., of Sydney, Cape Breton, Henry Poole, Esq., of Glace Bay, C.B., and G. F. and C. B. Matthew and C. F. Hartt, Esqs., St. John, New Brunswick, I am indebted to the kindness of those gentlemen. To Mr. Brown especially I am under great obligations for his liberality in placing at my disposal his large and valuable collection of the plants of the Cape Breton coal-field.

## EXPLANATION OF PLATES V.–XIII.

*Illustrative of the Coal-plants of British North America.*

### Plate V.

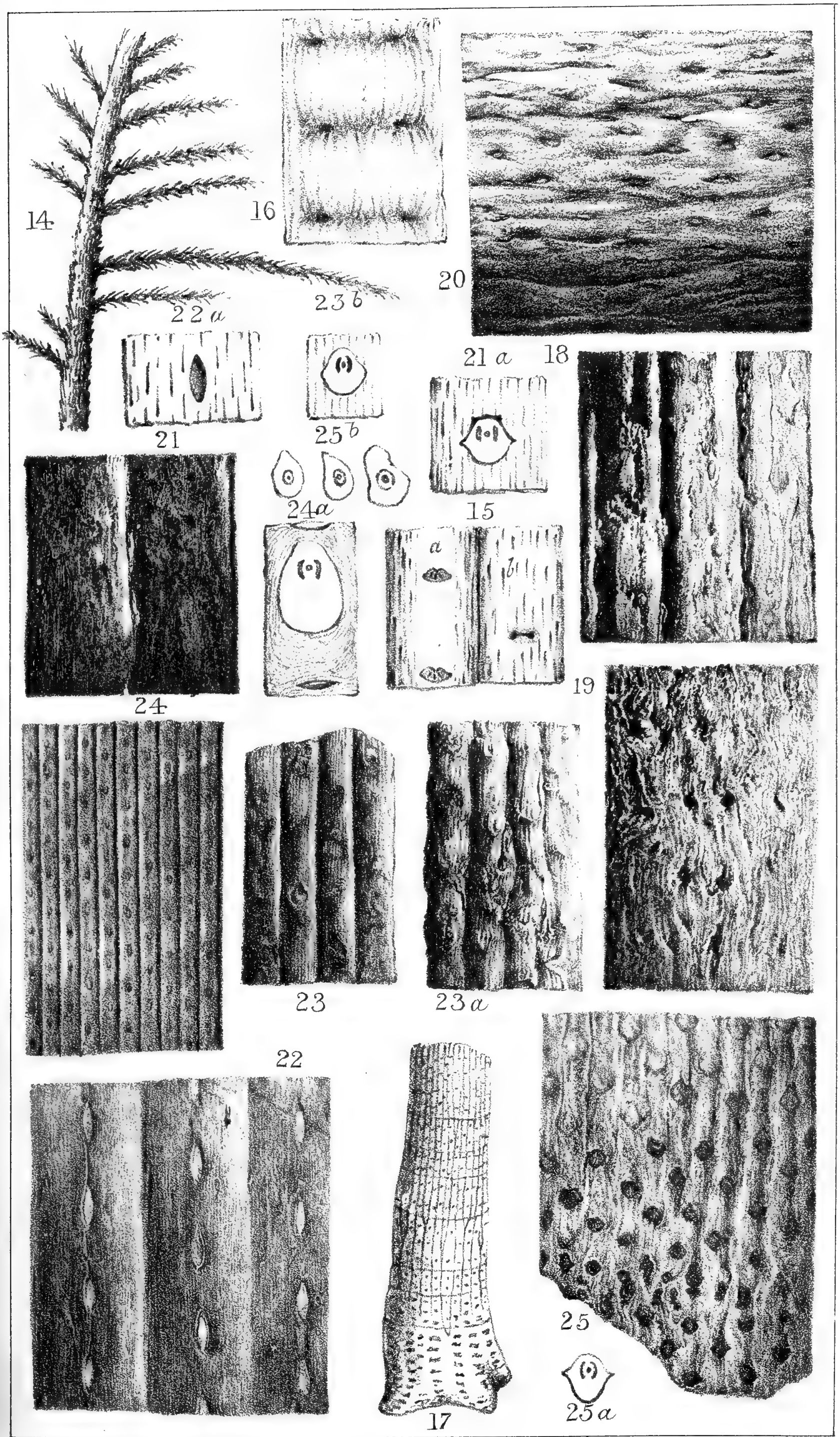
Fig. 1. *Dadoxylon antiquius*: longitudinal section, radial, magnified 90 diameters.
2. The same: longitudinal section, tangential, magnified 90 diameters: *a*, medullary rays.
3. The same: portions of cells showing areolation, magnified 250 diameters.
4. *Dadoxylon Acadianum*: longitudinal section, radial, magnified 90 diameters.
5. The same: longitudinal section, tangential, magnified 90 diameters: *a*, medullary rays.
6. The same: portion of cell showing areolations, magnified 250 diameters.
7. *Dadoxylon materiarium*: longitudinal section, radial, magnified 70 diameters.
8. The same: longitudinal section, tangential, magnified 70 diameters: *a*, medullary rays.
9. The same: portion of cell showing areolation, magnified 250 diameters.
10. *D. annulatum*: longitudinal section, radial, magnified 70 diameters.




E. M. Williams. F.L.S. F.Z.S. lith.

M. & N. Hanhart imp.

COAL-PLANTS OF BRITISH N. AMERICA.

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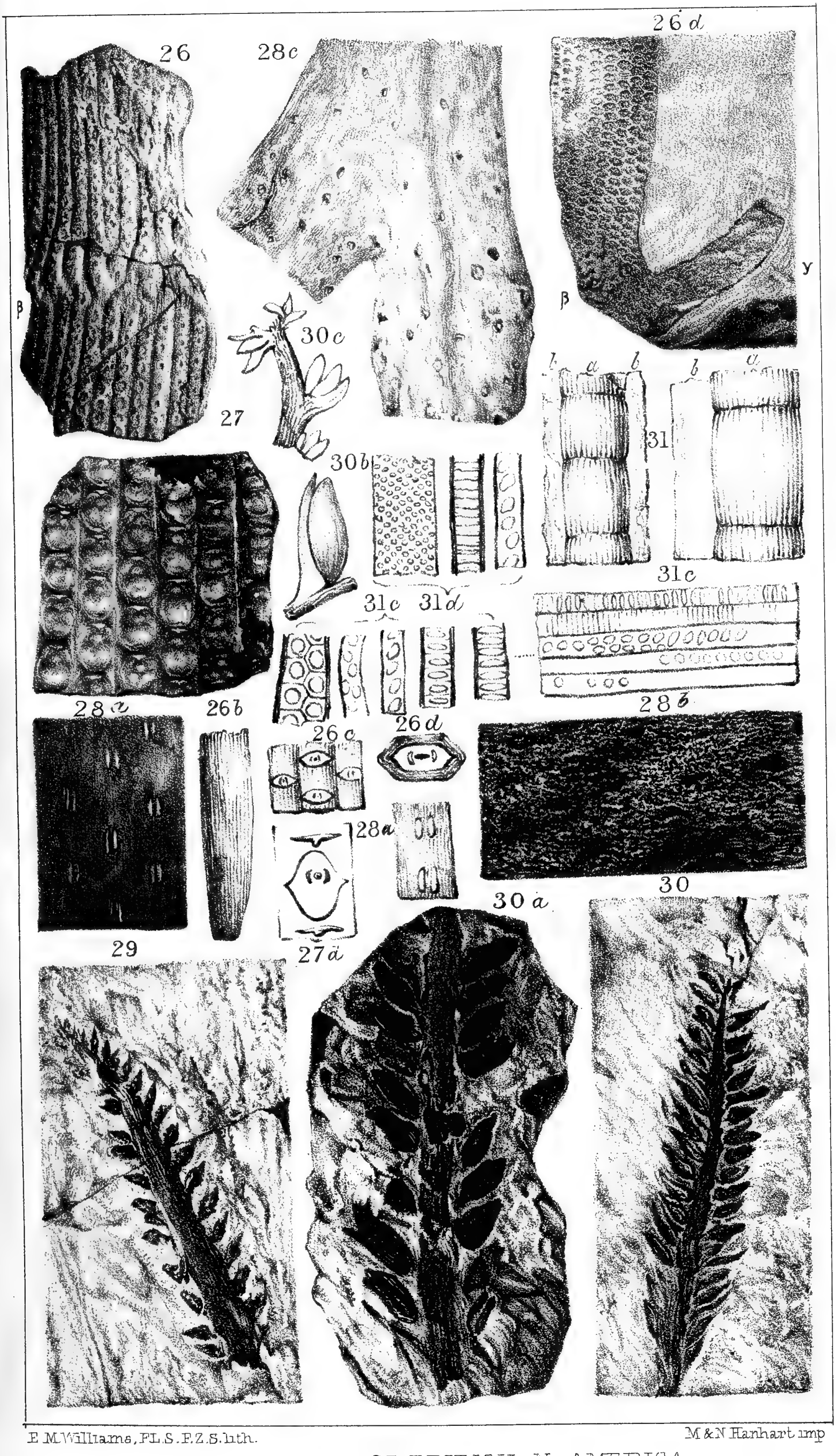


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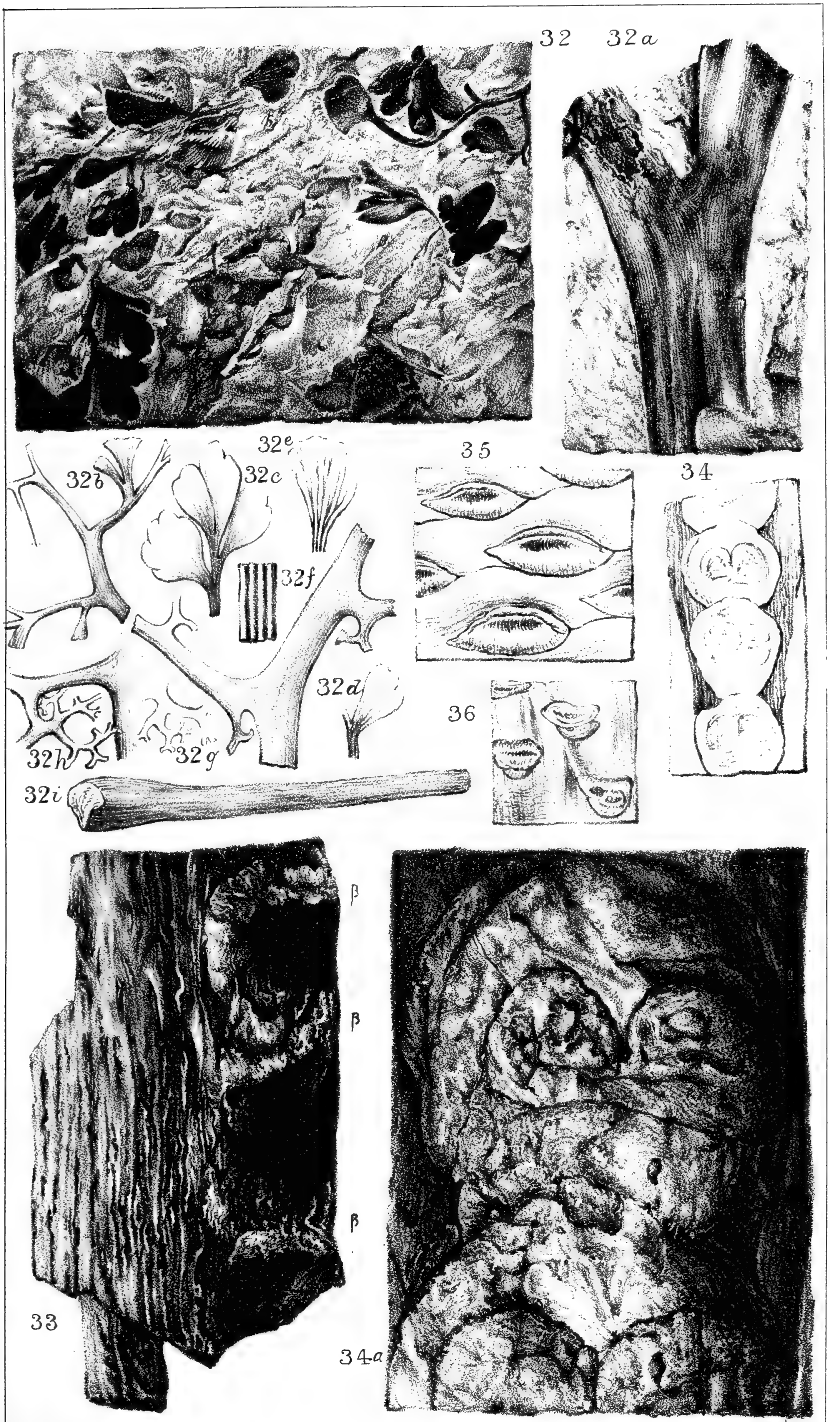


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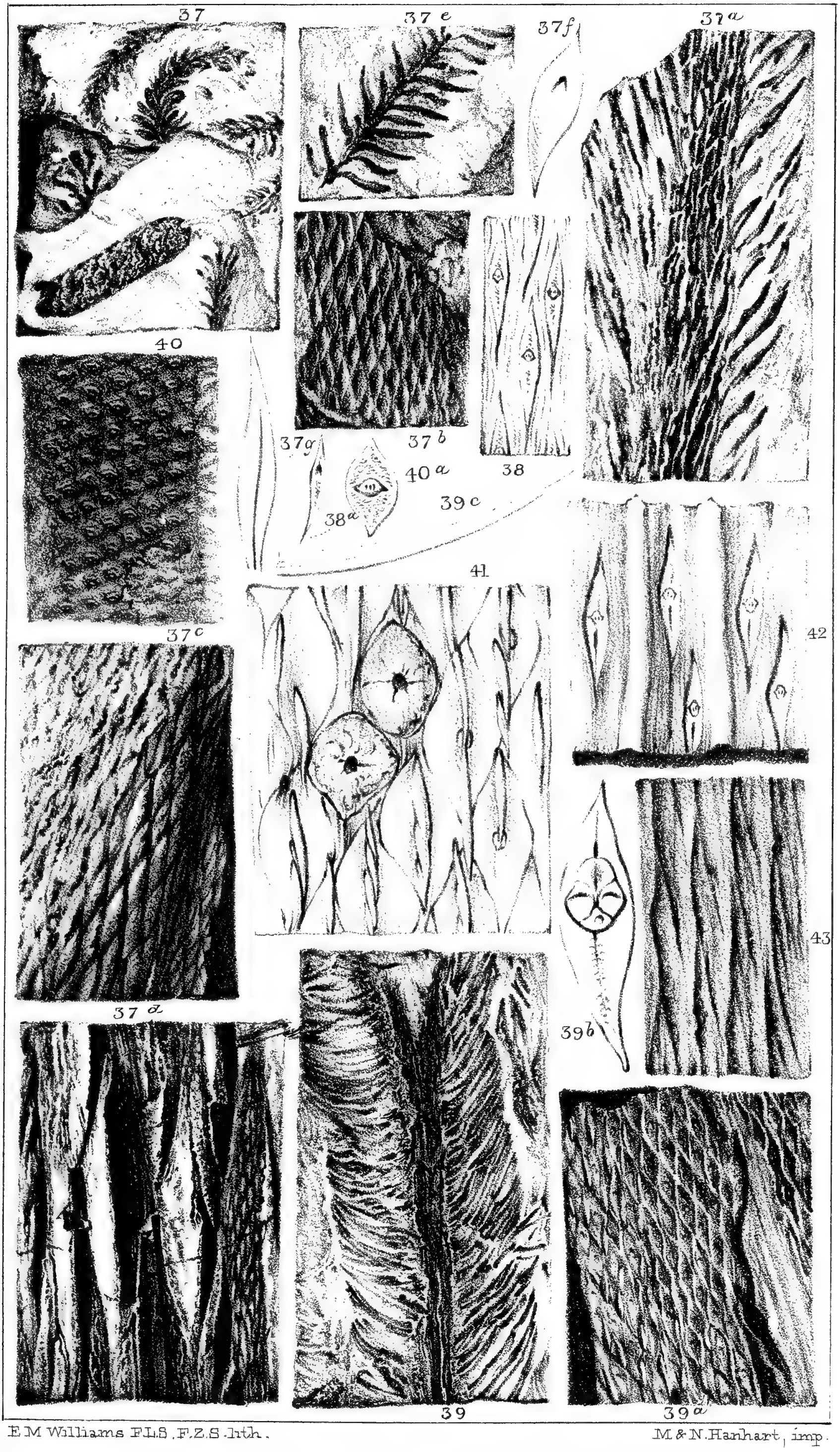


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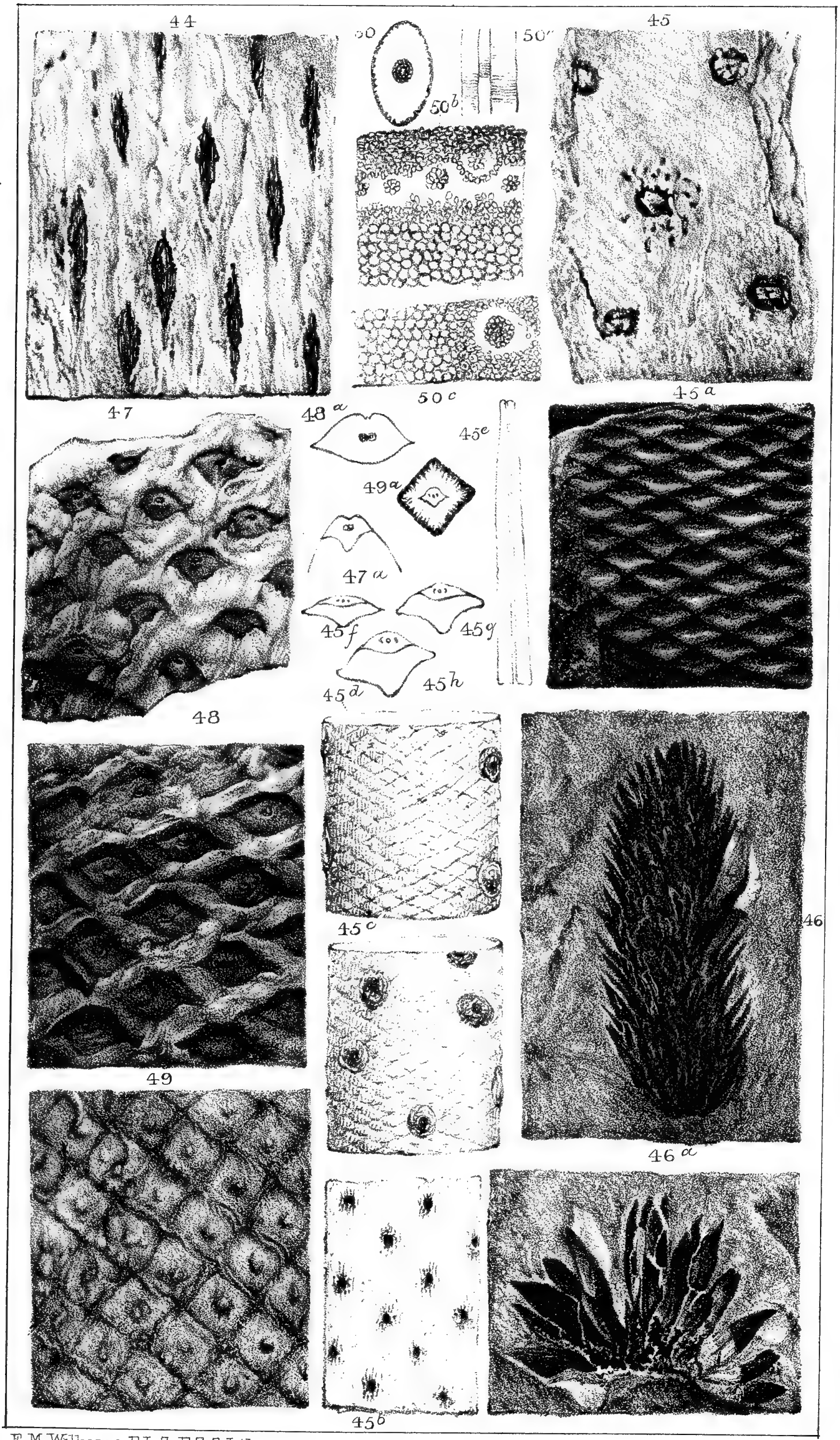


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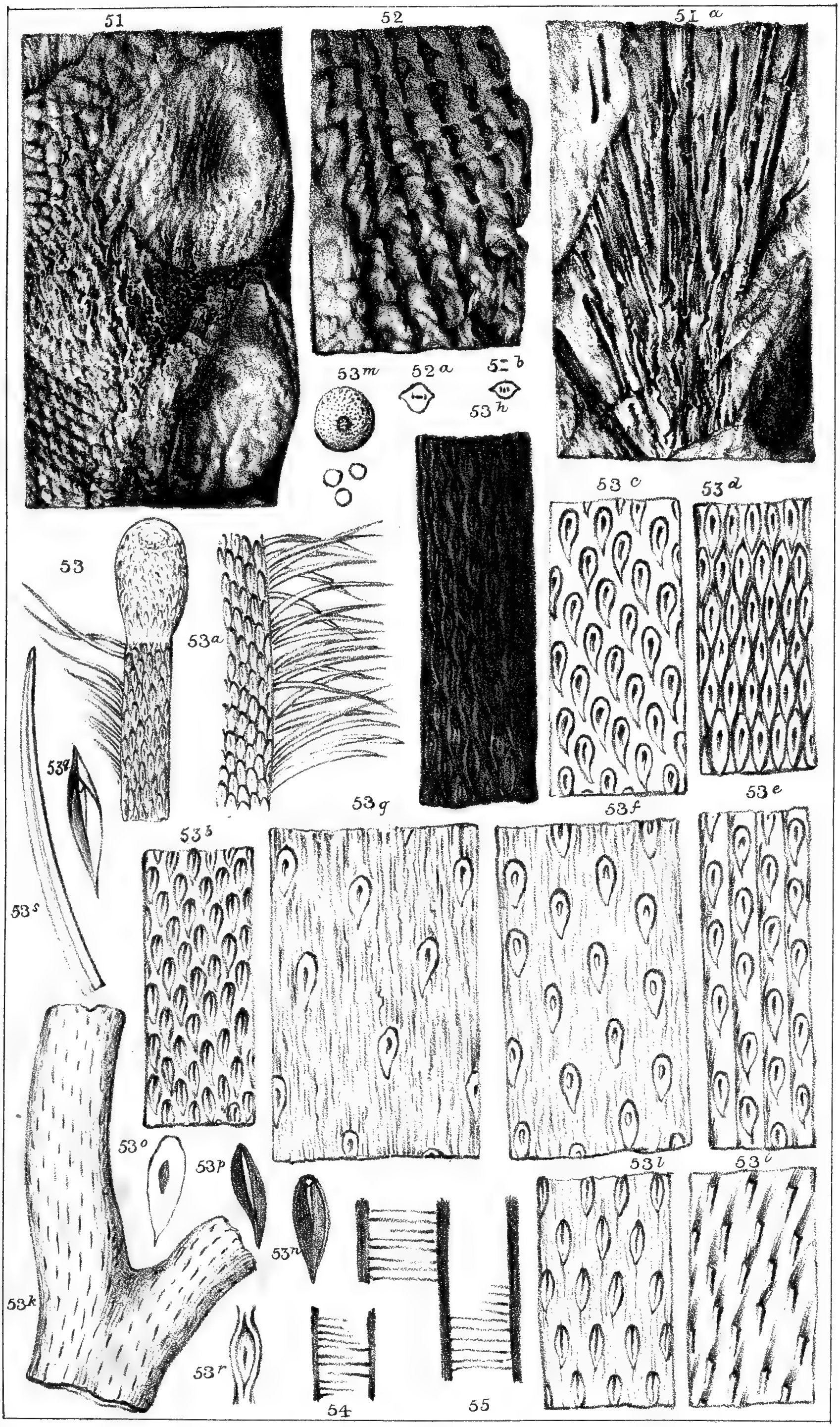


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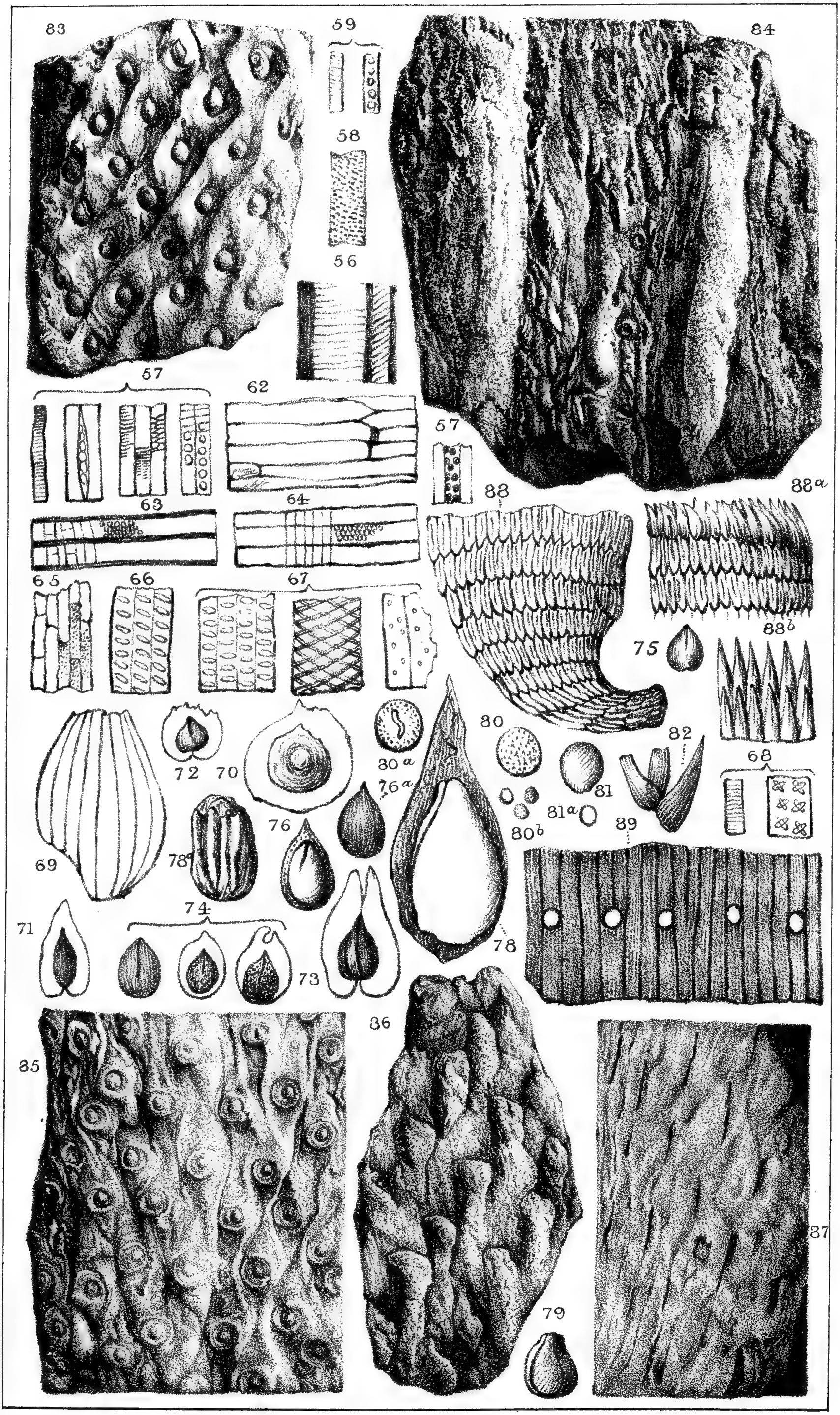


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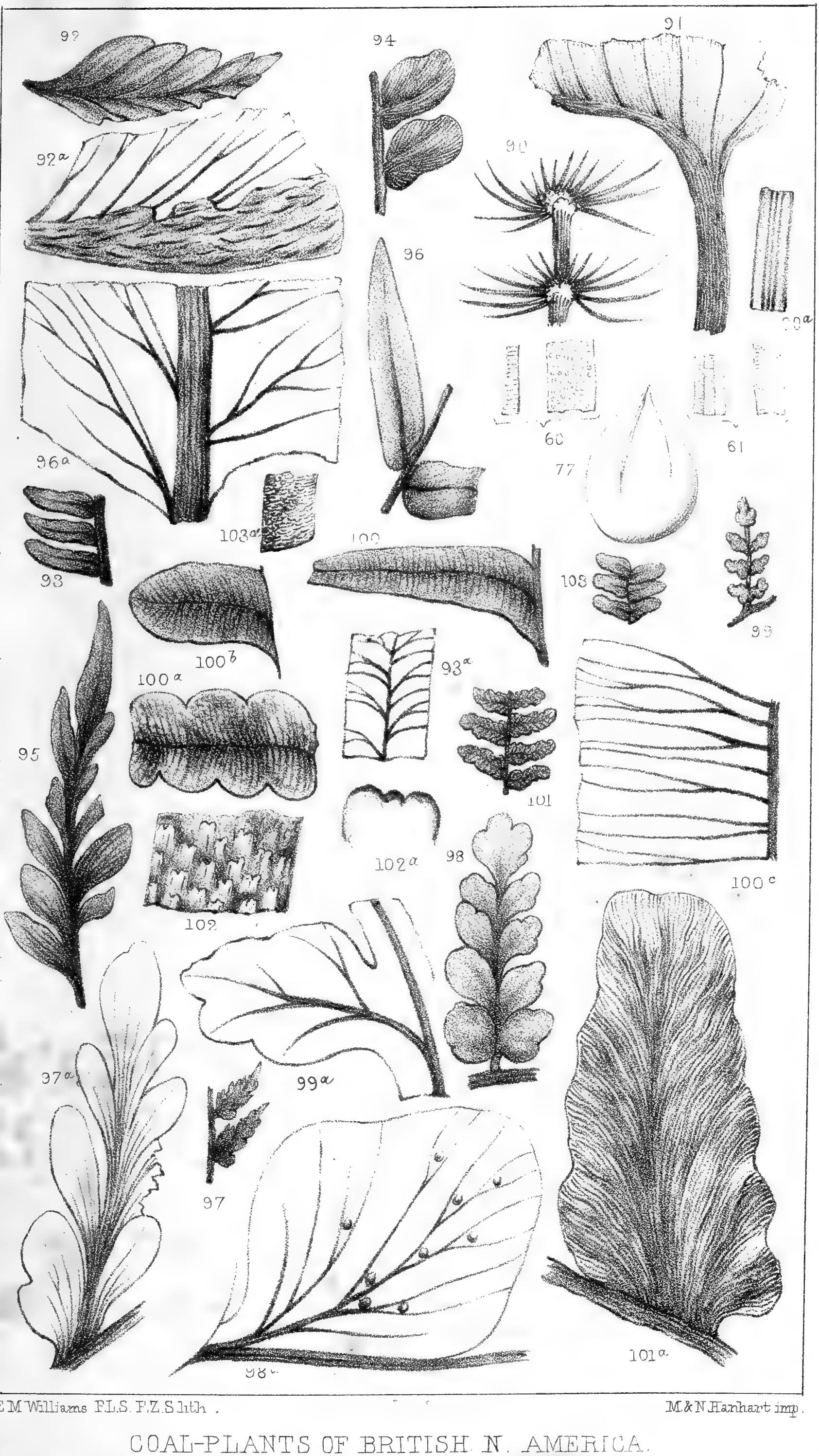


E. M. Williams F.L.S. F.Z.S. lith.

M. & N. Hanhart imp.

COAL-PLANTS OF BRITISH N. AMERICA.

Fig. 11. The same: longitudinal section, magnified 90 diameters: *a*, one of the concentric rings of compact coaly matter.

12. The same: portion of a cell showing areolation, natural size.

13. The same: transverse section, natural size: *a*, pith; *b*, wood, composed of alternate circles of areolated cells and compact coaly matter; *c*, coaly bark.

PLATE VI.

Fig. 14. *Araucarites gracilis*: branch with leaves, three-fourths the natural size.

15. *Sigillaria Brownii*: portion of two ribs, 4 feet above the level, one-half the natural size: *a*, cortical; *b*, decorticated.

16. The same: portion of one rib near the root, furrowed and with vascular scars widely separated.

17. The same: trunk 1 foot in diameter at the base, showing the origin of the ribs.

18. The same: photograph of a portion of the upper part of the stem, one-half the natural size.

19. The same: portion of the base of the stem, one-half the natural size, from a photograph.

20. The same: Sigillarian root of this or an allied species.

21. *Sigillaria planicosta*, from a photograph, one-half the natural size; 21 *a*, scar and part of rib, one-half the natural size.

22. —— *catenoides*, from a photograph, one-half the natural size; 22 *a*, scar and part of ribs, one-half the natural size.

23. —— *striata*: flattened stem, from a photograph, two-thirds the natural size; 23 *a*, part of stem, same size; 23 *b*, scar, enlarged.

24. —— *eminens*: decorticated stem, from a photograph, much reduced; 24 *a*, scar, one-half the natural size.

25. —— *scutellata*, from a photograph, two-thirds the natural size, with band of interrupted growth; 25 *a*, ordinary areole, natural size; 25 *b*, areoles from the regular band, natural size.

PLATE VII.

Fig. 26. *Sigillaria elegans*: decorticated stem, from a photograph, one-half the natural size, with band of interrupted growth at $\beta$; 26 *a*, corticated and flattened stem, one-half the natural size, with branches at $\beta$ & $\gamma$; 26 *b*, leaf of *S. elegans*; 26 *c*, areoles of a branch; 26 *d*, areole of main stem.

27. —— *Bretonensis*: corticated stem, from a photograph, two-thirds the natural size; 27 *a*, areole, natural size.

28. —— *Sydnensis*: decorticated stem, from a photograph, two-thirds the natural size; 28 *a*, areoles of decorticated stem; 28 *b* & *c*, variety of Stigmarian root attached to this species.

29. *Antholithes squamosus*, from a photograph, two-thirds the natural size.

30. —— *Rhabdocarpi*, from a photograph, two-thirds the natural size; 30 *a*, a larger specimen of the same; 30 *b*, single nutlet of the same, natural size.

30 *c*. —— *pygmæus*: fragment, natural size.

31. *Calamodendron approximatum*, one-half the natural size; 31 *a*, cast of pith; 31 *b*, coaly or woody investment; 31 *c*, tissues of wood of *Calamodendron*, magnified.

31 *d*. Tissues of a different species of *Calamodendron* or of *Calamites*.

PLATE VIII.

Fig. 32. Leaflets of *Cyclopteris Acadica*, from a photograph, one-third the natural size; 32 *a*, petiole of the same, one-third natural size; 32 *b*, divisions of petiole, one-half the natural size; 32 *c*, leaflets; 32 *d*, leaflet; 32 *e*, leaflet enlarged, showing venation; 32 *f*, striation of petiole enlarged; 32 *g*, *h*, remains of fructification; 32 *i*, base of petiole, much reduced.

33. *Megaphyton humile*: $\beta$, leaf-scars; $\gamma$, part of axis: from a photograph, two-thirds the natural size.

Fig. 34. *Megaphyton magnificum*: portion of stem, one-sixth the natural size; 34 *a*, leaf-scar, from a photograph, two-thirds the natural size.

35. *Palæopteris Hartii*, one-half the natural size.

36. —— *Acadica*, one-half the natural size.

### Plate IX.

Fig. 37. *Lepidodendron Pictoense*, branchlets and leaves, from a photograph, one-half the natural size (β, cone); 37 *a*, leafy branch; 37 *b*, branch with areoles; 37 *c*, larger branch; 37 *d*, old stem with deep furrows, and at β areoles, not enlarged; 37 *e*, leaves. Figs 37 *a* to 37 *e*, from photographs two-thirds the natural size. 37 *f*, areole enlarged; 37 *g*, leaf enlarged.

38. —— *plicatum*, portion of old stem; 38 *a*, areole of branch, these areoles being placed in contact on such young branches.

39. —— *personatum*, leafy branch; 39 *a*, larger stem with areoles; both from photographs, two-thirds the natural size; 39 *b*, areole, enlarged; 39 *c*, leaf, natural size.

40. —— *decurtatum*, from a photograph, two-thirds the natural size; 40 *a*, areole, enlarged.

41. —— *undulatum*, portion of old stem, showing enlarged areoles, furrows, and two cone-scars.

42, 43. Portions of old stems, probably of *L. rimosum* or allied species.

### Plate X.

Fig. 44. Portions of old stems, probably of *Lepidodendron rimosum* or an allied species.

45. *Lepidophloios Acadianus*, stem with marks of cones, from a photograph, one-half the natural size; 45 *a*, portion of stem with areoles, from a photograph, two-thirds the natural size; 45 *b*, decorticated stem, natural size; 45 *c* & *d*, opposite sides of the same stem, reduced, to show the different arrangement of the cone-scars; 45 *e*, part of a leaf, natural size; 45 *f*, *g*, *h*, areoles from different parts of stem.

46. Strobile of *Lepidophloios*; 46 *a*, transverse section of a similar strobile; from photographs, two-thirds the natural size.

47 & 48. *Lepidophloios platystigma*, from a photograph, two-thirds the natural size; 47 *a* & 48 *a*, areole of the same, natural size.

49. —— *tetragonus*, from photograph, two-thirds the natural size; 49 *a*, areole, two-thirds the natural size.

### Plate XI.

Fig. 50. *Lepidophloios parvus*, stem with areoles and scars of cones; 50 *a*, group of leaves; both from photographs, two-thirds the natural size; 50 *b*, areole, natural size.

51. Cross section of *Lepidophloios Acadianus*, showing the outer rind and woody axis, one-tenth the natural size; 51 *a*, scalariform vessels of axis, magnified; 51 *b*, transverse section of part of the axis, showing the vascular bundles which proceed to the leaves, and the different diameters of the outer and inner circles of vessels; 51 *c*, smaller portion of the axis, showing one bundle of vessels.

52. *Lepidophloios prominulus*, portion of cast, from a photograph, two-thirds the natural size; 52 *a*, areole, natural size.

53. *Lepidodendron corrugatum*, young branch with cone; 53 *a*, branch with leaves; 53 *c*, older branch with areoles beginning to separate; 53 *d*, variety with alternate areoles; 53 *e*, variety with areoles in vertical rows; 53 *f*, *g*, old trunks, with widely separated areoles; 53 *h*, photograph of branch; 53 *i*, Knorriæ, or decorticated state; 53 *k*, fragment, showing ramification; 53 *l*, bark with areoles in transverse rows; 53 *m*, spore-case, natural size and magnified; 53 *n* to *r*, areoles in various states; 53 *s*, leaf, enlarged.

54. Scalariform vessel of *Lepidodendron*.

55. " " *Stigmaria*.

## Plate XII.

Fig. 56. Scalariform vessel of *Lepidophloios*.
57. Tissues of *Sigillaria*.
58. Vessel of *Sphenophyllum*.
59. Tissues of *Calamodendron*.
60. Tissues of *Calamites*.
61. Scalariform tissue of Ferns.
62. Bast tissue of *Sigillaria*.
63. Cells of *Dadoxylon Acadianum*.
64. Cells of *D. materiarium*.
65. Cuticle of *Pinnularia*.
66. Vessel of *Sphenophyllum*, 200 diameters.
67. Vessels and cells from vascular bundles of Ferns, 200 diameters.
68. Tissues of *Sigillaria*, 200 diameters.
69. *Rhabdocarpus insignis*. 150
70–72. *Cardiocarpum*, spp.
73. *C. bisectum*.
74. *C. fluitans*.
75. *Trigonocarpum minus*.
76. *T. Sigillariæ*.
77. *T. avellanum*.
78. *T. intermedium*; 78 *a*, nucleus of do.
79. *T. Nœggerathi*.
80. *Sporangites papillata*; 80 *b*, nat. size.
81. *S. glabra*; 81 *b*, nat. size.
82. Fragment of *Antholithes*.
83. Stigmaria with scars in rhombic areoles.
84. Stigmaria with bark divided by vertical furrows (var. *alternans*).
85. Stigmaria with large scars in elongated areoles.
86. Stigmaria with elongated scars (*Knorria* form).
87. Stigmaria another variety, resembling *Diplotegium*.
88. *Equisetites curtus*.
89. *Calamites Nova-scoticus*.

Figs. 54–64 inclusive are drawn to a uniform scale of 90 diameters. Figs. 83 to 87 are taken from photographs, and are two-thirds the natural size.

## Plate XIII.

Fig. 90. *Asterophyllites trinervis*; 90 *a*, portion of leaf enlarged.
91. *Nœggerathia dispar*, one-half natural size.
92. *Cyclopteris hispida*; 92 *a*, portion of pinnule magnified, showing hairy surface and impressions of nervures.
93. *Neuropteris perelegans*; *a*, portion magnified, showing venation.
94. —— *cyclopteroides*.
95. *Cyclopteris antiqua*.
96. *Phyllopteris antiqua*; 96 *a*, portion magnified, showing venation.
97. *Sphenopteris munda*; 97 *a*, portion magnified.
98. —— *latior*; 98 *a*, pinnule magnified, showing venation and sori.
99. —— *Canadensis*; 99 *a*, pinnule magnified, showing venation.
100 and 100 *a* & *b*. Pinnules of *Alethopteris grandis*; 100 *a*, portion magnified, showing venation.
101. *Beinertia Goepperti*; 101 *a*, pinnule magnified, showing venation.
102. *Diplotegium retusum*; 102 *a*, leaf-scar magnified.
103. *Lonchopteris tenuis*; 103 *a*, portion enlarged, showing character of surface.

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P. W. Sheafer.—Relative Levels of Coal- and Oil-regions, 32.
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Anglo-Brazilian Times. Anno 1. No. 18. October 24, 1865. *From the late G. E. Roberts, Esq., F.G.S.*

Anthropological Review. Vol. iii. No. 11. October 1865.

Assurance Magazine. Vol. xii. Part 5. October 1865.

Athenæum Journal. Nos. 1980–1992. October to December 1865.

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Belfast Field-Naturalists' Club. Reports for 1863–64 and 1864–65. *From R. Tate, Esq., F.G.S.*

Berlin. Zeitschrift der deutschen geologischen Gesellschaft. Vol. xvii. Heft 2. February to April 1865.

F. Roemer.—Ueber das Vorkommen von *Rhizodus Hibberti*, Owen (*Megalichthys Hibberti*, Agassiz et Hibbert), in den Schieferthonen des Steinkohlengebirges von Volpersdorf in der Grafschaft Glatz, 272 (plate).

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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 10, 1866.

Woomes Chunder Bonnerjee, Esq., 108 Denbigh Street, St. George's Road, S.W.; Charles Pannel, Esq., Torquay; and Joseph Wright, Esq., 39 Duncan Street, Cork, Ireland, were elected Fellows.

The following communications were read:—

1. *On the so-called* "EOZOONAL ROCK." By Professors WILLIAM KING and T. H. ROWNEY, of the Queen's University in Ireland, and the Queen's College in Galway*.

[Communicated by Sir Roderick I. Murchison, Bart., K.C.B., &c.]

[PLATES XIV. & XV.]

CONTENTS.



### I. *Introduction.*

OUR attention was first directed to the subject of the present memoir by the communications of Sir William Logan, Dr. Dawson, and

* Since the reading of this paper, it has been revised and augmented, by permission of the Council.

Dr. Sterry Hunt, read at the Bath meeting of the British Association, "On the Occurrence of Organic Remains in the Laurentian Rocks of Canada." Besides, one of us, when in London last January, examining specimens of the "remains" in question, and observing how closely the rock containing them resembled the Ophite* of Connemara, was led to suspect an identity of origin for both deposits. Our interest in the matter was further excited on reading an announcement in the 'Geological Magazine' for last February, of the discovery by Mr. W. A. Sandford, "verified" by Professor T. Rupert Jones, of "Eozoonal structure in the Connemara marble"†.

Considering that we resided near the locality which yielded the latter rock, and that the determination whether, or not, it had resulted from the growth of "*Eozoon Canadense*" would enable us to form a positive opinion as to the age of the great metamorphic masses with which it is interstratified, we felt ourselves called upon to undertake an investigation promising so important a result‡.

We commenced with no misgivings as to the "eozoonal" origin of the Canadian Ophite, while our faith in the conclusion come to by Sir William Logan, and his able coadjutors, was strengthened by subsequently reading the masterly papers which appeared in No. 81 of the 'Quarterly Journal of the Geological Society.' Very few having any knowledge of the construction of the calcareous encasements of the various foraminifers, whether characterizing the simple nubecularias or the complex nummulinas, could rise from the perusal of those papers without feeling more or less disposed to adopt the view that the Canadian Ophite had originated from the superpositional, but otherwise indefinite, mode of growth of a gigantic sessile spreading representative of the lowest known group of animals, or without admitting that the view was based on sound reasoning and deep thought.

* The names *ophite* and *serpentine* have been indifferently employed by geologists for the rock under description and some others allied to it; but the first one, which was used by Vitruvius, having priority, we have determined, after some consideration, on employing it; and as the second is generally applied by mineralogists to the essential (silicated) mineral of Ophite, we shall restrict it to this application in the present memoir. By adopting this plan much confusion will be avoided, especially as many mineralogists and geologists are in the habit of calling both the rock and its essential mineral by the name of *serpentine*. Had it been necessary to call the rock serpentine, the name *retinalite* (as will be seen hereafter) might have been retained for the mineral.

† *Op. cit.* vol. ii. p. 88.

‡ Sir Roderick I. Murchison (Siluria, 2nd edit. p. 192) and Professor Harkness (Geological Magazine, vol. ii. pp. 147, 148) are of opinion that the Connemara metamorphic rocks are "Lower Silurian." From their discordance, both in strike and dip, with the overlying Upper Silurian beds, their highly altered condition, compared with the latter deposits (both of which circumstances favour a greater chronogeological gap than is sanctioned by the opinion stated), and their being devoid of Lower Silurian, Upper Cambrian, or other fossils, one of us placed them, in an edition of his 'Synoptical Table of Aqueous Rock-groups,' in the "Lower Cambrian system—Sedgwick (? Huronian, Logan)"—thus, "? Cliffden (Connemara) Quartzites." This edition was printed in 1862, by Mr. S. J. Mackie, F.G.S., editor of the 'Geologist,' and is entitled "Student's Series, No. 21."

## II. *General Description of the Chemical, Mineral, and Structural Characters of Grenville "Eozoonal" Ophite.*

In a chemical point of view this rock consists essentially, 1st, of hydro-magnesian silicates, the base being often more or less combined with alumina or iron-protoxide; and, 2nd, of carbonate of lime, a portion of which is sometimes replaced by carbonate of magnesia. Mineralogically, it consists of serpentine, pyrosclerite, or loganite, including their respective varieties, which may be referred to the first group of substances*; also calcite and dolomite, which belong to the second group. These may be regarded as its essential constituent minerals; but there are occasionally present diopside, pyrallolite, chondrodite, apatite, mica, pyrites, graphite, giobertite, and others.

Polished specimens of "eozoonal" Ophite, examined by an ordinary magnifier, are seen to consist of a more or less saccharoidal

* Several variously named ophitic minerals are known, which, although differing structurally, are identical in chemical composition. (a.) *Serpentine* is amorphous, uneven or conchoidal in fracture, and composed, according to Scheerer's analysis of pure specimens from Snarum in Norway, of $SiO_3$ 40·74, $MgO$ 41·48, $HO$ 12·64, &c. 48·2. Retinalite (Thompson), although stated to contain two or three per cent. more water, is considered by Sterry Hunt to be the same mineral. Bowenite, which occurs as scaly aggregations imbedded in saccharoidal calcite, may be regarded in the same light. (b.) *Chrysotile* (Kobell), found in layers often very thin, with a transverse fibrous structure identical with that of amianthus or the finest asbestus, is composed, according to Kobell's analysis of specimens from Reichenstein, Silesia (the original locality), of $SiO_3$ 43·50, $MgO$ 40·00, $HO$ 13·80, &c. 2·48: it passes into picrolite, in which the fibres are coarse or acicular, adherent laterally, or separated, and not always parallel. (c.) *Metaxite* (Breithaupt) occurs in tufts or dendritic aggregations of a dull or slightly silky lustre, and consists, according to Delesse, whose specimens were from Reichenstein, of $SiO_3$ 42·1, $MgO$ 41·9, $HO$ 13·6, &c. 2·4. Some other varieties are known, as thermophyllite and marmolite, having a similar chemical composition. All the foregoing may be regarded as allomorphs of one and the same mineral species, consisting, if we eliminate the minor ingredients, of "Silica 43, Magnesia 44, and Water 13" (Delafosse), or $2SiO_3$, $3MgO$, $2HO$. There also occur a number of other hydrous silicates of magnesia related to the one above formulated, agreeing with it in the percentage of HO, but differing therefrom in containing $Al_2O_3$, or $Fe_2O_3$, or both, or $CaO$,—namely, pyrosclerite, bastite, loganite, and chonicrite—every one, like serpentine, having its allomorphs. Besides, there are allied species containing more or less water, as deweylite, picrosmine, and others. Confining ourselves to serpentine, pyrosclerite, and loganite, these being essentially ophitic, they are respectively represented by an earthy variety—namely, aphrodite, saponite, pseudophite, and some containing an extra percentage of water. Minerals, it is well known, often present themselves under various forms without undergoing any chemical change, and without any relation to the different axial systems in which any one of them may crystallize. Thus, aragonite occurs (1) compact and amorphous; (2) massive and cleavable; (3) *coralloidal*, as flos ferri; (4) *asbestiform*, as satin spar. All these varieties are considered to belong to one axial system—the monoclinate; but being obviously of *other* forms than one, and as they are all chemically alike, we propose to call them *allomorphs*—from ἄλλος, *other*, and μορφή, *form*. Calcite is of the same chemical composition as aragonite; the fact, however, of its belonging to a different axial system—the rhombohedral—makes it a dimorph, and not, as in the above sense, an allomorph. Like aragonite, calcite is also subject to allomorphism; and so are a large number of other minerals. Not being aware that any distinctive term has been applied to the first class of precited modifications, the want of which has often been felt in our present investigations, we have been induced to propose for it the one already employed.

base, and of various-shaped granules, separated, or irregularly united and clustered together—the latter being imbedded in the former. The base consists of whitish-coloured calcite, or dolomite; while the granules, which "vary in size from the tenth to the fourth of an inch," are of serpentine, or the allied minerals loganite and pyrosclerite, conspicuous by their green colour of various shades: in some cases the granules consist of a white crystalline anhydrous mineral (non-essential in Ophite)—a variety of pyroxene called diopside. Often the granules are irregularly scattered through the base; and occasionally a number of them are united so as to form uneven-surfaced plates, which affect a more or less parallel arrangement. Ophite thus presents a spotted or laminated appearance. Besides, its essential mineral, serpentine, is frequently aggregated into thick complexly undulating layers, variously intermixed or intercalated with aggregations of other silicated minerals, chiefly anhydrous, differing in colour; and the calcite becomes expanded into layers of saccharoidal marble: under these conditions Ophite assumes features much more markedly stratified.

Examined with a high power, the granules are seen to be generally segmented or lobulated. Often the segmentations are very slight; and as often they are well pronounced, being here deep narrow chinks, and there long subcylindrical necks, straight, or tortuous.

The structure and composition of the granules, and their presence in a calcareous matrix, were first made out in Ophite from Canada, —most satisfactorily in that occurring at Grenville: this variety may therefore be regarded as typically "eozoonal," particularly as the above characters, and some others less obviously associated with them, have been considered specially determinative of its "foraminiferal origin." This being the case, we propose to include under the name "eozoonal" all rocks which do not materially differ in their internal structure from the one just described.

We have consequently placed in the "eozoonal" section the varieties of Ophite which occur in Connemara, Donegal, and the Isle of Skye, as well as others from India, Bavaria, and the State of Delaware, specimens of all having passed under our examination*. Ophitic rocks are also found in Anglesea, Saxony, Norway, the Tyrol, Cornwall†, and Switzerland; but in none of them have we detected "eozoonal" characters,—a circumstance which, taken in conjunction with some considerations hereafter noticed, disposes us to suspect that they belong to a different section.

### III. *General Characters of* "Eozoon Canadense."

According to the view which ascribes the formation of "eozoonal" Ophite to the growth and reproduction of a foraminifer, the sac-

* We have not had an opportunity of examining any specimens of Ophite from the Vosges; but from Delesse's description of this rock (Ann. des Mines, 4e sér. tome xviii. pp. 309–356), we are led to suspect that some of it will turn out to be "eozoonal."

† From a fact stated hereafter there is some probability that Cornish Ophite is "eozoonal."

charoidal calcite was originally the amorphous calcareous substance composing the septa which bounded or formed the " chambers " that were occupied by its sarcode-segments; while the granules of serpentine are "*casts*" of the "chambers" themselves. According to Sterry Hunt, " the vacant spaces left by the decay of the sarcode may be supposed to have been filled by a process of infiltration, in which the silicates were deposited from solution in water, like the silica which fills up the pores of wood in the process of silicification"*.

Considering the scattered and laminar modes of arrangement of the " chamber-casts," it is conceived that " *Eozoon Canadense* " became enlarged by the irregular heaping up or " acervuline " growth of the " sarcode-segments," as well as by their having grown in successive layers one upon another. On this view the calcareous septa, enclosing the sarcode-segments, formed a vesicular skeleton, its cavities affecting an " acervuline," or a laminar arrangement.

The calcareous septa are in some instances extremely thin, and in others of considerable thickness. In the latter state they have been described as consisting of two distinct portions. One of them, considered to have been the immediate covering of the sarcode substance, occurs as a thin fibrous or " asbestiform layer," the fibres passing from surface to surface—peculiarities which have given rise to the idea that the layer was originally the homologue of the finely tubulated " proper wall " characteristic of the skeleton of *Nummulina*, *Operculina*, *Calcarina*, and other allied foraminiferal genera, and consequently that the fibres are casts of tubules, such passages having served for the extrusion of fine thread-like " prolongations," called pseudopodia, from the " sarcode-segments :" the other portion, usually the thickest, and designated, from its position and other considerations, the " intermediate skeleton," contains imbedded in its substance (this is particularly the case in Canadian Ophite) a variety of branching and other structures, which are regarded as " internal casts " of tubular passages, such as are known to constitute the " canal system " (similarly circumstanced, and occupied by thickish " prolongations of the sarcode-substance ") of the foraminifers above mentioned. Certain of these structures, also some of the elongated constrictions already noticed, are supposed to be casts of passages occupied by " stolons," which connected both vertically adjacent and laterally adjacent " sarcode-segments."

When specimens of " eozoonal " rock are carefully digested in a weak solution of hydrochloric acid, the calcite may be completely dissolved out, leaving vacant passages which wind about amidst the undissolved granules and plates or " chamber-casts." As the branching structures imbedded in the septa are insoluble in this menstruum, like the latter parts they remain intact in the passages. Frequently, also, the surfaces of the granules may be seen crowded with aciculi—the so-called *casts* of the pseudopodial tubuli of the " proper wall."

At first our investigations were not attended with much success.

* Quart. Journ. Geol. Soc. vol. xxi. p. 67. Dr. Dawson adopts a similar view,—that the matter of the chamber-casts was "introduced by infiltration or as sediment" (*op. cit.* p. 52). Dr. Carpenter, however, holds a different view, which will be noticed hereafter.

The Connemara Ophite contained what we had no doubt had been taken for "chamber-casts;" but these parts differed in one respect considerably from those belonging to the Grenville variety. We had got the impression that in the latter they were rarely arranged otherwise than in laminæ; but in our home rock we found them to have a decidedly "acervuline" arrangement, and to be seemingly distinguished by some other characters.

In this dilemma we made free to apply to Sir William Logan, who very kindly supplied us with specimens from Grenville. These assisted us materially; for we now saw that the "acervuline" arrangement of the "chamber-casts" was likewise a characteristic feature of the Canadian Ophite. Still the two rocks presented some important differences. As we informed Sir William Logan, the "chamber-casts" in the variety from our locality varied considerably in size, some being large, often as much as half an inch in diameter, and others extremely small; while the septa are often very thin, resembling in this respect the cell-walls of ordinary vegetable tissue (parenchyma), and frequently the contrary, in many instances measuring half an inch in thickness. The contrast between the "chamber-casts" and the septa was not strikingly obvious, owing to the paleness of the green colour of the former and the greyish whiteness of the latter. Besides, the septa showed no decided appearance of being traversed by structures representing the "canal system." We also felt unconvinced of having detected *undoubted* examples of the "proper wall" or asbestiform layer.

At last, by mere accident, we procured from a dealer in Galway a specimen, cut in imitation of a bottle, containing "acervuline" patches, in which the "chamber-casts," composed of what we consider to be loganite*, and the septa, consisting of white calcite, were as decidedly in contrast as in Canadian specimens: the agreement was still closer, as the "walls" were of ordinary thickness, and they appeared to contain representatives of the "canal system." This proved to be the only specimen we could procure in Galway; but learning from the dealer that he recollected where it was got, we determined on taking him as our guide to the place and trying to procure more of the same variety.

We had the good fortune to be accompanied in our excursion by Professor Harkness, who, however, soon showed himself to have no sympathy with us in the view we then held, being as much a disbeliever in "*Eozoon Canadense*" as Mr. Bailey, who, a few days previously, had publicly declared his doubts that the "thing in question was a fossil at all"†. Our "compagnon de voyage" argued for its

* We learn from a paper by Professor Haughton, inserted in the 'Journal of the Geological Society of Dublin,' vol. v. p. 128, that the Rev. Joseph Galbraith analyzed a specimen of Connemara Ophite, and proved it to be a hydro-magnesian silicate, with a little lime and iron peroxide, from which we infer that it is impure. Doubtless the rock varies much according to locality: we have found specimens containing so much alumina as to show their close relationship to loganite.

† Meeting of the Royal Geological Society of Dublin, held April 12th. Mr. Bailey has since published his view in a note added to his paper on "The Cambrian Rocks of the British Islands." See 'Geological Magazine,' vol. ii. p. 388.

structures being merely the product of crystallization, illustrating the "chamber-casts" by a reference to the forms of wavellite, and referring the "proper wall" and "canal system" to tremolite*.

We succeeded in making a large collection of specimens at the principal "marble-quarries" of Barna-oran, Lisoughter, and Glan-ochan: the latter place yielded the variety we wanted.

### IV. "*Proper wall*" *of* "Eozoon Canadense."

Settled quietly before one of Smith and Beck's first-class binocular microscopes, and furnished with the best object-glasses and eye-pieces, we examined a number of specimens, both from Grenville and Connemara, prepared by polishing and decalcification. While thus engaged the question occurred to us, If, in the laminar portions of Ophite, the layers are the result of superpositional growth, how does it happen that the "proper wall" of the chambers "every-where presents" the tubules which served as passages for the pseudopods? In this case the *under* as well as the *upper* side of a layer of "chambers" must have been tubulated—just, in short, as represented by the transparent section in plate viii. fig. 3 *a*, *b*, *c*, and in the ideal diagram or woodcut in p. 61, of Dr. Carpenter's paper in No. 81 of the 'Quarterly Journal of the Geological Society.' There is no difficulty in conceiving the pseudopods of the exposed or *upper* "proper wall" of the top layer of "chambers" to play their proper part, as they could be freely protruded through and beyond the orifices of the tubules. But how could those act which belonged to the *under* "proper wall," considering that their egress would be effectually barred by the upper "proper wall" of the immediately *subjacent* layer of "chambers"? The difficulty, we felt persuaded, would be met by the following explanation:—The two layers were separated by vacant spaces, except at certain points or places occupied by "stolons:" in this case the pseudopods of the two layers could be freely thrust through the tubules into the vacancies, where they would be in free communication with the surrounding medium, and also enabled to elaborate the "interme-diate skeleton." But, unfortunately for this explanation, it has been stated that the successive layers of chambers, each having its own proper wall, are often superposed one upon another without the intervention of any "intermediate skeleton"†; also, that "where there is little trace of the intermediate skeleton between the cham-bers, the characteristic structure of the proper wall is still unmis-takeably exhibited"‡.

We next considered that, although it is quite true the "casts of the tubules" are often seen standing apart, they also occur so closely packed together, "standing side by side like the fibres of asbestus," as to forbid the idea that there are any interspaces between them. Again, the tubules must of necessity have had walls. Now if the

* Professor Harkness has stated his opinion before the Geological Section of the British Association at the Birmingham meeting. See 'Reader,' Sept. 30, 1865.

† Carpenter, Quart. Journ. Geol. Soc. vol. xxi. p. 63, pl. ix. fig. 4.

‡ Carpenter, 'Intellectual Observer,' vol. vii. p. 294.

fibres are casts of tubules, how could such be the case in places where the asbestiform layer, as just noticed, consists of intimately juxtaposed fibres, with nothing between them*? For anything that we observed to the contrary, the fibres thus circumstanced displayed quite as little evidence of having been parietally separated as those of asbestus. Moreover the fibres "sometimes pass off obliquely or even tangentially, so as to run for considerable distances in the chamber-walls,"—a peculiarity which, as it has "no parallel" among foraminifers, we were disposed to accept as negative evidence against their foraminiferal origin.

These facts and considerations produced in us in the early stage of our investigations simply a scepticism as to the organic origin of the asbestiform layer. Entertaining no doubt regarding Dawson's view of the other structures, we were merely led to suspect that this part was the product of crystallization.

Subsequently our suspicion became a settled conviction on discovering examples of the "proper wall" under circumstances which clearly showed it to be altogether *independent* of the "calcareous skeleton." The conclusion just stated we hold to be demonstrated by the example represented in fig. 2, Plate XIV., than which nothing can more intelligibly explain the purely crystalline origin and nature of the part in question. This remarkably beautiful example, selected out of a number of the same kind, is taken from an undecalcified slice of Grenville Ophite†: it consists of three or four closely conjoined granules of serpentine (a plate of slightly individualized "chamber-casts"), having on one side a continuous border of "proper wall," which, when examined with a sufficiently high power, is seen to have, for the most part, a perfectly *compact* asbestiform or indefinitely fibrous structure; while in two places (*a* and *b*) this structure is in an incipient state of development, consisting of a number of parallel thread-like lines clearly and somewhat widely separated: the one kind passes into the other. That it is no other than the serpentine thus crystallized is rendered evident by the lines in the part marked *b* being extended only partly across the width of the "proper wall," leaving, without a shadow of doubt, a narrow external zone of the mineral *devoid of all traces of lineation* immediately in contact with, but plainly distinct from, the "calcareous skeleton." If, in this case, the "proper wall" had been originally calcareous, like the "skeleton," as main-

* In *Nummulina lævigata* we find the width of a parietal interstice between two adjacent tubules to slightly exceed their diameter; so that casts of the tubules would, if their walls were dissolved out, be separated by strongly-defined linear openings. Possibly it may be suggested that the "appearance of a minute prismatic arrangement" which nummulines occasionally display, and which is conceived to have been produced by "metamorphosis" or "fossilization" (see Carpenter, Quart. Journ. Geol. Soc. vol. vi. p. 25, and 'Introduction to the Study of the Foraminifera,' p. 270), explains the compact fibrous structure of the "proper wall" of "*Eozoon Canadense*;" but this is obviously too unsatisfactory a case to be of any assistance, it being merely one of *appearance*, which is possibly in some measure due, as believed by Dr. Carpenter, to the "areolation" of the "tubules," similar to what prevails in *Operculina*.

† Our other examples are generally decalcified.

tained by Rhizopodists, it never could have presented such appearances; the calcite, and not the serpentine, would have exhibited the lineated and asbestiform structure.

Considering that there is an allomorphic variety of serpentine known as chrysotile, which possesses characters identical with those of the so-called "proper wall," we feel ourselves warranted in assuming that this part is a layer of the latter mineral.

Moreover, not only does the serpentine become asbestiform, but it is frequently found changed into a white flocculent substance*, which takes the place of the "proper wall"—occurring on the surface of the granules as a crust of varying thickness, and frequently intermixing with the calcite of the skeleton†. Instances have occurred to us of the serpentine alternately assuming both kinds of structure, as shown in fig. 3, Plate XIV., which represents a thin transparent section, seen by transmitted light, of three granules with an irregular notched border: the projections consist of incipiently chrysotilized serpentine, and the interspaces or notches of flocculent matter.

The substance under notice has generally a loosish granular texture; and often it is compact like starch; it is also rudely lamellar or prismatic. Occasionally we find it colourless and pellucid, like chalcedony, and having no appearance of structure under a low power; but when examined with an object-glass magnifying 350 diameters, it is seen to be fibrous. In short, one of our specimens of Ophite from Lisoughter shows the surface of a granule of serpentine imperceptibly passing into the asbestiform layer, and this part, here and there, gradually changing into the flocculent crust; while closely adjacent there occurs a mass of the flocculent substance enclosing, or rather *passing imperceptibly* into, asbestiform crystallization, the crystals being fine, long, and well developed.

The granules are not always furnished with an asbestiform layer, or a flocculent crust; for highly polished, and consequently translucent specimens, which have not been submitted to decalcification, occasionally show them wholly devoid of any covering, their surface being in immediate contact with the "calcareous skeleton;" and in decalcified specimens we have also seen granules with surfaces quite smooth, and appearing as if nothing had ever been attached to them.

Reverting to the cases which show the fibres or aciculi of the asbestiform layer standing apart, attention may be first directed to

* For the sake of brevity and distinction, we propose to name this substance *flocculite*—not, however, under the idea of its being a new mineral. It is our present impression that flocculite is merely an allomorph of serpentine; we are quite ready, nevertheless, to accept it as a chemically different, though closely related substance. Saponite, pseudophite, and some other allied minerals, are similarly structureless. Aphrodite, except that its silica and magnesia are in different relative proportions to those prevailing in serpentine, appears to come nearest to flocculite. The granular mineral occurring as a bed in the crystalline limestone at Grenville, and which Dr. Sterry Hunt has identified with pyrallolite (Geology of Canada, 1863, p. 470), may be identical with it.

† In thin transparent sections, examined by transmitted light, the serpentine has a metallic appearance resembling brass. Very minute particles of *unchanged* serpentine may be detected by this character, intermixed with the flocculent substance, both being interspersed amongst the calcite of the skeleton.

the one represented in fig. 1, Plate XIV. In this instance there are two layers belonging to a single granule. The innermost layer is for the most part perfectly compact and indefinitely fibrous; and, although not demonstrable, it cannot be considered other than a modified form of the pertaining serpentine: the outer layer consists of distinctly individualized fibres or aciculi, generally thick, occasionally very fine, and separated from one another on the left half (that is, of the figure), but closely adherent by their sides on the right half, except at their points. The innermost layer is in one place separately acicular, like the outermost one, showing clearly the *intimate relationship between the two extremes of structure* assumed by the "proper wall"*.

Now such cases as this have been represented as "exactly corresponding" with the fine tubulation characteristic of the shells of nummuline foraminifers; but from what has already been adduced, and other evidences to be brought forward, we, on the contrary, contend for their being merely simulations of such tubulation.

But this case is not to be compared with others we are acquainted with. We have seen in Grenville Ophite some truly striking examples, which show the aciculi of the "proper wall" far surpassing in their mimicry of nummuline tubulation anything hitherto published—cylindrical rods, uniform in length, thickness, and in their distance from one another, and standing perpendicularly to the surface of the "chamber-casts." At first sight these instances, if studied by themselves, might be taken for "internal casts" of tubules; but such a view speedily vanishes when they are properly examined and studied in all their relations. Besides being perpendicular, the rods are occasionally seen leaning, arching, creeping, and twisting about in all directions: they also unite wholly or partially, converging, diverging, branching, and anastomosing, so as to produce conical, cuneiform, dendritic, "brush-like," and an infinite variety of "bundles, of which no two are precisely similar." Other aggregations occur, forming small or wide-spreading patches, which have uniform, or variously disrupted, surfaces.

Whether viewed transversely or longitudinally, all these modifications are structurally alike. If examined with a magnifying power of 350, the *patches* are seen to consist of "closely packed" parallel fibres—in other words, to have a "uniform surface so close in texture as to be with difficulty resolvable into the points of their constituent aciculi"†. Place the *bundles* under the same object-

* This is a case inexplicable on the idea that it has resulted from pseudopodial tubulation; but there is no difficulty in conceiving it to be one of double allomorphism. The outer layer, which we assume to have been formed first, has lost its finely fibrous structure, the fibres having become individualized or transformed into aciculi,—a change characteristic of chrysotile. As the "proper wall" of *Nummulites* is formed of a number of laminæ, it may be thought that this double layer is a parallel case; but the tubules, belonging to the former part, pass uninterruptedly or continuously through the laminæ; whereas in the latter each of the two layers is composed of an independent series of fibres, or aciculi.

† It is quite evident Dr. Carpenter has observed examples similar to ours. See 'Intellectual Observer,' vol. vii. p. 292, &c.

glass, they, too, are seen to have a precisely identical structure, "every individual thread glistening brightly under appropriate illumination." Apply the same high power to the rods, even the finest; they are likewise resolved into asbestiform fibre*. Does anything of the kind exist in recent or fossil foraminifers, even in *Operculina*, the genus which, owing to its tubuli "separating from each other in some parts and becoming more closely crowded in others," has been referred to as offering in this respect a complete agreement with "Eozoon"? Is it conceivable that *casts* of pseudopodial tubuli could be compound or fibrous, like asbestus? It is manifestly superfluous to make a reply in the negative.

Dr. Carpenter has given representations of the proper wall of *Amphistegina*, *Operculina*, *Cycloclypeus*, and some other genera, showing pseudopodial tubulation†; but in every case the tubules are distinctly separated one from another from base to apex. In marked contrast to such separation are those cases in "eozoonal" Ophite, already noticed, in which the *casts* are intimately united throughout their entire length.

According to the view we are opposing, the *surface* of a "chamber-cast" or granule, from which the "proper wall" has been detached, ought to be "rendered hispid by the minute projections which passed into the entrances of the tubuli," as in the recent siliceous casts of an Amphistegina from the Australian coast, described by Dr. Carpenter; but instead of exhibiting any definite projections, such as would result from the cylindrical and *separated* tubulation of the "proper wall," like those represented in a "small portion" from another specimen of apparently the same species ("to show the free openings of the tubuli on the internal surface of the chambers"‡), the representative part or surface of the serpentine granules, from which the asbestiform layer, whether compact or open, has been artificially broken off, is irregularly, compactly, and indefinitely hispid, precisely as obtains on the freshly fractured terminal surfaces of finely fibrous minerals.

It may be contended that the isolated aciculi "exactly correspond" with the hispid projections on the siliceous cast of the Amphistegina just alluded to. This cannot be admitted, since it is impossible to separate such aciculi from others immediately adjacent, which com-

* Often the asbestiform structure of the aciculi has disappeared, which we believe to be simply a molecular change. Delesse states that the fibres of chrysotile occurring in the Ophite of the Vosges, which are described as "excessively fine," "swell out and become opaque and whitish on exposure to air" (Ann. des Mines, 4e sér. tome xviii. p. 328). Taking this fact in connexion with the consideration that Ophite must have passed through considerable variations of temperature, pressure, &c., and that its essential mineral—serpentine—is eminently unstable in its molecular constitution, as shown by its various allomorphs, we feel persuaded that our belief, expressed above, cannot be set aside. The modifications presented by the double asbestiform layer, noticed in a previous paper, and several others which have fallen under our observation, offer an analogy to the one observed by Delesse.

† Introduction to the Study of the Foraminifera, pl. 13. fig. 25 *a*; pl. 17. figs. 8, 9, 12, 13; pl. 19. figs. 3, 4.

‡ *Op. cit.* p. 245, pl. 13. fig. 25 A, and Explanation.

pletely adhere to one another by their sides: besides, the latter imperceptibly pass into the state of an indefinitely fibrous layer. The examples, and they are numerous, to which reference is made, clearly show that these modifications belong to one form of crystallization, and cannot be the result of "nummuline tubulation." But in order to place our conclusion beyond the shadow of a doubt, we shall add another demonstrative evidence to the number already adduced.

We have repeatedly seen fissures in the serpentine—*true cracks striking right across a number of "chamber-casts"* and the intervening calcareous skeleton—filled with calcite and flocculent matter, separated and intermixed. The conditions of these examples incontestably prove that the latter substance is a modification of the serpentine, and the former an infiltration. One of our specimens from Lisoughter, which is decalcified, shows the phenomenon most instructively; a portion of the flocculent matter still remains, and the calcite has disappeared. But this is not all: considerable portions of the walls of the fissure are crowded with as fine examples of isolated perpendicular parallel aciculi and rods (the latter consisting of *asbestiform fibre*) as those composing the so-called "proper wall" of the adjacent "chamber-casts"*! It is unnecessary to add another sentence by way of evidence or argument in opposition to the view which ascribes the asbestiform layer to pseudopodial tubulation†.

Evidences strongly in favour of the conclusion that the "*chamber-casts*" and "proper wall" were never otherwise than composed of one and the same mineral substance, have occurred to us in Ophite from Donegal and from the State of Delaware; the granules of serpentine, in the former of a dark-green colour, and in the latter quite yellow, may be observed passing imperceptibly and completely into the asbestiform condition. We also find exactly the same change in Ophite (from Snarum in Norway) wholly devoid of anything like organic structure: a specimen now before us shows here and there its essential mineral, serpentine, becoming changed into films structurally indistinguishable from the asbestiform covering of "eozoonal" sarcode-chambers, even often presenting its identical intermitted and incipient crystallization. More cogent evidence could not be adduced to prove that the "proper wall" is no other than an allomorphic phenomenon.

A strictly identical case, however, and one which may be regarded as conclusively proving the original mineral nature of the "proper wall," has occurred to us in another mineral. Chondrodite, a spe-

* See Plate XIV. fig. 4, magnified 110 diameters. In this particular example the aciculi on one of the walls of the fissure are exceedingly minute, being with difficulty detected except under a power of 210; similar aciculi are interspersed amongst the larger kind on the opposite wall. The large aciculi at one part of the wall are closely crowded together: from this condition they graduate into a compact layer indefinitely fibrous.

† M. Delesse mentions a fact which equally shows the fallacy of the view taken by Rhizopodists as to the origin of the asbestiform layer. The Ophite of Xettes, in the Vosges, contains nodules (les rognons) possessing the mineralogical characters of granite, surrounded by an envelope composed of radiately fibrous chrysotile (see Ann. des Mines, 4e sér. tome xviii. p. 335).

cies agreeing with serpentine in its mode of aggregation, is often found in a finely granular condition imbedded in saccharoidal calcite. In numerous instances we have found imbedded grains of this mineral from New Jersey more or less incrusted with an asbestiform layer which exhibits modifications, speaking advisedly, the exact parallel of those common to the "proper wall of *Eozoon Canadense.*" Three cases have been selected to illustrate the layer in question. In one of them, represented in Plate XIV. fig. 5, magnified 120 diameters, the fibres form a finely asbestiform plate, perfectly compact in texture except where it curves, lying between two grains of chondrodite, which plate, when examined with a power of 210, presents exactly the appearance of translucent compactly fibrous selenite; in the second case, Pl, XIV. fig. 6, magnified 60 diameters, the fibres are white, silky, somewhat coarse, rarely otherwise than parallel to one another, oftenslightly apart, and lying obliquely between two grains; in the third, shown in Pl. XIV. fig. 7, magnified 120 diameters, the fibres are aggregated into very slender, pointed, separated rods, projecting from one end of a grain. In the last case the interspaces appear to have been once filled with fibres that have become detached, possibly by decalcification; in the others they appear to be the result of some slight tensional or torsional movements.

Is any naturalist prepared to assent to the notion that in these examples the asbestiform layer represents the "proper wall" of a foraminifer, and that the fibres are casts of pseudopodial tubules? If not, he must at once relinquish his belief in the "nummuline tubulation" diagnosed, for the investment of the granules of serpentine, as characteristic of "eozoonal" Ophite.

Before concluding the present section, it is necessary to give a general description of the coat belonging to the serpentine of Connemara Ophite. Like that characterizing the granules of the Grenville rock, the coat is both fibrous and flocculent, both modifications being often intermixed, distinctly separated or changing imperceptibly into each other; but in the former state, instead of being generally composed of parallel fibres, it consists of acicular crystals radiately or divergently disposed, or variously intersecting one another, also occasionally curving or twisting, forming aggregations or tufts irregularly dispersed over the granules. Occasionally, however, as in the cases already noticed, the granules are covered with a true asbestiform layer, its fibres standing perpendicularly, parallel to one another, and completely adhering by their sides or separated—offering in every respect the most perfect agreement with the corresponding part in Grenville "eozoonal" Ophite*. The flocculent coat closely resembles that which has been described as characteristic of the latter rock: it varies from a mere film to a covering of considerable thickness, a granule often having half of its mass flocculent and its other half composed of translucent serpentine, both varieties being clearly modifications of each other. An example from Lisoughter, magnified 210 diameters, is represented in fig. 9,

* In addition to the specimens from Lisoughter, at which place we collected by far the finest examples exhibiting the "proper wall," we have detected this part in Ophite from Barna-oran and Glanochan.

Plate XIV., which shows the layer flocculent here and fibrous there: in the latter state the constituent aciculi are generally parallel, and in one place divergent*. Such examples clearly form independent and decisive testimony in favour of the conclusion we have come to with respect to the corresponding structural modifications presented by the granules of serpentine in Grenville Ophite—that they are allomorphic conditions of one and the same substance†.

With respect to the cases of isolated rods, and other modifications of the asbestiform layer, Dr. Carpenter has incidently mentioned that this part "is often thrown off by the disengagement of gas in the process of decalcification"‡. Instances of the kind have occurred to us in the specimen presenting the double layer: loose fibres are seen hanging on the free side of the outer one; and the innermost is for a considerable extent separated from the surface of the granule. We have also seen portions of the flocculent coat lying loose in the decalcified passages, and others raised above the plane of the section. At one time we were disposed to believe that decalcification, likewise internal movements which the rock has evidently undergone, as well as mechanical action consequent on breaking, grinding down, and otherwise preparing specimens for examination, had mainly contributed to produce the cases under notice; but we are now more inclined to consider them for the most part to be the result of other agencies.

It has been made clear that Serpentine is transformed into both the asbestiform layer and the flocculent coat, and that the former of these epigenes is converted into the latter. Was the process elaborated solely during some remote "primordial" period? Had the Grenville Ophite precisely the same structure it now possesses previously to the deposition of the rocks transgressive to it§? Has it remained chemically and structurally unaltered during the immensity of time which has intervened between the Potsdam (Cambrian) period and the present epoch? We are certainly strongly indisposed to answer in the affirmative to these questions. For why may not pseudomorphic, allomorphic, and other metamorphosing actions, induced by heat, pressure, electricity, gaseous and hydrous permeations, have been going on throughout all such time, more or less changing the Serpentine into flocculent matter, transferring the latter from the granules, and replacing it by their imbedding calcite, or intermixing it with the latter body, or variously substituting the chemical constituents of the Serpentine by their isomorphous compounds? These remarks express our hypothesis as to the changes which have been and are being effected in the essential minerals of "Eozoonal" Ophite, and we believe that it

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* So many instances have occurred to us, showing the changes mentioned in the text, that we could readily fill a Plate with them. We could have shown much finer examples of the asbestiform layer; but the one selected for illustration has been given because it shows, what is rare, the parallel and divergent aciculi associated on one granule.

† Professor Tennant has kindly presented us with a beautiful "moss agate" of transparent chalcedony, enclosing a number of vermicular bodies, variously knotted, which appear to be composed of yellowish ferruginous matter; in some cases they are completely invested with a dense crop of subparallel acicular crystals, seemingly of the same substance, which penetrate the chalcedony, and form a well-defined coat remarkably uniform in thickness (see fig. 16, Plate XV.). This case is a proof that certain substances shoot out from the surface of the body they form, as crystals, and, as such, penetrate a dissimilar surrounding medium, in a fluid, gelatinous, earthy, or otherwise yielding condition. A similar origin might with some reason be advanced to account for the aciculi on the granules of Serpentine; but we regard the conclusion already adopted as too clearly established to be induced to entertain any other.

‡ Intellectual Observer, vol. vii. p. 292.

§ We allude to the Potsdam sandstone, beds of which occur, both in Canada and in the northern parts of the State of New York, unconformably overlying highly contorted Laurentian rocks, and composed in many places of pebbles of the latter in their metamorphosed condition (see Geology of Canada, p. 96).

is sustained by many of the pseudomorphic phenomena made known of late years by Bischof, Breithaupt, Blum, Daubrée, Delesse, Fallou, Fournet, Müller, G. Rose, and others.

We offer this hypothesis to explain the intermixture of flocculent matter and calcite, which occurs so commonly in the so-called skeleton of "*Eozoon*," and the change of the surfaces of its "chamber-casts" into chrysotile and flocculent matter; also to account for the occasional absence of the latter two substances from the surfaces of the "chamber-casts," and their replacement by calcite: in short, we offer it in explanation of most of the cases of isolated *aciculi*, *rods*, *bundles*, and *patches* of the asbestiform layer and the fillings in of their separating spaces by calcite.

## V. "*Canal-System*" *of* "Eozoon Canadense."

Although feeling it necessary to relinquish the idea of the "asbestiform layer" having been originally an organic structure, we still adhered for some time afterwards to the foraminiferal origin of Ophite. But having made, as we conceived, an important rectification in the *diagnosis* of "*Eozoon Canadense*," we naturally felt ourselves stimulated to endeavour to elucidate the "canal-system," which it was considered had in certain instances been confounded with "stolon-passages."

It is unnecessary for us to give a history of our investigations into the speciality now entered upon; suffice it to say that the longer we examined the more our opinions became unsettled. Something new was continually turning up to the prejudice of the belief we had firmly and tenaciously adhered to; so that at last we found ourselves under the necessity of completely abandoning a point which had often proved a sheet-anchor whenever either of us was losing ground in our mutual discussions*.

Lying in the decalcified passages of both Canadian and other varieties of "eozoonal" Ophite, of the Connemara variety especially, there are frequently seen irregularly shaped "amorphous masses" of a mineral substance slightly compact in texture, of a milk-white colour, and lustreless like starch. Neither Dawson nor Sterry Hunt has alluded to them; and Carpenter, by whom they appear to have been overlooked at first, has only briefly described the Canadian examples in his last paper, published in the 'Intellectual Observer.' He finds them "to consist in some instances of parallel lamellæ, disposed like the leaves of a book, and in others of solid bunches of rounded filaments, reminding one of a sailor's 'swab.'" The Canadian examples are apparently more compact in texture than the Irish. When detached and crushed, a quarter-inch object-glass discloses in the former a more or less granular, and in the latter a somewhat fibrous structure.

Besides the foregoing, there are present, especially in Grenville Ophite, the simple and branching structures noticed in the early part of this memoir, or, as they have been named, "definite shapes,"

* As soon as we had become fully convinced that all the parts of "*Eozoon Canadense*" were of mineral or crystalline origin, we announced the circumstance in one of the weekly periodicals, promising at the same time to lay before the public at an early opportunity the various evidences and considerations which sustained us in our views. (See 'Reader,' June 10, 1865, p. 660.)

which "differ remarkably in size and form," being caulescent, scopiform, ramose, dendritic, claviform, or sheaf-like, and resembling in many respects certain cryptocrystalline aggregations known to mineralogists. They occur in immediate contact with the "chamber-casts," rising directly out of them, occasionally resting against the asbestiform layer, likewise seemingly in no way connected with anything, being in appearance isolately imbedded in the calcite of the septa*. In general their physical characters have a resemblance to those of the "white amorphous masses," excepting that they are somewhat more compact, and have a lustre and colour, especially in their centre, approaching to the translucency and green tint of the "chamber-casts."

Comparing the "amorphous masses" with the "definite shapes," there is certainly considerable dissimilarity between them; nevertheless the more examples we examined, the more we felt ourselves constrained to agree with Dr. Carpenter that both are *modifications of one type*†. But as regards their *origin*, we are under the necessity of entirely discarding the opinion which ascribes it to organic structures.

Previously, however, to going into this question, we deem it right to show that similar bodies, more or less agreeing with the "amorphous masses" and "definite shapes," are not uncommon as imbedded crystalline aggregations. The subject hitherto has received but little attention, all that is known of it being confined to a few papers which seem to have attracted scarcely any notice.

As far back as 1813 and 1815, Dr. Macculloch brought under the notice of the Geological Society some singular vermicular "forms in which chlorite is disposed," occurring in chalcedony and quartz‡; and in 1849, Francis Alger briefly described some similar "imitative shapes" of mica enclosed in crystals of quartz from Vermont, which, had they occurred in "eozoonal rock," would have been taken for casts of tortuous canals§. Native metals, notably copper and silver, likewise metallic oxides, are well known to occur as imbedded arborescences||. The Museum of Trinity College, Dublin, contains a beautiful arborescent example of native silver, imbedded in calcite, strikingly resembling the dendritic ramifications in Grenville Ophite; and there is now before us a singularly apposite specimen, of a less complex character however, for which we are indebted to Dr. Frazer of Dublin, consisting of slender simple as well as branching stems of pyrites, imbedded in the same kind of matrix. But it is from decalcification that the most important results may be expected to be obtained in our favour. Many of the examples of the so-called "siliceous skeleton," got by M. Alphonse Gages from various rock-

* In polished specimens of Grenville Ophite, both the "amorphous masses" and the "definite shapes" may with a good pocket-lens often be detected lying imbedded in the calcite of the septa, from which they are well distinguished by their milk-white appearance.

† See 'Intellectual Observer,' vol. vii. pp. 293, 294.

‡ Trans. Geol. Soc. 1st ser. vol. ii. pl. 36. figs. 2 & 3; also vol. iv. pl. 27. fig. 1.

§ American Journal of Science, 2nd ser. vol. x. pp. 14 & 15.

|| Most specimens of the kind seen in cabinets are partially or wholly decalcified.

specimens which he digested, are, in our opinion, homologous to the "definite shapes"*. Pieces of impure "primary" marble from Barna-Oran, Connemara, treated in the same way, have yielded to us numerous aggregations of crystals apparently belonging to actinolite. Another marble of the like kind, from a neighbouring locality, contains irregular lumps, having a lamello-prismatic structure, which appear to be diopside. A very impure "primary" limestone, from Donegal, containing large crystals of a brown mineral, apparently Epidote, is filled with prismatic masses, the prisms being either parallel or radiating. These examples have certainly no resemblance to the "definite shapes;" but it will shortly be seen that there is a relationship between the former and certain representatives of the latter occurring in different varieties of "eozoonal" Ophite.

The so-called "Moss-agates" often contain beautiful arborescent and foliated forms. The specimen already noticed contains a number of thickish vermicular shapes, seemingly composed of hydrous peroxide of iron: their branchings and anastomosings, amidst a mass of transparent chalcedony, forcibly remind one of some of the simplest of the "definite shapes." We have also in our possession a beautiful specimen, obtained along with a large number collected at Oberstein, which is crowded with slender cylindrical dendritic ramifications, red, green, and yellow, evidently all hydrous oxides of iron: several of these so decidedly resemble the more complex structures in question as to surprise us that no one has suggested the possibility of their identity of origin. For our part, we unhesitatingly accept this last case as proving that the so-called "canal-system" of "*Eozoon Canadense*" is a phenomenon of "imitative crystallization."

Perhaps none of the imbedded crystallizations we have brought forward agree chemically with the "definite shapes." Those which are most nearly allied to them in this respect do not present their identical form. There is a case, however, as yet unnoticed, against which such an objection cannot be urged—namely, metaxite from Reichenstein. This mineral, which occurs imbedded in saccharoidal calcite, crystallizes in ramose and dendritic forms of a pale-green or whitish colour, opaque or somewhat porcellanous, and compact or fibro-foliaceous in texture. The crystallizations occur both erect and spreading: our largest specimen is about an inch in diameter; but they are found much less. One of our smallest, obtained by decalcification, is represented in Pl. XV. fig. 12, magnified 110 diameters. It is undistinguishable from some of the palmated dendritic "definite shapes" characteristic of Grenville and Connemara Ophite; and, according to Delesse's analysis, it is doubtless chemically identical with them†. We have therefore no hesitation in concluding that the so-called "representatives of the canal-system" of "*Eozoon Canadense*" are no other than crystallizations of metaxite, an allomorphic variety of serpentine.

Reverting to the "amorphous masses," Dr. Carpenter, while investigating the structure of "eozoonal" Ophite, undoubtedly passed

* See 'Philosophical Magazine,' 4th ser. vol. xvii. pp. 169–176.

† See analysis of metaxite in a preceding page.

beyond the lines reached by others. He made discoveries which, followed to their legitimate issue, clearly show that the explanation advanced by Dawson and Sterry Hunt as to the filling in of the "chambers" and other presumed sarcode-encasements is at fault.

The "amorphous masses," as will be seen by referring to fig. 17, Pl. XV., occasionally assume a prismatic structure, with the prisms closely adherent to one another laterally. We presume that this example, if not strictly identical with, is closely related to those which have been described as consisting of "parallel lamellæ disposed like the leaves of a book," or of "solid bunches of rounded filaments, reminding one of a sailor's 'swab.'" The "nature" of these bodies "was for a long time a puzzle" to Dr. Carpenter; but, doubtless perceiving that they are often compact and solid—that their "parallel lamellæ" and "rounded filaments" have not been bounded by walls, the conclusion is drawn that they are "are in each case but a mere aggregation of the elementary forms of sarcode-prolongation:" in what way will be seen immediately. Thus the same difficulty or puzzle meets us here which we encountered when considering the nature of the asbestiform layer, numerous examples of which, it will be recollected, showed no appearance of its presumed pseudopodial tubules having been separated by parietal partitions.

Now, considering that, on the foraminiferal view, all the parts of "*Eozoon Canadense*," with the exception of the "intermediate skeleton," must be regarded as the result of infiltration, mechanical or chemical, it is obvious that the mode in which this process has been effected is of primary importance in the main question under discussion; we may therefore be excused accepting any explanation of the process, unless it accounts for the present appearances of all the presumed sarcode-encasements.

Dr. Dawson and Dr. Sterry Hunt's explanation, although simple, scientific, and supported by numerous cases among existing and fossil foraminifers, becomes a failure if carried beyond the "chamber-casts" and the ramose or branching representative of the "canal-system." Dr. Carpenter has proposed another, which, although intended to account for the usual appearances of the "amorphous masses" and the "asbestiform layer," has failed in our opinion more signally—no known fact or principle of geology, mineralogy, palæontology, and chemistry being known, as far as we are cognizant of them, to support the view that "the siliceous mineral found its way into the cavities of the Eozoon, not by mere *mechanical infiltration* occasioned by pressure from without, but by a process of *chemical substitution*, which took place, particle by particle, between the sarcode-body of the animal and certain constituents of the ocean waters, *before* the destruction of the former by ordinary decomposition"*.

* The italics are Dr. Carpenter's. This hypothesis is more fully given in the *Intellectual Observer*, vol. vii. p. 290, and p. 294 (upper paragraph); also in the *Proceedings of the Royal Society of London*, vol. xiii. p. 546. Having never seen any account of the suggestion made by Professor Milne-Edwards "with regard to the infiltration of fossil bones and teeth, in the course of the discussion which took place on the Abbeville jaw," we are necessarily unac-

We feel ourselves next called upon to show that the "amorphous masses" are purely of mineral or inorganic origin.

The Canadian examples of these bodies are remarkably uniform in possessing no more than a rude divisional structure and a starch-like dullness; but occasionally they present a different appearance. Referring again to figure 17, the specimen which it represents has a somewhat rhomboidal shape, a well-defined prismatic structure, and an incipient lustre: its prisms are for the most part parallel and closely adherent to one another; but at the sides they separate, diverge, or curve outwardly, thus approximating to the scopiform and sheaf-like "definite shapes"*.

In these compact specimens the divisional structure is so essentially mineral, such as may be seen in tremolite, kyanite, wollastonite, scapolite, &c., as to prevent any mineralogist believing otherwise than that it is in no respect related to anything organic: and the belief is powerfully supported by the fact that specimens approximately similar, both in form and structure, are common, as mentioned before, imbedded in some of the primary calcareous marbles of Connemara and Donegal; nay, it may be regarded as demonstrated by the occurrence of similar prismatic specimens which we find lying adjacent to grains of chondrodite in saccharoidal calcite.

The "definite shapes" are essentially Canadian, since rarely are they detected in Ophite from other places. For a long time our decalcifications of Connemara specimens of this rock yielded no more than a few imperfectly formed rod-like and caulescent bodies, which differ mainly from the simplest of the Canadian forms in having a more crystalline appearance. We have been rewarded, however, just before finishing this paper, by the discovery in Ophite from Glanochan and Lisoughter of perfectly genuine examples—complex ramose and dendritic forms, with more or less cylindrical stems and branches—which occur crowding the decalcified passages. Both in appearance, and circumstances of occurrence, they cannot be distinguished from ordinary examples in Grenville Ophite†; and they closely resemble those figured by Dawson‡, Carpenter§, and Rupert Jones‖.

Nothing of the kind has yet occurred to us in any varieties of Ophite we have examined from the Isle of Skye, India, Donegal,

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quainted with it; but possibly its bearing has been misunderstood, as certainly is Dr. Sterry Hunt's opinion (thus stated by Dr. Carpenter), "that the siliceous infiltration of the cavities of the Eozoon was the result of changes occurring *before* the decomposition of the animal." (See Proc. Roy. Soc. London, vol. xiii. p. 546.)

* Another specimen before us approaches still nearer to the sheaf-like forms by having *all* the prisms, which are somewhat apart, ranged in two divergent series.

† Whatever doubts may have hitherto existed in the mind of some as to the Connemara Ophite being "eozoonal," the existence therein of the "definite shapes" and the "proper wall" completely identifies it with that from Grenville.

‡ Quart. Journ. Geol. Soc. vol. xxi. pl. vii. fig. 4.

§ *Ibid.* pl. viii. fig. 5 *b*, *c*.

‖ Popular Science Review, vol. iv. pl. xv. figs. 6 and 7.

Bavaria, and the State of Delaware. In the Skye variety, the decalcified passages exhibit, in addition to the "white amorphous masses," several thickish dendritic aggregations, composed of minute granules, which agree in colour, and apparently in composition, with the "chamber-casts"*.

The passages in the Indian Ophite contain a few ill-defined branching bodies of a somewhat crystalline appearance, along with a large number of six-sided tabular crystals, apparently of chlorite, which cross the passages in all directions†.

The Donegal Ophite contains an abundance of crystalline aggregations similarly situated—and, in addition, a number of plates, some laminated, and others formed of intersecting crystals, which appear to correspond to the Canadian and Connemara "amorphous masses"‡.

The Delaware Ophite is somewhat different, inasmuch as the crystalline aggregations and amorphous masses are oftener closely associated than usual; and the former are frequently masked with the latter. The crystals of the aggregations sometimes assume a dendritic disposition; but they are more generally interlacing, and thus form thickish reticulated plates. A number of associated passages are occasionally nearly filled with amorphous (*i. e.* flocculent) matter, broken up into parallel or divergent plates, with a loose texture§.

In a variety of Ophite from Bavaria, a specimen of which has been obligingly presented to us by Sir Charles Lyell, Bart., the decalcified passages contain a large number of white crystalline tufts, more or less resembling those characterizing the Donegal and Connemara rocks. They are unaccompanied, however, by crystals of mica,

* In the Isle of Skye Ophite, the "chamber-casts," which affect a sort of lamino-acervuline arrangement, have the ordinary form and mode of attachment, and consist of a dull-white or pale-green serpentine, or possibly pyrosclerite: they are small, and much crowded together, resembling in these respects the granules in some of our Lisoughter specimens. The decalcified passages, in addition to the "amorphous masses" and "dendritic aggregations" noticed in the text, are filled with very minute filiform crystals, similar to those occurring, as will be seen hereafter, under the same circumstances in Grenville and Connemara Ophite. The "chamber-casts" are occasionally invested with the "proper wall, which consists of both parallel and divergent aciculi. Hence no doubt can be entertained as to the "eozoonal" character of the Isle of Skye Ophite.

† The "chamber-casts" of this variety are connected as ordinarily, and arranged acervulinely, but aggregated into various groups, differently coloured, a group consisting of either green, blue, buff, or white granules of serpentine (?). In some groups the granules are unusually small. The various colours give a beautiful appearance to this Ophite.

‡ The plates occasionally consist internally of serpentine, more or less split up, and coated with white crystals. Nay, the serpentine of the "chamber-casts" may be seen similarly divided, also changing into a substance resembling that of the "amorphous masses."

§ The asbestiform investment, which the "chamber-casts" or granules of the Delaware Ophite usually display, has already been noticed. The latter, composed of a yellowish-coloured serpentine (?), are imbedded in saccharoidal calcite. They are more irregularly shaped and of larger size than usual, often completely separated and wide apart, frequently attached to one another by long neck-like connecting pieces, and acervuline in their arrangement. We are indebted to the Rev. Dr. Haughton for this variety, as well as that from India.

pyrosclerite, chlorite, &c.; but associated with them are numerous "white amorphous masses" of a granular texture—some vitreous, and others opaque. The tufts are aggregations of stout, tapering, slightly translucent crystals, which divide or rudely radiate, strike off from points on the surface of the "chamber-casts," spring out of the "amorphous masses," or lie imbedded in the residual calcite of the passages. The crystals are not so slender as those in the Connemara Ophite; nor do any of them, individually or aggregately, show such a decided tendency as those of the latter rock to simulate the Canadian dendritic ramifications*.

If so few "definite shapes" occur in the Connemara Ophite, they are undoubtedly well represented by numerous crystalline aggregations, which, together with the "amorphous masses," occupy the decalcified passages, often to the almost entire exclusion of the calcareous matter proper to the "skeleton" or septa†. The crystals, which are acicular, and separated, or in contact, variously diverge, radiate, or intersect one another, shooting athwart the passages in all directions. The aggregations may be completely followed into the true "definite shapes," already noticed, through a variety of intermediate forms‡.

The conformity between the Connemara and Grenville varieties of Ophite, declares Dr. Carpenter, "is so close as to leave no doubt on my mind as to the organic origin of the former." "I find, in place of a continuous asbestiform layer covering the segments§, long straight bundles of asbestiform filaments radiating from them. What is the import of these—whether they represent a part of the original structure of the animal, or are (as I am disposed to suspect) a product of subsequent metamorphism—is a point which must be reserved for further investigation"‖. If our interpretation of the supposition contained in this passage be correct, it implies that, in Dr. Carpenter's opinion, the crystalline aggregations were originally "definite shapes"—internal *casts of tubular passages*—which have

* This Ophite presents a somewhat unusual appearance, inasmuch as the "chamber-casts" are aggregated in the form of comparatively thin plates, which frequently anastomose, producing a sort of network, its meshes, which are wide, being the "calcareous septa." Nor are the "chamber-casts" in general so neatly segmented as in other varieties of Ophite. They are composed of two kinds of minerals: one, of an impure leek-green colour, displays, on fracture, a lamellar cleavage, with pearly planes; the other is darker, often quite black. The former is possibly pyrosclerite, and the latter may be impure loganite. They are occasionally coated with a forest of short slender diverging crystals, which might be taken to represent the "proper wall."

† See Pl. XV. fig. 13. In this example the crystalline aggregations are less numerous than usual, and they are remarkably free from the "white amorphous masses."

‡ We find these aggregations to be soluble in hot sulphuric acid, like the granules and other "eozoonal" parts; from which it may be inferred that they are composed of a hydrous silicated magnesia, and consequently cannot belong to a variety of pyroxene or augite. They probably represent another allomorph of serpentine, and are in all probability a more crystalline form of metaxite.

§ The asbestiform layer, however, as will have been seen, does exist in Connemara Ophite.

‖ Intellectual Observer, vol. vii. pp. 297, 298.

lost their original forms (*cylindrical, flattened, or branching*) through superinduced crystallization. If such an hypothesis be admitted, the imbedded crystalline aggregations, with which many of the Connemara, Donegal, and other saccharoidal marbles are loaded, may be considered, with equal reason, to be the metamorphosed or crystallized representatives of the "canal-system of *Eozoon*." Another consideration may be adduced: Ophite, consisting of dark-green serpentine, or more probably loganite, is of common occurrence at Lisoughter, intermixed with, and passing into white or yellowish crystalline tufts, averaging an inch in length. We find the latter to be structurally and, to all appearance, chemically identical with the micro-crystalline aggregations which occur in the true "eozoonal" variety from the same place.

Now we would ask any mineralogist to make himself acquainted with the known modifications of the "canal-system" of foraminifers*, and to conceive the possibility of such modifications assuming characters identical in every respect with ordinary scopiform crystallization—precisely such as are met with among zeolites, kermesite, and a number of other minerals†. Let him compare the latter with the presumed metamorphosed representative of the "canal-system," given in figure 14, Pl. XV., magnified 210 diameters, of which the original occurs in a decalcified specimen of "eozoonal" Ophite from Lisoughter; and let him consider that this is a fair example of what he is required to believe was once "an internal cast of an arborescent 'cluster' of passages originally occupied with sarcodic prolongations."

The dissimilarities existing between the "definite shapes" and the crystalline aggregations are simply such as obtain among a number of minerals‡. Aragonite differentiates itself in a similar manner, being crystallized or coralloidal according to circumstances§. Native silver is perhaps more in point, as beautiful dendritic forms, some composed of microscopic crystals, others of the metal in the amorphous state, frequently occur imbedded in calcite.

But admitting in the widest sense the dissimilarities which have been noticed, they nevertheless do not, in our opinion, weaken in the

* Numerous examples are given in Carpenter's 'Introduction to the Study of the Foraminifera.'

† Fossil corals, echinoderms, and shells may have their skeletons replaced by dolomite, calcite, selenite, and other mineral substances; but we confess to be unacquainted with a single instance in which a portion of this part has become transformed into crystals passing beyond its surface. As a case in point, the corals occurring in the dioritic rock of Rothau, in the Vosges, are changed into hornblende, garnet, and axinite, without any alteration of form. (See 'Annales des Mines,' 5e série, vol. xii. p. 318.)

‡ To show one of the principal differences referred to, we may instance the example under fig. 3 in the "tinted plate" appended to Dr. Carpenter's paper in the 'Intellectual Observer, and the one represented in our figure 14, pl. XV.

§ Beudant has given, in his 'Minéralogie,' p. 49, a representation of a coralloidal form of Aragonite, which strikingly resembles the "representative of the canal-system," given by Dr. Carpenter in the plate cited in the last note. Of course the former may have been developed in a fluid medium,—a condition, however, to which we do not attach much importance.

least the view we have taken as to the origin of the "definite shapes;" rather the contrary, inasmuch as if it be admitted that these parts represent an essential structural element, like the "canal-system" of certain existing foraminifers, it follows that what are considered to be the fossilized remains of the system in Ophite from the other side of the Atlantic ought to be present in that occurring in other countries, provided the two rocks agree in other essential respects. Now the "definite shapes" imbedded in the calcareous "septa" of the Canadian Ophite are relatively situated just as the crystalline aggregations are in the Irish and other varieties.

Reviewing all that has been brought forward in connexion with the subject before us, what other conclusion can we come to than that it is of crystalline origin*? Lastly, the "very remarkable differences in size and form" which the "definite shapes" display is opposed to the idea of their being representatives of the "canal-system,"—considering that Nature generally adheres to uniformity of plan in essential parts, even amongst the lowest animal organisms, and, more especially, that no such "very remarkable differences" have been seen to characterize the "canal-system" of any known foraminifer, fossil or recent.

### VI. "*Stolon-passages.*"

No one having examined specimens of the various kinds of "eozoonal" Ophite can read the papers by Dawson, Carpenter, and Rupert Jones, without arriving at the conclusion that certain simple forms, which they have regarded as "casts of stolon-passages," are only modifications of other structures associated with them. We possess some remarkably fine specimens of the rock from Lisoughter, in which may be frequently seen, not only a long scopiform tuft, composed of divergent or subparallel crystals, forming a union between two "chamber-casts" or granules of serpentine, but occasionally a well-defined plate holding the same office: in some instances as many as three separated parallel plates are seen lying together. The latter have frequently a granular texture, like that of the "white amorphous masses;" occasionally, however, they are somewhat compact, slightly translucent, and of a greenish-white colour. Thus, "stolon-passages" are formed by representatives both of the "definite shapes," and the "chamber-casts." Fig. 13, Pl. XV. shows a decalcified specimen from Lisoughter, magnified 25 diameters times, containing a well-marked case of three adjacent granules united by means of crystalline tufts; also another (in the middle of the lower part of the figure), consisting of two granules connected by three slightly granular plates: this last is additionally illustrated in fig. 15, Pl. XV., magnified 120 diameters. One of these granules is con-

* Canadian "eozoonal" rock, it would appear, does not always differ, in its "representatives of the canal-system," from Connemara Ophite, inasmuch as Dr. Dawson notices specimens in which there is a "development of certain dendritic crystallizations." Are these in place of the "definite shapes"? (See Quart. Journ. Geol. Soc. vol. xxi. p. 68.)

nected with another to the left by an elongated neck-like constriction composed of their own substance—serpentine.

Undoubtedly there also occur bodies having no relation to either the "definite shapes" or the "chamber-casts." We, too, have seen examples in Grenville Ophite "of a mode of communication, of the chambers when they are completely separated, which," *in certain aspects, appears* to "have its exact parallel in *Cycloclypeus*:" it consists of thickish, pale-grey, translucent, parallel-sided pieces, with a subdued silky lustre, stretching across the decalcified passages, and connecting opposite "chamber-casts," as in Pl. XIV. fig. 10, magnified 105 diameters. When these pieces were first detected, we had no doubt whatever of their being true "casts of stolon-passages;" but afterwards, on a rigid reexamination, we found every one of them to be nothing more than a flattened or table-shaped crystal of what appears to be pyrosclerite* placed edgeways or perpendicular to the plane of section, and wedged in between two granules. The total distinctiveness of the former from the latter, a circumstance inconsistent with their being "casts of stolon-passages," is unmistakeably marked by their colour, lustre, and well-defined terminations. It thus becomes evident that the position of these crystals had misled us (and we may be allowed to suggest this to have been the case with other investigators), and that certain of the "narrow passages" which have been regarded as "*exactly* corresponding to those in *Cycloclypeus*" are not so; for instead of being cylindrical, like the "canals" represented in figures of this foraminifer, they are broad, *flat*, and parallel-sided. In numerous instances the crystals of pyrosclerite extend only partially across the passages, "forming mere tongues," which have been misconceived to "represent corresponding extensions of the sarcode-body"†. When two or more crystals are associated and lie parallel to one another, or when a single crystal is divided by cleavage-partings, we are strongly reminded of the example represented in the 'Quarterly Journal of the Geological Society,' vol. xxi. pl. vii. fig. 2. In some cases, a "white amorphous mass," rudely laminated, as in Pl. XIV. fig. 11, magnified 105 diameters, is interposed between a crystal and a granule, linking the two together.

We have also seen similarly flattened crystals fixed in the calcite of incompletely decalcified passages. Crystals of the same mineral, occurring under precisely similar circumstances, characterize the Ophite from Glanochan and other Connemara localities; also numerous tabular crystals of mica. Crystals of chlorite, occupying the same situation, occur numerously in the Indian Ophite.

* Pyrosclerite or white chlorite, a hydrous silicate of magnesia and alumina, occurs both amorphous and crystallized. Dana describes it as "hexagonal(?)," and having a "perfect basal cleavage." The crystals noticed in the text might be considered to be modified rhombic tables: they are translucent, of a pale greenish colour, have a weak lustre, and show a transverse lamellar cleavage. We took them at first for crystals of some kind of mica; but their lustre is not sufficiently glistening. Amorphous pyrosclerite, in large lumps, occurs near the Barna-Oran Ophite-quarry (Connemara). This variety was analyzed by one of us a few years ago. (See British Association Report for 1860, Sect. pp. 71, 72.)

† Carpenter, Quart. Journ. Geol. Soc. vol. xxi. p. 62.

### VII. " *Sarcode-chambers.*"

As already noticed, the granules considered to represent these parts are simulated by wavellite. The same may be said of prehnite and several other minerals. The imbedded aggregations of garnet and leucite may be regarded as modified examples. We often find a close resemblance between them and the concretions of native copper in porphyry from Canada, of olivine in lava from the Ponza Islands, and of small zeolitic kernels in amygdaloidal trap. The crystalloids of pargasite, whether imbedded in calcite or in wollastonite, are even closer parallels. The isolated grains of coccolite, diopside, and other minerals, in Tyree marble, are strictly analogous to the large granules of serpentine isolately dispersed through the calcite of some specimens of Ophite from Lisoughter*. Chondrodite frequently affords cases identical in every respect with the " chamber-casts:" specimens of this mineral from New Jersey are common in a finely granular state: the grains, which are imbedded in calcite, press closely against one another, their individuality being defined only by faint segmentations; or, lying more or less apart, they are either completely separated or attached to one another by stolon-like necks of varying lengths.

The characters and circumstances of condition of chondrodite, when it occurs as just mentioned, are so similar to those displayed by serpentine in some varieties of " eozoonal " Ophite, especially the one examined by us from the State of Delaware (also the variety represented in figure 13, Pl. XV., from Lisoughter, in which the granules are large, often isolated, and unusually wide apart), that it is impossible to resist believing in the complete genetic identity of the two minerals. Nay, carry the examination as far as it is possible, we feel certain that the result will be a full and unqualified surrender to this belief. If, as Dr. Dawson observes, the granules of serpentine in Grenville Ophite have "no appearance of concretionary structure," certainly the same must be said of the grains of chondrodite, pargasite, and coccolite in the precited cases. Moreover, if it be admitted that the former are " casts of sarcode-chambers," the same admission must be made with respect to the latter.

Sir William Logan has noticed two remarkable varieties of "eozoonal rock," identical with Ophite in structure, but differing from it mineralogically. In one of them, occurring at Burgess, the granules or plates are composed of dark-green loganite, and the intervening spaces, or matrix, of dolomite; while in the other, from the Grand Calumet, the former consist of "crystalline white pyroxene" or diopside, and the latter of calcite. Sir William remarked in 1859, with reference to these two varieties, that if they "are to be regarded as the result of unaided mineral arrangement, it would seem strange that identical forms should be derived from minerals of such different composition." Hence, also observing their structure to have a resemblance to that of *Stromatopora rugosa,* he was led to suppose both varieties to represent a fossil. (See Geology of Canada, 1863, pp. 48, 49; and Quart. Journ. Geol. Soc. vol. xxi. p. 48.) At first sight, we admit, there is some reason for this conclusion; but when it is considered that serpentine and diopside are mutually pseudomorphous, and that

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* Specimens of this rock from other places in Connemara, after having been immersed for a few hours in dilute hydrochloric acid, are often resolved into a mass of isolated granules scattered over the bottom of the vessel.

dolomite and calcite are isomorphous, the mineralogical differences presented by "identical forms" become at once scientifically explained. If the opinion of Gustav Rose be correct, that "serpentine is always a product of alteration" (see Chem. and Phys. Geol. vol. ii. p. 417), it would not surprise us that what have been called "chamber-casts" will, in some cases, be found to consist of pyrallolite, chondrodite, or "green pyroxene" (? pargasite), as, inaddition to diopside, these minerals, in a finely granular state, arranged in layers and imbedded in calcite, are often mingled with the serpentine, or its varieties, of this rock in Canada (see Geology of Canada, 1863, pp. 26, 465, &c.). We may here take up a point alluded to in the early part of this memoir. In all the specimens of Cornish Ophite which we have examined, nothing like "eozoonal" structure has occurred to us, except in a variety formed principally of saponite. This mineral, in one of our specimens, is here and there associated with calcite, and in these places it shows a granular structure as well developed as that characteristic of serpentine. An object-glass magnifying 60 diameters, exhibits the granules as true "chamber-casts," generally spherical in shape, but occasionally elongated or cylindrical like those which have occurred to us in "eozoonal" Ophite from Pennsylvania. They are aggregated in clusters, and defined by deep constrictions or slight segmentations. They also occur attached to one another by stolon-like necks. As yet we have failed to detect the asbestiform layer and the "definite shapes." Saponite, if Klaproth's analysis of it be correct, may be regarded as an allomorph of pyrosclerite; or, as it contains more water than is allowable in such a view, it may be a pseudomorph of some other ophitic mineral. But, whatever may be the origin of these granules of saponite, we leave the question for further investigation.

With regard to the arrangement of the granules of serpentine in Ophite, the same differences which they display in this respect obtain with those of pargasite and other minerals. Crystalloids of the one named occur irregularly or "acervulinely" scattered through a matrix of saccharoidal calcite; but they are also known to occur arranged with more or less parallelism in the same base. And, according to Sterry Hunt, Canadian Ophite contains chondrodite in grains which are sometimes so disposed as to mark "the stratification of the rock" *. It is also added that apatite occurs "with the same banded arrangement."

Connemara Ophite is certainly in general laminated or banded in a very irregular wavy manner, and difficult to understand, often presenting the most singular and beautiful delineations. In the early stage of our investigations, we considered the question as to the origin of the phenomenon to be set at rest on the view that the rock had resulted from the irregular hummocky growth of "eozoon." But it so happens that the same kind of lamination frequently characterizes the gneissoid limestones of Connemara. Sir William Logan has given a representation of a precisely similar case, occurring in the Laurentian rocks on the river Madawaska (see Geology of Canada, 1863, p. 27), which consists of *highly contorted* thin layers of gneiss, included in a thickish bed of limestone, lying between masses of evenly laminated gneiss.

From the fact that certain minerals, when imbedded in rocks, often affect a definite or parallel arrangement, which is remarkably the case in graphic granite, globular diorite (napoleonite), &c., it is conceivable that some of the more remarkable cases of lamination presented by Grenville Ophite, instead of being depositional, are the result of segregation. But whatever view may be taken as to the cause of the phenomenon in general, it is quite clear, from the Madawaska and the like instances, that such a cause is in no way connected with organic agencies.

Certain rocks, both eruptive and sedimentary, exhibit concretionary or segregated forms simulating the granules of serpentine. Refer-

* Geology of Canada, 1863, p. 465.

ence has already been made to the cupriferous porpyhry of Canada, some zeolitic traps, and the olivine-lava of the Ponza Islands. We shall next refer to a remarkable deposit of sedimentary origin.

Few rocks in the entire series of geological formations present anything like the singular configurations which characterize the Permian Magnesian Limestone of the neighbourhood of Sunderland*. In other parts of Durham, as along the coast from Ryhope to Hartlepool southward, and from Marsden to near South Shields northward, this rock has the ordinary lithological structure—earthy, or compact, occasionally oolitic, &c.; but in many places on both sides of the mouth of the Wear, it is more or less crystalline; and where this is the case, there are often exhibited the most remarkable forms—honey-combed, discoidal, mammillated, and hemispherical, coralloidal, stalactitic, reniform, globular, and botryoidal. Very frequently the amorphous and the crystalline varieties are intimately associated, the former serving as a matrix for the latter. Thus constituted, the rock often displays the most unusual appearances, especially where the amorphous kind is weathered out—resembling, as the case may be, massive courses of ruined masonry, reefs of petrified coral, or beds of brown-rusted shot and cannon-balls.

Like most sedimentary rocks, the Primary especially, the one under consideration has its beds often very much and continuously divided by joints, varying extremely in their distance from one another. The beds, in consequence of this divisional structure and the frequency of depositional partings, often occur as if consisting of huge quasi-rhombohedral blocks. And it frequently happens that the crystalline forms, wherever they are numerous in such masses, are seen to strike indifferently from the planes of jointing and the planes of bedding: hence it is, that dark-brown branching crystalline coralloids (imbedded in a lighter-coloured matrix) may be frequently observed striking inwardly from every face of a block.

Where the beds are not divided by jointing, large and small mammillary and stalactitic forms may often be seen shooting off, both *upwards* and *downwards*, base to base, from two adjacent planes of bedding, the law of gravitation having been altogether discarded by the mysterious agent which produced them.

From various analyses of the rock, it has been ascertained that the configurations are composed of carbonate of lime, and that the matrix consists (as is also the case with the associated ordinary limestones) of carbonate of lime and magnesia. It is therefore highly probable that the absence of the magnesian constituent in the configurations is not an original condition, but the result of some kind of segregative action: and it would seem that the agent which produced this result had gained admission into the very heart of the beds through their joints and depositional partings, indifferently

* These configurations were first described by Professor Sedgwick, in his classical memoir "On the Geological Relations and Internal Structure of the Magnesian Limestone," &c., published in the 'Transactions of the Geological Society of London,' 2nd ser. vol. iii. 1826–1828. They have also been described by one of us in the "Introduction" to the 'Monograph of the Permian Fossils of England,' 1850.

acting transversely to the planes of the one or of the other, thereby metamorphosing the rock to the extent of thoroughly crystallizing it, and even in many cases producing a lamination often honeycombed perpendicular to its bedding.

But what is of special importance, as bearing on the subject of the present memoir, is the complete similarity existing between many of the configurations, and the granules and plates of serpentine, in shape, mutual attachment, and arrangement.

Building Hill, near Sunderland, affords (at least this was the case some years ago, before it was converted into the People's Park) innumerable specimens of the globular and botryoidal kinds, which, when cleared of the earthy matrix, are perfect imitations, on a gigantic scale, of the "chamber-casts," in their form and "acervuline" arrangement*. We have given a representation in fig. 18, Pl. XV., of a specimen freed of its matrix, collected many years ago, without, of course, any reference to the question at issue. Its general resemblance to decalcified specimens of Ophite, where there is an association of " acervuline " and laminar " growths," cannot but be admitted to be most striking.

But not only do the configurations simulate the forms and arrangement of the granules and plates of serpentine; they equally simulate and illustrate the " definite shapes." Specimens may be procured presenting dendritic ramifications, or a sheaf-like divergence, or appearing like solid bunches of rounded forms, composed of carbonate of lime, and imbedded in or penetrating the calcareo-magnesian matrix, just as the hydro-silicated magnesian "definite shapes," and imitations of a " sailor's swab," occur in the calcareous septa of " eozoonal " rocks. Reduced to microscopic dimensions, many of them would resemble certain of the structures represented by Dawson †, Carpenter ‡, and Jones §.

### VIII. " *Intermediate Skeleton.*"

Already sufficient has been stated to show that this part is completely paralleled by the matrix of certain minerals. The saccharoidal calcareous gangues of chondrodite and pargasite closely correspond to the " skeleton," as it exists in " eozoonal" Ophite from the State of Delaware, and in specimens we have collected at Barna Oran and Lisoughter: in the rocks alluded to the septa exceed in width the diameter of the granules ‖. The matrix of bowenite from Rhode Island, and that of metaxite from Reichenstein, also the saccharoidal calcite of the coccolite marble of Tyree, may be adduced as other instances in point.

The part under notice passes into the layers and beds of saccha-

* An association of the kind is shown in the coloured plate accompanying Dr. Carpenter's paper in the 'Intellectual Observer.'

† Quart. Journ. Geol. Soc. vol. xxi. pl. vii. fig. 3 (*a*, *a*).

‡ *Ibid.* vol. xxi. pl. viii. fig. 5 *b*, and pl. ix. figs. 5 *a*, *b*, *c*, *d*; also 'Intellectual Observer,' vol. vii. " uncoloured plate," fig. 3.

§ Popular Science Review, vol. iv. pl. xv. figs. 5, 6, 7, and 8.

‖ Is not this the case occasionally in Burgess Ophite? its septa being " in some parts more than 3·0 millimetres in thickness " (Hunt, Quart. Journ. Geol. Soc. vol. xxi. p. 69).

roidal marble associated with Ophite in Connemara. In our days of implicit belief, we naturally considered that these masses were reefs of "eozoon," its "sarcode-chambers" having got filled with calcareous instead of hydro-silicated magnesian infiltrations—or that they were accumulations of its disintegrated "skeleton." But our subsequent decalcifications and microscopic observations completely failed in revealing the least vestige of foraminiferal structure. We detected imbedded crystalline tufts, more or less agreeing with those in the decalcified passages of Ophite, but no traces of "sarcode-chambers" or their "proper wall." We felt perplexed at this unlooked-for absence of confirmatory evidence: in those days, however, our scepticism was only dawning.

The "intermediate skeleton" of both Canadian and Connemara Ophite, when partially dissolved out, besides exhibiting the crystalline aggregations, shows what appears under a low power to be white granular matter scattered over its surfaces, but which, under a power above 100 diameters, is resolved into minute, short, slender, bluntish, filiform crystals, generally simple, rarely branching, twisting, leaning, erect, or crooked—in the latter state appearing as if unable to hold themselves in an upright position; they stand separated from one another, or are packed together, forming bundles or lumps—the latter semitransparent, and of a granular-crystalline structure. The lumps, like the "amorphous masses," often block up the decalcified passages; and they are intersected by well-developed cleavage-partings, which appear to agree with those of diopside. We have observed the filiform crystals disposed in lines, conforming to the cleavage-partings of their imbedding calcite; and in this way they form plates, which, from occasionally connecting opposite granules of serpentine, we have little doubt have been taken for "casts of stolon-passages." Alphonse Gages has evidently detected the same things in dolomite from Miask.

The filiform crystals, the bundles and lumps, and also the "amorphous masses" supposed to represent the "canal-system," as well as the occasional coassociation of crystals of pyrites and fragments of what appears to be titaniferous iron—the occurrence of all these bodies in the "skeleton" shows that this part is far from being "uniform and homogeneous" as conceived by Dr. Dawson. This point, however, we do not regard as of much importance; it is merely introduced to show that if the organic origin of the calcareous septa depended on the absence of foreign substances, their presence in these parts must be accepted as supporting the opposite view.

### IX. *Geological Considerations bearing on the nature of "Eozoonal" Ophite.*

There yet remains another class of evidences to be considered. Rocks more or less agreeing with "eozoonal" Ophite occur, not only in the Laurentian system, but in others representing widely separated geological periods. The "more abundant" masses of Ophite found in the "Quebec series" or Upper Cambrian system are apparently "eozoonal," being described as "granular" and "fine-grained"*. The Delaware Ophite has indisputably the essential characters of the type rock; and, considering that its locality lies somewhat in the direction of the strike of the "Quebec series" in eastern Canada, there is some probability of this variety being systemally contemporaneous with the former.

The Connemara Ophite is considered to be Lower Silurian by Sir Roderick Murchison and Professor Harkness; but there are reasons which weigh with us, as already stated, in assigning it to the Lower Cambrian period. With regard to the varieties from India and Bavaria, we are unable to offer any opinion as to their geological age. A "remarkable" Ophite, occurring in the Devonian system at Syracuse in the State of New York, is described as consisting of an "aggregation of grains,"—a character which leads us to infer that it is "eozoonal"†. The Isle-of-Skye Ophite, which unmistakeably possesses the leading features of the Grenville type, brings us to a much more recent systemal period, it being no other than Liassic!

The fact of "eozoonal rock" being a member of various Lower Primary systems is enough to throw considerable doubt on its presumed organic origin. The Devonian example at Syracuse, if it be of the same kind, is a still greater stumblingblock‡. But how are we to explain the presence of "eozoonal" Ophite among the Liassic saccharoid marbles of Strath, in the Isle of Skye§? The bare fact of the existence of such a rock, separated as its epoch is by several vast systemal periods from that occurring at Grenville, must be regarded as a conclusive argument against the view we are opposing. But when it is considered that the so called "Eozoon" has never yet been found except in *metamorphic* rocks—that there are

* See 'Geology of Canada,' 1863, pp. 248, 266, 611, and 824. The Laurentian or Grenville Ophite appears, in comparison with that belonging to the "Quebec series," to occur on a much less extensive scale, forming very subordinate portions in masses of pyroxene, and zones of limestone (*op. cit.* p. 25; Quart. Journ. Geol. Soc. vol. xxi. p. 50, &c.). Even the Connemara Ophite seems to be more abundantly developed and less fragmentary than the latter.

† See Vanuxem, 'Geology of New York,' vol. iii. p. 109; also 'Geology of Canada,' 1863, p. 635.

‡ If this Ophite is an "example of local metamorphism," and it possesses "eozoonal" structure, it may be held as another geological evidence totally subversive of the organic origin of the Grenville rock.

§ It is only fair to mention that Professor Harkness, to whom we are indebted for a specimen of the Isle-of-Skye Ophite, first brought this point under our notice, when he was with us in Connemara. But at that time, although Dr. Maculloch, as far back as 1819, had expressed himself "inclined to attribute the whole metamorphism of the Liassic beds of Strath to the influence of the Syenite" with which they are in contact (see 'Western Isles of Scotland,' vol. i. p. 331), we entertained considerable doubts, countenanced by Sterry Hunt's opinion that the hypersthenites around Lough Coruisk belong to the Upper Laurentian or Labrador system (See Silliman's Journal, 2nd ser. vol. xxxvi. p. 226), of the metamorphosed beds above noticed being Liassic. Now, whatever may be the age of the neighbouring hypersthenites, all our doubts have been dispelled regarding the chronology of the saccharoid marbles, and their included layers of Ophite, after reading Geikie's paper "On the geology of Strath, Skye," as this author, with Dr. Wright's palæontological assistance, has clearly shown them to be altered limestones, shales, and grits of the Liassic period (See Quart. Journ. Geol. Soc. vol. xiv. pp. 1–36).

miles in thickness of primary *unaltered* calcareous argillaceous and mixed deposits in which no vestige of this "fossil" has been found, and in which its occurrence ought to be certain, had it been a foraminiferal organisim,—we shall be much surprised if, with such plain, simple, and elementary facts before him, this "creature of the dawn"—the "oldest type of organic life yet known"—does not soon become to the geologist a memorable nonentity.

### X. *Summary.*

Although zealous advocates at one time for the organic origin of "eozoonal" Ophite, we now, after a prolonged investigation, and after, as we believe, leaving no point unnoticed, feel ourselves under the necessity of totally relinquishing that opinion.

It has been seen (1) that the "chamber-casts" or granules of serpentine are more or less simulated by chondrodite, coccolite, pargasite, &c., also by the botryoidal configurations common in Permian Magnesian Limestone; (2) that the "intermediate skeleton" is closely represented, both in chemical composition and other conditions, by the matrix of the above and other minerals; (3) that the "proper wall" is structurally identical with the asbestiform layer which frequently invests the grains of chondrodite—that, instead of belonging to the skeleton, as must be the case on the eozoonal view, it is altogether independent of that part, and forms, on the contrary, an integral portion of the serpentine constituting the "chamber-casts," under the allomorphic form of chrysotile—and that perfectly genuine specimens of it, completely simulating *casts* of separated nummuline tubules, occur in true fissures of the serpentine-granules; (4) that the "canal-system" is analogous to the imbedded crystallizations of native silver and other similarly conditioned minerals, also to the coralloids imbedded in Permian Magnesian Limestone—that its typical Grenville form occurs as metaxite, a chemically identical mineral imbedded in saccharoidal calcite; (5) that the type examples of "casts of stolon-passages" are isolated crystals apparently of pyrosclerite. Furthermore, considering that there has been a complete failure to explain the characters of the so-called internal casts of the "pseudopodial tubules" and other "passages" on the hypothesis of ordinary mechanical or chemical infiltration, also bearing in mind the significant fact that the "intermediate skeleton," in Irish and other varieties of "eozoonal rock," contains modified examples of the "definite shapes" more or less resembling the crystalline aggregations and prismatic lumps in primary saccharoidal marbles—that "eozoonal" structure is only found in metamorphic rocks belonging to widely separated geological systems, never in their unaltered sedimentary deposits,—taking all these points into consideration, also the arguments and other evidences contained in the present memoir, we feel the conclusion to be fully established, that every one of the specialities which have been diagnosed for "*Eozoon Canadense*" is solely and purely of crystalline origin: in short, we hold, without the least reservation, that, from every available standing point—foraminiferal, mineralogical, chemical, and geological—the opposite view has been shown to be utterly untenable.

## XI. *Conclusion.*

From what has been stated in some of the preceding pages, respecting the various chemical changes which "eozoonal" Ophite appears to have undergone, and its mineralogical constituents, we are strongly inclined to believe that it is a pseudomorphic rock, that it existed at one time in the ordinary metamorphic state, perhaps as hornblendic or augitic gneiss, and that it is primarily of sedimentary origin*. Whether the same may be concluded of all ophitic rocks is a question on which we cannot offer any opinion—negative, or affirmative. There are some grounds for believing, however, that certain dolerites, generally considered to be of eruptive origin, have become changed into Ophite: and though we have not detected any "eozoonal" structure in an example apparently of the kind, from Monzoni in the Tyrol, which has fallen under our observation, it would not surprise us if this structure were found in ophitic rocks supposed to belong to the eruptive section, considering that the essential mineral (augite) of dolerite contains a large percentage of silicate of lime†.

* Dr. Sterry Hunt states that "pseudomorphism, which is the change of one mineral species into another by the introduction or the elimination of some element or elements, presupposes metamorphism, since only definite mineral species can be subject to this process" (see Journal of the Geological Soc. of Dublin, vol. x. p. 88). We accept this view of pseudomorphism; but we see no reason why the change can only have "taken place in some mineral species, in veins, and near the surface"—why it cannot have operated on a sufficiently extensive scale to generate the layers and beds of Ophite interstratified with the Laurentian limestones and gneiss of Canada. It may be, that "the alteration of great masses of silicated rocks by such a process is as yet an unproved hypothesis:" we cannot but think, however, that Dr. Hunt has insufficiently estimated the evidence which may be adduced in its favour. One which we shall now cite seems to bear us out in this idea: alluding to Blum's discovery of pseudomorphs of serpentine after augite, at Monzoni, Bischof expressly states, "it is not merely the fine crystals, which occur in its drusy cavities and fissures, that are changed, but the *whole mass of the rock* is converted into serpentine" (See Chem. and Phys. Geology, vol. ii. p. 322).

† Sir Charles Lyell has stated that "even if we had not discovered the *Eozoon*, we might fairly have inferred" that the "calcareous masses, from 400 to 1000 feet and more in thickness," associated with it "were originally of organic origin" (Elements of Geology, 6th edition, p. 580). Now, whatever the "calcareous masses" may have originated from, the idea of their being "eozoonal" must be abandoned. We do not dispute the above inference, which, be it considered, does not necessarily involve animal agency alone, as such "masses" may be the debris of calciphytes, like the calcareous accumulations still abundant on many of our present sea-bottoms and resulting from the growth and decay of various kinds of nullipores. But it may turn out that they are not of organic origin at all. Doubtless some, calling to mind the beds of travertine occurring at Rome, may be disposed to regard them as of chemical origin. Another idea, however, strikes us just now. Feeling confident in the view herein taken of the origin of "eozoonal" Ophite, we are strongly inclined to believe that its calcareous portions are segregations derived partly, or wholly, from the silicate of lime contained in hornblendic or augitic rocks, such silicate having been converted into a carbonate by the introduction of water containing free or combined carbonic acid. (In lime-magnesia augite, as diopside, these bases, important in "eozoonal" Ophite, amount to about 43 per cent.) There are some grounds for believing that the lenticular masses of saccharoidal calcite, or "primary" marble, often imbedded in metamorphic rocks, have originated in the same way. But whether the vast "calcareous masses," referred to by Lyell, are of pseudomorphic origin is a question on which it behoves us to speak with less confidence; at any rate, such a view, as will now be seen, ought to command due consideration.

## EXPLANATIONS OF PLATES XIV. & XV.

*Illustrative of the view of the inorganic nature of* Eozoon.

### PLATE XIV.

Fig. 1. Section, viewed as an opaque object, of a portion of a granule ("chamber-cast") of serpentine, having one edge, facing a decalcified passage, furnished with two asbestiform layers. The inner layer is *perfectly compact*, except at the left end; the outer one has the fibres in the left half *standing apart*, but in the right half they are in *close contact.* The outer layer is nearly separated from the inner one. The granule is green and translucent; the layers are white and vitreous. Magnified 210 diameters. From Grenville.

2. Section, viewed as an opaque object, embracing a lobulated granule of green serpentine, and a portion of its matrix (lower part), composed of white saccharoidal calcite; the specimen is not decalcified. The striated portion represents the asbestiform layer ("pseudopodial" or "proper wall"), which is *perfectly compact*, except at the places marked *a* and *b*, in which the fibrous structure is in an intermittent or *incipient* state of development. The peculiarities of its structure show that the layer is an *integral portion of the serpentine.* Magnified 210 diameters. The specimen has been examined with a power of 350, with the same result. From Grenville.

3. Section, viewed as a transparent object, of three granules of serpentine ("chamber-casts"), with their edges notched or broken up into separated bundles of asbestiform fibre. The interspaces between the bundles, as well as those between the granules, are *filled with flocculent matter.* Our view of the specimen is, that the spaces between the bundles of asbestiform fibre originally consisted of serpentine, which has been converted into flocculite; also, that possibly the entire mass of the latter between the granules was once serpentine. Magnified 120 diameters. The specimen has also been examined as an opaque object, under a power of 350, with the same result. From Grenville.

4. Section, viewed as an opaque object, representing a small portion of a *long fissure, which intersects a number of granules* of serpentine. One of the walls of the fissure is crowded with *aciculi* (*identical* with "casts of pseudopodial tubuli" of "*Eozoon Canadense*"), separated, as well as in close contact: in a few places the *aciculi* form bundles; see centre of the lower wall. The upper wall is crowded with a very thin asbestiform layer. Magnified 110 diameters. From Lisoughter.

5. Section, viewed as an opaque object, of a portion of asbestiform layer (*identical* with that of "*Eozoon Canadense*"), lying between, and attached to, two grains of yellowish-brown chondrodite. In the left half, the layer, which is white, translucent, and silky, is *perfectly compact*; but in the other half, its fibres are in some places *separated* and a little twisted. Magnified 120 diameters. From New Jersey.

6. Section, viewed as an opaque object, of grains of chondrodite separated by an asbestiform layer, the fibres of which are here and there *apart,* and in some places not strictly parallel. Magnified 60 diameters. From New Jersey.

7. A grain of chondrodite, viewed as an opaque object. It is furnished at one end with the remains of an asbestiform layer, the fibres of which form slender *aciculi*; or, in other words, the *aciculi* are composed of *asbestiform fibre.* The vacant spaces appear to have been occupied by fibres or *aciculi,* which, through some cause have disappeared. Magnified 120 diameters. From New Jersey.

8. Section, viewed as an opaque object, of a granule ("chamber-cast") of serpentine, showing a fringe of asbestiform layer ("tubulated proper wall"), which generally consists of *parallel fibres*; but in some places the fibres are *divergent.* In one place the layer is replaced by a coat of *flocculite.* It is our opinion that the latter has resulted from a change either of the asbestiform layer or of the serpentine. Magnified

210 diameters. From Lisoughter. (The figure is represented more compressed than it really is, so as to occupy as little space as possible.)

Fig. 9. This figure represents, by reflected light, a mass of flocculite lying between, or adjacent to, two granules of serpentine. One of the granules is fringed with *aciculi*. The flocculite shows here and there a rude *divisional or prismatic structure, which becomes acicular*; in two places well-developed *aciculi* rise out of the mass. Magnified 210 diameters. From Lisoughter.

10. Two granules ("chamber-casts"), viewed by reflected light, of serpentine connected by a crystal of pyrosclerite? (answering to a "cast of a stolon-passage"), lying across a decalcified passage. The crystal has a thin layer of white granular matter adhering to each of its sides; and the granules are furnished with a portion of asbestiform layer. Magnified 105 diameters. From Grenville.

11. Crystal of pyrosclerite (?), answering to a "cast of a stolon-passage," lying across a decalcified passage; it is not long enough to connect two opposite granules of serpentine, but the connexion is completed by the interposition of a "white amorphous mass," *b*, rudely laminated. The other connecting body, which may also be taken for a "cast of a stolon-passage," consists entirely of a rudely laminated "white amorphous mass." Magnified 105 diameters. From Grenville.

PLATE XV.

12. This figure represents a dendritic specimen of metaxite (*identical* with representatives of the "canal-system" of "*Eozoon Canadense*"), as it appears under an object-glass magnifying 110 diameters. Obtained by decalcifying its matrix—saccharoidal calcite. From Reichenstein, Silesia.

13. A small portion of Ophite, decalcified, from Lisoughter. The spheroidal bodies are granules ("chamber-casts" of "*Eozoon*") of translucent serpentine, imbedded in saccharoidal calcite ("skeleton")—the dark portions. Tufts of crystals ("metamorphosed" examples of the "canal-system") are variously attached to the granules, while other tufts are fixed in the calcite. Two granules in the middle of the lower portion of the figure are connected by three *white, slightly granular, parallel plates*, representing "stolon-passages;" other granules are connected by *tufts of crystals*. Magnified 25 diameters.

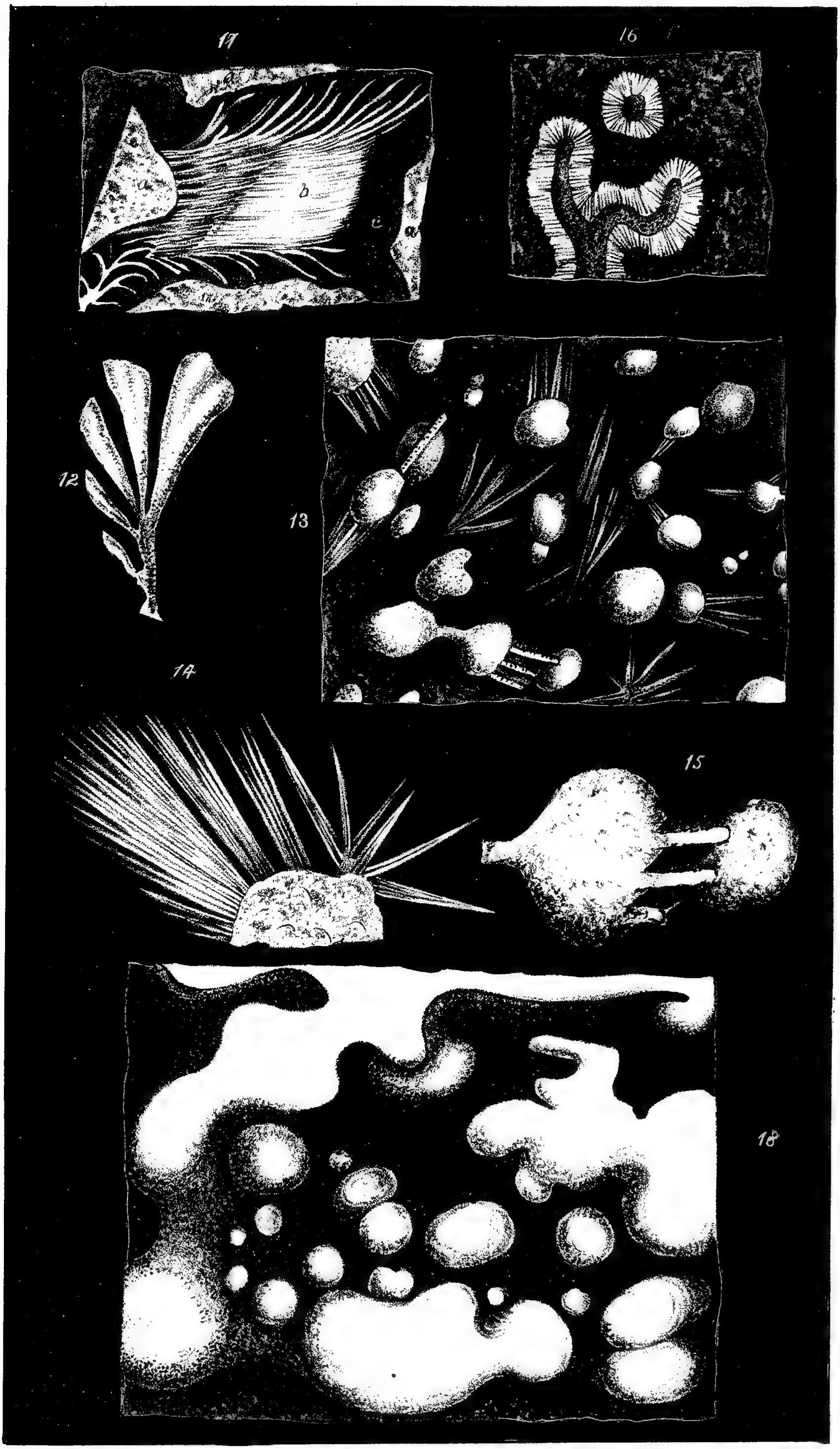
14. Granule of serpentine ("chamber-cast"), from a decalcified specimen of Lisoughter Ophite, to which are attached scopiform bundles of crystals, representing "metamorphosed" examples of the "canal-system." The crystals are divergent, also subparallel. Magnified 210 diameters.

15. Represents the two granules of serpentine noticed under figure 13. Magnified 120 diameters.

16. Representations of a branching vermicular body, *a*, lying lengthways, and of a transverse section of another, *b*, both showing *aciculi* shooting off from their surfaces. The vermicules and *aciculi*, of a yellowish-brown colour, are imbedded in transparent chalcedony. Magnified 210 diameters. From a "Moss-agate" presented by Professor Tennant.

17. An "amorphous mass," representing the "canal-system," of a prismatic structure, lying in a decalcified passage, *c*, between four irregular-shaped granules of serpentine, *a*. The "mass," *b*, at its sides, is separated into prisms, which curve off, and in a few places become branched; it is, for the most part, however, *compactly prismatic*, and has an incipient lustre. Magnified 60 diameters. From Grenville.

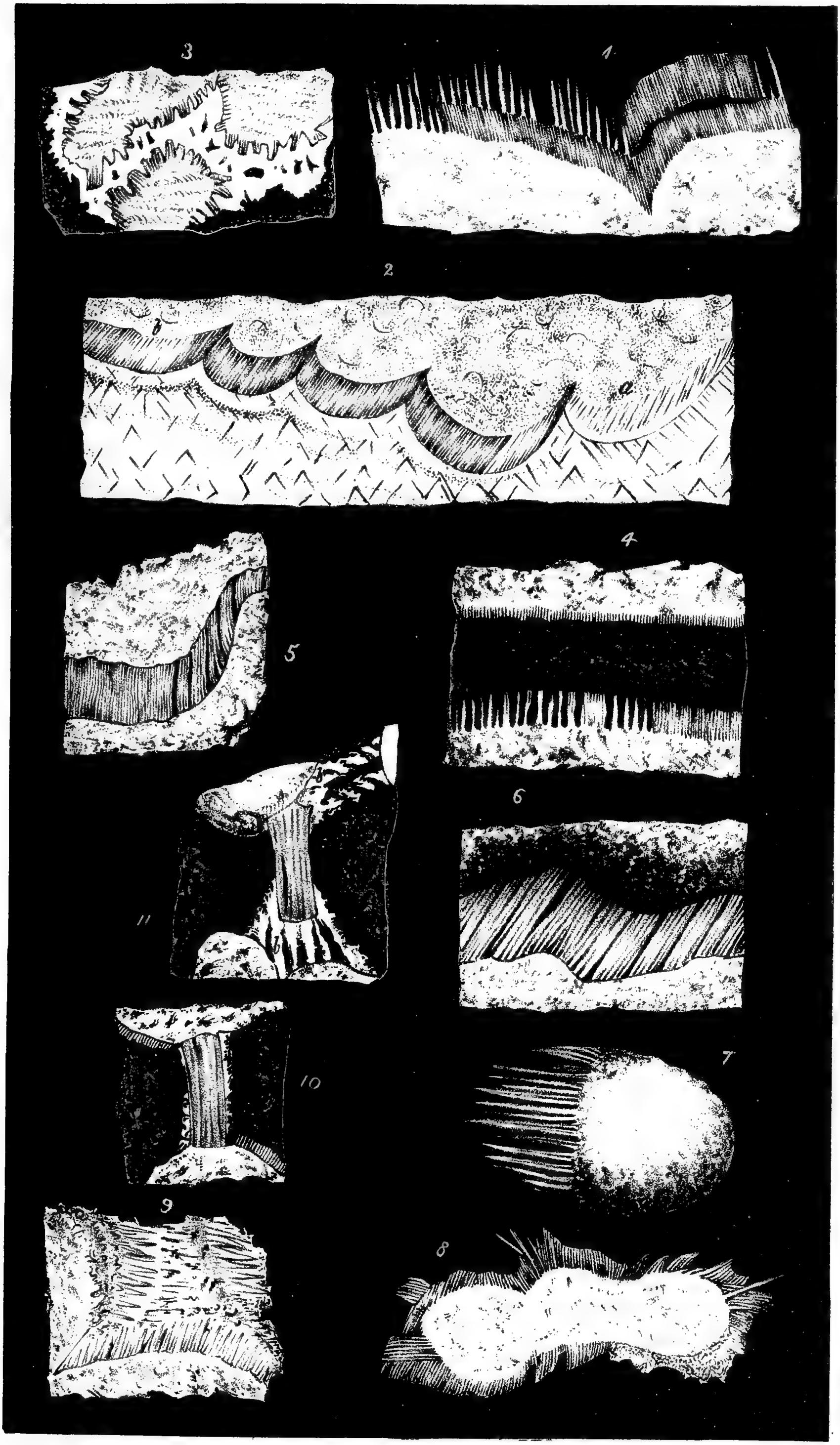
18. Representation, natural size, of a botryoidal specimen of Permian limestone, from Building Hill (People's Park), near Sunderland. The rounded and irregular-shaped bodies, formed of brown subcrystalline carbonate of lime, *simulate the "chamber-casts"* of "*Eozoon Canadense*:" the vacant spaces, once filled with earthy carbonate of lime and magnesia (which has been weathered out), correspond to the decalcified passages or the so-called "calcareous skeleton."




E. M. Williams F.L.S. F.Z.S. lith.

M. & N. Hanhart imp.

EOZOONAL ROCKS.




E. M. Williams F.L.S. F.Z.S. lith.

M. & N. Hanhart imp.

EOZOONAL ROCKS.

## 2. Supplemental Notes *on the* Structure *and* Affinities *of* Eozoon Canadense. By William B. Carpenter, M.D., F.R.S., F.G.S.

Since the date of my communication to the Geological Society made through Sir William Logan, upon the remarkable fossil discovered by him in the Laurentian rocks of Canada, I have given a considerable amount of time and attention to the further investigation of its characters; and I am desirous of recording certain additional features in its structure, which seem to me to strengthen the view originally put forward by Dr. Dawson, and confirmed by my own inquiries, of its Foraminiferal affinities.

It will be remembered that this view was originally propounded by Dr. Dawson as the result of his investigations (1) into the relations of the calcareous and siliceous layers, which appeared to him to indicate that a chambered calcareous skeleton had been infiltrated by silicates in solution, so as to leave a siliceous * deposit in the spaces previously occupied by the animal body; and (2) into the distribution of an arborescent "canal-system" which he detected in the calcareous skeleton, bearing a most remarkable resemblance to the canal-system described by myself in *Calcarina*†.

My own observations upon the specimens placed in my hands by Sir W. Logan supplied an important confirmation to this view, for these disclosed the fact that the *proper wall of the chambers*, when well preserved, exhibits the finely tubular structure of the Nummuline Foraminifera; which is demonstrable as well in thin transparent sections‡, as in decalcified specimens, which show the siliceous casts of the interior of the chambers to be covered with a thin "asbestiform layer" composed of acicular fibres standing upon end, usually parallel to each other§. These fibres I regard as the *internal casts of the tubuli* of the shelly layer, which were originally occupied by minute filaments (pseudopodia) proceeding from the sarcodic body of the animal. And I feel justified in doing so by the fact that a recent siliceous cast of an *Amphistegina* from which the shell has been removed by decalcification, kindly presented to me by my friend Mr. W. K. Parker, affords a perfect representation of this "asbestiform layer"—the only difference being that the fibres are larger and more separate, in accordance with the characteristic tubulation of the shell in this genus. This cast gives a perfect model in a green silicate (glauconite?) of the lobes of the body, of the canal-system, and of the tubuli of the shell-wall; and as the shell within which it was formed was brought up with many similar ones by Mr. Jukes in his dredgings on the Australian coast, it is obvious that the complete replacement of the segments of the animal body

* I use the term *siliceous*, here and elsewhere, to mean compounds of which *silicic acid* is the characteristic ingredient.

† Compare Dr. Dawson's delineations of the canal-system of *Eozoon Canadense*, in Quart. Journ. Geol. Soc. vol. xxi. Plate vii. figs. 3 (*a a*) and 5, with the representations of the canal-system of *Calcarina* in my 'Introduction to the study of the Foraminifera,' Plate, xiv. figs. 4, 8, 9.

‡ Quart. Journ. Geol. Soc. vol. xxi. Plate viii. figs. 4 *a*, 4 *b*.

§ Op. cit. Plate ix. fig. 4.

and of their minute filamentous prolongations, by a siliceous deposit in the cavities and tubes which they occupied, was effected by some process at present in operation upon the sea-bottom. And whatever view we may take of the nature of this process,—whether we suppose these chambers and tubes to have filled when empty by infiltration, or regard the animal matter which originally occupied them to have given place to the siliceous deposit by a process of *chemical substitution**,—the fact remains, that an undoubted internal cast of a recent Foraminifer presents the exact *parallel* to the model of the animal body of *Eozoon* obtained by the removal of its calcareous skeleton. Indeed it was in consequence of the suggestion afforded by this specimen of *Amphistegina*, that I was led to look for the corresponding structure in the decalcified *Eozoon*; the discovery of which affords no slight confirmation of the view previously arrived at by the examination of thin transparent sections.

My observations upon the Nummuline structure of the proper walls of the chambers have been fully confirmed by Dr. Dawson, who thus speaks in an Appendix to the Canadian reprint of his paper on *Eozoon*. "Since the above was published, I have had opportunities of examining slices and decalcified specimens of *Eozoon* from Petite Nation, the locality which afforded the specimens referred to by Dr. Carpenter; and I have much pleasure in adding my testimony to his observation of the distinctness of the proper wall of the chambers from the supplemental or intermediate skeleton, as exhibited in these specimens."

This Nummuline tubulated structure comes to be of special importance, now that the organic nature of the Eozoic serpentine-limestone has been formally called in question. For even if it be admitted that the peculiar arrangement of the calcareous and siliceous components of the Eozoic limestone, and the remarkable dendritic passages hollowed out in the calcareous layers, are capable of being

* Notwithstanding that this idea has been designated by Profs. King and Rowney as so completely destitute of the characters of a scientific hypothesis as to be wholly unworthy of consideration, I believe it to be the one commonly entertained by those who have given most thought to the mode in which the silicification of Woods and of the soft tissues of Sponges and other organisms has been effected, so as to preserve the minutest features of their structures. And those eminent geologists who were present with me at the discussion which took place in Paris upon the subject of the Abbeville Jaw, will recollect that no less an authority than Prof. Milne-Edwards stated that he believed that infiltration of bones and teeth was more likely to take place when their cavities were occupied by animal matter at the time they were imbedded, than when those cavities had been emptied by its decay; the minute tubuli being, in his view, more readily and completely filled by the process of *substitution*, during the decomposition of their animal contents, than they could be by mere *percolation*. This suggestion was thrown out to account for the fact mentioned by M. Lartet, that *completely infiltrated* and *non-infiltrated* bones are often found in the same stalagmitic deposit. My own early investigations into the structure of Nummulites had long before led me to the conclusion that among those found imbedded in the clay of Bracklesham Bay, the specimens most completely infiltrated with carbonate of lime had their chambers occupied with animal matter at the time when this fossilizing process commenced (see Quart. Journ. Geol. Soc. vol. vi. p. 23, Plate iii. fig. 2); traces of it being distinguishable even to the very centre of the spire.

accounted for by inorganic agencies, there remains the Nummuline structure of the chamber-walls, to which—I venture confidently to assert—no parallel can be shown in any undoubted mineral product*.

The "asbestiform layer" obtained by the decalcification of the Nummuline shell-wall, which sets free the siliceous internal casts of its tubuli, presents a series of remarkable variations, which can be closely paralleled by the variations existing in the course of the tubuli in the shells of living Nummuline Foraminifera. What we may consider the normal arrangement is the passage of the tubuli in a straight and parallel course from the internal to the external surface of the shell-wall; and this is represented in *Eozoon* by a regular disposition of the acicular fibres, which stand side by side, like the filaments that form the pile of velvet, their lower ends resting on the subjacent segment, whilst their upper form a uniform surface so close in texture as to be scarcely resolvable into the points of its constituent aciculi†. But, as is often the case in *Operculina*‡, the tubuli may depart from their normal parallelism, separating from each other in some parts, and becoming more closely crowded in others;

* It may be thought a matter for regret that, before putting themselves in a position of antagonism to those who have made a special study of the minute structure of Foraminifera, Profs. King and Rowney should not have availed themselves of the opportunity publicly offered them some months since (see the 'Reader' for July 8th, 1865) of inspecting my preparations of *Eozoon*. I have recently learned from personal communication with Prof. Rowney, not only that he had no practical knowledge of the structure of Nnmmuline shells, but that he had not, until I myself showed them to him, ever seen any transparent sections of *Eozoon* thin enough to give a good view of its tubuliferous layer,—his observations having been almost exclusively made upon decalcified specimens. And it is obviously from this limitation to one method of inquiry, that Profs. King and Rowney have fallen into what I feel able to demonstrate to be the fundamental error of their whole treatment of this part of the subject,—the assumption that the "asbestiform layer" is, *in its original state*, before having been acted on by acid, a mere bundle of siliceous fibres, instead of being (as I maintain) a continuous layer of calcareous shell, the vertical tubuli of which have been filled up by the substitution of siliceous deposit for the threads of animal matter which originally occupied them. If they had made the experiment, which I have over and over again repeated, of subjecting a very thin transparent section of *Eozoon*, cemented on glass by Canada balsam, to the action of dilute acid, they would have been at once convinced by the complete alteration in the appearance of this layer, that a transparent substance intervening between the asbestiform fibres and cementing them together, has been dissolved out. This becomes still more obvious where the fibres diverge from one another in some parts and converge in others, as will be described in the next paragraph.

† It is apparently from this continuity of the external surface of the asbestiform layer, that Profs. King and Rowney have been led to the inference that its fibres are so closely compacted together that there is no room for any intervening calcareous cement. But if they had been familiar with the study of living Foraminifera, they would have been aware that the pseudopodia which have passed through the pores of the shell, coalesce on its external surface into a continuous layer of sarcode; so that the continuity of the external surface of the asbestiform layer is precisely what we should expect, if this layer represents the filamentous extensions of the original sarcode-body of the animal. A still more remarkable representation of this sarcodic layer in the siliceous model of the animal of *Eozoon* will be presently described.

‡ See Memoir on *Operculina* in the Phil. Trans. for 1859, p. 54, and Plate iv. figs. 2, 4, 11.

so that instead of the uniform punctation which the *internal* surface of the chamber-wall exhibits, we may find great diversities in the disposition of their *external* orifices, these being often congregated in bands and clusters, with intervals of non-tubular shell-substance between them. The same is the case in the recent *Amphistegina*; and the internal cast, or model of its animal, already referred to presents the same *kind* of variations in the course of the siliceous threads which represent the pseudopodia, as those which are exhibited in a higher *degree* by the "asbestiform layer" of *Eozoon*. For decalcified specimens of this often show us fissures in the asbestiform layer, resembling those left in the surface of a piece of velvet-pile by doubling it back; these fissures represent the non-tubular spaces of the shell-wall, which are left by the convergence of the tubuli in other parts into bands and tufts. A more marked degree of the same convergence, bringing a large number of the pseudopodia that proceed from each segment into one bundle, is frequently to be seen in parts in which there is an unusual development of the intermediate skeleton and canal-system. And here an additional peculiarity often presents itself, which is in such remarkable accordance with what I had previously observed and recorded in the recent Foraminifera to which *Eozoon* seems most nearly allied, that it is difficult to conceive that accordance to be without a meaning. In my description of the canal-system of *Calcarina* I had expressed my belief that the usual origin of the canals of the intermediate skeleton is not from the cavities of the chambers, but from lacunar spaces intervening between the outside of the proper walls of the chambers and the intermediate skeleton by which they come to be overgrown; and in my previous communication upon *Eozoon* (p. 63) I expressed the opinion that the same was probably the case in that organism. These lacunar spaces, in the living animal, would be occupied by films of sarcode formed by the coalescence of the pseudopodia on the external surface of the proper wall of the chambers; and from these films would pass off the sarcodic extensions which occupy the canal-sytem. Now in those varieties of the asbestiform layer which exhibit a foliated or penicillate arrangement of the silicified threads, the bands or tufts which the surface of the asbestiform layer then presents are often connected by plates of the same siliceous material, in which the stems of the dendritic models of the canal-system are frequently implanted. And these plates can in many instances be plainly seen to be formed by the spreading-out of the material which formed the coalesced bands and tufts; just as the sarcodic layer on the surface of the living shell is formed by the spreading-out of coalesced bundles of the pseudopodia that have emerged from the chamber-wall*.

I have thought it desirable to dwell thus fully upon the structure of the Nummuline chamber-wall, and the parallel between the variety of appearances which it presents in *Eozoon* and those exhibited by

* This structure may be what has been described by Profs. King and Rowney as "a double asbestiform layer." If so, its presence, instead of affording an argument against the Foraminiferal nature of Eozoon, supplies an unexpected confirmation of that doctrine.

recent Foraminifera*, because it is by this feature that the organic origin of *Eozoon* is capable of being most unmistakeably recognized. If my account of it is correct, no more doubt can be reasonably entertained of the animal nature of *Eozoon* than of the animal nature of any extinct type of Nummuline Foraminifera; and all the other curious features of its structure, including the singular varieties in the distribution of its canal-system, may be accepted without hesitation.

But even if some undoubtedly mineral product could be shown to present the characteristic peculiarities of the Nummuline shell-wall, I should be still prepared to maintain the organic origin of *Eozoon* on the broad basis of cumulative evidence afforded by the *combination*, in every single mass, of an assemblage of features which can be only *separately* paralleled elsewhere; and in the *repetition* of this combination with the most wonderful exactness, over areas of immense extent. This evidence, indeed, is very much of the same nature as that on which the doctrine of the Human fabrication of the "flint implements" is now universally accepted. No one, on looking at such an implement, would be justified in saying of any single fracture presented by its surface, that it *might not* have been accidental; yet that man must have a strong faith, who could honestly maintain that any succession of accidental fractures would have been likely to shape out even a single specimen. But admitting such a possibility in regard to *one*, it is narrowed down by every repetition of the same or of a similar form, to a vanishing point which the intellect refuses to apprehend.

Although not perhaps entitled to any great weight, yet the antecedent probabilities of the case are not to be disregarded. Geologists are now, I believe, very generally agreed in the opinion that all the great beds of limestone in the formations known to be fossiliferous are the products of animal agency, which separated carbonate of lime from its solution in the waters of the ocean in the form of Corals, Shells, Encrinite-skeletons, &c. And it is also fully admitted that the crystalline condition of a limestone affords no argument against this view; many comparatively modern rocks, of whose organic origin there can be no reasonable doubt, having been brought to this condition by subsequent metamorphism. The, occurrence of limestone beds in the Laurentian rocks, therefore, affords a presumption in favour of the existence of marine animal life at that epoch; in the same manner as the occurrence of beds of graphite may be fairly regarded as indicative of the antecedent existence of vegetation. And while this presumption is in no degree invalidated by the crystalline condition which usually prevails in these rocks, it derives additional weight from the fact noticed by Sir

* It may serve to show the necessity of practical familiarity with the microscopic appearances in question, if I mention the fact, that an eminent Palæontologist who had previously committed himself to the opinion that the Nummuline layer of *Eozoon* is simply "an agatized mineral," gave precisely the same verdict upon a section of a recent Nummuline shell,—thus unintentionally bearing the strongest testimony to the identity of the two structures, and consequently to the *organic* nature of the former.

W. Logan, that some of the Laurentian marbles when struck give forth the same overpowering smell of carburetted hydrogen, as is well known to be given off from many beds of Carboniferous Limestone whose organic origin is most distinct.

Another probability is afforded by the striking resemblance observed by Sir W. Logan in the general arrangement of the masses of *Eozoon* in Foraminiferal reefs, to the reefs formed by the stony Corals; and the evidence of successional building-up of these, as shown by the disintegration of some parts of what would have been once the living surface by currents and eddies, which have left cavities and recesses that were subsequently filled by a new overgrowth.

The alternating succession of calcareous and siliceous lamellæ, of which as many as fifty may be counted in a single mass of *Eozoon*, is a feature which if not absolutely without parallel in the inorganic world, is a very singular one; and the difficulty of accounting for it is greatly increased when we look upon the vast multitude and the singular uniformity of its repetitions in the separate masses of *Eozoon*. The difficulty is yet further augmented when it is taken into account that the alternating minerals, though invariably calcareous and siliceous, are not constantly the same; the serpentine being often replaced either by pyroxene or by loganite, and the carbonate of lime by dolomite. Now on the hypothesis of organic origin, nothing is easier than to account for the regular alternation of calcareous and siliceous layers,—the former representing the original skeleton formed by successional growth; and the latter representing its chambers, originally filled with a living sarcode-body, which was subsequently replaced by siliceous minerals by a process which (whatever its nature) has been repeated upon the bodies of Foraminifera in every great geological epoch from the Silurian to the present. And it was the coexistence of this uniformity in structural arrangement with diversity in the component minerals, which first impressed upon the mind of Sir W. Logan the idea of the organic nature of these masses.

The greater variability in the thickness of the calcareous lamellæ than in that of the siliceous, is a point of minor importance, but not without its relevancy; for it is exactly paralleled among recent Foraminifera. As Unios and other freshwater mollusks will form thick or thin shells according to the abundance of Carbonate of Lime in the water they inhabit, so do we find among the Nummulites of different localities extraordinary diversities of form produced by variations in the thickness of their shelly layers; the same species having sometimes a thickness equal to only one third of its diameter, whilst in other specimens the thickness equals three-fourths of the diameter,—the dimensions of the chambers being nearly the same in both cases. The difference in the thickness of the calcareous layers of Eozoon, on the hypothesis of its organic origin, depends upon the amount of superficial addition made in the form of "supplemental" or "intermediate skeleton" to the proper walls of the chambers, the cavities of which are represented by the siliceous layers; and wherever the interval between two siliceous layers is unusually wide, an unusual manifestation of the canal-system is almost sure to present itself. This constant relation between the development of the "intermediate skeleton" and that of the "canal-system" is in such precise accordance with what I have uniformly found to exist in Foraminifera*, as to add another fact of no mean significance to our growing accumulation of evidence.

Having dwelt sufficiently in my former note on the characters which I regard as essentially Foraminiferal, I need not here do more than recapitulate them as follows:—1. The constant *segmental division* of the siliceous layers, indicating a series of chambers only partially divided from each other, as in *Carpenteria*, but occasionally separated completely by interposed calcareous septa. 2. The perforation of these septa by several passages of communication between the chambers, as in *Cycloclypeus*†. 3. The substitution of the acervuline piling-together of the chambers, in the latter stages, for the regularly storied arrangement of the earlier; a change very common among Foraminifera. It is further not a little significant that the siliceous segments in this acervuline portion have the same average dimensions as those of which the subjacent laminæ are composed. The uniformity with which the acervuline mode of aggregation *succeeds* the lamellar could scarcely be expected if these masses were of purely mineral origin. 4. The distinctness of the proper wall of the chambers from the intermediate skeleton; a feature especially characteristic of the higher Foraminifera. 5. The precise conformity in the structure of the former to that of the Nummuline Foraminifera‡. 6. The constant proportion between the development of the latter and that of the canal-system. 7. The correspondence in *size* between the elementary parts of *Eozoon* and those of the Foraminifera to which it is most nearly related. This is a feature of no little importance, when we take into account the extreme variability in the size of the elementary parts of Mineral aggregations§. It is almost

* Introduction to the study of the Foraminifera, p. 63.

† The explanation of these passages offered by Messrs. King and Rowney, is based on the representation of them given in the somewhat diagrammatic figure illustrating my former note (Plate VIII. fig. 2). That it is totally inapplicable to the case, becomes at once apparent on miscroscopic examination of the large number of examples I now possess of this very characteristic feature.

‡ It is urged by Profs. King and Rowney as an objection to the Foraminiferal doctrine, that this supposed tubular wall is found on the under or attached side of each lamella, as well as on the upper or free surface, and that it is inconceivable that a layer thus perforated for the passage of pseudopodia should be formed where there is no exit for them. The objection only shows their want of acquaintance with the fact that many Foraminifera (both recent and fossil), having perforated shells, habitually grow affixed to seaweeds, corals, shells, &c.; and that the attached side possesses the characteristic tubular structure no less than the free. I believe that in all these cases there intervenes in the living state a thin layer of sarcode between the shell and the subjacent surface, the evidence of whose presence in *Eozoon* is afforded by the continuous siliceous lamellæ already referred to as often connecting the outer ends of the aciculi of the asbestiform layer.

§ The only other objection of any weight advanced by Messrs. King and Rowney, is the fact that a chambered structure and asbestiform layers are sometimes met with in the midst of the thick purely serpentinous layer which usually underlies the masses of *Eozoon*. Now if such be really the fact, it would only prove the persistence of bands of the original structure in parts which had been inconceivable that throughout the enormous masses of Eozoic serpentine, the siliceous segments, if merely concretionary, should never exceed a minuteness that is rarely encountered among ordinary minerals.

Every one who has been accustomed to attend to the subject of evidence is well aware that the concurrence of a number of separate and independent facts, not one of them possessing much probative value in itself, may lead to a moral certainty scarcely inferior to that obtained from demonstration. This is the case when the aggregate of these facts is capable of being reconciled with *a single hypothesis*, and with that one only, and when the facts can only be otherwise accounted for by *a number of separate hypotheses* having no mutual connexion.—The consistency of all the characters I have enumerated with the theory of the organic origin of the Eozoic limestone is no less remarkable than the difficulty of accounting for their concurrence by any hypothetical combination of chemical and physical agencies. It will be sufficient here to advert to a few points of the case under this double aspect. If the relation of the calcareous and siliceous components be such as is here maintained—the siliceous residue left by decalcification being the internal cast of the cavities, canals, and tubuli of the calcareous skeleton, and therefore being the model of the original body of the animal—every feature which it presents is found to be closely paralleled by the internal cast of a recent Nummuline shell. But if the collocation of these two minerals has been the result of inorganic agencies, the following points have to be separately accounted for:—1. The succession of regularly alternating lamellæ; 2. the segmental aggregation uniformly presented by the siliceous lamellæ; 3. the occasional separation of the segments by calcareous septa; 4. the structural union of both minerals in the proper wall of the chambers; 5. the peculiar dendritic formations carrying the siliceous component into the very midst of the calcareous. Was the calcareous portion first formed and the siliceous afterwards deposited by infiltration, or was the siliceous portion first formed and subsequently penetrated by calcareous deposit? if so, by what conceivable process of fissuring could a system of cavities of such regularity and constancy of arrangement have been produced? or if it be supposed that the laminæ were successively superposed, what agency can be imagined to have brought about the regular alternation of the materials? and how can the segmental arrangement of *both sides* of the siliceous laminæ be accounted for? If each siliceous lamina were deposited upon a preexisting calcareous lamina, its under side would take the form of the subjacent surface: and how can the calcareous surface

altered by subsequent metamorphism,—a circumstance frequently met with in rocks of undoubtedly organic origin. But in the numerous examples I have met with of the arrangement referred to by Messrs. King and Rowney, it is so destitute of the characters of the true chambered structure and asbestiform layer, that I should have no hesitation in regarding it as either originally a product of inorganic agencies, or as the result of metamorphic changes in a structure originally organic, which have caused the formation of the thick serpentinous layers in which these appearances present themselves.

be supposed to have been hollowed out, so as to give to the siliceous lamina exactly the same kind of tuberculation on its *under* surface, as it is supposed on the mineral hypothesis to acquire on its *upper* by agencies inherent in itself? or if it be supposed that the calcareous and siliceous salts were in solution in the same liquid, and that the peculiar arrangement in question was due to their separation in the act of solidification, the siliceous taking on the form of botryoidal concretions, and the calcareous filling up the spaces between these, the objectors may be challenged to bring forward any example of an undoubted mineral produced by inorganic agencies which shows anything like the structural regularity in the size and disposition of its component parts that is presented by characteristic specimens of the Canadian *Eozoon**.

In addition to the localities in which it has been already announced that the Eozoic characters have been detected in Serpentine Limestone, I may record three as of special interest as indicating the prevalence of the same features in that fundamental Gneissic formation of Central Europe, which the labours of Sir Roderick Murchison have shown to be the equivalent of the Canadian Laurentians. Three months ago I received from Dr. Fritsch, of Prague, through Mr. H. B. Brady, of Newcastle, a specimen of Ophicalcite from Cesha Lipa in Bohemia, which gave on decalcification a form of *Eozoon* closely resembling that exhibited by the "Irish Green." Not long afterwards I received from Dr. Hochstetter a specimen from the fundamental gneissic rocks of the neighbourhood of Moldau, which exhibited the same characters. And Sir Charles Lyell has recently placed in my hands a specimen of Serpentinous Limestone sent him by Dr. Gümbel, the Director of the Government Survey of Bavaria, in which I have found what appears to me distinct evidence of Eozoic structure, although it has been greatly altered by subsequent metamorphism.

* This difficulty has not been met, so far as I can understand, by any of the cases adduced as parallel by Messrs. King and Rowney. And it is further to be observed, with regard to many of their arguments, that they are based rather upon the appearances presented by the Serpentine Marbles of Connemara and other localities which present the Eozoic structure in its least characteristic development, than upon that of the Canadian specimens, which present it in its least metamorphic condition. Every palæontologist who is acquainted with the fact that even a recent Coral may be changed by atmospheric agencies into a crystalline limestone (see Sir C. Lyell's 'Principles of Geology,' 9th edit., p. 794), would feel the absurdity of maintaining that because the great mass of the Carboniferous Limestone has now a crystalline or subcrystalline aggregation, it cannot have been originally deposited as Coral in the manner indicated by the structure of the parts in which the original characters of these ancient reefs are best preserved. Yet this is precisely the line of argument taken by Profs. King and Rowney in regard to the Eozoic limestones. It is the striking contrast between the features of the comparatively unchanged *Eozoon* of Petite Nation, in Canada, and those of the obviously metamorphosed and perhaps *disintegrated* *Eozoon* of Connemara, which most satisfactorily indicates the organic structure of the former, by showing what mineralization has done, and therefore can do, in the latter; all this being in the contrary direction (if I may so express myself) to the *constructive* action so obvious in the regular disposition of the component parts of the former.

[*Note*, June 29, 1866.—To the foregoing I may now add, that having subsequently examined an extensive series of specimens of Serpentinous Limestones from the "Fundamental Gneiss," sent to me by Dr. Gümbel, I find in some of them the precise parallel as to Microscopic appearances with the most characteristic forms of the Connemara *Eozoon*; whilst from these I can trace a continuous gradation, through a series of phases which appear due to subsequent metamorphism, to specimens whose characters seem purely mineral. Appearances of precisely the same character are presented by a series of specimens of the Serpentinous Limestones from the "Primitive Gneiss" of Scandinavia, kindly transmitted to me by Prof. Lovén.—In a communication I have received from Dr. Dawson, dated March 28th, he says:—"I have lately had my attention directed to a point of importance noticed in my paper on *Eozoon*, but since somewhat overlooked, *the occurrence of Eozoon preserved simply in Carbonate of Lime*, without any Serpentine or other foreign mineral, and showing the structure (that is of the canal-system, for I have not yet seen the fine tubulation) as perfectly, though not so prettily in the matter of colour, as the Serpentinous specimens. This fact alone, which was noticed in my original Paper, and which I have now verified, is of itself *a conclusive answer* to Professors King and Rowney's objections." "I may also say that a careful reexamination of the Chrysotile or fibrous Serpentine, with additional specimens, enables me to reaffirm, if possible with still greater confidence, its entire distinctness from any of the structures of the Canadian Eozoon."]

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January 24, 1866.

James Mason, Esq., F.C.S., Brighton; William Nevill, Esq., of Langham Cottage, Godalming; and Henry T. L. von Uster, Esq., 3 Duke Street, Portland Place, W., were elected Fellows.

The following communication was read:—

## *On the* Kainozoic Formations *of* Belgium. By R. A. C. Godwin-Austen, Esq., F.R.S., For. Sec. G.S.

Contents.

## I. Introduction.

The following notes relating to the Kainozoic or Tertiary * formations of Belgium were put together in the course of an interesting excursion through that country in the spring of 1865, in company with Mr. Hamilton, Mr. Prestwich, Captain D. Galton, Mr. W. W. Smyth, Mr. Busk, and Mr. Gwyn Jeffreys. Our route was from Harwich to Antwerp, Louvain, Hasselt, Maestricht, Liége (whence to Engis and Engihoul), Namur. Some of the party went into Brussels to see the collection in the Museum there; some to the Grotte de Han; in company with M. van Beneden I had the advantage of seeing, under the guidance of M. Malaise, the lower Palæozoic and fossiliferous rocks of Gembloux, which he considers to be of the age of the Lower Silurian series of Sir. R. Murchison.

From Dinant, where we were joined by the late Mr. H. Christy, we all visited, under the escort of MM. van Beneden, Dupont, and other Belgian geologists and antiquaries, the caves of Furfooz on the Lesse. An excursion in the neighbourhood of Mons, and a visit to the coast at Sangatte, near Calais, completed the trip.

Some of our party had been in Belgium before, even repeatedly. The points in its geology which on this occasion chiefly interested us were the Crag-formation of Antwerp and elsewhere, the Boldérien beds of M. Dumont, and the caves and recent researches at Furfooz.

To what extent the several members of our party may concur in the views here recorded is a point on which I will not venture to speculate; they are offered as my own exclusively; but I feel bound to acknowledge the great advantage I derived from visiting the district in company with so many experienced observers as naturalists and geologists; and we can all testify to the kind interest and assistance of the Belgian geologists, as also to that of the military authorities at Antwerp, for which last we were indebted to the exertions of Mr. J. Jones.

The cave-researches of Furfooz are under the superintendence of MM. van Beneden and Dupont; for this reason it would not be fitting that any comments should be made with respect to the views which were freely communicated to us, until such time as the final official report shall have been published. The question relating to some portion of the in-filling is so closely connected with that very complicated period to which the Löss, the Sables de Campine, and the Cailloux Ardennais belong, that a few short references are necessary.

## II. Older Kainozoic or Crag Beds of Antwerp.

1. *General Remarks.*—By permission of the Belgian war department, we were enabled to examine at leisure the deep sections connected with the extensive military works in course of execution around Antwerp; in addition we received the cordial assistance of Captain Cocheteux and other Engineer officers.

The monograph of Mr. Searles Wood † had long since informed

* In this paper the author restricts the application of the terms Kainozoic and Tertiary to deposits of the age of the Faluns and of more recent date.—Edit.

† Palæontographical Soc. 1848–1850.

geologists how close an agreement existed between the marine fauna of the Suffolk Crag and that of Antwerp. At the same time it was evident from the work of M. Nyst * that there were many forms met with in one area which were apparently wanting in the other, and rendering it a matter of some interest in comparative geology that such a difference within such narrow limits should be accounted for; this difficulty has long been a point of special interest in Tertiary geology. The solution has been heretofore attempted by various applications of the percentage test, as by the proportion of recent forms to such as are unknown as living, or again by the proportion which a given parcel of shells might contain, either of Arctic or of more Southern forms. There has been so little agreement in the results thus arrived at that some fresh solution should be attempted. Percentage results, from their very nature, must ever be fluctuating; the process when first proposed seemed specious, inasmuch as it had the appearance of possessing arithmetical accuracy, but in reality it is the very reverse of this, in consequence of the uncertainty of all the elements of the calculation and of their negative character.

M. Dumont proposed a twofold division for the Tertiary or Kainozoic series of Antwerp, an upper or Scaldésien, a lower or Diestien. Sir Charles Lyell's account of the Antwerp Crag was prepared under disadvantageous circumstances. At that time a few detached excavations afforded the only attainable stratigraphical information, and hence it became necessary to give the fossils collected at each locality in separate lists, thus producing the impression that the Crag-formation there was both complicated and of considerable vertical thickness, but such is not the case.

At the time of our visit an examination of the Antwerp beds was extremely easy by means of two long artificial sections, one passing along the main ditch of the new "enceinte," 14,000 metres in length, the other along the ditch of the detached Forts, with a length of 17,000 metres; thus giving 31,000 metres of continuous section. These sections formed the subject of a short but very useful memoir by M. Dejardin, Capt. de Génie, one of the officers engaged on the work†.

In the excellent Memoir by Sir Charles Lyell‡, which has done so much to make English geologists acquainted with the relations of the various subdivisions of the Nummulitic and Tertiary formations of Belgium to those of this country, the Tertiary series is arranged as follows:—

§ 3. Antwerp Crag.

| | | |
|---|---|---|
| 1. Yellow Crag = Upper Crag | Calloo, tab. ii.<br>Steuvenberg, tab. iii. | Système Scaldésien, *Dum.* |
| 2. Crag gris—Middle Crag— | tab. iv. | |
| 3. Crag noir—Lower Crag— | tab. v. | |

§ 4. Sands and Iron Sandstone of Diest—"Système Diestien" of *Dumont.*
§ 5. Bolderberg Sands— "Système Boldérien."

* Coquilles Tertiaires de la Belgique.
† Bull. de l'Acad. R. des Sc. de Belgique, t. xiii. p. 470.
‡ Quart. Journ. Geol. Soc. vol. viii. p. 277, 1852.

Of this arrangement it may be remarked that the "Crag noir" of the local Antwerp geologists is distinguished from and made superior to the *Système Diestien* of Dumont, whose *S. Diestien* at that place (see Map, small edition) is described as consisting of "sable glauconifère coquillier" *.

M. Nyst's latest subdivision of the Belgian Kainozoic series is as follows:—

| | |
|---|---|
| 1. Yellow Sands, Steuvenberg, Calloo. | Cyprina, Isocardia, Astarte. |
| 2. Argillaceous Sands, Deurne. | Cetacean bones, Pecten, Cyprina, Astarte. |
| 3. Grey Sands. | Pecten Gerardii, broken shells abundant. |
| 4. Grey running Sand. | Bryozoa, shells scarce, same as 3. |
| 5. Black Sands, Edeghem, Berchem, F$^{t}$. Herenthals. | Includes *Pectunculus*-band. |

In 1861 M. Nyst published a very interesting paper †, to which is appended a list of 146 species of fossil shells and four Zoophytes; of these, 58 had not been previously noticed as occurring in the Kainozoic beds of Belgium.

The object of this paper is to state the result of that particular enquiry which was of chief interest in connexion with the Antwerp sections, namely the Zoological value of the subdivisions of the crag beds there, and whether the proposed vertical order of arrangement was correct in fact. Mr. Lankester visited Antwerp in 1864, and a memoir communicated to this Society ‡ served to revive the interest of these questions.

2. *Système Scaldésien.*—In order that the position of the Kainozoic series about Antwerp may be understood, it must be borne in mind that from the North Citadel on the Scheldt, as far as Deurne (about half the extent of the "enceinte"), the level of the country is below that of the river at high-water, which now rises 4·50 metres; low-water being 0·15 metre above that at Ostend. At this, the north end of the section, where the Crag beds have been laid bare beneath polder mud, its upper surface is at about low-water level, and at nearly the same level are the beds so rich in shells, out of which the Docks have been excavated, from beneath peaty beds and polder mud. We collected largely from these shell-beds, or rather from the spoil-banks. The assemblage is that given by Sir Charles Lyell, tab. ii. and iii., and by M. Nyst, list 34, p. 601§.

North of Deurne the glacis has been formed out of the spoil from the main ditch, and shows that it has been excavated out of an extension of the same mass of sands, gravel, and broken shells, as above. South of Deurne the ground rises somewhat, and as the works were then in progress, good sections were to be seen from 4

* Tabl. des Terr. &c. de la Belgique.

† Notice sur un nouveau gîte de fossiles, se rapportant aux espèces faluniennes du Midi de l'Europe, découvert à Edeghem près d'Anvers. Bull de l'Acad. R. des Sc. de Belg. t. xiii. p. 29. See also Lyell's 'Elements,' 6th edit. p. 232.

‡ Quart. Journ. Geol. Soc. vol. xxi. p. 221, 1865.

§ Omalius, Abrégé de Géologie, 7$^{e}$ édit. 1862.

to 6 metres deep. The blocks left for measuring the work done show such sections as the following:—

| | |
|---|---|
| *a.* Système Scaldésien... | Yellow sands, gravel and broken shells.<br>Grey sands, numerous broken shells.<br>Brown sands. |
| *b.* Système Diestien...... | Pale-green sands, shells few, not much broken.<br>Dark-green sands, *Pectunculus*-band.<br>Very dark compact beds. |

The relative thicknesses vary much from place to place; the whole not being more than 12 feet thick, of which the upper brown and yellow sands form about 6 feet. In the Dock-sections these upper beds may have been somewhat thicker, but at no place do they probably exceed 8 feet.

The upper series (*a*) constituting the "*Système Scaldésien*" of M. Dumont, viewed as a marine accumulation, presents a very common condition of sea-bed, consisting of dead-shell gravel, mostly forming banks, and heaped up under inconsiderable depths of water. This is a good division of the series, inasmuch as it marks a change in the depth and moving power of the water at this particular spot, the result, doubtless, of a physical change of wider extent; the effect of which was the disturbance of previously formed sea-beds and their rearrangement. At the same time there was an outward distribution of the materials of a higher or sublittoral zone, as seen in the gravel.

The "Système Scaldésien," as exhibited at Antwerp in the form of "couches remaniés," very closely resembles both in the condition of its materials and fossils, the Red Crag beds of Suffolk; nor is there any reason why the physical change which caused the Red Crag to succeed the Bryozoan should not be referred to the same geological change which made the Scaldésien follow on the Diestien.

3. *Système Diestien.*—In the section given above, which is just such as is to be seen everywhere from the Porte de Tournhout to that of Malines, the Scaldésien beds, or yellow and grey coarse series, contain either fine pale-green, somewhat loose sands, or else dark-green, almost black, and compact sands; these are the Diestien beds of Dumont. With reference to condition of sea-bed, it is that form well known as deep-water sandy and muddy ooze, and was the deposit of tranquil depths.

Although the whole thickness of this lower series has not been cut through within the area of the fortifications, even in the section above referred to, which presents the deepest cuttings, yet it has been proved, as we were informed by the Engineer officers on the spot, that the Diestien beds extended only a few feet below the excavations for the main ditch, and that within the area as well as without, the dark-green Diestien beds overlie compact Rupellien clay.

A maximum thickness of about 4 metres may be assigned to the Diestien beds; generally they are less, and small as are the vertical dimensions of the whole of the Crag series at Antwerp; there is no other place in Belgium where they are so thick—indeed, beds of the true Scaldésien, Crag-like type, occur only at that place: it is also the only spot where fossiliferous Diestien beds have been observed.

The Diestien beds of Antwerp represent a condition of sea-bed over which submarine life is abundantly developed, and that with a distinctive facies. Viewed in this way the sections from the Porte de Tournhout are exceedingly interesting, presenting a rich and varied fauna, of which a full enumeration has recently been given by M. Nyst (Bull. de l'Acad. Roy. des Sciences de Belg. 1861, sér. 2. t. xii. p. 20). One particular form, the *Pectunculus glycimeris*, numerically exceeds all others by 1000 to 1; it colonized this area of the Crag sea, attaining a large size, and forming banks which in places are not less than 2½ feet in thickness. The Diestien was a true life-zone, and exceedingly prolific, and as such it is in striking contrast to the Scaldésien division, of which the whole of the assigned fauna is from dead and drifted shells: it may safely be asserted that of the shells met with in the Scaldésien beds not one lived where it is now found; this, from a natural-history point of view, is the real difference between the upper and lower Crag of Antwerp.

The area over which the Scaldésien shell-gravel and the fossiliferous Diestien ooze are to be seen together is even now so limited that much generalization would be hazardous. Traced from below upwards, the Antwerp sections show a gradual passage from very fine and dark muddy ooze into sandy ooze, and finally into fine pale-green clean sand; in this there is a clear indication of a slight increase in the moving power of the water: a slightly diminishing depth might cause such a change. The more sandy beds, where they remain, form the uppermost portion of the Diestien division, and contain but few shells.

The Scaldésien division overlies an eroded surface of the Diestien, and is found on every component portion of the series down to the lowest and most compact beds. The line of separation is always to be traced, and is mostly very distinct—it marks a sudden change of condition;—but as in the Diestien so in the Scaldésien series, the rearranged pale-green sands, brown sands with shells whole or broken, the dead-shell banks, and uppermost the thickest layer of gravel with pounded shells, indicate a progressive change and slow shallowing.

The bathymetrical conditions indicated by the Scaldésien and Diestien accumulations may be judged of by the guidance of the soundings over the English channel; the difference may have been as much as from 30 to 40 fathoms, or to such an extent must the crag-sea have shallowed about Antwerp from the time of the shell-bearing Diestien beds, their denudation, and the formation of the dead-shell sand and gravel bank. The *Pectunculus glycimeris*, the most abundant member of the fauna, ranges from 25 to 60, and, according to some, to 100 fathoms; but no part of the Diestien beds indicate a depth at which *Dentalia* become abundant and characteristic, such as 80 to 100 fathoms.

I received from Captain Cocheteux, a small but very interesting collection of fossils from the lowest Diestien beds in the neighbourhood of Fort 4, towards Edeghem (see list); but we did not visit the Edeghem brickfield-section above referred to as described by M. Nyst. From a recollection of what I saw in 1861, the Diestien beds exactly corresponded in colour and composition with those of the enceinte. The only place near Antwerp at which we saw the superposition of the Diestien Crag to the Rupellien clay was at Schelle.

4. *Schelle.*—The Crag-sea accumulations of the several localities to be noticed have been called Diestien, but they belong to very different submarine conditions from those of the base of the Antwerp Crag.

As at Edeghem, beds of Rupellien clay are worked extensively for bricks and tiles at Schelle. This Rupellien clay is an upper member of the Nummulitic series of Belgium, corresponding in age and condition with, and externally very like, our Barton clay of Hants.

The Rupellien clay is capped by sandy beds, which, towards their base, and particularly at the upper end of the section, become as dark as those about Antwerp, though they are not so thick. These sands are altogether about 3·5 metres thick. A very distinctly marked line separates these formations; at one place there is unconformity on an eroded surface, and throughout there is a line or band of flints, some large, remaining in place, together with Septariæ from the Rupellien clay; one of these measured more than a foot across. These Crag beds belong for the most part to the drift-sand sea zone.

At Schelle the upper surface of the Crag sand has been eroded, and at either end of the section the denudation has been carried down to the Rupellien clay. Schelle is 10 kilomètres south of Antwerp, and the great interest of the section, as of that of Edeghem, consists in the evidence it affords of the complete break of continuity between the Rupellien clay beds and the overlying Crag.

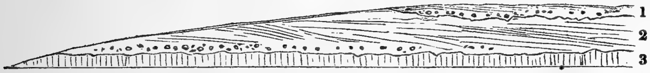
5. *Louvain.*—Louvain is between 4 and 5 myriamètres south-east of Antwerp. The remains of the Crag-sea beds occur only over the Belgian area in detached patches, and the interest of this locality consists in the evidence it affords of the great depth to which denudation of a date subsequent to the Crag period has been carried.

We were conducted to an interesting section on the side of a line of hill, on the road from Louvain to Pellenberg, and Tirlemont, by M. Van Beneden, who had with him a diagram prepared by M. Dumont. The upper part of this section alone is referable to the Crag, the details are given in fig. 1.

On an eroded surface of white and yellow marls, the equivalents of the Rupellien clays, according to Dumont, is first a line of chalk-flint shingle and gravel, surmounted by brown and ferruginous Diestien sands; these beds belong in a marked manner to the sea-zone of drifting sand. The uppermost portion of this capping to the hill consists of ferruginous sands distinctly bedded, occasionally diagonally, and below this is a line of waterworn flints on a scored surface. The upper series is somewhat coarser than the lower, and indicates a local change, or disturbance of sea-bed; the whole of the crag accumulation at this place is sublittoral.

Along the valley of the Dyle denudation has removed all beds from the Crag down to the Bruxellien of Dumont, or Lower Nummulitic.

Fig. 1.—*Section showing Crag-sand and Shingle capping a hill east of Louvain.*




1. Flint shingle.
2. Very ferruginous sands, with flint shingle at the base.
3. White and yellow marl (Argile de Boom) underlain by Lower Rupellien sands.

6. *Berg.*—The furthest point to the E.S.E. of Antwerp, distant 7 myriamètres, at which we saw the rolled flints and yellow sands of the Crag-sea area, was at Berg; these gravel beds were pointed out to us as belonging to the base of the Campine sands, but the circumstance that the gravel is wholly composed of chalk flints is against such a supposition. These Crag beds, which indicate littoral conditions, overlie the uppermost portion of the Nummulitic series (Tongrien).

7. *Bolderberg.*—Our visit to this place was the most interesting point of the excursion: the locality had suggested to M. Dumont his "Système Boldérien;" as such it was adopted by Sir Charles Lyell (*ubi supra*, tab. 1. p. 270) as also by MM. d'Orbigny* and Beyrich†. The Boldérien formation or division has therefore a two-fold interest:—1st, in respect of its distinctiveness or place as a marine sedimentary group, 2nd, as to its zoological value.

The section of the Bolderberg is well given by Sir Charles Lyell (*u. s.* p. 295), except that the position of the shingle-bed on an eroded uneven surface of the subjacent sandy strata is not represented in the woodcut. To whatever period the lower sands may belong, it is evident that they had become consolidated before the accumulation of the shingle. The shingle is wholly made up of chalk-flints, in which respect it agrees with the lines of gravel and shingle in the Louvain section (fig. 1), and also with that at Berg.

M. Dumont's systematic subdivisions were based on considerations of composition or mineral character; and in accordance with an assumed theory of geological change he considered that shingle-beds represented a break or division in a series of accumulations, and further, that the shingle- or gravel-beds were referable to the close

* Cours Elémentaire de Paléontologie, t. ii. p. 765.

† Ueber den Zusammenhang der Norddeutschen Tertiärbildungen, Abhandl. der k. Akad. der Wissensch. zu Berlin, Aus dem Jahre 1855, pp. 1 *et seq.*

s 2

of a geological period. In the case of the Bolderberg there was no difficulty in identifying the upper ferruginous sands with those of Diest, and overlying some older system, ending upwards in a shingle-bed.

So far as the "Système Boldérien" of M. Dumont is concerned, its geological value is dependent on this simple consideration,—Is the shingle-band connected with the sands below or the sands above? In nine cases out of 10 throughout the whole series of geological formations the shingle, gravel, and conglomerate beds form the base of each natural group of accumulations. In the case of the Bolderberg there is no ambiguity whatever, the break and unconformity, whatever it may be worth, occurs below, and from this line there is a progressive change upwards from sands with shingle to sands without; the whole mass of the upper ferruginous sands forming a continuous series, and differing from the capping to the hills about Louvain only in the circumstance of the fossils it contains. The lowest bed represents a littoral line; the higher sandy beds, the zone of drift-sand and of the Crag sea; the whole having been accumulated slowly as the area was being depressed or submerged.

Zoologically, the "Système Boldérien" has been represented as a true Miocene formation of the age of the Faluns of Touraine*, and this has constituted its palæontological interest. Sir Charles Lyell, with the assistance of MM. Nyst and Bosquet, gave a list of 47 species of fossil shells which presented this difficulty—that whereas the Faluns of Touraine do not contain a single form belonging to the Nummulitic formations, even those of its latest stage, but have a marine fauna, which so far as accurate identification has gone, is wholly Eastern Atlantic, the reputed Boldérien Miocene fauna has had assigned to it a mixed assemblage of North-Sea Crag shells, (recent species), and those of the Belgian equivalents of our Barton beds. It was this consideration probably which caused M. d'Orbigny to refer it to his "Sous-étage Tongrien"†; indeed, it is evident that it was the Bolderberg list which produced this double error.

We collected a considerable number of the fossils of this locality. They occurred, as stated by Sir Charles Lyell, in the pebble-beds and associated sands, they are for the most part broken and worn, and "resemble shells thrown on a sea-beach" (*u. s.* p. 296). The great preponderance of single valves and of fragments of *Pectunculus glycimeris*, and Crag forms of *Pecten*, *Venus*, &c., gives to the assemblage the aspect of the Scaldésien fauna; but with these are Diestien forms of *Lunulites*, *Flabellum*, and the little *Oliva flammulata*, all exceedingly well preserved. Even at first glance the fauna of the Bolderberg sands is to a very great extent identical with that of the Belgian Crag.

Sir Charles Lyell's list, when cleared of all species respecting which doubts were felt, leaves 23 forms. M. Nyst's more recent list also contains 47 species, but differing from the 47 given by Sir C. Lyell. Taking the first list, some of the identifications were erro-

* Quart. Journ. Geol. Soc. vol. viii. p. 279.
† Cours Elém. de Paléont. &c. t. 11. p. 764.

neous—*Corbula pisum, Cancellaria evulsa*, &c., have been recognized as such—some, it will be seen, are as yet peculiar, others have been described from imperfect or single specimens; eliminating these, the remainder are true Crag-shells and also recent species, so that the list no longer presents the admixture of Nummulitic and recent species as was once supposed.

The Boldérien fauna was considered to indicate a warmer climate than that of the Antwerp Crag (*u. s.* p. 297); but since the publication of Sir Charles Lyell's Memoir, the "Crag Noir," or "Système Diestien" has afforded all the forms of *Oliva, Conus, Ancillaria*, and *Cancellaria*, from which such conditions were inferred.

The Bolderberg is the only locality where the evidence of a Boldérien system, stage, or subdivision has been met with in Belgium. Of the newer formations of the Rhine valley, those of Grafenberg near Dusseldorf can alone, says Beyrich, be placed on the level of those of the Bolderberg; but he adds that it is very doubtful whether these do not rather belong to the older Sternberg beds or Tongrien; so that, both on purely geological as on zoological considerations, the Boldérien system may be removed from the general series of distinctive geological groups.

Since the above was written, I have met with the following passage by M. Nyst—the result of a comparison of the Edeghem shells with those of the Bolderberg:—"Ce qui nous fait penser que le système Boldérien n'est que la base du système Diestien de Dumont." It is true that the Bolderberg shells agree with those of Edeghem and Fort Herenthals; but inasmuch as the Bolderberg shells have been washed out of older beds, the Système Boldérien, as an accumulation, must necessarily be of *later* date in the Crag series, and not its base or oldest portion.

8. *General Results*.—The study of the Antwerp sections leads to the impression that the vertical dimensions of the whole of the Crag formation there are exceedingly small. From the highest ground (ligne culminante) down to the sea-level, the depth is only 9 metres, and within this is comprised the whole formation, including the Campine sands. As it happens in Suffolk *, so here, where the upper or Scaldésien Crag is thickest, the lower is thinnest; and where the Diestien is thickest, the upper is thinnest, or at times wholly wanting. If the Diestien beds be divided into upper sandy ooze and lower muddy ooze, the sections show that where the first has been removed and "remanié," the resulting Scaldésien beds take the form of "Crag gris;" and that where it has not, there are then yellowish, argillaceous, and gravelly sands. The real difference between the "Crag gris" and the "Crag jaune" of the Belgian geologists is, that the first contains a larger proportion of the "remanié fauna" of the Diestien beds; and although they may, as already stated, have been produced under slightly differing conditions, and in sequence, yet in the horizontal sections they replace one another, and have not an aggregate thickness of 4 metres. If, as

* In the Deben valley the Crag does not exceed 25 feet, and even in the Ipswich district it is of small amount.

was most probably the case, the Scaldésien accumulation was of the nature of a dead-shell sand and gravel-bank, like the "cordons littoraux" of the English Channel and North Sea, and so merely a local condition of sea-bed, the estimate for the thickness of the Crag must be still further reduced: the ordinary minute subdivisions of systematizing geologists are wholly inapplicable to such accumulations as these.

From this it is evident that the Antwerp sections fully satisfy the inquiry as to relative age. The Scaldésien division there is younger than the Diestien, as it has been accumulated over it. So likewise the upper Scaldésien must be younger than the lower; but this is merely relative age in respect of rearrangement. The corresponding conditions on the English and Belgian areas of the Crag sea are the Red Crag and the Scaldésien; both are "remanié" accumulations. The difference which these present in respect of the marine fauna they contain, is not of much amount numerically, and, viewed in detail, it is just such as would arise from the different sources whence each was derived. The Red Crag was from the break up of a neighbouring Bryozoan sea-zone, the Scaldésien from Ooze depths. Any comparison of the fossil contents of the "Coralline Crag" and of the "Crag noir" must be subject to the consideration of differences which result from depth and condition of sea-bed. From the nature of the question, therefore, a percentage calculation for determining relative age is inapplicable with respect to the component parts of the English and Belgian Crag, or even of one part with another of the same series.

The fossils of the Système Diestien are proper to it; and from them may be inferred the condition of that part of the Crag sea for that particular time. The fossils of the Scaldésien beds are wholly extraneous to them, belonging to all regions of depth, and all periods of the Crag formation—from them no guidance in geological chronology can be derived.

### III. Conditions of Crag-Sea Area.

By combining the results obtainable from the East Anglian and Belgian Crag beds, some general views may be deduced as to the Crag sea, both physical (1) and zoological (2).

1. *Physical Features.*—Along the lower courses of the Orwell and Deben, and thence towards Orford and Aldborough, the Crag beds occupy an old depression. The greatest extension which the sea had here was by Bentley, Ipswich, and Woodbridge. The Red Crag of these places being a true sub-littoral accumulation.

Corresponding beds, as to age, occur in two other old depressions, those of the Blyth and the Yare. At Yarmouth it may be inferred that there is a considerable thickness of Crag (Prestwich, Quart. Journ. Geol. Soc. vol. xvi. p. 449). Finally, a sea-bed of the same age is seen at Mundesley. In tracing the outline of the Crag sea, it may safely be made to include a rather wide area, about the lower courses of the Waveney, Yare, and Bure.

Rivers discharged at several places, bringing down the land and freshwater shells of the period into the Crag sea, of which forms the *Unio litoralis* and *Cyrena consobrina* are the best guides. On one side of this sea, the Grays beds represent the purely fluviatile or estuarine beds of the great tributary of the Thames valley; whilst the Norwich beds and those of Kelsey belong to the fluvio-marine facies, in connection with the streams or rivers of the Yare and Humber.

North of the East Anglian area the Crag sea is indicated at intervals, as at Bridlington and Stains (Aberdeenshire), and by its fossils over the bed of the North Sea.

In addition to the conditions here given, we have on the English side of the area the Coralline Crag, or Bryozoan facies of its sea-bed.

From near Maastricht the Crag beds extend beneath newer accumulations into Guelderland (Winterswyk, Rekken)*.

The shelly sands which in North Holland occur beneath the Dune-sand, Polder-, and Peaty-beds, are, undoubtedly, of the Crag Period, and the same sea-bed is met with in Segeberg, Lüneberg, and Sylt; but it does not extend eastwards into the Baltic area, and that depression owes its origin to a subsidence or depression of the great Scandinavian mass, the line of which, very probably, is that of the deep-sea soundings, and which accordingly has been taken (*vide* Map, fig. 2).

The Crag sea opened out northwards. On the extreme south its condition is indicated, first, by the great breadth of the sand-zone, extending the whole length of the axis of Artois, and the Ardennes chain; and next by the transport, along a line of coast, of the flint-gravel and shingle, which must necessarily have been derived from the English side of the area. As these materials occur from the basement bed to the uppermost, such a coast-line must have been continued during the whole of the Crag-sea period, as a limit on the South. Structurally, the limitation was dependent on the extension of the axis of Artois, and of our own Wealden elevation. The Sangatte section shows that this barrier was maintained until the close of the Glacial Period†.

At this time the Northern hemisphere presented a broad belt of circumpolar land, and these geographical arrangements influenced the character of the Crag-sea fauna.

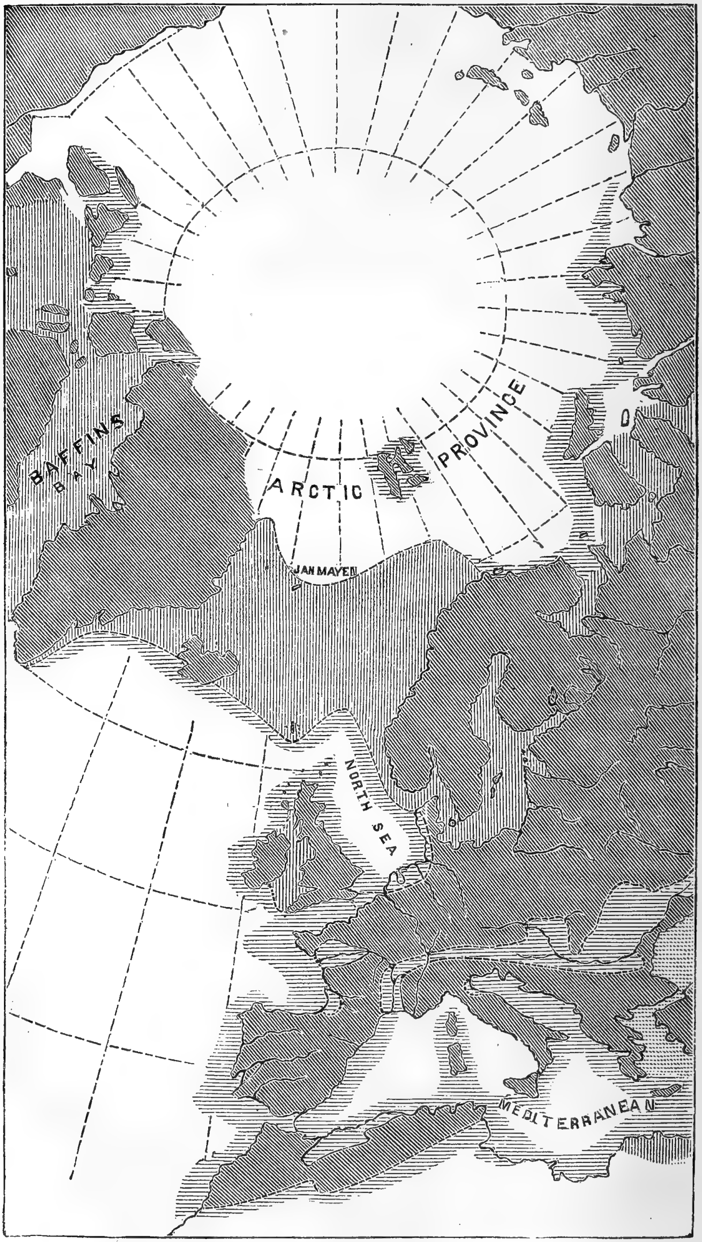
Such a communication as the present does not admit of a detailed analysis of the Crag-sea fauna in respect of its origin, though the materials are amply sufficient, but the subject may be alluded to, inasmuch as the peculiarities can alone be explained by reference to bygone geographical arrangements.

What these must have been is given in the accompanying small sketch-map, which shows why the Crag Molluscan fauna, which is wholly Atlantic, like that of the synchronous sea-beds of Selsey, the Cotentin, the Faluns of Touraine and Bordeaux, &c., should differ from these last to so great an extent. The Crag-sea area included the representatives of two distinct Atlantic provinces, the Boreal or

* Staring. Bodem van Nederland. vol. ii. p. 284.

† See Nat. Hist. of European Seas, p. 286, and Map II.

Fig. 2.—*Map showing the extent of the Crag-sea area.*




The vertical tint indicates ancient land.
The horizontal tint indicates ancient seas.
The inclined tint indicates present land that has not been submerged during the Crag period.

North Atlantic, both Eastern and Western, and the Southern or Lusitanian.

The greater extent of circumpolar land would exercise a great influence on the course of the North Atlantic Ocean-current, and the general temperature of its waters, from 55° to 65° N. lat., would have been much higher than at present. Under these conditions there would have been an extension eastward of the transatlantic littoral fauna, whilst at the same time the temperature would encourage a more northern range of Lusitanian forms.

The marine beds of the Tagus, of the Adour, of the Loire, and of the English Channel, which were indents from the Eastern Atlantic, have this common characteristic, that the fauna of each, so far as living species can guide us, is more southern than that of the corresponding coast at present; and this order of difference is progressive from south northwards, so that whilst the beds of the English Channel have Lusitanian relations, those of Touraine, and to a greater extent those of Bordeaux* and the places south connect themselves with the West African marine fauna.

2. *Zoological Features.*—The Crag fauna of the English area is incomplete, so also is that of Belgium; taken together, they form a completer marine fauna, representing a greater range of sea-zones.

Various comparisons have been made for percentage calculations between the shells of the "Crag jaune" and the "Crag gris," and again between those from the Scaldésien generally and the "Crag noir" or Diestien.

It will not be necessary here to reproduce the whole of M. Nyst's latest lists, given in the work of Omalius; for the first comparison the differences in the first two lists will suffice. It might be expected, from the extent to which the Diestien beds have been denuded, that the whole of their proper fauna should be met with in the Scaldésien beds which resulted from that change; it is so to a great extent, but it is also evident on the spot that it is mainly the stronger shells which have endured removal; besides this, in the Antwerp district, where alone true Scaldésien beds occur, the Diestien beds on which they lie have not been denuded quite so low as the second life-zone (Edeghem, Fort Herenthal), in which the deepest water assemblage is met with.

It would appear, so far as collections at present indicate, that of 143 species enumerated by M. Nyst, there are some in the "Crag jaune" which are scarce or wanting in the "Crag gris" (Tab. I.), and in the latter, some wanting in the other (Tab. II.); but the lists may be somewhat reduced by removing such species as are known only as Belgic at present. *Paludestrina? terebellata*, N.; *Turbinella internodula*, N.; *Eulima lævis*, N.; *Natica proxima* (a doubtful species); *Cancellaria minuta*, N. (un seul individu); *Pleurotoma turrifera? P. costata*; *P. histrix*; *P. Woodii*; *Murex tortuosus*, M. C.

* The boundary of the Crag sea is so traced on its eastern side as to include the Upper Kainozoic formations near Cassel, Luithorst, Freden, and Dichholtz; these are all in the latitude of the Belgian crag, and along the courses of the Weser and Lesse.

(a deformity of *M. erinaceus*); *Trophon striatum*; *Cerithium Woodwardii*, N.; leaving for Tab. I. 16 peculiar species.

### Table I.

(*The species with an asterisk occur in the Edeghem zone.*)

| | | |
|---|---|---|
| **Rissoa.** | | |
| vitrea, *Mont.* | Wt. Brit. to N. Spain, 4–40 faths. | Bryozoan Crag. |
| **Turbo.** | | |
| *plicata, *Mont.* | Brit. and Lusit. 10–60 faths. | Bry. Cr. Subap. |
| **Actæon.** | | |
| *Noæ, *M. C.* = A. tornatilis | Boreal and Lusit. 40 faths. | Bry. Cr. |
| **Tornatella.** | | |
| conoidea, *Brc.* = T. plicata, *Mont.*; fide Alder, *Lovén.* | | |
| **Natica.** | | |
| Sowerbyi, *N.* = catenoides = nitida | Boreal and Lusit., litt., 40 faths. | Red Cr. |
| **Trochus.** | | |
| papillosus, *Da C.* = similis, *M. C.* | Sth. Brit. to Lusit. litt., 50 faths. | Red Cr. *T. similis* in "Crag gris." |
| cinerarius, *L.* | Boreal to Sth. Brit. litt., 20 faths. | Red Cr. |
| **Cancellaria.** | | |
| costellifera, *M. C.* = viridula | Greenland Eur. Boreal, 10–50 faths. | Bry. and Red Cr. |
| umbilicaris, *Brc.* = cancellata = similaris | Lusit., W. African, 4–25 faths. | |
| **Pleurotoma.** | | |
| *turricula, *Brc.* non Belatur. | .................................... | Red Cr. It. Sic. (Bolderberg). |
| elegans, *Scac.* = attenuatum, *Mont.* | N. Lusit. to Mediterranean, 6–25 faths. | Touraine (*Pl. incrassata*, Dej.). |
| gracilis, *Scac.* | Brit. to Lusit., 8–30 faths. | |
| **Trophon.** | | |
| scalariforme, *Gould* = clathratum, *L.* fide Lovén. | Boreal and Brit. litt. to 100 faths. | Red Cr. |
| tetragona, *M. C.* = capillus, L. | Boreal to N. Lusit., 5–10 faths. | Red Cr. (a deformed variety). |
| **Cerithium.** | | |
| punctatum, *Woodw.* | | Red Cr. Tour. Subap. |
| **Nassa.** | | |
| prismatica, *Brc.* | Lusit., 20–40 faths. | Bry. and Red Cr. Tour. Subap. |
| **Buccinum.** | | |
| crassum, *N.* = Dalei, *M. C.* | Boreal and Lusit., 81 faths. | Red Cr. |
| **Patella.** | | |
| virginea, *Müll.* | Boreal to Lusit. litt., to 50 faths. | Red Crag. |

In like manner the following may be deducted from the list of "Crag gris" shells :—*Scalaria Woodiana*, N.; *Turbinella similis*; *Cerithium sinistrorsum*; *Nassa flexuosa*; *N. crassilabra*; *N. contorta*; *Pileopsis militaris*, Mont. (a spurious West-India shell, F. and H. ii. p. 462); *Dentalium semiclausum*; leaving 16 peculiar species, viz. :—

TABLE II.

| | | |
|---|---|---|
| PYRAMIDELLA. | | |
| læviuscula, *Sw.* | ......... | Bry. Cr. Tourain. fal. jaune. Bord. |
| SCALARIA. | | |
| clathratula | S. W. Brit. to Canaries, 10–80 faths. | Bry. Cr. |
| ACTÆON. | | |
| *levidensis, *Sw.*=tornatilis, *L.*=Noæ, *M. C.* | Brit. to Spain, litt. to 40 faths. | Bry. and Red Cr. (in tab. i.). |
| RINGICULA. | | |
| *buccinea, *M. C.*=auriculata, *Mont.* | Lusit. 4–60 faths. | Bry. and Red Cr. Bord. Subap. |
| TROCHUS. | | |
| similis, *M. C.*=papillosus | W. Brit. to Canaries | also in tab. i. |
| Kickxii, *N.*=Adansonii, *Payr.* | Lusit. | Bry. and Red Cr. |
| Robynsii, *N.* | | |
| conulus, *L.*=zizyphinus, southern form of | Lusit. litt. to 40 faths. | Bry. Cr. |
| MARGARITA. | | |
| ? monilifera, *N.*=maculata, *Sw.* | ......... | Bry. Cr. |
| PLEUROTOMA. | | |
| *intorta, *Brc.* | ......... | Red Cr. Dax. Subap. (Steuvenberg). |
| TROPHON. | | |
| alveolatum, *M. C.* | ......... | Bry. Cr. com. Red Cr. |
| antiquum, *Müll.* | Boreal to W. Lusit. and Med. | Cr. passim. |
| muricatum, *Mont.* | Brit. and Lusit. 12–50 faths. | Bry. and Red Cr. |
| PYRULA. | | |
| *reticulata, *Lam.* | ......... | Br. and Red Cr. Tour. Subap. |
| NASSA. | | |
| *granulata, *M. C.*, var. of incrassata | Boreal and Lusit. litt. to 50 faths. | Bry. and Red Cr. |
| CASSIDARIA. | | |
| *bicarinata, *M. C.*=echinophora | Lusit. 6 faths. | Bry. and Red Cr., rare. |
| PILEOPSIS. | | |
| obliquus, *Sw.*=ungaricus, var. | Brit. and Lusit. 15–30 faths. | |
| DENTALIUM. | | |
| costatum=dentale, *Lin.* | Lusit. 2–30 faths. | Bry. and Red. Cr. |

The Conchifera from the "Crag jaune" and "Crag gris" are the same; the differences are solely in respect of the gasteropods. The distribution in depth of the living analogues of the Crag conchifers will satisfactorily explain this; and the only other inferences which these tables suggest are, 1st, that the species generally indicate a greater depth of water, as their life-zone, than that of remanié Scaldésien beds in which they occur; and, 2nd, that these deeper zones of the Crag-sea had very decided southern or Lusitanian relations.

M. Nyst is of opinion that the marine fauna of the lower Diestien beds (Crag noir) is more nearly allied to that of the Faluns of Bordeaux, Piedmont, Sicily, and Austria, than that of the Scaldésien Crag. This view is hardly supported by a consideration of the 25 species of Conchifera which occur in the Edeghem and Fort Herenthal zone. As the product of the shallower-water sea-zones which contributed the Scaldésien fauna, shows decided southern relations, the deeper-water zones would necessarily show a like relation somewhat more strongly, from the more uniform conditions which obtain there. This is just what happens now. This impression as to the Falunien facies of the lower Crag is very likely to suggest itself, from the presence of corals such as *Stephanophyllia*, *Flabellum*, and the marked preponderance of such genera as *Cancellaria*, *Fusus*, *Pleurotoma*, *Conus*, many of which are so very like Barton and Rupellien species as to give an even older aspect to these beds. All the Diestien species are, however, distinct, and these resemblances are good illustrations of that system of representation which is to be observed in respect of the products of like conditions and zones of depth of every geological period.

M. Nyst's list of Edeghem shells may be reduced from 145 to 130 in respect of uncertainties; of these 47 are known as living. This gives a seemingly larger proportion of unknown to known forms than is the case with the Scaldésien Crag. The question which arises is, whether this difference is connected with relative age,—whether it is any proof that the Edeghem beds are of greater antiquity than the Scaldésien. Geologists have so considered it.

The 47 species above referred to are as follows,—L. signifying Lusitanian province, Br. British, B. Boreal.

Table III.

Chemnitzia similis, *Forbes*. L.
Pyramidella plicosa, *Bronn*. L.
Odostomia plicata, *Broc*. B. & S. L. 10–70 f.
Actæon tornatilis, *Lin*. B.–L., 3–60 f.
Ringicula buccinea. L., 4–60 f.
Natica millepunctata, *Lin*. L. litt.–40 f.
—— Josephinea = Olla. L., 8–12 f.
Cypræa pyrum, *Gm*. L., uncertain.
—— Europæa, *Mont*. B. & L., litt.–20 f.
Oliva flammulata. West Afr.
Mitra fusiformis, *Broc*. L.
Aporrhais pes-pelecani, *Lin*. B.–L., 100 f.
Pleurotoma intorta, *Broc*.
Nassa incrassata, *Müll*. B.–L., litt.–50 f.
Cassis Saburon. L.–W. Africa, 8– ?.
Calyptræa sinensis, *Lin*. S. Br.–L., litt.–10 f.
Crepidula unguiformis. L.
Emarginula fissura, *Lin*.
Dentalium entalis, *Lin*. L., 2–200 f.

TABLE III. (*continued*).

Bulla lignaria, *Lin.* B.–L., litt.–40 f.
—— cylindracea, *Brug.* B.–S.L., litt. –90.
—— acuminata, *Brug.*
—— conuloidea, *Wood.*
—— utricula, *Broc.*
Vaginella depressa. Lusit. latitudes.
Spirialis rostralis. „
Pholas papyracea. S. Br., litt.–20 f.
Solen ensis, *Lin.* B.–L., litt.
—— strigillatus. L., litt.–10 f.
Saxicava arctica. Litt.–160 f.
—— rugosa. Br. & L., 6–20 f.
—— fragilis.
Syndosmya prismatica. B.–L., 3–100 f.
Leda pygmæa, *Phil.* E. & W. B., L., 25–50 f.
Venus rudis, *Poli.* L.
Venus chione, *Lin.* S. Br. & L., litt. 40 f.
Corbula gibba, *Oliv.* B.–L., 5–30 f.
Cyprina Islandica. B. & Br., 5–80 f.
Mya ferruginosa. N. Br., L., 3–80 f.
Axinus sinuosus. B.–L., 8–80 f.
Lucina borealis. B.–L., litt.–80 f.
Pectunculus glycimeris. 10–50–100 f.
Modiola marmorata, *Forbes.* B.–L., litt.–40 f.
Pecten tigrinus. B.–L., 10–100 f.
—— Sowerbyi.
—— pusio. Litt.–90 f.
Anomia ephippium. B.–L., litt.–160f.

It is evident from the foregoing list that the Edeghem fauna is referable generally to a much deeper bed than the Scaldésien. This consideration by itself shuts out such comparisons as have been made; things so unlike as the assemblages of fossil shells from very different ranges and conditions of sea-bed can only be compared for the purpose of obtaining a knowledge of what those depths were. Our acquaintance with the distribution of marine species over deep-sea beds is as yet imperfect, but we know that it has its peculiar facies; and geologists have not sufficiently regarded this, hence much erroneous generalization. It is well observed by Mr. J. G. Jeffreys*: "It is obvious that negative evidence of the occurrence of any species (and especially of those which inhabit deep water) in any given area of sea is inadmissible; and naturalists do not differ from logicians or lawyers in rejecting such evidence." The peculiar forms of the "Crag Noir" could not possibly occur in Scaldésien beds, in respect of their conditions of existence, though they should have been inhabitants of the same sea at the same time. The occupation of the North Sea area by the true Crag fauna was not of lengthened duration, nor does the fauna itself indicate that change in time which is so clearly to be traced in the accumulations of long periods, whether Palæozoic, Secondary, or Nummulitic. The Crag is not a formation, but merely a single stage in the Kainozoic series.

3. *Denudation.*—The extent to which portions of the rock-formations have been removed, and the character of the surface denudations, are amongst the most interesting of the geological phenomena of Belgium. Such is the denudation which occurred antecedently to the Cretaceous series, and again before the Nummulitic. For the present I would call attention to that which followed the completion of the Crag-sea beds, because the evidence is very striking, and has a bearing on some views recently put forward by English geologists, to the effect that there is evidence of continuity and unbroken marine conditions, from the Suffolk Crag upwards into the Boulder-formation.

* Ann. and Mag. Nat. Hist. ser. 2. vol. xvii. p. 168.

Abundant illustration might be derived from our own East Anglian area to controvert this view, and prove that a great break and a long interval of time intervened between the Crag beds and the Boulder series, during which the North Sea was a terrestial area. The Belgian evidence bears most on the length of the interval or the lapse of time.

Over the whole of the broad area of the Scaldésien, Diestien, and Boldérien systems of the map of Dumont the formations are severally at present represented only by isolated masses or patches: away from Antwerp, and as the country rises southwards, these occur as the cappings of hills, or ridges. These sandy strata, which perhaps may have admitted of easy denudation, must, from their composition, have extended from place to place; and what now remains is not a thousandth part of what once was. In the case of the valley of the Dyle, by Louvain, the denudation has extended down to the Bruxellian beds of the Nummulitic series to a depth of 100 feet; and the completeness with which all the materials have been removed is well seen in the slope of the hills, as also on the level, along the railway cutting. The denudation about the Bolderberg is of nearly like amount as at Louvain.

In these cases, as in that of Schelle, the löss and Campine sands were spread out after the denudation of the Crag-sea beds; and as these belong to the later portion of the glacial period, the denudation of the country must be referred to some intermediate stage *.

4. *Variation in Depth.*—The movements of elevation and depression of the water-level which the North-Sea area experienced during the Crag period, are very simple, and so far are in harmony with the apparent short duration of that period.

The chalk flints, and the Septarian blocks derived from the subjacent Rupellien beds, which also occur elsewhere at the base of the Diestien system (Edeghem) are the remains of shallower water conditions than such as followed, or are proofs of depression.

Both on our own Suffolk area, as on that of Belgium, the change indicated from the Red Crag to the Bryozoan, and from the Scaldésien to the Diestien, was of diminished depth, or is evidence of elevation. Its subsequent emergence was in the same direction.

The earliest condition of the Crag-sea area here indicated is supported by a study of the list of shells given by Mr. Nyst, as obtained from the gravel bed at the base of the Diestien system at Edeghem †.

The Faluns of Touraine have experienced an amount of denudation such as is presented by the Belgian Crag. M. d'Orbigny has made this remark with respect to the first-named formation, that removal to so great an extent should have happened to synchronous accumu-

* Considered with reference to a line of section from Fort 2. towards the North citadel, the whole of the Crag series has been planed off from N.E. to S.W., so that lower beds come to the surface; and this has happened twice:—1. during the Crag period, when by diminution of depth the deeper sea-bed was denuded, and covered up by the Scaldésien; 2. when its general surface was eroded and removed.

† Bull. de l'Acad. Roy. de Sciences de Belg. sér. 2, vol. xiii. p. 29.

lations, though somewhat distant, is curious as a coincidence, but in both cases it perhaps may be explained by the inconsiderable thickness, as also the loose materials, of the two formations.

## IV. Newer Kainozoic.

1. *Cailloux Ardennais.*—In the sections about Antwerp we seldom failed to detect the thin line of quartz pebbles, to which the Belgian geologists have called attention, as underlying the Campine sands. They were here very small, few in number, but perfectly rounded; they have been derived from the quartz veins of Palæozoic rocks. These are the *Cailloux Ardennais* of M. Omalius, and came originally from that ridge or axis. As compared with other places to the north and east they have evidently at Antwerp reached their extreme limit of dispersion*.

In the section at Schelle the quartz pebbles serve to separate the Campine sand from the older sandy accumulation; but for these the line might easily escape detection, so closely do the surface-sands resemble the Crag sands beneath. At this place it is evident that Campine sand has been spread over the country since the denudation of the Crag, as at either end of the section it rests on the surface of the Rupellien clay, and in this position the quartz pebbles are mixed up with the chalk-flints which originally occurred at the base of the Crag, and still remain *en place.*

About Hasselt the quartz pebbles occur in great abundance and of large size; with them are chalk-flints, somewhat less water-worn. Towards Maestricht the quartz gravel, as seen in the railway banks, underlies a considerable thickness of argillaceous sand; the accumulation increases in thickness as it approaches the line of the valley of the Meuse, ending abruptly at a considerable elevation above the present level of that river, which has deepened its course out of these gravel beds.

From Hasselt towards the Bolderberg the plain presents a continuous spread of siliceous sands, overlying coarse quartz shingle with flints. These sands and gravels end off at the base of the Bolderberg ridge.

Quartz pebbles, beneath löss, occur in the high ground above Liege on the north, as also north of Namur, both on the surface of the Carboniferous limestone, beneath the löss, as also in the wide fissures of those rocks. Wherever patches of Nummulitic sands occur (Bruxelles beds), the quartz shingle separates the older sands from the löss.

At Dinant, in the Condroz, the quartz shingle occurs everywhere over the surface on the high ground; and lastly we met it in the fissures which have been enlarged into the caves of Furfooz.

These caves occur in a mass of Carboniferous limestone overlooking the river Lesse, a tributary of the Meuse, and taking its rise in the high ground of the Ardennes, near St. Hubert.

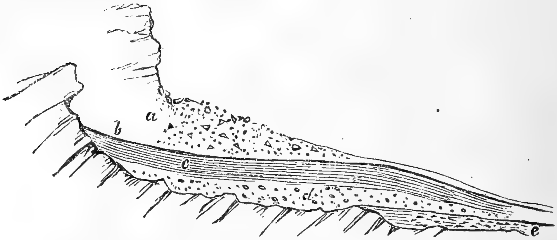
* I did not notice any quartz pebbles on the summit of the hill east of Louvain.

In the first cave, which is established on a line of fracture of the limestone, enlarged by the passage of water, the general order of the accumulation which occupies the lower portion, is as follows (as traced for me in my note-book by M. Dupont; a layer of "argile smectique" of M. Dupont, next to the limestone rock, is merely the product of the decomposition of the impure limestone):—

1. A thick accumulation of limestone talus, from the face of the cliff.
2. Loamy sand.
3. Rounded quartz pebbles.

Beds 2 and 3 extend back into the cave, sloping upwards.

Fig. 3.—*Section of the deposits at the entrance of the Furfooz Cave.*




*a.* Angular débris—Argile à blocs anguleux.
*b.* Stalagmite.
*c.* Sandy Clay. *Bear* and *Reindeer.*
*d.* Shingle—Cailloux Ardennais.
*e.* Fluviatile sands. *Beaver*, &c.

In the second cave, which is lower in the cliff, there is outside, an accumulation of debris, beneath which, and passing into the cave, are

1. Sandy and marly beds, in which are a few angular blocks, such as may have fallen from above whilst the bed was forming. Lines of successive accumulation.
2. Bed of quartz pebbles, in layers, sloping outwards.
3. Sands, bedded, like river sand; remains of beaver.

The upper level of the pebbles in the second cave* is wholly below that of the pebbles of the first cave; this circumstance entirely disconnects the shingle from any alluvial action of the Lesse. Even were the two accumulations at the same level, and had they been lodged in these caverns by a river flowing down the valley at a very high level, the arrangement of the pebbles would probably have been the reverse of what it is.

The materials of beds 1 and 2 seem to have been introduced from above; and the only portion of the accumulation which has the character of a fluviatile deposit is the sandy bed No. 3. Numerous specimens of the shingle are scattered over the upper platform of the

* Ten metres above the level of the river.

limestone mass in which these caves occur, and show that the dispersion of the pebbles belongs to some broader agency than river-action; whilst bed No. 3, with the remains of beaver, indicates that antecedently to these conditions the valley of the Lesse was much in the same state then as it is at present, or a line of river-drainage.

Bed No. 1 of the caves may be referred to the period of the löss, and

Bed No. 2 to the *Cailloux Ardennais,* which here consist of large coarse shingle.

There are no remains of any shingle banks at high levels along the northern slopes of the Ardennes, which have been produced at any Secondary, Nummulitic, or Tertiary period. Nor has the Palæozoic series of Belgium been the source of any shingle met with in the Nummulitic series of that country, the pebble beds in which are wholly of chalk-flints. At low levels, as in the Tournay district, there are great accumulations of quartz shingle at the base of the Cretaceous series (Tourtia); but this is the direction in which the *Cailloux Ardennais* are not met with. These Ardennais pebbles, which have been distributed at a definite stage of the Glacial Period, could not have been formed then, inasmuch as the region whence they have been derived was not submerged, and the only other source which suggests itself is that remarkable shingle bank which underlies the Devonian series of Belgium, in the Condroz, from Pepinster to Nassogne and Couvin, along the Ardennes, namely, the "Poudingue de Burnot" of Dumont.

2. *Glacial Drift.*—Detrital beds are in places interposed between the Campine sands and the Crag-formation. We were conducted by Captain Cocheteux to an interesting section exhibited in the outer ditch of Fort No. 4. The beds consisted of loose sands, loamy sand, ending with somewhat coarse sands; at the base were pebbles of white and black flint, and occasionally flint flakes (naturally formed); there were also small white quartz pebbles; with these were bones of Cetaceans, sharks' teeth, Crag shells, and other spoil from older Tertiary formations. All this material may be called local, such as might have been derived from beds at no great distance; but there were also many large ragged unworn chalk-flints; these occurred for the most part in the upper portion of the accumulation.

The Scaldésien beds were much reduced in thickness at this spot, so that the Campine sands and underlying detritus lay partly on green Diestien beds; these last were also much eroded, and blocks of the more tenacious portions had been cut out and caught up in the detritus; the whole surface was scored out, in one case to a considerable depth.

This accumulation in all its circumstances was very like some of the lower drift-beds of Suffolk; and enough was to be seen at this place to warrant a reference to that stage of the East Anglian marine drift-beds, which are represented by the sandy gravel-beds below or beyond the margin of the Boulder-clay.

Rocks of Scandinavian origin have not been met with beneath the Campine sands of this part, or indeed of any part of Belgium, nor did any occur to us. The transport of northern detritus southwards, both over our own area and that of northern Europe, took place during the later Glacial period, and does not appear to have extended to this part of Belgium.

3. *Campine Sand.—Sables de la Campine.*—In every section which we saw about Antwerp, there was to be observed at the surface a very uniform layer, which has been referred by the Belgian geologists to that very remarkable sandy formation covering so large a district on the confines of Belgium and Holland, the Campine, or Kempenland, whence the "Sable Campinien" of Dumont.

About the city of Antwerp this accumulation seems to be thickest where the ground is highest, as outside the Malines Gate, in the direction of the roads to Schelle and Boom by Fort No. 7. The cuttings going on in this direction, beyond the "Enceinte," show good sections, six feet and upwards in thickness, of fine sand; though where the soil is moist, the beds have much the appearance, and even character, of some of the buff-coloured Löss of Brabant.

It is noticed by Dejardin that the limited area on which the city of Antwerp stands is bare of this formation. "Cette ville a dû former une île dans la mer Campinienne."

No fossil remains of any kind have ever been met with in this accumulation.

These sandy beds extend from Antwerp over the Campine, and thence into North Holland; they form for the most part a barren tract, which the Belgian Government has striven hard to bring into cultivation, with only partial success, owing to the extreme lightness of the sands, which are easily blown about, and are constantly shifting.

The superficial sands of Hasselt, towards the Bolderberg and Beverloo, belong to the Campine formation.

The manner in which this covering of sand follows the rise of the country from north southwards, overlapping all older formations, and its inconsiderable thickness compared with its great superficial extent, forbid the supposition of accumulation by water, or of a "Mer Campinienne." On the other hand, the aspect and uniform composition of these sands, the manner in which, when dry, they are lifted about by the wind, suggest that they have originated as Dune-sand, which has travelled inland from the coast-line of some former condition of the North Sea.

The age of the "Campine Sands" has often been discussed. They are now* very generally referred by Belgian geologists to the "Système Diluvien."

Though the true Campine sand has never been found to contain animal remains of any kind; it *overlies* a surface with *Elephas primigenius*. It is certainly older than the Polder-mud deposits, and

* M. Omalius, on the consideration that at Antwerp the Campine sands conform to the Crag, is disposed to refer them to that formation. The Antwerp sections show very clearly that those sands have been spread out since the general surface of the Crag sea-beds has been extensively denuded; occasional conformity is a mere accident.

their equivalents, the peat-growths. However, there may still be a great range between these extreme periods.

In like manner the Löss *overlies* the gravel beds in which the fragmentary remains of the great Pachyderm fauna occur.

Both the Campine sands and the Löss are subsequent accumulations to the Ardennes quartz pebbles; but the occurrence of these pebbles at the base of both does not necessarily connect them with either, but it suggests that these two accumulations must be nearly of the same age; and such, it seems, was M. Dumont's latest view.

The presence of quartz pebbles in the detrital beds at Fort 4 supplies another link to the chronology.

To what extent the surface of Belgium was submerged during the Glacial Period cannot easily be determined, owing to the thick coverings of subsequent date. Antwerp probably marks very nearly its marginal line; and this agrees very well with the range of the true "Boulder Formation" with northern rocks extending from Arnheim to Groningen and into Hanover. If the fine sands (Zand diluvium) which in North Holland form the overlying portions of the Boulder-formation, be connected with the Campine sands of South Holland and Belgium, they present a line parallel with that of the Boulder-coast; and then, as all their characters would indicate, they might be the blown sands from the marginal beds of that period, and of that stage of it when the Northern Hemisphere began to re-emerge—a process which took place from south to north.

4. *Löss.*—During our visit we came upon good illustrations of the superficial layer known in Belgium as the "Limon de Hisbaye."

It occurs at considerable elevations to the north of the Sambre and Meuse, along the line from Liege to Namur and north of Charleroi; but it does not rise to corresponding elevations on the south of those rivers, on which side, though of great thickness, it is at low levels. During the excursion of 1852 we saw a thick accumulation, with *Succinea oblonga* and *Pupæ*, at Audregnies; and this year I saw good sections of it, both above Namur and about Gembloux. From Liege westwards the Löss may generally be separated from any beds it may overlie by the presence of a seam of quartz pebbles.

The land-shells cited above are not commonly met with, but they increase in frequency towards the line of the Ardennes. The Löss in its arrangement, when in great masses, shows that it has been deposited by water. The "Sable de Campine" and the "Limon de Hisbaye" form, as was long since said by M. Omalius, the "manteau de la Belgique." The two accumulations have never been noticed to overlap, they rather pass into one another, along a line from west to east, the sands being to the north and the fresh-water Löss to the south. The opinion of M. Dumont, that they were somewhat synchronous, has been alluded to.

5. *Polder Mud.*—The Polders, or brackish-water mud-flats of the low coast of Belgium and Holland reach up on either side of the Scheldt as far as Antwerp. This is the most recent sedimentary formation we saw, consisting of blue mud, as may be seen in the

banks of the Scheldt and on the slopes of the broad ditch of the north citadel, where it is full of small shells of the common *Cardium* and *Scrobicularia*; land and fresh-water shells also occur. The whole district of Zeeland, as the name implies, is of this sea mud. The "argile d'Ostende" is of the same age, with the same shells. Along the whole of this coast the Polder-mud passes below the present sea-level, as may be seen occasionally off the Ostend coast at low water, where the compact mud resists the action of the sea. The composition of the Ostend Polders differs a little from that of those to the north, in the large proportion of calcareous matter, which has probably been derived from the waste of the chalk. The Zeeklei of the North Holland coast is also Polder.

The Polder formation indicates a change of level, or of relative elevation of the land, of small amount, but of remarkable uniformity, from Ostend to the coast of Hanover; it also corresponds with alluvial accumulations and mud flats to be met with in suitable situations about our own coasts, whether of the English, Irish, or German Seas.

The Dunes, or great sand hills, along the coast south-west of Ostende, as well as those of North Holland, have all been accumulated on the Polder mud, and since the change of level.

The Polder mud differs from the accumulations of the present coast-line of Belgium and Holland, which consist of fine siliceous sands, and must have been deposited in brackish water lagoons, into which the rivers discharged, and which were separated from the open sea by sand-banks.

6. *Terrestrial Surface.*—From specimens in the Antwerp Museum it would appear that when a breach is made in the Polder mud, a terrestrial surface with large trees is exposed. The like was met with in the excavations for the new docks, consisting of rich peat. This old land-surface is to be seen at low water, beneath the Polder mud. In like manner it underlies the Zeeklei of Holland; and much, probably, of the surface of peat or old fen of Belgium and Holland (Hooge Veenen), above the level of the Polders, is merely an upward and inland extension of the same surface of plant-growth.

In the Antwerp collection are some Mammalian remains, which were obtained at West Capellen, the extreme seaward point of the Island of Walcheren, when the sea had made a breach there. Mr. Busk recognized the perfect lower jaw, tibia, and other bones of a young *Elephas primigenius*, also two teeth of *Rhinoceros tichorhinus*.

Belgium for the most part belonged to that particular zone which was a limit to the area of the last great north circumpolar depression; and its superficial geological phenomena belong to the subaerial agencies of the glacial period; such are the "Cailloux Ardennais" and the Löss, as well as the Sables de Campine.

At some time antecedently to that of greatest submersion, the line of Artois, and of the Ardennes (like our own Wealden), had been placed at a much greater elevation than at present, with respect to Brabant and the Hesbaye; the position of the Löss shows this. The surface may have been brought to its present levels partly by depression of the line of the axis of the country, partly by the elevation of the district north of it (Brabant and Hesbaye); but had the valley of the Meuse existed as it is now, at the time of the dispersion of the Ardennes pebbles, or of the accumulation of the Löss, it must necessarily have been choked by them; but the very reverse is the case, and that valley (which is a line of fracture) may be safely pointed out as the line of one of the changes of relative level which have happened since the later Glacial Period.

Should the supposition be correct as to the source of the Ardennais pebbles, the disintegration of the surface by which the pebbles of the "Poudingue de Burnot" were set free along the slopes of the Ardennes, must be referred to the period of greatest elevation, of cold, and great river-courses; the larger and coarser accumulations connected with the line of the Meuse from Liege having been brought down by the Ourte and the Amblève. The quartz pebbles of the line of the Meuse having come from the upper sources of the Lesse, are of less size, inasmuch as the streams are smaller.

In like manner the Löss was the deposit of the turbid waters which, at the break up of every winter, periodically accumulated over the low area (now part of Brabant and the Hesbaye) between the slopes of the Condroz and the Dune sands from the coast.

Viewed in this light, the Belgian area seems to offer some very interesting illustrations of the varying conditions of the last great Glacial Period.

7. *Sangatte Beach.*—Before leaving the geological phenomena belonging to this period, I would briefly call attention to a few points connected with the section of the coast from Sangatte,—a section of very great interest, relative to which Mr. Prestwich has recently given a second paper, and which we visited together.

At the base of a vertical cliff of chalk there is a coarse shingle beach, and a little in advance of it are horizontal sands, with a few flint pebbles; these are of marine origin, and the section corresponds with that at the base of the subaerial beds at Rottingdean and Brighton.

Above the marine sand and shingle is a black band, occasionally very strongly marked, the evidence of an old terrestrial surface. The level of the old coast-line was very little above the present, but subsequently there must have been a rise, to what extent cannot here be determined; but the subsequent accumulations all indicate subaerial conditions.

Above all are blown sands; next below these, near Sangatte, is an angular débris of flints, with blocks of ferruginous sandstone, following the coast-line; layers of Löss succeed, with occasional flints, also land shells. The thickness of the beds of sandy Löss and of loam (as of the angular materials) increases in the direction of the chalk hills, and at last the mass passes by alternations from earthy Löss to chalky marl, and seams of chalk nodules; these become a chalk rubble; and angular blocks of chalk of considerable size, have been accumulated against and at the foot of the old cliff, and above the marine beds.

All these materials have been swept off the northern slopes of the chalk hills. The thickness of the accumulation is remarkable, as also is the distance to which the materials have been carried forward; and may serve as a measure doth of the duration and intensity of the Glacial Period.

The great plain of flint shingle which may be observed about Calais, and extending inland, belongs to the same level as that at the base of the old cliff, and is probably of the same age. The beds of chalk-marl which underlie the peat in the direction of St. Omer are also of the age of the Löss of the Sangatte section; and the details of that section may be assumed with respect to the base of the chalk range on the north, so far at least as the shingle extends.

The character of the subaerial glaciation of the south slopes of the Ardennes and axis of Artois is the same throughout; and if the phenomena are on a broader scale when they are in connexion with the higher parts of the range, the history of the period is perhaps more completely indicated in the Sangatte section.

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February 7, 1866.

Thomas Belt, Esq., Prince of Wales Mine, Dolgelly; Thomas John Bewick, Esq., Haydon Bridge; Thomas Forster Brown, Esq., H.M. Deputy Gaveller of the Forest of Dean, Coleford; John F. Campbell, Esq., of Islay, Neddry Lodge, Kensington; William Cory, Esq., 4 Gordon Place, W.; Anastasius Gowdas, M.D., Athens; William Frederick Cowell Stepney, Esq., 9 Bolton Street, Piccadilly, W.; and John Young, M.D., Geological Survey of Great Britain, Jermyn-street, S.W., were elected Fellows.

The following communications were read:—

## 1. *On the* Formation *of* Lake-basins *in* New Zealand. By W. T. Locke-Travers, Esq.

[In a letter to Sir Charles Lyell, Bart., F.R.S., F.G.S.]

In consequence of reading a notice in the 6th volume of the 'Intellectual Observer,' p. 461, of what I presume to have been a communication from Dr. Haast to the Geological Society, in reference to the formation of lake-basins in this country, and of my inability to subscribe to the views of Dr. Haast, I venture to submit my reasons for dissenting from them.

My observations have been chiefly directed to the great mountain-system named by me the "Spencer Mountains," which occupies the centre of the block of country constituting the Provinces of Nelson and Marlborough, in the Middle Island. The highest point of the range is Mount Franklin, estimated at 10,000 feet, whilst around it are several lower peaks, averaging from 7000 to 8000 feet.

A number of the largest rivers in the northern part of the island

*Sketch Map of parts of the Provinces of Nelson and Marlborough, in the neighbourhood of the Spencer Mountains.*

have their sources in these mountains, flowing from them to the north, south, east, and west. Amongst the rivers on the northern side of the range is the Buller or Rotoiti flowing out of Lake Arthur, and the Roturoa flowing out of Lake Howick. On the south side of Mount Franklin is the River Waiau or Dillon, and the Clarence, which flows out of Lake Tennyson. It is chiefly to the above-named lakes and the valleys of the rivers that I shall refer.

A line of road leads from the town of Nelson, in Blind Bay, to a place called the "Old Pass," nearly due south of Ben Nevis, and continues thence past Lake Arthur and along the course of the Rotoiti and Buller rivers to the junction of the Roturoa with the latter. If from this point a line be drawn to the source of the Todmor river (a feeder of the Motueka) and continued down the eastern bank of the latter, it will again reach the sea.

Stretching along the northern bank of the Rotoiti river, and commencing nearly due north of Lake Arthur, is a range of hills marked as being 2324 feet in height. Now this range of hills, and all the spurs running north from it within the space above described, are composed of post-Pliocene boulder-beds, gravels, and sands, *in no degree cemented*, very little inclined in stratification, and in many places exhibiting perpendicular sections several hundred feet high, particularly wherever the foot of the hills has been washed by rivers. The materials are all water-worn, and exhibit the common appearance of river or beach shingle; they overlie older Tertiary rocks, to which Dr. Haast assigned a Miocene age; but I am inclined to think he is in error in this respect, looking to the great similarity between most of the embedded fossil shells, and the shells now living in the adjacent seas.

These post-Pliocene beds extend northward as far as "Wakefield," terminating abruptly in cliffs, the bases of which have evidently been formerly washed by the Wairoa river.

A little to the westward of the north-western corner of Lake Arthur is a small stream flowing into the outlet, and some miles further south a river called the Howard flows through a valley* bounded on both sides by hills composed of *extremely loose material.*

Now the whole valley, nearly a mile and a half wide, between the the margin of Lake Arthur and the above-mentioned range of hills in front of it, is occupied by a huge moraine, the extremity of which rests upon the flanks of these hills, stretching right and left along their line in the direction, on the one side, of the Old Pass, and on the other, of the course of the Rotoiti. Many of the blocks of rock composing this moraine measure from 15 to 20 feet square, and all are composed of débris from the ranges on each side of the lake, affording sufficient proof that they were deposited by a huge glacier which formerly occupied its site.

In the direction of the Old Pass the moraine does not stretch fur-

* The hills lying between this small stream and the Howard are also composed of the same Post-pliocene boulders, gravels, and sands as those above mentioned. In effect the River Rotoiti runs, as far as its confluence, with the Howard.

ther than the watershed beyond the Rotoiti and the Wairau, whilst, on the course of the Rotoiti river, it stretches for several miles down the valley, and we find erratics on the flanks of the hills on both sides nearly as far the Howard. At this point the Rotoiti enters the granitic zone of Mount Murchison, isolated peaks of this granite appearing on the north side of the river " rising " (in the words of Dr. Haast, in his 'Report on the Geology of the Province of Nelson') " through the alluvium ; " but the great mass of the hills stretching along the north bank of the river as far as the junction of the Roturoa is still composed of the before-mentioned Post-pliocene formation.

Lake Arthur lies between a great spur of Mount Robert on the one side, and the foot of the St. Arnaud Range on the other ; its principal feeder rising in Mount Travers. Now, this lake is several hundred feet deep, the depth gradually increasing from its upper end until you approach its broadest part, when it again begins to shoal. In front of it lies the great moraine before referred to, rising about 100 or 150 feet above the level of the water, the outlet having made its way through this at the north-west corner of the lake, exhibiting a section of from 100 to 120 feet in height.

Passing on now to Lake Howick, I may mention that on the flank of the granite range between the Howard and this lake, I found Tertiary strata containing thin bands of lignite. These beds were brought to light by a large side cutting, made during the construction of a road, long after Dr. Haast had visited the district, and were very likely then to have escaped his observation, as the whole district is densely wooded, and the surface so encumbered with dead and living vegetable matter, as entirely to conceal the soil, except where actually cut into. Dr. Haast, in the report before alluded to, refers to the existence of seams of lignite in this neighbourhood, stating, however, that " he had not seen them *in situ*, but had found large pieces lying upon the shingly banks of the Howard."

On descending into the valley of the Roturoa (which is densely wooded throughout) I found it was filled, in front of the lake, with moraine matter derived from the mountains on each side. I did not travel down the valley to the junction of the outlet with the Buller, but I was informed by the solitary ferryman at the lake that it was " very rough," and full of " big stones," from which I conjectured that it was probably filled throughout with ice-borne matter. The D'Urville and Sabine rivers, the principal feeders of the lake, flow through frightfully rugged valleys. I ascended the range between them to the height of nearly 8000 feet, but being alone I did not care to attempt Mount Franklin. I saw enough, however, to satisfy me, that enormous glaciers formerly descended the valleys of the Sabine and D'Urville, and after uniting at the extremity of the dividing spur, filled the site of the lake. I had no opportunity of examining the range of hills on the north bank of the Buller, opposite the mouth of the Roturoa, so that I am unable to say whether moraine matter occurs on their flank, in the same manner as on the flanks of the hills in front of Lake Arthur. I think it extremely probable, however, looking to the course and general appearance of the valley of the Roturoa, that the glacier stretched as far as the Buller, filling the present valley with moraine matter as it receded, becoming stationary for some time near the present margin of the lake where the moraine attains its greatest height.

Lake Howick, in its deepest part (rather less than halfway up), is upwards of 1000 feet deep, and again shallows as you approach the moraine. The outlet has made its way through the moraine, exhibiting a section about 30 feet in height.

Of course it is impossible to say to what depth the moraine matter in front of these two lakes extends; but I cannot help thinking that, if it could be traced downwards, we should find it lying on the same foundations as the post-Pliocene beds above referred to,—from which we might conclude that, enormous as the period must have been, the sites of these lakes were occupied by ice when the period of depression commenced during which those beds were deposited, and so continued for some time after the reelevation of the land above the level of the sea. At all events it appears to me, in view of the facts above mentioned, impossible to admit that these basins owe their existence to the scooping power of ice. I should gladly have devoted a longer time than I was able to give to the examination of this district at the period of my visit to it, but the fact was, that my son and one of my men had several of their toe nails washed off, and our hands and bodies were so stained that it took nearly three weeks to get them clean again. The utmost devotion to science was scarcely proof against such weather.

I will now mention the facts observed by me in the valleys of the Dillon and Clarence, as these valleys present features of exceeding interest in connexion with former glacial action. As a general rule in this country, in valleys which have never been occupied by glaciers, the spurs of the ranges on each side interlock; whilst in those which have been occupied by glaciers we constantly find the points of the spurs on one side or other of the valley cut off, the faces of the spurs then being Λ-shaped, and rising at a very steep angle. I have observed the latter feature to obtain in all the valleys in which I have found old moraines, and I think it may be a good guide in determining the longitudinal extent of former glacier action.

The upper part of the river Dillon flows through a valley now occupied by me as a cattle-station. Now, stretching across the valley, from the mouth of the "Henry" to the range on the eastern side of the river, is a huge moraine, filling the valley for nearly three miles of its length. This moraine rises about 100 feet above the level of the valley on its upper side. After the retreat of the glacier, and until the river, aided by the waters of the Henry, had worn a channel through this moraine, the upper valley was filled with water, and the margin of the lake so formed, as seen on the moraine, about 30 feet above the level of the valley, *is as fresh as if it had only been emptied a week ago.* About 14 miles up the valley is another and much smaller moraine, showing where the glacier had rested during its retreat.

The glacier which deposited the lower moraine must have been a stupendous one, for there are erratics and "roches moutonnées" on the sides of the mountains, to the height of 1000 feet and upwards. The valley is about a mile wide at the moraine, increasing in breadth opposite the "Ada" and "Christopher" rivers, the valleys of which were evidently occupied by branches of the great glacier. The length of the main glacier was about 23 to 24 miles, that of the Ada branch about 8, and that of the Christopher branch 5 or 6. The mountains on each side of these valleys are *extremely steep*, and the main valley now rises about 35 feet to the mile.

Looking to the appearance of the valley below the moraine, there is no doubt that the glacier formerly extended as far as the junction of the Dillon and Hope, but I did not see in the upper part of the latter river, or in the Dillon below the junction, any traces of glacial action. About ten miles below the junction the waters of the united rivers debouch upon the Hanmer Plains, and thence find their way through a rocky gorge into the Hurunui Plains. On the sides of the mountains bounding the Hanmer Plains, south of the river, we find a succession of old terraces, the uppermost of which is fully 700 feet above the general level of the plains. The lowest terrace rests upon the rock through which the river now flows, upon which it forms a capping of considerable thickness. I conceive that the material of these terraces was deposited during the same period of depression which gave rise to the Post-pliocene boulder beds and gravels on the north side of the range, and that the now rocky channel of the river has been excavated since the reelevation of the land.

Reverting to the great moraine above referred to, I found that the main river, aided by the Henry, had cut a way through the moraine matter, exhibiting sections from 80 to 100 feet in height.

In its course through the gorge below the Hanmer Plain, the river has cut a channel through solid rock 120 *feet deep below the level of the lowest shingle terrace*, showing the enormous wearing power of water charged with sediment, even though flowing on so apparently slight a fall as 35 feet to the mile.

There is, I conceive, every probablity that the valleys of the Dillon and Clarence were filled with ice at the same time as the present sites of lakes Arthur and Howick, although the bed of the lake formerly existing behind the moraine dam of the Dillon has since been filled up, the river-borne matter being banked up against the sloping face of the moraine. What the original depth of that lake may have been it is impossible to say; but there is no reason to suppose that it may not have rivalled those on the north side of the chain. I attribute the rapid filling up of this lake-bed to the facts, that the mountains bounding the valley of the Dillon are exceedingly steep, are composed of easily disintegrated sandstone, are very bare of vegetation, and present in many places for thousands of feet in height and for miles in length, little else than avalanches of broken stone; whilst those which bound the Lakes Arthur and Howick are densely wooded, are very much less steep, and are composed of granite and other hard crystalline rocks.

Passing from the valley of the Dillon into that of the Clarence, distant about six miles in a direct line, and running parallel to it for some thirty miles, but fully 1000 feet higher in point of level, we find Lake Tennyson, dammed in by a moraine which rises about fourteen or fifteen feet above the level of the water. This moraine stretches about a mile and a half down the valley, sloping very rapidly. I had no means of ascertaining the depth of the lake; but I do not believe it exceeds 400 to 500 feet: at all events, there is nothing to lead to the supposition that its bed is lower than the foundations of the moraine by which it is dammed in.

In the case of these inland glaciers we have to assume that a considerable body of the ice of which they were formed lay below the upper level of the terminal moraine; but this would not prevent the water arising from the melting of the ice from escaping in the same manner as that which flows from a retreating glacier.

My knowledge of geology is not sufficiently great to enable me to see any difficulty in supposing that ice may have existed in the localities referred to during the enormous period required for the deposition and reelevation of the above-mentioned Post-pliocene beds, and this, therefore, I must leave to more competent judges; but I really cannot see anything to justify the opinion, that the lake-basins owe their existence to the "scooping power of ice."

I have confined my remarks to the lake-basins found among the spurs of the Spencer Mountains, which, however, afford a fair example of all the lake-basins north of the river Waitki. In fact, I firmly believe that all the lakes which lie in the valleys of rivers debouching on the Canterbury Plains owe their existence to moraine dams, which have the same foundations as the Post-pliocene shingle of which the plains themselves are formed, and that, therefore, the sites of those lakes were occupied by ice at the commencement of the period of depression, and so continued for some time after the re-emergence of the upper part of the plains above the level of the sea.

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## 2. *On the* Occurrence *of* dead Littoral Shells *in the* bed *of the* German Ocean, *forty miles from the coast of* Aberdeen. By Robert Dawson, Esq.

[Communicated by T. F. Jamieson, Esq., F.G.S.]

(Abridged.)

The bank called the "Long Forties," from 35 to 40 miles from land, extends from opposite Kinnaird's Head in a direction nearly parallel to the shore. Inside of this bank the depth varies from 90 fathoms at the northern end to about 50 fathoms opposite Aberdeen. Being becalmed we dredged on this bank for a considerable time in 36 fathoms, 40 fathoms, and 42 fathoms, on a bottom of broken shells and shingle. I remarked at the time that these dredgings contained none of the Arctic fossils found so plentifully in every haul when dredging nearer the shore, and from this I inferred that the fossiliferous bed, which seems to stretch along the coast at a distance of from six to fifteen miles, does not extend beyond this deep water to the "Long Forties." On examination of the materials brought up by the dredge from the top of the bank, there were found shells of the following species in a worn and semi-fossil condition, namely:—

*Purpura lapillus*, one specimen.
*Litorina rudis*, one specimen.
*Solen siliqua*, two specimens.
*Mytilus edulis*, one large broken valve and several fragments of smaller specimens.

Before it occurred to me that these fragmentary fossils might be interesting in a geological point of view, the greater part of the dredgings had been examined. It is quite possible, therefore, that other specimens may have escaped notice.

Now as *Litorina rudis* is generally found on rocks above high-water mark, and never beyond low-water, and as all the other species are highly characteristic of the shore, or very shallow water, it seems a fair conclusion that at the period when these were living, the relative levels of land and sea were very different from what they now are, and that the bank had then formed the shore of the German Ocean. If only one specimen had been found it might have been accounted for by some of the many accidents which occasionally bring even a foreign shell into the dredger's bag; but four species having been found in the course of one day's dredging, it appears very probable that they lived and died where they were found.

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## 3. *On the* Glacial phenomena *of* Caithness.

By T. F. Jamieson, F.G.S.

Contents.



1. *Introduction.*—In August 1865 I paid a visit to Caithness, in order to study the last geological changes in that north-eastern corner of Scotland. Mr. Peach has lately given us an excellent account of the fossil-contents of its glacial beds, from which he enumerates seventy-five species of Mollusca, besides various other forms of Invertebrata. The object, however, of my visit was not so much to look after the fossils as to satisfy myself about the conditions

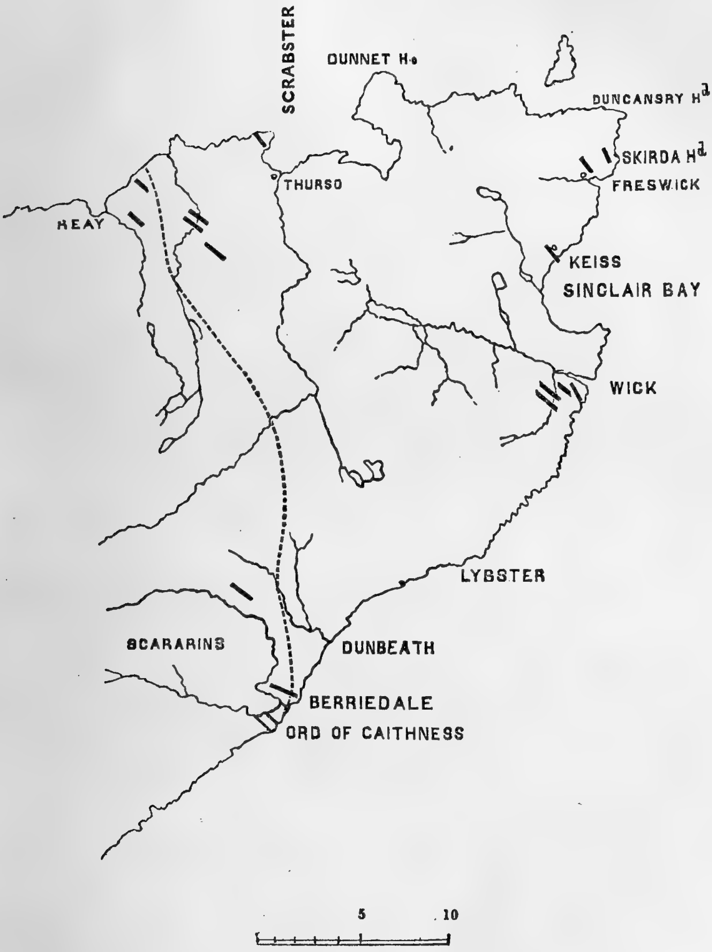
under which the beds containing them had been accumulated, and to compare them with those of other districts with which I was already acquainted.

In the neighbourhood of Glasgow, and along the east coast from Aberdeen to Edinburgh, we find the beds containing Arctic shells lying on the top of a rough boulder-clay destitute of such fossils; and these marine fossiliferous beds are often of great depth and finely laminated, presenting all the features of tranquil and regular deposition. The remains of mollusca and starfishes in them are, in many instances, quite entire and uninjured, as if they had been gradually enveloped in the fine mud in which the animals lived and died, while the crust of large barnacles on some of the stones points to a like stillness of the sea-bottom. In Caithness nothing of this sort has been observed; no distinction has been made of a rough boulder-clay destitute of fossils and an overlying marine fossiliferous bed; the shells, according to all observers—Dick, Cleghorn, Hugh Miller, Peach, and others—are described as being scattered in a broken state all through a mass of rough boulder-clay, and no such thing as a bed of tranquilly deposited marine sediment containing entire shells has been reported. This seemed to me to indicate that the conditions under which the glacial beds of Caithness were accumulated must have differed in some way from those that prevailed in the other districts, and I was therefore desirous of studying the locality in order to make out, if I could, the cause of the difference.

2. *General distribution of the Drift, its colour, texture, and contents.*—Viewed from a distance, Caithness has the appearance of a bare undulating plain, sloping very gently to the north and north-east, and terminating in lines of rocky cliff which are battered by a restless and stormy sea. Along the southern border of this plain there is a fine group of hills, of which Morven (2331 feet), the Scarabins (2048 feet), and the Pap of Caithness (1229 feet) are the most conspicuous; there are, also, some straggling heights of lesser importance along the western side of the county. These hills form a sort of separation or boundary between the low district of Caithness and the more mountainous region of Sutherlandshire. Geologically it is a country of Old Red Sandstone. The hills just mentioned consist of quartzose mica-schist and granite, on the flanks of which repose thick masses of conglomerate and grit forming the base of the Old Red in this region. These beds of conglomerate and grit pass up into a great series of thin-bedded shales, flags, and sandstones, generally of a dark-grey colour, which stretch away in billowy undulations over the surface of the country to its north-eastern corner, as has been well shown by Sir Roderick Murchison.

It is in the low troughs and winding hollows which form the beds of the various streams that we find any quantity of glacial débris; on the higher ground the rocks are either bare and devoid of earthy cover, or hidden by a growth of peat and heather. Some of these low tracts run across the country from side to side, as, for example, from Wick to Thurso by way of Loch Watten, and between

Fig. 1.—*Sketch Map of Caithness, showing the boundary of the dark-grey drift, and the direction of the glacial markings.*




Scale of English miles.

—— Direction of glacial markings.
.... Boundary of dark-grey drift.

Dunnet Bay and Sinclair Bay. Another low tract passes up the bed of the Thurso water and along to the east coast by way of Dunbeath. The drift is spread in sheets filling up these troughs and levelling the irregularities of the rocky strata so as to impart a smoother and softer outline to the surface. So far as I saw, it does not form irregular mounds and hillocks, neither is it very rough on the surface with erratic blocks; it seems confined in a great measure to the lower levels, thinning out at altitudes of 100 or 150 feet. The thickness, therefore, varies much, being greatest in those depressions which descend nearly to the sea-level. Thus at Scrabster harbour, in Thurso bay, there are banks of it more than 100 feet high, and in some of the troughs of the south branch of the Dunbeath water it is nearly as thick. Deep masses occupy the hollow from Watten to the Bay of Wick, and also stretch along the Thurso river into the very centre of the county. There is also a good deal of it in the bed of the Forss and at Lybster, but at the Freswick Burn it is comparatively thin. In all these places it is of very much the same hue, being of a deep leaden-grey or slate-colour, very dark when moist, and considerably paler when dry, similar, in fact, to the colour of the Caithness flags on which it rests. Occasionally the upper portion is of a browner, more ferruginous tint, which may be owing to the influence of the atmosphere, the percolation of surface-water, or to some other cause.

Fig. 2.—*Scrabster Harbour.*

E. W.

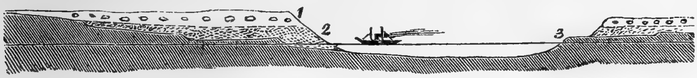

1. Unstratified pebbly clay with very few broken shells.
2. Old Red Sandstone.

The texture, however, varies a good deal in different places. At Scrabster harbour, where it reaches a thickness of more than 100 feet, no difference can be perceived from top to bottom; it is just the same at the base, where it is in contact with the ice-worn surface of the subjacent rock, as it is 100 or 150 feet higher up. It shows no stratification nor traces of gradual deposition. It is a coarse gritty mud, exceedingly firm and difficult to pierce, and thickly charged with small stones, which are dispersed very uniformly throughout all parts of the deposit. Pebbles of all sizes below that of a man's fist or foot are the prevailing dimensions, but stones of from two to three feet in length also occur; I saw no great erratic blocks. The stones are more or less worn and rubbed, and many of them show the glacial scratches. A few small fragments of shells are dispersed through all parts of the bank, from the bottom to within at least 15 feet of the top, but are by no means common. Such is the character of the section at Scrabster, and it is very much the same along the banks of the Thurso water for several miles up its course; but for a mile or two above Halkirk pieces of shells are more common, and occasionally an entire valve may be met with. So thickly packed is this drift with small stony rubbish that in many places almost every handful of mud contains several fragments.

Along the banks of the Haster Burn, near Wick, large stones are more common in the drift, and there are even some considerable boulders; but notwithstanding the coarse stony nature of the deposit, this is one of the best localities for fossils, fragments of shells being of frequent occurrence dispersed in the unstratified rough stony mud; and in the course of a single visit to this stream, in company with Mr. Joseph Anderson of Wick, I got an entire valve of *Astarte borealis*, and one or two specimens of *Turritella* and *Natica* nearly perfect.

At the south branch of the Dunbeath stream, the sections are similar to those on the Thurso river, and pieces of shells about equally common. In the bed of the Forss the drift is very full of stones, and shells are exceedingly rare; otherwise it resembles that of the localities just mentioned.

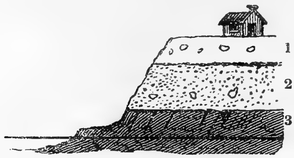
Fig. 3.—*Section at Wick Bay.*




1. Reddish-brown clay with boulders.
2. Dark pebbly silt with broken shells.
3. Old Red Sandstone.

At Wick, however, it is somewhat different; in the banks beside the harbour (at Pulteney town) the drift is 50 or 60 feet deep. The lowermost two-thirds of it are a sandy mud, or silt, of a very dark grey colour, solid and firm as if much compressed; and although there are a good many small pebbles dispersed through it, yet they do not form a large proportion of the mass, and there is an absence of big stones. Fragments of shells are in many places not uncommon, and are scattered through it in an irregular manner, not occurring in horizontal lines or seams. There is, in short, no distinct stratification, although in some places there is an approach to it, owing to patches of a more sandy nature occurring; it is an unstratified pebbly silt, the greater part of the mass consisting of fine sand. The upper part of the bank, on the other hand, is of a browner, more ferruginous colour, much coarser in quality, with more muddy sediment and few or no shells; it is also full of stones and large ice-worn boulders of sandstone, quartzose, mica-schist, and granite, on which the glacial scoring is well marked. One of these granite blocks is 12 feet in length. I cannot say that there is any clear sharp line of separation between this coarse upper stuff and the dark siltier matter beneath; for although in some places the distinction is pretty well marked, in others they seem to graduate into each other. Where the rock rises in the cliff, the dark silty portion thins out, and the coarse brown mud full of boulders rests immediately upon the ice-worn surface of the Caithness flags.

Fig. 4.—*Section at Keiss Harbour.*



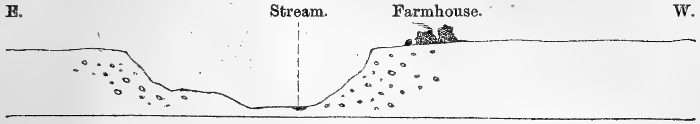

1. Reddish-brown stony clay.
2. Dark-grey pebbly silt with broken shells.
3. Sandstone, iceworn.

At Keiss harbour, which lies seven or eight miles further to the north, the character of the section is very much the same as at Wick. The total thickness of the drift near the harbour is about 40 feet. The lowermost 23 feet consist of an unstratified mass of dark sandy mud, with a few broken shells and some stones dispersed through it, which reposes directly upon the ice-worn surface of a red sandstone rock, without the intervention of any other deposit. The scratches and grooves point N. 35° to 40° W., and some of the imbedded stones are likewise scratched. The upper 17 feet of the bank consists of a browner coarse mud with more stones, and, so far as I observed, no shells. Although the lowermost sandy portion of the drift at Keiss and Wick has no distinct stratification, it is nevertheless more like an ordinary marine deposit than what I saw in the other sections throughout Caithness.

3. *Character of the Stones imbedded in the Drift.*—The stones imbedded in the Caithness Drift consist for the most part of the débris of the Caithness flags—those beds which Murchison terms the middle division of the Old Red Sandstone of this part of Scotland—and accordingly the general hue of the drift closely resembles the prevailing dark bluish-grey tint of these strata. There is, however, always a mixture of other sorts; fragments of quartzose mica-schist, and granite occur, so far as I observed, very frequently in the drift of all parts of Caithness. I noticed them at the Burn of Freswick, which is only a few miles from Duncansby Head, also at Keiss, and all about the neighbourhood of Wick, and along the whole of the Thurso water. There are likewise generally some fragments of sandstone and conglomerate, and occasionally one of hornblende-schist; this latter, however, is not common. Mr. Peach also mentions the occurrence of porphyry, gneiss, Oolite, Lias, and Chalk-flints. Mr. Dick told me that fragments of Oolite are not uncommon; I myself observed many pieces of it in the drift at the mouth of Berriedale.

I did not see many large erratic blocks, but Mr. Peach tells me that some big ones of conglomerate are scattered across the country, more particularly between Weydale and Stonegun, near Thurso. He saw *very* few on the Scarabin hills. Mr. Dick told me he had not observed any large blocks which might not have been derived

Fig. 5.—*On the Thurso Water, near Thurso.*




The high banks on both sides of the stream consist of unstratified pebbly clay or gritty mud with a few traces of broken shells.

from rocks in some part of the county, with the exception of one of granite near Castletown, which he thought was different from any of the Caithness granites, and had probably come from Sutherland, where a similar quality of rock is known to occur.

4. *State of the Shells.*—The shells, as a rule, occur in broken fragments. The most common kinds are the *Cyprina Islandica, Turritella ungulina, Astarte borealis, A. elliptica, Tellina calcaria,* and *T. Balthica.* Although broken pieces are the rule, yet exceptions sometimes occur. Thus, during the search that I myself made, I found one entire valve of *Astarte borealis,* another of *A. elliptica,* and two small ones of *A. compressa,* likewise a specimen of *Natica nitida* and another of *N. Islandica,* both almost perfect. And in the collections of Mr. Joseph Anderson and Mr. Robert Dick I saw several entire single valves of *Astarte* and *Leda,* on which there were occasionally small portions of the epidermis or skin remaining, also entire specimens of *Mangelia* and *Nassa.* Mr. Peach has even got a specimen of *Anomia* with both valves complete, in a fine state of preservation, and this was in the drift containing the usual assemblage of ice-worn stones and broken shells, the only instance of an entire bivalve that I have heard of. The *Turritella,* which is one of the most common of all the species, although always more or less imperfect, yet frequently occurs in large pieces, some of them not far from being entire. I nowhere observed any instance of the shells being found in an undisturbed condition, nor could I hear of any such having been found; there seems to be no such thing as a bed of laminated silt with shells *in situ.* Even the *Foraminifera,* when seen through the microscope have a rubbed, worn appearance. No clay suitable for the manufacture of bricks and tiles or drain-pipes has been got in Caithnes, it is all too sandy and full of stones. The laminated brick-clays are, in short, entirely absent.

Many of the shell-fragments show marks of glacial action. It is generally on the stouter pieces of *Cyprina* and *Astarte* that these are to be seen, but I found some fragments of *Tellina calcaria* distinctly marked. Now this is rather a delicate fragile shell, and the fact of its being so marked and yet not crushed to powder, shows how gentle, in some cases, the action must have been that imprinted these markings. Where the shell-fragments are of an elongated form, the scratches run lengthways along them, just as they do on the pebbles. I have one piece of shell, which I picked up myself, not quite an inch long, most beautifully marked with a multitude of fine parallel scratches as if done by the point of a needle, and quite polished even on the broken edges. The fragments of *Turritella* somehow seldom show these markings.

5. *The Glaciation of the Rocks and Boulders.*—One of the objects I had particularly in view was to note the direction of the glacial markings on the rocks, and to ascertain whether they could be accounted for by a movement of ice proceeding from the interior of the country towards the coast. I therefore lost no opportunity of noting the bearings of the scratches wherever I saw them. The result showed a pretty uniform direction over the whole district, the lines running N.W. and S.E. Thus:—

| | |
|---|---|
| At Reay | N. 45° to 55° W. |
| Ditto at another place | N. 50° W. |
| About halfway between Forss and Reay | N.W. |
| In the bed of the Forss water | N. 45° W. |
| On the top of Leurery hill (about five miles S.W. of Thurso) | N. 55° to 60° W. |
| At Scrabster harbour | N. 30° W. |
| On the top of a cliff near Skirza Head | N. 65° W. |
| In the bed of the Freswick stream | N. 35° to 40° W. |
| At Keiss harbour | N. 35° to 40° W. |
| At the new pier at Pulteney (Wick) | N. 15° W. |
| On the top of the cliff near the old castle of Wick | N. 15° W. |
| Some cross markings here pointing W. 15° S. | |
| In the bed of the Milton Burn (near Wick) | N. 43° to 45° W. |
| In the bed of the Haster Burn (near Wick), in several places finely displayed | N. 55° W. |
| On a hill-slope between the streams of Dunbeath and Berriedale, on conglomerate, well marked | N. 60. W. |
| On the roadside, near Berriedale Church | N. 60° to 65° W. |
| Ditto, one mile south of Berriedale inn | N. 45° W. |
| Ditto, two miles south of Berriedale inn | N. 40° W. |
| On Lumps of conglomerate (having an evident *stos-seite* on the N.W.) about two miles south of Berriedale | N. 34° to 40° W. |

In the above the correction for compass variation has been applied. Mr. Peach in reference to this subject says, "All the grooves that I have met with on the rocks below the clay in Caithness run N. and S. with deviations to the E. and W.; I have found them almost all over the county." Upon inquiring of Mr. Peach, I find that his bearings are by compass. Remembering, therefore, that the compass in that district at present points fully 25° to the west of north, it will be seen that his account of the matter nearly corresponds with my own.

The impression left upon me by all I saw was, that the movement had been *from* north-west to south-east; for where I observed any indication of a *Stosseite* it was on the north-west side. In order to obtain further evidence on this point, I endeavoured to trace the boundary of the dark-grey drift; for I thought that, had the movement come from the north-west, the dark-grey mud derived from the Caithness flags should overlap the red grit and conglomerate towards Dunbeath and Berriedale, while the flags themselves should be overlapped at their north-western boundary towards Reay by a different-coloured drift. This I found to be the case. The dark-grey mud fills the bed of the Forss water, but does not extend beyond the watershed between that stream and the Burn of Isauld; and at Reay, the drift covering the grey flags is of a reddish brown colour. On the other hand, the dark-grey mud stretches south-eastward, past Lybster, into the bed of the water of Dunbeath, and lies in heavy masses even in the south branch of that stream. I also traced it to the mouth of Berriedale water, where it mingles with the reddish-brown drift that prevails from there to the Ord; but further up the Berriedale Glen to the base of the Scarabin hills the colour is reddish brown. The distribution of the dark-grey mud therefore harmonizes with the supposition that the transport had been from the north-west; and a movement of ice from north-west to south-east across Caithness is totally at variance with the notion of the scratches having been caused by glacier-action proceeding from the interior of the country towards the present coast.

I have already mentioned that the stones imbedded in the drift of Caithness very often show the glacial striæ. When examining the sections along the Haster Burn, in company with Mr. Joseph Anderson, I remarked that the striæ on the imbedded fragments generally agreed in direction with those on the rock beneath. The scratches on the boulders, as usual, run lengthways along the stones when they are of an elongated form; and the position of these stones, as they lie imbedded in the drift, is, as a rule, such that their longer axes point in the same direction as do the scratches on the solid rock beneath, showing that the same agency that scored the rocks also ground and pushed along the drift. Interspersed amongst these ice-worn stones were many fragments of shells—themselves also scratched—and some univalves almost entire.

This coincidence of direction between the scratches on the stones and those on the subjacent rock I also observed in the section along the Milton Burn; and I am inclined to think it is a characteristic feature, and will be found of general occurrence. In my paper "On the last Geological changes in Scotland," I have described it as a feature of the boulder-earth or glacial-mud which lies beneath the marine beds in the midland region of Scotland. The appearance of the drift along the Haster Burn and in many other places in Caithness is, in fact, precisely the same as that of the Old Boulder-clay of the rest of Scotland, except that it is charged with remains of sea-shells and other marine organisms*. Mr. Anderson told me that

* The glacial drift of Caithness is particularly interesting as an example of a boulder-clay which, in its mode of accumulation and ice-scratched débris, very much resembles that unstratified stony mud which occurs underneath glaciers—the '*moraine profonde*' as some have called it. But the presence of marine organisms, and the direction of the glacial striæ, which indicate a movement of ice from the north-west, where there is now nothing but open sea for an immense distance, together with the absence of moraines, are all suggestive of marine conditions having prevailed during the deposition of the Caithness drift. It would therefore seem that sea-borne ice can in some places accumulate a mass of unstratified stony mud so like that which is found underneath a glacier as to be undistinguishable from it, except by containing remains of sea-animals. The scratched boulders used to be looked upon by some as a certain test of glacier-action. "Ces cailloux," says Ch. Martins, "sont, pour ainsi dire, *le fossile caractéristique* de la présence d'anciens glaciers."—Bull. Geol. Soc. of France, 2 ser. iv. 1191, 1847. In the Caithness drift, however, not only the stones, but the very sea-shells are glacially scratched, a circumstance which I have also observed in some of the glacial marine beds of Aberdeenshire.

specimens of this drift from the Haster Burn had, upon microscopical examination, yielded him abundance of *Foraminifera* and other minute remains of animal life. Mr. Anderson was the first to apply the test of washing and microscopic examination to the Caithness Drift, and Mr. Peach says that all the samples tried from between John O'Groats and Wick had yielded them in this way more or fewer *Foraminifera*, *Entomostraca*, &c.

6. *Absence of Moraines and Gravel-hillocks.*—I saw no abrupt mounds of gravel and boulders in Caithness, nothing like the Kaims or Esker ridges, nor anything like a moraine. Mr. Dick told me he had noticed some gravel-hillocks near Dirlet, but nowhere else. Circumstances prevented me from exploring the neighbourhood of Morven and the adjoining hills, but in a walk along the Berriedale Glen, from the base of the Scarabins to the sea, I observed no moraines. This part of the glen is deep, narrow, and winding. There is a good deal of unstratified reddish-brown stony earth in some places along the foot of the hills, in which some ice-scratched stones occur, and where the mouth of the glen opens upon the sea there is a great depth of it on the south bank. Large boulders of many different kinds—granite, sandstone, conglomerate, quartzose mica-schist—occur here, also fragments of shelly limestone, and bits of dark sandstone containing lignite. Most of this accumulation of drift has a reddish-brown colour, but there is also a mixture of dark bluish-grey stuff, in which after some search I got nine or ten small pieces of shell and a bit of a *Balanus*. This drift is likewise to be seen on the face of the sea-cliffs on the north side of the stream.

There is also, so far as I observed, very little valley-gravel; indeed I am inclined to think that the valley-gravel, such as we find it in the midland region of Scotland, is not developed in Caithness. That which occurs in the ruts of the various streams is merely what might be produced by the long-continued action of currents such as we see flowing in them at present. The gravel in these channels seems to be merely the stones derived from the banks of drift along their course, the finer sediment having been washed away by the current. So far as I saw, these beds of gravel are not extensive, and are confined to the bottom of the channels in which the streams run. These watercourses are trenches which appear to have been cut out of the drift by ordinary river-action.

7. *Relation of the Caithness Drift to that of the rest of Scotland.*—Caithness, therefore, differs from the midland region of Scotland in regard to its glacial phenomena:—

1st. In that the glaciation of its rocks seems to have been produced by a movement of ice proceeding, not from the interior of the country, but apparently from an external region to the north-west.

2nd. In its covering of drift, which resembles the Old Boulder-clay of the middle of Scotland in regard to its physical arrangement, but differs therefrom in the prevalence of marine organisms scattered through it.

3rd. In the absence of glacial-marine beds deposited with the indications of tranquillity that we observe in the regions further to the south.

4th. In the deficiency of valley-gravel, and the absence of moraines and gravel-hillocks.

It is very desirable to ascertain the area over which these features prevail. From what Mr. Peach says of Shetland, I am inclined to think it will embrace both these islands and the Orkneys. I did not examine the north coast of Sutherlandshire, and cannot say how far in that direction the same characters extend; but in passing rapidly along the east coast of Sutherland and Ross it seemed to me that there was a change after going south of the Ord of Caithness, the shelly drift vanishing, while great moraine-like heaps of gravel make their appearance at the mouths of the several valleys. At Brora, for example, there is a remarkable assemblage of hillocks which come down close upon the shore, and at Dornoch Frith I noticed similar deposits on the north side near Clashmore, and on the south side along the base of Struie hill. At Muir of Ord, between Beauly and Dingwall, I examined another fine range of gravel-hillocks, extending from the neighbourhood of the railway-station westward up the flank of the hill to a considerable height. But the finest of all is a most remarkable series of ridges commencing at a place called Kildrummy, about two miles from Nairn, and ranging south-westward by the Loch of the Clans and Loch Flemington towards Culloden moor, in the neighbourhood of Inverness.

The direction of the glacial scoring in Caithness, if produced south-eastward, would pass the corner of Aberdeenshire near Fraserburgh; and here I may mention that I have recently observed traces of glacial action at a few places in the neighbourhood of that town, and it is interesting to remark that their direction corresponds with that in Caithness, being N.W. and S.E., and produced by an agency which seems to have come from the north-west. Thus:—

| | |
|---|---|
| On a rock surface newly exposed in a railway-cutting near Rathen | N. 65° W. |
| At another spot in the same cutting | N. 45° W. |
| At Fraserburgh quarry | N. 40° to 65° W. |
| On the coast at St. Colms, about five miles south-east of Fraserburgh, there are some rocks which have a strong appearance of glaciation and a north-west *Stosseite*, while long fluted hollows point | N. 65° W.; |
| but there are no trustworthy scratches. | |
| The rocks also on the south side of Fraserburgh harbour have an appearance of glaciation coming from the north-west or west-north-west, and beside the turntable at the railway-station there are some scratches on the rock in varying directions. | |

Again, it is worthy of remark that along the coast from Banff to Peterhead, the prevailing colour of the glacial clay is dark bluish-grey, quite like that of Caithness. This, however, may be owing to the sediment from the clay-slate of Banffshire having drifted eastward; but it may also be partly due to a drift of fine muddy matter from Caithness. The dark bluish-grey clay ranges south to Peterhead, where it thins out and is interstratified with the red clay which prevails thence all along the east coast as far south as Fifeshire. In the neighbourhood of Peterhead, as for example, at the Invernettie brickwork (See Quart. Journ. Geol. Soc. vol. xiv. p. 518, 1858), there are many boulders of red and grey sandstone, and also of a tough greenish-coloured stone, all of which resemble rocks that occur in Caithness, but, so far as I know, not in the adjoining parts of Aberdeenshire. I have always been at a loss to account for these boulders near Peterhead, and also for the dark-grey tint of the clay between that town and Fraserburgh, seeing that the rocks of the district consist of mica-slate and granite. But looking at the direction of the glacial markings, I am somewhat inclined to think that both the boulders and the dark muddy sediment in this low projecting corner of Aberdeenshire may have drifted from Caithness.

8. *Place of the Caithness Drift in the history of the Glacial period.*—I have now to consider the relation in time of the glacial phenomena I have been describing to those of the rest of Scotland. In the parts of Caithness which I examined, it seems to me that we have only one glacial deposit, and I am further of opinion that we cannot separate, in point of time, the period of its accumulation and present arrangement from that of the scratching of the rocks on which it lies: for the coincidence in direction of the scores on the rocks with those on the stones imbedded in the drift shows that it was one great movement—long-continued probably—that marked the rocks and carried along the mass of stony mud that now rests upon them; in fact it was the movement of the drift across the surface of the rocks that scratched them. Now in the midland region of Scotland we have evidence of three well-marked stages in the Glacial period—1st, the great glaciation of the surface and deposition of the Old Boulder-clay or till; 2nd, the finely laminated glacial-marine beds; 3rd, the overlying gravels and moraines. To which of the divisions represented by these three are we to refer the Caithness drift? or is it the equivalent of any two of them, or of all the three?

The Caithness Drift contains remains of sea-shells all through it, often from top to bottom, and these shells are broken, rubbed, and scratched, evidently by the same agency that marked the rocks and boulders. This is an important fact, for it gives us a date for the action. The scratching and breaking of the shells was an event at least as late as the time when the Mollusca lived that formed the shells; and, seeing that the shells extend to the bottom of all the sections of the drift, it is further evident that none of it was lodged in its present position at a more remote date. Indeed, it is in the lower part of the sections that the fragments of shells chiefly occur; in some cases, as for example at Wick and Keiss, they are scarcely to be found in the upper portion. If, then, we could find the date of the shells, we should have a clue to the age of the drift itself. In the midland region of Scotland the Old Boulder-clay, and the scratching of the ice-worn surface of rock on which it rests, evidently preceded the time when the mollusca lived whose remains we find in the marine beds above it. At Loch Gilphead, in Argyleshire, rows of *Mya Uddevallensis*, entire in their burrows, are found in the fine marine sediment overlying the Boulder-clay, and many other facts of a like nature might be cited. Now if the Caithness Drift is the equivalent of the Old Boulder-clay of the rest of Scotland, why do we not find some fine laminated clay above it, as we do in other places?

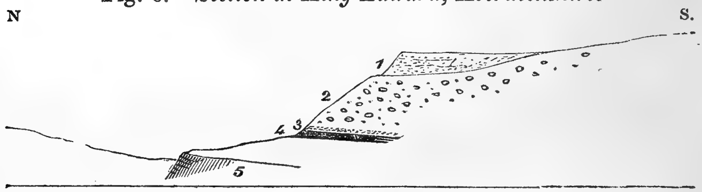
It may be said that the mollusca of the Caithness Drift are an older group than those found in the marine clays of the other parts of Scotland, and therefore, although these mollusca lived during the Caithness Drift, it does not necessarily follow that the latter deposit is more recent than the Old Boulder-clay of the rest of Scotland. An inspection, however, of the list given in the Appendix to this paper does not suggest an older age, but the contrary. In order to place this in a clearer light I have drawn up Table 2, in which the geographical relations of the Caithness shells may be compared with those of groups from the glacial beds of other parts of Scotland. Thanks to the efforts of Mr. Peach, we have a very good list from Caithness; moreover, the specimens have been all examined and named by Mr. Jeffreys, an eminent authority in these matters, so that the list may be used with all confidence.

I think it is a fair inference that the more nearly a group of British fossil mollusca resembles the assemblage of species now living upon the shores of Britain the more recent is the period to which that group belongs. I have accordingly ranged the groups in a series, those which show the lowest percentage of British forms being reckoned oldest. From this Table it will be seen that the Caithness group is the most modern, except that of Fort William, which in a former paper I had referred to the very close of the Glacial-marine period (Quart. Journ. Geol. Soc. vol. xxi. p. 174, 1865), while the proportion of Arctic species is less at Caithness than at any of the other localities—less even than at Fort William. It is not pretended that all these groups represent distinct stages in the Glacial period; several of them I have no doubt were contemporaneous, but I think we are entitled to suppose that the Errol, Elie, and other groups at the beginning of the list are older than the Caithness and Fort William ones. Here, then, we have further evidence to show that the accumulation, or at least the final arrangement, of the Caithness Drift was a comparatively late affair; it therefore ought not to be confounded with the Old Boulder-clay. It seems to me that it ought to be referred to the Glacial-marine period. A set of marine beds containing Arctic shells were probably deposited over the low part of Caithness; and much drifting ice seems to have passed over the district from the north-west, which crushed and destroyed these marine beds, broke the shells, and mixed them up with other superficial débris into that mass of rough pebbly mud which now overspreads the surface. These marine beds were probably of different ages, the older containing Arctic species, the later containing chiefly Boreal and southern forms. This would account for that mixture of species which we observe in the Caithness list.

At Invernettie, near Peterhead (see Quart. Journ. Geol. Soc. vol. xiv. p. 518, 1858), the base of the section shows fine stratified clay and sand free from stones, above which there is a thick mass of rough pebbly clay like that of Caithness, containing well-scratched boulders of granite, sandstone, &c., with some broken sea-shells, which also show traces of glacial scratching. Here, then, we have a mass of unstratified drift closely resembling that of Caithness, and from its position above the fine laminated clay apparently later than at least a part of the glacial-marine beds.

But the glacial deposits at King-Edward, in Aberdeenshire, throw still more light upon the relations of the Caithness beds. Some sections recently laid open there have enabled me to understand their arrangement far better than formerly. At this locality there are deep masses of unstratified pebbly mud of a dark-grey colour, very hard and firm, containing stones (some of which are ice-worn and striated) and fragments of shells, which are likewise occasionally scratched. It is, in short, so like the Caithness Drift in every respect—in colour, texture, and organic contents—that I can perceive no difference between them. It has been called "*the Boulder-clay*" by Mr. Robert Chambers, who visited the locality in 1855*. Besides this coarse stony mud there are some beds of fine stratified sand, which often contain remains of shells in considerable abundance, most of them broken, but many of them entire. The bivalves always occur in detached pieces and want the epidermis, as if they had been washed about by water. This, I believe, is the bed that yielded Hugh Miller's specimens, and from which I have obtained most of the species enumerated from King-Edward in my paper on the last geological changes in Scotland. But there is another bed of fine dark-grey silt, free from stones, containing Arctic shells entire, and apparently *in situ*, with the epidermis on. The *Tellina calcaria* occurs here of large size, with both valves connected by the ligament and shut, also *Leda*, *Natica*, and others; they are very sparingly dispersed in the silt, which contains streaks of black carbonaceous matter, proceeding probably from the decay of seaweed. It also contains *Foraminifera*. This bed of silt I noticed in 1857;

Fig. 6.—*Section at King-Edward, Aberdeenshire.*




1. Valley-gravel.
2. Pebbly clay.
3. Fine sand with shells.
4. Fine silt with shells *in situ*.
5. Rock.

* See 'Proceedings of Royal Society of Edinburgh,' Dec. 17, 1855.

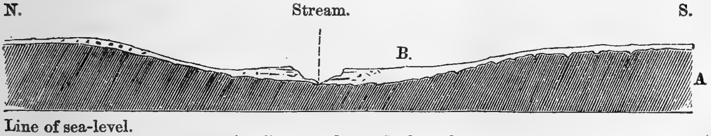
but, owing to the want of good sections, the arrangement of these various deposits was then obscure. It is, however, as follows:—

Commencing at the surface we have—

| | Thickness in feet. |
|---|---|
| 1st. Water-worn gravel and sand, stratified, often rather coarse and pebbly, and somewhat ferruginous. Contains no fossils, so far as I have seen | 10 to 25 |
| 2nd. Unstratified pebbly mud of a dark-grey tint, hard, and difficult to pierce. The stones in it are of small size, but numerous, and some of them glacially scratched. In the upper part I could see no shells; but shell-fragments occur in the lower part, increasing in numbers towards the base. Some of the shell-fragments show distinct traces of glacial action | 20 to 30 |
| 3rd. Fine brownish sand, in some places rich in shells. This sand is interstratified with the upper part of the subjacent bed | 1 to 2 |
| 4th. Fine dark-grey silt, free from stones, containing Arctic shells complete, and apparently *in situ*; they are, however, mostly decayed and somewhat crushed, so that it is difficult to extract them. This silt is very firm, as if much compressed, and the greater proportion of it consists of fine muddy sand. The base of this bed has not been exposed, but it has been excavated by Mr. James Runciman (who was so good as to lay it open at my request) to a depth of 10 feet. No difference in the quality is to be seen to this depth; no stones. The upper surface of this silt is about 150 feet above the sea. | |

Here, then, we have a thick mass of drift, exactly like that of Caithness, clearly overlying a glacial-marine silt, with shells *in situ*. The broken shells in this coarse upper drift seem to have been derived from the beds below. In one part of the bank I found, at the bottom of the coarse pebbly mud, beds of fine silt with broken shells and confused stratification; these seemed to be ordinary marine beds disturbed from their original position by the agency that lodged the overlying drift. Where this disturbing action was so great as to completely break up and destroy the fine silty layers then we should have sections like those of Caithness, where the mass is unstratified from top to bottom, and I believe in many places of the King-Edward banks this will be found to be the case. Large boulders are rare in the King-Edward district, but I saw one of Greywacke from 3 to 4 feet in length, which seemed to have dropped out of the coarse pebbly mud.

Fig. 7.—*Section across King-Edward valley.*




A. Greywacke and clay-slate,
B. Glacial deposits.

In a notice of these King-Edward (the name is a corruption of *Kinedart*) beds in the 14th vol. of the Quart. Journ. Geol. Soc. 1858, p. 525, I remarked that the shells in the fine silt were often crushed in a remarkable way, as if by sudden pressure from above.

The glacial beds of the south of Arran (first described by the Rev. R. B. Watson, and more recently explored by Dr. Bryce and the Rev. H. W. Crosskey) seem to have many points of resemblance to those of King-Edward. There are beds of fine clay containing Arctic shells, sometimes in a broken or crushed state, but occasionally entire and apparently *in situ*. This fossiliferous stratum is covered by a great thickness of what Mr. Watson calls "*Boulder-clay*," but which Messrs. Bryce and Crosskey term "*Upper Drift beds*." If I understand Mr. Watson rightly, this upper stuff occasionally contains broken shells. The fine fossiliferous clay sometimes rests immediately on the older rocks, at other times, according to Messrs. Bryce and Crosskey, there is a mass of clay beneath it of harder, coarser texture than what lies above, and containing stones and boulders on which glacial action is more apparent, and they would restrict the term "*boulder-clay*" solely to this lower stuff. Mr. Watson mentions the occurrence of glacial beds beneath the fine shelly clay, but, according to him, they vary a good deal in character, and he does not draw the same strict distinction between them and the upper beds.

If want of stratification, hardness of texture, and abundance of well-glaciated stones and boulders are to be the tests for what we should call genuine Boulder-clay, then much of the Caithness Drift will stand the ordeal, and, moreover, the shells are as well glaciated as the boulders. The upper pebbly mud of King-Edward is also often very hard and firm.

If the Old Boulder-clay or till has been produced, not in the sea but by glacier-ice moving on the land, it ought to be devoid of marine fossils. What we now want is a microscopic examination of our various so-called Boulder-clays. Messrs. Anderson and Peach have made a commencement with those of Caithness, and find them full of minute organisms. This was to be expected from the presence of the sea-shells. The Boulder-clay, however, which lies beneath the beds of Arctic shells in the midland region of Scotland is remarkable for the absence of fossils, but it yet remains to be seen how it will stand the test of washing and microscopic examination.

9. *The post-Glacial period in Caithness.*—So far as I observed, the post-glacial conditions in Caithness do not appear to have differed much from those in the rest of Scotland. Some indications of a submerged forest, or old land-surface, occur at Sinclair Bay. The peat bed, close upon the shore at Ackergill, contains clusters of seeds of land-plants and also some remains of trees or bushes. Mr. Cleghorn, of Wick, thinks this peat bed is a marine deposit of matter carried into the sea by the rivers. After examining it in company with him I am inclined to differ from this opinion. The peat is covered by a mass of blown sand, which has insinuated itself into some of the crevices and openings of the peat, but I saw nothing to induce me to believe that there was any interstratification of peaty matter with marine sediment.

Mr. Dick told me that at Thurso some peat, containing hazel-nuts and twigs, had been got near the beach on the west side of the town, but I could not learn whether it was *in situ* or transported.

There are some traces of a recent change in the relative level of sea and land along the coast, but only to a very slight extent. The elevation of beds of coast-shingle cannot be depended on with much exactitude as evidence of the former level of the sea, for storm-waves fling up banks of pebbles to various heights, according to the nature of the coast. Even large boulders and great heavy blocks are moved in this way far above the reach of the tide in calm weather. A remarkable instance of this may be seen a little to the south of Wick, which has been cited by some as an example of iceberg-action. But I was assured by Mr. Joseph Anderson that within the last four or five years some of these blocks have been tossed about by the great waves which occasionally break upon the coast during severe gales, a statement which is confirmed by the observations of Mr. Peach. Mr. Cleghorn also told me that he had seen blocks of thirty tons' weight turned over by the surf 15 or 20 feet above the present level of the sea. Beds of estuarine silt, that have been accumulated in well-sheltered positions, afford a better means of determining the former sea-level. There are, however, no estuaries in Caithness, and I therefore cannot speak with confidence as to the amount of this recent change of level, but from all I saw I should think the present position of the land is only a very few feet higher than formerly. The beds of old estuarine mud at the firths of Dornoch, Cromarty, and Beauly attain no great height above the present sea-level—not so much as in the firths of Tay and Forth, or even at the Montrose basin.

Later than this last rise, as shown by their position, are two ancient tumuli in Sinclair Bay, known as "*the Birkle Hills*;" they are of large size and of a bee-hive form. They seem to contain some internal chambers, or stone structures of some sort, but have not been properly explored. One of them was partially opened last year by Mr. Laing. The bases of both are only a few feet above the present reach of spring tides; one of them, at least, is not more than 4 or 5 feet above it. The fact of these old remains being later than the raised beach agrees with my observations at the Estuary of the Ythan, in Aberdeenshire.

*Kjokken-möddings*, or heaps of edible shells mixed with burnt stones and the teeth and bones of various animals, abound along all the sandy bays of Caithness; I observed them in great numbers at Reay, at Freswick, and at Sinclair Bay. They are often covered by a considerable thickness of blown sand. At Reay I noticed a great quantity of the shells of *Helix nemoralis* in these heaps, as if it had been eaten there along with the limpets and periwinkles. Several teeth which I picked up from these heaps were examined by Dr. Turner, Demonstrator of Anatomy in the University of Edinburgh, who pronounced them to belong to the Pig, Horse, Ox, Deer, and Sheep.

## Appendix.

In regard to the following Tables I have again to acknowledge the kind assistance of Mr. Jeffreys, who has done me the favour of revising the Caithness list, as well as the lists from which the abstract, Table no. 2, has been prepared.

The list of Caithness shells combines Mr. Peach's two lists (for which see 'Brit. Assoc. Report' for 1862, Trans. of the Sections, p. 83, *ibid.* for 1864, p. 61), and also some additional species enumerated in a paper lately communicated by him to the Physical Society of Edinburgh.

For the Fort William list see Jeffreys in the 'Brit. Assoc. Report' for 1862, Trans. of the Sections, p. 73. For that from Elie see the Rev. Thomas Brown in the 'Proceedings of the Royal Society of Edinburgh' for March 2nd, 1863. The others will be found in the Appendix to my paper in the 'Quart. Journ. Geol. Soc.' vol. xxi. p. 161, 1865.

In the two following Tables

*Southern* means species living on the west coast of Europe, to the south of lat. 50°.
*British* means species living on the coasts of Britain.
*Northern* means species living on the west coast of Europe, south of lat. 60° and the Arctic circle.
*Arctic* means species living within the Arctic circle.
*N. E. American* means species living on the east coast of North America.

Table I.—*List of Mollusca whose Shells are found in the Glacial Drift of Caithness.*

| No. | | Southern. | British. | Northern. | Arctic. | N. E. American. |
|---|---|---|---|---|---|---|
| 1 | Anomia ephippium, var. squamula | * | * | * | * | * |
| 2 | Aporrhais pes-pelecani | * | * | * | * | |
| 3 | Astarte borealis=A. arctica, of *Forbes & Hanley* | .. | .. | * | * | * |
| 4 | —— compressa | .. | * | * | * | * |
| 5 | —— sulcata | * | * | * | * | |
| 6 | —— sulcata, var. elliptica | .. | * | * | * | * |
| 7 | Buccinum undatum | * | * | * | * | |
| 8 | Cardium echinatum | * | * | * | * | * |
| 9 | —— edule | * | * | * | * | |
| 10 | —— exiguum=C. pygmæum, *F. & H.* | * | * | * | * | |
| 11 | —— fasciatum | * | * | * | * | |
| 12 | —— Grœnlandicum | .. | .. | .. | * | * |
| 13 | —— Norvegicum | * | * | * | *? | |
| 14 | Cerithiopsis costulata=Turritella? costulata, *Möller.* | .. | * | * | * | * |
| 15 | Chiton cinereus | * | * | * | * | * |
| 16 | Crenella decussata | .. | * | * | * | * |
| 17 | Cyprina Islandica | * | * | * | * | * |
| 18 | Cyrtodaria (Glycimeris) siliqua | .. | .. | .. | * | * |
| 19 | Dentalium abyssorum | .. | .. | * | * | * |
| 20 | —— entalis | * | * | * | * | * |
| 21 | Donax vittatus=D. anatinus, *F. & H.* | * | * | * | * | |
| 22 | Fusus antiquus | ? | * | * | * | |
| 23 | Lacuna divaricata=L. vincta, *F. & H.* | * | * | * | * | * |
| 24 | Leda minuta=L. caudata, *F. & H.* | .. | * | * | * | * |
| 25 | —— pernula, var. buccata | .. | .. | * | * | * |
| 26 | —— pygmæa | ? | * | * | * | * |
| 27 | Littorina litorea | * | * | * | * | * |

Table I. (*continued*).

| No. | | Southern. | British. | Northern. | Arctic. | N. E. American. |
|---|---|---|---|---|---|---|
| 28 | Littorina obtusata = L. littoralis, *F. & H.* | * | * | * | ? | |
| 29 | Lucina borealis | * | * | * | * | |
| 30 | —— spinifera | * | * | * | * | |
| 31 | Mactra solida | * | * | * | * | |
| 32 | Mangelia lævigata = M. nebula, *F. & H.* | * | * | | | |
| 33 | —— Leufroyi | * | * | | | |
| 34 | —— pyramidalis | .. | .. | * | * | * |
| 35 | —— Trevelliana | .. | * | * | * | |
| 36 | —— turricula | * | * | * | * | * |
| 37 | Mya truncata | * | * | * | * | * |
| 38 | —— ——, var. Uddevallensis | .. | .. | .. | * | * |
| 39 | Mytilus edulis | * | * | * | * | * |
| 40 | —— modiolus = Modiola modiolus, *F. & H.* | .. | * | * | * | * |
| 41 | Nassa incrassata | * | * | * | * | * |
| 42 | Natica affinis = N. clausa, *Brod. & Sow.* | .. | .. | * | * | * |
| 43 | —— Islandica = N. helicoides, *F. & H.* | .. | * | * | * | * |
| 44 | —— nitida | * | * | * | * | |
| 45 | —— pallida = N. Grœnlandica = N. pusilla, *F. & H.* | .. | * | * | * | * |
| 46 | —— sordida | * | * | | | |
| 47 | Nucula nucleus | * | * | * | * | |
| 48 | —— sulcata = N. decussata, *F. & H.* | * | * | * | | |
| 49 | Odostomia acicula = Eulimella acicula, *F. & H.* | * | * | * | | |
| 50 | —— albella (see *F. & H.* vol. iii. p. 286) | * | * | * | | |
| 51 | Ostrea edulis | * | * | * | .. | * |
| 52 | Patella vulgata | * | * | * | * | |
| 53 | Pecten Islandicus | .. | .. | * | * | * |
| 54 | —— maximus | * | * | * | | |
| 55 | —— opercularis | * | * | * | * | |
| 56 | Purpura lapillus | * | * | * | * | * |
| 57 | Rhynchonella psittacea | .. | .. | *? | * | * |
| 58 | Rissoa parva, var. interrupta | * | * | * | * | |
| 59 | Saxicava Norvegica = Panopæa norvegica, *F. & H.* | .. | * | * | * | * |
| 60 | —— rugosa. Large form | .. | .. | .. | * | * |
| 61 | Solecurtus candidus | * | * | | | |
| 62 | Tellina calcaria = T. proxima, *F. & H.* | .. | .. | * | * | * |
| 63 | —— Balthica = T. solidula, *F. & H.* | * | * | * | * | * |
| 64 | Tornatella fasciata | * | * | * | * | |
| 65 | Trochus Grœnlandicus = T. undulatus, *F. & H.* | .. | * | * | * | * |
| 66 | —— Vahli | .. | .. | .. | * | * |
| 67 | —— zizyphinus | * | * | * | * | |
| 68 | Trophon clathratus = Fusus scalariformis, *Gould* | .. | .. | * | * | * |
| 69 | —— ——, var. Gunneri | .. | .. | * | * | * |
| 70 | —— truncatus = T. clathratus, *F. & H.* | .. | * | * | * | * |
| 71 | Turritella ungulina = T. communis, *F. & H.* | * | * | * | * | |
| 72 | Venus casina | * | * | * | | |
| 73 | —— gallina = V. strictula, *F. & H.* | * | * | * | * | |
| 74 | —— lincta = Artemis lincta, *F. & H.* | * | * | * | | |
| 75 | —— ovata | * | * | * | * | |
| | | 46 | 60 | 66 | 63 | 41 |
| | = per cent. | 61 | 80 | 88 | 84 | 55 |

Of the above shells the *Turritella* and *Cyprina* are probably the most common. *Astarte, Natica, Tellina, Saxicava,* and *Mya* are also pretty frequent, and so likewise are *Dentalium entalis, Leda pernula, Cardium echinatum,* and *Mangelia turricula.* The scale of frequency, however, differs in different localities. Some of the species have been determined from single fragments, as, for example, *Venus ovata* and *Trochus zizyphinus.*

*Patella vulgata* is a shell I have never myself found in any of our Scotch glacial beds, but Mr. Peach informs me he got one pretty perfect specimen, besides two or three fragments. Mr. Dick also told me he had found it. In regard to some of the other species Mr. Peach has supplied me with the following information:—"*Pecten maximus* and *opercularis,* in fragments, occur frequently. *Cardium Norvegicum,* two or three hinge-pieces. *Fusus antiquus,* two pillar-lips. *Ostrea edulis,* one pretty large shell and several fragments"; and he says there can be no doubt whatever that these occur in the very same deposits as the more Arctic forms.

Table II.—*Showing the Geographical relations of groups of Mollusca whose Shells occur in some of the Scottish Glacial beds.*

| Localities | Errol. | Elie. | King-Edward. | Paisley. | Kilchattan. | Gamrie. | Caithness. | Fort William. |
|---|---|---|---|---|---|---|---|---|
| Total number of species at each locality | 13 | 14 | 27 | 26 | 16 | 25 | 75 | 47 |
| Southern, per cent. | 8 | 14 | 44 | 38 | 50 | 52 | 61 | 55 |
| British, ,, | 38 | 43 | 59 | 61 | 69 | 72 | 80 | 85 |
| Northern, ,, | 62 | 57 | 93 | 100 | 100 | 96 | 88 | 96 |
| Arctic, ,, | 100 | 100 | 100 | 100 | 100 | 100 | 84 | 89 |
| N.E. American, ,, | 100 | 100 | 89 | 85 | 87 | 88 | 55 | 70 |

Some interesting information may be gathered from the foregoing Table.

The Errol and Elie groups, it will be seen, are intensely Arctic; the shells are just such as we might find in the sea of Spitzbergen at the present day, many of the species not ranging south of the Arctic circle. In them the proportion of British species is less than 50 per cent., while that of the Southern has dwindled down to a very small fraction. These two groups I take to represent an early stage of the glacial-marine beds when the rigour of the climate was at its height.

The groups from King-Edward, Paisley, Kilchattan, and Gamrie probably belong to a somewhat later stage, for although the general character is still Arctic, yet it is less strictly so than in the two preceding. The proportion of Southern forms is far greater, and the British exceed 50 per cent.

The Fort William group is probably the latest of all; it is no longer Arctic but Northern, and the British species exceed 80 per cent.

The Caithness group seems to be a mixture of species from glacial beds of both earlier and later date.

The high percentage of North American forms in all the groups, but more especially in the first six, is a feature of much interest.

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February 21, 1866.

William Henry Corfield, Esq., B.A., Fellow of Pembroke College, Oxford, University College Hospital, Gower Street, W.C.; Henry Lee, Esq., The Waldrons, Croydon; Henry Skiffington Poole, Esq., B.A., Cape Breton, Nova Scotia; Alexander Ramsay, jun., Esq., 45 Norland Square, Notting Hill, W.; Charles Pearce Serscold, Esq., Taplow Hill, and 24 Oxford Square; George Suche, Esq., 77 Grosvenor Street, W.; and James Maurice Wilson, Esq., M.A., Fellow of St. John's College, Cambridge, Rugby School, were elected Fellows.

The following communications were read:—

## 1. *On the* Tertiary Mollusca *of* Jamaica.

By R. J. Lechmere Guppy, Esq., Civil Service, Trinidad.

(Communicated by Henry Woodward, Esq., F.G.S., F.Z.S.)

[Plates XVI.-XVIII.]

### § 1. The Relationships of the Miocene of Jamaica.

In 1862 Mr. Lucas Barrett, Director of the Geological Survey of the West Indies, brought over from Jamaica and deposited in the British Museum a collection of Miocene fossils. In 1863 Mr. Carrick Moore communicated to the Geological Society the results of his examination of the shells, Dr. Duncan described the corals, and Prof. Rupert Jones gave an account of the Foraminifera *. In 1864 Dr. Duncan and Mr. Wall gave a sketch of the geology of a part of Jamaica, showing the relations of the Cretaceous and Tertiary formations exposed in that island †. In the same communication Dr. Duncan described several new and interesting corals from the Cretaceous, Eocene, and Miocene strata; but beyond the general results given in Mr. Carrick Moore's paper above referred to, the shells have remained untouched. It was, I believe, the intention of Mr. Barrett to have worked out this portion of the subject, and, indeed, he had already had one plate engraved, which has since been destroyed for want of instructions; but as his untimely and lamented death has intervened to prevent our receiving the benefit of his illustration of the fossils alluded to, I have undertaken to furnish an account of these remains ‡.

* Quart. Journ. Geol. Soc., vol xix. p. 510.

† *Ibid.*, vol. xxi. p. 1.

‡ The following extract from a letter of Mr. Barrett was published by Dr. Woodward in an obituary notice of that naturalist: "The Tertiary system of

In the paper by Dr. Duncan and Mr. Wall, before cited, the relations of the various strata are so well and succinctly described, that it is unnecessary for me to do more in this place than to allude to the fact that the formation whence the mollusca to be described were derived consists of shales, sands, and marls exposed in several parts of Jamaica, and that it has suffered great disturbance, in common with the Tertiary strata of other parts of the West Indies, and is frequently found in a position approaching to the vertical. The identity of many of the species found in these rocks with forms from San Domingo, Cuba, Cumana, Antigua, Anguilla, and Trinidad, shows the very extended development of Miocene formations in the Caribean area. The period appears to have been one of exuberant development of marine life, and the conditions seem on the whole to have been favourable to the preservation of the shells and other remains.

The general remarks made by Mr. Carrick Moore in his papers on the San Domingan Tertiary fossils * are as a rule applicable to those of Jamaica; and many of those observations have been confirmed by Dr. Duncan's investigations of the corals, and those of Prof. Rupert Jones of the Rhizopoda. Among the new facts brought to light is the very remarkable resemblance of a portion of the West Indian Miocene fauna to that of the Maltese beds.

The great difference between the Miocene faunas of the American and Caribean areas is particularly remarkable when we take into consideration the alliances of the latter with the European Mid-tertiaries, and the more we investigate the subject, the more we find to confirm the conclusions already arrived at on this head. Still, there is a certain amount of resemblance, and, upon examination, I find that the *Petaloconchus Domingensis* of Sowerby, appears identical with *P. sculpturatus* of Lea, from the Miocene of Virginia.

From my examination of the Jamaican fossils, I am of opinion that, with the Middle Tertiary beds of San Domingo and Cuba, those of Cumana, and the Caroni series in Trinidad, the Miocene of Jamaica is to be considered as representing the upper or later part of the West Indian Miocene as at present known; while the Chert-formation in Antigua, the Anguilla beds, and the beds exposed at San Fernando in Trinidad, belong to the lower and older part of the Miocene.

In Jamaica the Miocene strata consist of highly inclined marls and shales, which are especially characterized by *Conus, Strombi,* and large *Pleurotomæ,* with small *Nummulinæ* and *Orbitoides,* as well as corals. At Cumana we have a fauna almost identical with that of Jamaica, including similar foraminifera and corals; among the latter is *Flabellum exaratum,* Dunc. The beds consist in part of

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Jamaica is very interesting, though I have not been able to separate it into Sir Charles Lyell's divisions. I must first study the recent shells of Jamaica. The newer Tertiary strata contain a *Terebratula* (with a short loop) a *Terebratulina* (like *caput-serpentis*) and an *Argiope*. There is a marl-bed, probably formed in the deep sea, containing abundance of Pteropods (*Cleodora, Creseis, Cuvieria*)." —'Critic,' February 1, 1863.

* Quart. Journ. Geol. Soc. vol. vi. p. 39, and vol. ix. p. 129.

sands, with a calcareous conglomerate, which latter yields the coral alluded to. The Caroni series in Trinidad consists of shales, clays and sands, and some marls, which are characterized by large *Ostreæ* (*O. Haitensis*, Sow.). In Cuba the formation consists apparently of strata resembling those of Anguilla, in which the shells are found chiefly as casts, most of which have been referred by d'Orbigny to existing species, but which in all probability will be found to be identical for the most part with the extinct species found in Jamaica and San Domingo. *Tellina biplicata*, Conrad, related to *T. ephippium* of the Indian seas, and to *T. Sobralensis*, Sharp, of the Portuguese Tertiaries, and *Natica phasianelloides*, d'Orb., the *Tellina* occurring in the Caroni series in Trinidad, and also in San Domingo, and the *Natica* in Jamaica, San Domingo, Anguilla, and at San Fernando in Trinidad, are recorded by d'Orbigny from the Cuba beds. The Chert-formation of Antigua has been fully remarked upon by Dr. Duncan*, who correlates it with the Lower Limestone of Malta. The Miocene of Anguilla is a light-coloured marly limestone containing numerous mollusca, chiefly as casts. Among the better-preserved shells are *Solarium quadriseriatum*, Sow., and *Natica phasianelloides*, d'Orb. The Echinoderms in this deposit are in better condition, and exhibit a strong resemblance to those found in the Miocene beds of Malta. Among the species which are specifically identical, we have *Schizaster Scillæ*, and *Cidaris Melitensis*, occurring in association with an extinct species of *Echinolampas*, only to be distinguished critically from *E. hemisphæricus*, and another almost as near to *E. scutiformis*. *Clypeaster ellipticus*, Michelin, and three living species of Echinoderms also occur in these beds. At San Fernando, in Trinidad, we have a numerous succession of gypseous marls, shales, and some partial limestones, enclosing *Natica phasianelloides*, *Orbitoides Mantelli*, *Nummulina*, and *Echinolampas ovum-serpentis*, as well as some *Terebratulæ*.

It must be understood that while there remains but little doubt as to the very close proximity in age of the Miocene formations of Cumana, Jamaica, and San Domingo, our information is not quite so exact with respect to those of Cuba, Anguilla, and Trinidad, owing to the bad state of preservation of the fossils at the latter localities. And in endeavouring to correlate these beds, I have used the terms Upper and Lower Miocene, not as implying that these formatious are respectively equivalent to the Upper and Lower Miocene of Europe, but merely as marking what seems to be the relative antiquity of the Middle Tertiary beds of the Caribean area.

The connexion between the formations found in all the localities mentioned could only be shown by a general table, including all the known species from those localities. On the present occasion my remarks must necessarily be confined to the Jamaican fossils.

As yet I only know of one species common to Jamaica and Cuba (*Natica phasianelloides*) and only two common to Jamaica, Anguilla, and the Caroni beds in Trinidad. Mr. G. P. Wall, F.G.S., has kindly favoured me with a small collection of Tertiary fossils from Cumana,

* Geol. Mag. 1864, vol. i. p. 97.

and among these I find fourteen species common to Jamaica. There are thirty-four species common to Jamaica and San Domingo; and if the Haitian species not found in Jamaica were now under consideration, the intimate relationship of all the Caribean Miocene beds would be clearly shown.

Thirteen species have been identified with living forms out of the total of sixty-one species which are described in this communication. This would give a proportion of about twenty-one per cent., a somewhat larger proportion than was arrived at by Mr. Carrick Moore for the San Domingo fossils. Yet I cannot lay much stress upon the exact ratio of recent species in considering the relative age of the Jamaica and San Domingo beds; for we have seen that thirty-four species are common to both localities, and out of these, seven are existing species, many of which are widely distributed and have been found in the Miocene of other localities. Such are *Lucina Pennsylvanica* and *Venus paphia*, which both occur in the Miocene of Europe. Moreover some of the species identified with living forms do not now inhabit the West Indies. Among these are *Pectunculus pennaceus* and *Natica mammillaris*. There are several shells in the Jamaica collection which are too imperfect for specific determination, the generic names of which are given in Mr. Carrick Moore's paper on these fossils. Among them is a small *Ancillaria*, a genus which is now extinct, or nearly so, in the West Indies.

The most characteristic fossils of the West Indian Miocene appear to be *Natica phasianelloides*, *Solarium quadriseriatum*, and *Orbitoides Mantelli*, these species having been found in nearly all the Miocene localities, exclusive of Cumana; and they will doubtless be ultimately found there also.

The eastern affinities of the West Indian Miocene fauna is evidenced in the most unequivocal manner by a portion of the collection now described. *Cytherea planivieta* is very closely allied to *C. erycina*; *Cardium lingua-leonis* is nearer to *C. rubicundum* of Madagascar than it is to *C. elongatum* of the West Indies; and so on with several of the species. But it must not be overlooked that while there is undoubtedly a closer resemblance of a part of the mollusca to living eastern forms, than to living West Indian forms, another part of the fauna presents nearer affinities to that now inhabiting the contiguous waters. Again, a certain number of the species (*e. g.*, those of the genera *Cassis, Cassidaria, Conus* and *Natica*) seem to have their nearest congeners in the European early and middle Tertiaries.

I shall mention another point which has some bearing on the affinities of faunas distant in time and in space. Mr. Jenkins has shown me a small collection of fossils from Travancore, in the Society's Museum. These fossils seemed to me to be probably of older Pliocene or Upper Miocene date; but without prejudice to the conclusions which may be arrived at after a closer examination of the fossils in question, I may state that several of them appeared to me to have near resemblances to species now existing in the West Indies. From this it would appear that while the fauna of the West Indies in Miocene times appears to have been more closely related to the existing eastern fauna than it is at present, there was a fauna in the eastern area during some part of the Tertiary Period with a stronger resemblance to that of the present Caribean seas than now exists. Thus these various geologico-geographical groups bear a somewhat similar sort of affinity to one another, that we find displayed between certain recent and fossil species of animals.

When taken as a whole, the resemblace of the Caribean Miocene fauna to that of Bordeaux, Dax, and Malta is striking, and it is closer than its likeness to the American Miocene*. The present molluscan fauna of the West Indies is not altogether devoid of affinities to that of the Mediterranean, and even to that of the Red Sea. Several of the species are, if not identical, at least so near, that they are known by the same names. Hence arises some of the confusion with respect to localities that we occasionally find in conchological books; the same species being attributed in one to the Mediterranean or to the Red Sea, in another to the West Indies.

The series of mollusca now described, with those previously described by Mr. Sowerby, and the corals published by Dr. Duncan, will furnish a basis for future investigations into the geology of the Tertiary formations of the West Indies and Tropical America, and we may expect conclusions of no small interest therefrom.

## § 2. List of Species.

| Species. | Distribution. | | | |
|---|---|---|---|---|
| | Recent. | Fossil. Cumana. | Fossil. S. Domingo. | Fossil. Other localities. |
| Cassis sulcifera, *Sow.* | ...... | ...... | * | |
| —— monilifera, *Guppy* | ...... | ...... | ...... | |
| Malea camura, *Guppy* | ...... | ...... | ...... | |
| Cassidaria sublævigata, *Guppy* | ...... | ...... | ...... | |
| Strombus pugilis, *Linn.* | * | ...... | ...... | Cuba; Anguilla. |
| —— bifrons, *Sow.* | ...... | ...... | * | Trinidad? |
| Conus planiliratus, *Sow.* | ...... | ...... | * | |
| —— solidus, *Sow.* | ...... | ...... | * | |
| —— stenostoma, *Sow.* | ...... | ...... | * | |
| —— granozonatus, *Guppy* | ...... | ...... | ...... | |
| —— interstinctus, *Guppy* | ...... | ...... | * | |
| —— gracilissimus, *Guppy* | ...... | ...... | ...... | |
| Murex Domingensis, *Sow.* | ...... | * | * | |
| Persona simillima, *Sow.* | ...... | * | * | |
| Ranella crassa, *Dillw.* | * | ...... | ...... | |
| Oliva reticularis, *Lam.* | * | ...... | ...... | |
| Mitra Henekeni, *Sow.* | ...... | ...... | * | |
| Fasciolaria semistriata, *Sow.* | ...... | ...... | * | |
| Latirus infundibulum, *Gmel.* | * | ...... | * | N. America. |

* By this I mean that there is such a number of types common to the Miocene of Bordeaux, &c., that they resemble deposits formed within the same great zoological province. It is in this respect that the resemblance is less close with the American Miocene.

List of Species (*continued*).

| Species. | Distribution. | | | |
|---|---|---|---|---|
| | Recent. | Fossil. Cumana. | Fossil. S. Domingo. | Fossil. Other localities. |
| Marginella coniformis, *Sow.* | ...... | * | * | |
| Columbella ambigua, *Guppy* | ...... | ...... | ...... | |
| —— gradata, *Guppy* | ...... | * | ...... | |
| Cancellaria Barretti, *Guppy* | ...... | ...... | * | |
| —— lævescens, *Guppy* | ...... | ...... | * | |
| —— Moorei, *Guppy* | ...... | * | * | |
| Pleurotoma consors, *Sow.* | ...... | ...... | * | |
| —— venustum, *Sow.* | ...... | ...... | * | |
| —— Barretti, *Guppy* | ...... | * | ...... | |
| —— Jamaicense, *Guppy* | ...... | ...... | ...... | |
| Terebra inæqualis, *Sow.* | ...... | * | * | |
| Phos Moorei, *Guppy* | ...... | ...... | * | |
| —— elegans, *Guppy* | ...... | ...... | ...... | |
| Cerithium plebeium, *Sow.* | ...... | ...... | * | |
| Natica subclausa, *Sow.* | ...... | ...... | * | |
| —— sulcata, *Born* | * | * | * | |
| —— mammillaris, *Lam.* | * | ...... | ...... | |
| —— phasianelloides, *d'Orb.* | ...... | ...... | * | Cuba; Anguilla; Trinidad. |
| Turbo castaneus, *Chemn.* | * | * | * | |
| Solarium quadriseriatum, *Sow.* | ...... | ...... | * | Anguilla; Trinidad. |
| Cyclostrema bicarinata, *Guppy* | ...... | ...... | ...... | |
| Neritina Woodwardi, *Guppy* | ...... | ...... | ...... | |
| Dentalium dissimile, *Guppy* | ...... | ...... | ...... | |
| Vermetus papulosus, *Guppy* | ...... | ...... | * | |
| Venus paphia, *Linn.* | * | * | * | Vienna. |
| —— Woodwardi, *Guppy* | ...... | * | ...... | |
| Cytherea planivieta, *Guppy* | ...... | ...... | ...... | |
| —— carbasea, *Guppy* | ...... | ...... | ...... | |
| Lucina Pennsylvanica, *Linn.* | * | * | * | Piedmont; N. America. |
| Cardita scabricostata, *Guppy* | ...... | ...... | * | |
| Cardium Haitense, *Sow.* | ...... | * | * | |
| —— lingua-leonis, *Guppy* | ...... | ...... | ...... | |
| —— inconspicuum, *Guppy* | ...... | ...... | ...... | |
| Corbula viminea, *Guppy* | ...... | ...... | ...... | |
| Pectunculus pennaceus, *Lam.* | * | ...... | ...... | |
| —— acuticostatus, *Sow.* | ...... | * | * | |
| Arca consobrina, *Sow.* | ...... | * | * | |
| —— Noæ, *Linn.* | * | ...... | * | |
| —— inæquilateralis, *Guppy* | ...... | ...... | ...... | |
| Pecten exasperatus, *Sow.* | * | ...... | ...... | |
| —— inæqualis, *Sow.* | ...... | ...... | * | |
| Chama arcinella, *Lam.* | * | ...... | * | N. America. |

## § 3. Description of the Species.

1, Cassis sulcifera, Sow.

Quart. Journ. Geol. Soc. vol. vi. p. 47, pl. 10. f. 1.

A form allied to the recent *C. tuberosa.*

2. Cassis monilifera, spec. nov. Pl. XVII. fig. 8.

Shell ovate, scarcely ventricose; whorls 5, varices few (1–2) or none; ornamented with obsoletely nodose, low, round, spiral ridges, and bearing on the superior angle a somewhat moniliform row of tubercles; spire small, conic; columellar callus granose; outer lip thickened and dentate; columella very tortuous beneath the callus; canal recurved.

Allied to *C. abbreviata*, Lam. (recent), and still closer to *C. diadema*, Defr. of the Bordeaux Miocene.

3. Malea camura, spec. nov. Pl. XVII. fig. 9.

Shell ovate, ventricose; whorls 6–7, destitute of varices, zoned by about 16 low spiral ridges; spire short, conic; aperture rather narrow, outer lip thickened, dentate; inner lip sinuate, dentate; columella tortuous, irregularly folded or plaited; callus thin.

4. Cassidaria sublævigata, spec. nov. Pl. XVII. fig. 10.

Shell ovate, rimate, striated by transverse grooves which are decussated by numerous fine longitudinal lines; varices scarcely prominent, few; whorls 6–7; spire small, acuminate; suture impressed; aperture elongate; outer lip forming a varix which is scarcely prominent externally, thickened and strongly toothed internally; columellar margin covered by a spreading callus, on which are several folds or plaits; canal short, narrow, slightly reflected.

Allied to the *C. lævigata*, Sow., of the San Domingan Miocene, from which it is easily distinguished by its short spire and larger size. Among recent species it is most nearly related to *C. striata*, but the shorter spire, among other characters, serves to distinguish it.

5. Strombus pugilis, Linn.
Syst. Nat. (ed. 12) p. 1209; Reeve, C. I. Strombus, No. 39.

A common shell in the Caribean Sea.

6. Strombus bifrons, Sow.
Quart. Journ. Geol. Soc. vol. vi. p. 48, pl. 9. f. 8.

7. Conus planiliratus, Sow. Pl. XVI. fig. 7.
Quart. Journ. Geol. Soc. vol. vi. p. 44.

8. Conus solidus, Sow. Pl. I. fig. XVI.
Quart. Journ. Geol. Soc. vol. vi. p. 45.

9. Conus stenostoma, Sow. Pl. XVI. fig. 2.
Quart. Journ. Geol. Soc. vol. vi. p. 45.

10. Conus granozonatus, spec. nov. Pl. XVI. fig. 5.

Shell elongate, ornamented with numerous (18) transverse nodose ridges, and longitudinally striated by lines of growth, which are most distinct in the sulcations between the ridges; uppermost keel or ridge on the angle of the whorl bearing larger tubercles; spire elevated, acuminate.

11. Conus interstinctus, spec. nov. Pl. XVI. fig. 3.

Shell obconic, transversely ornamented with many small ridges bearing moniliform granules, which are most distinct anteriorly, but become simple striations near the anterior canal; whorls 10, superiorly carinate; spire rather elevated, acuminate.

12. Conus gracilissimus, spec. nov. Pl. XVI. fig. 4.

Shell elongate, subfusiform, slender, ornamented with flattened spiral ribs which are crossed by longitudinal striæ most distinct in the interstices of the ribs; spire elevated, acuminate; whorls angular above, the angle ornamented with a single row of small obtuse tubercles; aperture very narrow, elongate; outer lip prominent; posterior sinus distinct.

13. Murex Domingensis, Sow.
Quart. Journ. Geol. Soc. vol. vi. p. 49, pl. 10. fig. 5.

14. Persona simillima, Sow., sp. Pl. XVII. fig. 13.
*Triton simillimus*, Sow. Quart. Journ. Geol. Soc. vol. vi. p. 48.

15. Ranella crassa, Dillw. Pl. XVIII. fig. 9.
Dillwyn, Descr. Cat. 692; Reeve, C. I. Ranella, No. 18.

16. Oliva reticularis, Lam.
Lamarck, Animaux sans Vert. (ed. Desh.) vol. x. p. 613; Reeve, C. I. Oliva, No. 16.

This species still lives in the Gulf of California, and also in the West Indies, where it is rather rare.

17. Mitra Henekeni, Sow.
*M. Henikeri*, Sow. Quart. Journ. Geol. Soc. vol. vi. p. 46, pl. 9. f. 5.

A small example of this species occurs in the Jamaica collection.

18. Fasciolaria semistriata, Sow. Pl. XVI. fig. 12
Quart. Journ. Geol. Soc. vol. vi. p. 49.

19. Latirus infundibulum, Gmel.
Lamarck, An. s. Vert. (ed. Desh.) vol. ix. p. 386; Reeve, C. I. Turbinella, No. 3.

20. Marginella coniformis, Sow. Pl. XVII. fig. 2.
Quart. Journ. Geol. Soc. vol. vi. p. 45.

21. Columbella ambigua, spec. nov. Pl. XVI. fig. 8.

Shell elongate, acuminate, thick, longitudinally ribbed with stout somewhat undulated costæ; whorls about 10, flattened laterally, gradually increasing; aperture narrow, outer lip thickened, blunt, toothed within, scarcely indented by an obsolete posterior sinus; canal short, recurved; columellar callus with prominent edges.

22. Columbella gradata, spec. nov. Pl. XVI. fig. 10.

Shell thick, elongate, whorls about 9, flattened and ornamented above with a series of longitudinally elongate tubercles, and somewhat ribbed near the aperture; the last whorl spirally grooved anteriorly; spire small, elevated, acuminate; outer lip thickened, toothed internally; columellar callus with a prominent edge.

This shell is distinguished from the preceding, which it somewhat resembles, by the middle part of the whorls being smooth, by the shorter spire, and the somewhat steplike overlapping of the whorls. Both these species, as well as *C. venusta* from the San Domingan Miocene, seem to have relations with *Pleurotoma*. They belong to the subgenus *Strombina* of Mörch.

23. Cancellaria Barretti, spec. nov. Pl. XVII. fig. 11.

Shell stout, ovate-turreted, cancellated by numerous equidistant and close longitudinal and transverse ribs, of which the transverse are somewhat more distinct than the longitudinal; whorls 8, somewhat compressed, very slightly angulated near the suture; aperture ovate, rather narrow: columella strongly folded; outer lip blunt, very slightly sinuate anteriorly, deeply grooved within.

The specimens seem to be scarcely adult, and the species may, when full grown, have a columellar callus like that in the next species.

24. Cancellaria lævescens, spec. nov. Pl. XVII. fig. 12.

Shell very thick, ovate, spire cancellated by numerous ribs, of which the longitudinal are the more distant and more prominent; whorls 8; last one forming about two-thirds of the height of the shell, nearly smooth, but with fine lines of growth decussated by low distant ridges, the latter becoming quite obsolete near the aperture, except anteriorly, where they are more distinct; aperture widest anteriorly; columella strongly folded with two very prominent plaits; callus thick, spreading; outer lip blunt, obsoletely dentate, grooved internally; canal short, tortuous.

This species, allied to *C. reticulata*, Dillw., was at first considered as a variety of that species, an opinion afterwards abandoned. The characters given will readily distinguish it from that recent species. It partakes in some measure of the characters of *C. obesa* and *C. solida*, Sow.

25. Cancellaria Moorei, spec. nov. Pl. XVII. fig. 7.

Shell ovate, ventricose, subrimate, longitudinally striated and ornamented with stout, rounded, distant, variciform costæ, which are crossed by spiral ribs; whorls about 7, increasing rapidly; aperture rounded ovate; columellar callus thin, with prominent edges; columella twisted, with three plaits; canal reflected.

26. Pleurotoma consors, Sow.
Quart. Journ. Geol. Soc. vol. vi. p. 50.

27. Pleurotoma venustum, Sow.
Quart. Journ. Geol. Soc. vol. vi. p. 50, pl. 10. f. 7.

28. Pleurotoma Barretti, spec. nov. Pl. XVII. fig. 6.

Shell solid, fusiform, elongate, whorls 9–10, carinate, spirally keeled and striated; keels visible on the upper whorls three, with 3–4 intermediate striæ, decussated by lines of growth; second and largest keel decurrent, with the notch divided by an obsolete groove; aperture elongate; canal long, straight.

A shell like *P. virgo*, but with more acute keels.

There are some small shells in the collection which I take to be the young of this species. In these the cross striæ between the keels are more distinct and more delicate.

29. Pleurotoma Jamaicense, spec. nov. Pl. XVI. fig. 6.

Shell ovate-turreted; whorls stoutly transversely ribbed below the small round keel which follows the suture; the interstices between the ribs crossed by numerous fine striæ, which are decussated by still finer striæ; aperture rather narrow; outer lip somewhat thickened; anterior canal very short; posterior canal scarcely forming a notch in the peristome.

This shell belongs to a type which has several recent representatives both in the West Indies and on the West Coast of America. Its nearest relative is perhaps *P. granulosa*, Sow., from Panama.

30. Terebra inæqualis, Sow.
Quart. Journ. Geol. Soc. vol. vi. p. 47.

The Jamaican examples are small and fragmentary.

31. Phos Moorei, spec. nov. Pl. XVI. fig. 11.

Shell ovate-turreted, conical, with longitudinal distant ribs which are cancellated by transverse costæ rising into tubercles upon the longitudinal ribs; whorls 9, rather convex, increasing gradually; spire sharp, regularly turreted; aperture ovate; columella somewhat twisted; outer lip internally distantly grooved; peristome crenate, blunt, somewhat sinuate anteriorly; canal short, open.

This species is so close to *P. Veraguensis*, Hinds, that it was at first considered by Mr. Carrick Moore as a variety of that species; an opinion which he subsequently modified.

32. Phos elegans, spec. nov. Pl. XVI. fig. 13.

Shell conical-turreted, elongate, cancellated by longitudinal and transverse ribs, the latter rising into tubercles upon the former, which are the largest and most distant; whorls 8, convex, gradually increasing; aperture ovate; columella somewhat twisted; outer lip simple, blunt, grooved within.

33. Cerithium plebeium, Sow. Pl. XVI. fig. 9.
Quart. Journ. Geol. Soc. vol. vi. p. 51.

34. Natica subclausa, Sow. Pl. XVIII. fig. 8.
Quart. Journ. Geol. Soc. vol. vi. p. 51.

35. Natica sulcata, Bom. Pl. XVIII. figs. 14, 15.
*N. cancellata*, Gmel.; Reeve, C. I., Natica, No. 95.

36. Natica mammillaris, Lam.
Lamarck, An. s. vert. (ed. Desh.) vol. viii. p. 628; Reeve, C. I. Natica, No. 29.

I do not feel sure of this identification; but as the fossil seems to have been referred to this species, I am not at present able to suggest an amendment.

37. Natica phasianelloides, D'Orb. Pl. XVII. fig. 1.
D'Orbigny, Paléontologie de Cuba, pl. 1. f. 7.

Shell ovate-globose, smooth, scarcely rimate; spire elevated; columellar callus narrow, its margin sinuate on the penultimate whorl.

Although D'Orbigny has not, as far as I can ascertain, pubished any text explanatory of his plates of Cuban fossils, and although the specimen figured by him is only a cast, I believe the present shell to be identical with the species to which I have referred it. It seems to be very characteristic of the West Indian Miocene, and occurs in a perfect state in San Domingo, and as casts in Anguilla and Trinidad. The Jamaican example is small, and has lost its spire. This fossil belongs to that group of *Naticæ* so well represented in the Eocene of Europe by *N. ambulacrum*, Sow., *N. hybrida*, Desh., and *N. acuta*, Sow. It has a somewhat taller spire than any of these. The absence of an umbilicus and the elevated spire seem to indicate for it a place in the group *Amaura*, Möller (1842).

38. Turbo castaneus, Chemn.

The fossil is remarkable for retaining some of the chestnut colour characteristic of the recent shell with which I am acquainted under this name. It seems to be the *T. hippocastaneus* of Lamarck. It is certainly not the form known as *T. crenulatus*, Gmel. (*T. articulatus*, Reeve); but whether the latter is to be considered a variety or not, I am not now prepared to state.

39. Solarium quadriseriatum, Sow.
Quart. Journ. Geol. Soc. vol. vi. p. 51, pl. 10. f. 8.

Fine examples of this species occur in Jamaica.

40. Cyclostrema bicarinata, spec. nov. Pl. XVII. fig. 5.

Shell discoidal, broadly umbilicate; whorls concave beneath, flat above, with four small spiral keels on the flat upper part, the periphery formed by two larger and more distant spiral keels, including between them a somewhat concave smooth spiral area; peristome continuous.

41. Neritina Woodwardi, spec. nov. Pl. XVIII. figs. 4, 5.

Shell oval-globose, flattened, with coarse lines of growth; spire wanting; mouth very narrow, semilunate; columella-lip very broad, flat; columella simple, slightly curved, and furnished with an obsolete tooth-like projection anteriorly.

The spire of the single example has completely disappeared by erosion, so that nothing but the last whorl is left, and even that seems to have been somewhat encroached upon by the dissolving properties of the water in which this mollusk lived. The shell is different from that of any of the genus I know of inhabiting the West Indies or South America.

42. Dentalium dissimile, spec. nov. Pl. XVII. fig. 4.

Shell subpolygonal and striated at the apex, becoming gradually round, smooth, and shining near the aperture, which is circular.

43. Vermetus papulosus, spec. nov. Pl. XVII. fig. 3.

Shell nearly straight, rather irregularly spirally contorted, ornamented with regular longitudinal rows of tubercles interlined with crenate striæ; aperture subcircular.

44. Venus paphia, Linn.
Syst. Nat. p. 1129; Lamarck, An. s. vert. (ed. Desh.) vol. vi. p. 371.

45. Venus Woodwardi, spec. nov. Pl. XVIII. fig. 1.

Shell subtrigonal, somewhat inequilateral, anteriorly rounded, posteriorly somewhat angulated; ornamented with numerous fine radiating costellæ, interrupted by equidistant concentric crenulate ridges, which are continued across the large lunule; margin beneath the lunule internally obsoletely toothed.

A form allied to *V. cancellata*, Linn., abundant in the Caribean Sea.

46. Cytherea (Callista) planivieta, spec. nov. Pl. XVIII. fig. 3.

Shell inequilateral, transverse, oval, compressed; valves polished, ornamented with numerous flat, slightly irregular, concentric ribs, which are much closer than their interstices; umbones prominent, approximated; lunule scarcely impressed.

This bivalve approaches closely to *C. erycina* of the Eastern seas. It is also allied to *C. striatella* of the Belgian Tertiaries, and even more closely to *C. erycinoides* of the Bordeaux beds.

47. Cytherea (Circe) carbasea, spec. nov. Pl. XVIII. fig. 13.

Shell rounded, rather inequilateral, tumid, sulcated by lines of growth decussating with numerous radiating striæ, which divaricate on the anterior part of the disk, and become subrugose towards the posterior margin; lunule large, scarcely distinct; posterior margin rounded; anterior margin somewhat produced.

The character of the ornamentation in this species approaches to that of *C. divaricata*, Chemn., and in general form it is related to that species and to several others of the same group inhabiting both the eastern and western seas, or found fossil in Tertiary formations.

48. Lucina Pennsylvanica, Linn.
Syst. Nat., p. 1134.

This well-known species is also found fossil in the Miocene deposits of Piedmont and of North America.

49. Cardita scabricostata, spec. nov. Pl. XVIII. fig. 10.

Shell suborbicular, nearly as high as wide, with about 18 regularly nodosely muricate impressed ribs; posterior margin nearly straight, forming an angle with the ventral margin, which is rounded; anterior margin rounded; umbones prominent; margins strongly crenate, hinge with two teeth, of which the posterior one is long and narrow.

50. Cardium Haitense, Sow.
Quart. Journ. Geol. Soc. vol. vi. p. 52, pl. 10. fig. 11.

51. Cardium lingua-leonis, spec. nov. Pl. XVIII. fig. 7.

Shell elongate, subquadrate; valves deep, ornamented with numerous (32) nodosely muricate ribs, which are lower and more distant towards the anterior and posterior margins; margins coarsely crenulate, the posterior one strongly serrate: hinge with three large and stout teeth.

The nearest ally of this shell is *C. rubicundum* of Madagascar. It is distinguished both from that species and from *C. elongatum* by its deeper valves and by the ribs on the disk being somewhat muricate. It is also rather narrower than those species.

52. Cardium inconspicuum, spec. nov. Pl. XVIII. fig. 12.

Shell elongate, subtrigonal, ovate, ornamented with numerous (38) imbricate radiating ribs broader than their regularly squamose interstices; umbones scarcely prominent; margins strongly dentate; hinge small, with three teeth.

53. Corbula viminea, spec. nov. Pl. XVIII. fig. 11.

Shell thick, transversely oblong, rounded anteriorly, produced posteriorly into an acute beak; valves ornamented with stout, rather round, concentric ribs; hinge with a single prominent tooth and a deep orbicular pit in front of it.

54. Pectunculus pennaceus, Lam.
Lamarck, Anim. sans vert. (ed. Desh.) vol. vi. p. 490; Reeve, C. I. Pectunculus, No. 24.

55. Pectunculus acuticostatus, Sow.
Quart. Journ. Geol. Soc. vol. vi. p. 53, pl. 10. f. 13.

56. Arca consobrina, Sow.
Quart. Journ. Geol. Soc. vol. vi. p. 52, pl. 10. fig. 12.

57. Arca Noæ, Linn.
Syst. Nat. p. 1140; Reeve, C. I. Arca, No. 72.

Abundant in most of the West Indian later Tertiaries, and in the existing seas.

58. Arca inæquilateralis, spec. nov. Pl. XVIII. fig. 2.

Shell transverse, slightly oblique, very inequilateral, produced posteriorly; valves with about 30 crenate radiating ribs, single on the disk, where they are not broader than one-third of their interstices; double anteriorly and posteriorly, where they are equal in width to the interstices; hinge-line long, straight, forming an abrupt angle with the rounded anterior margin; posterior margin with an oblique slope.

59. Pecten exasperatus, Sow.
Sow. Thesaurus Conch. vol. i. p. 54, pl. 18. f. 183–6; Reeve, C. I. Pecten, pl. 2. f. 7 & 8.

This Pecten still lives in the West Indian seas. The fossil has 20 ribs, and is slightly longer than the recent shell; but I cannot regard the differences as specific.

60. Pecten inæqualis, Sow. Pl. XVIII. fig. 6.
Quart. Journ. Geol. Soc. vol. vi. p. 52.

61. Chama arcinella, Lam.

The Jamaican shells do not differ from the recent examples; but the San Domingan specimens may be considered a variety. The former have more numerous imbricating subtubular spines, which in the latter are not so regularly arranged in rows, and assume more the character of coarse squamose granules.

## EXPLANATION OF PLATES XVI.–XVIII.

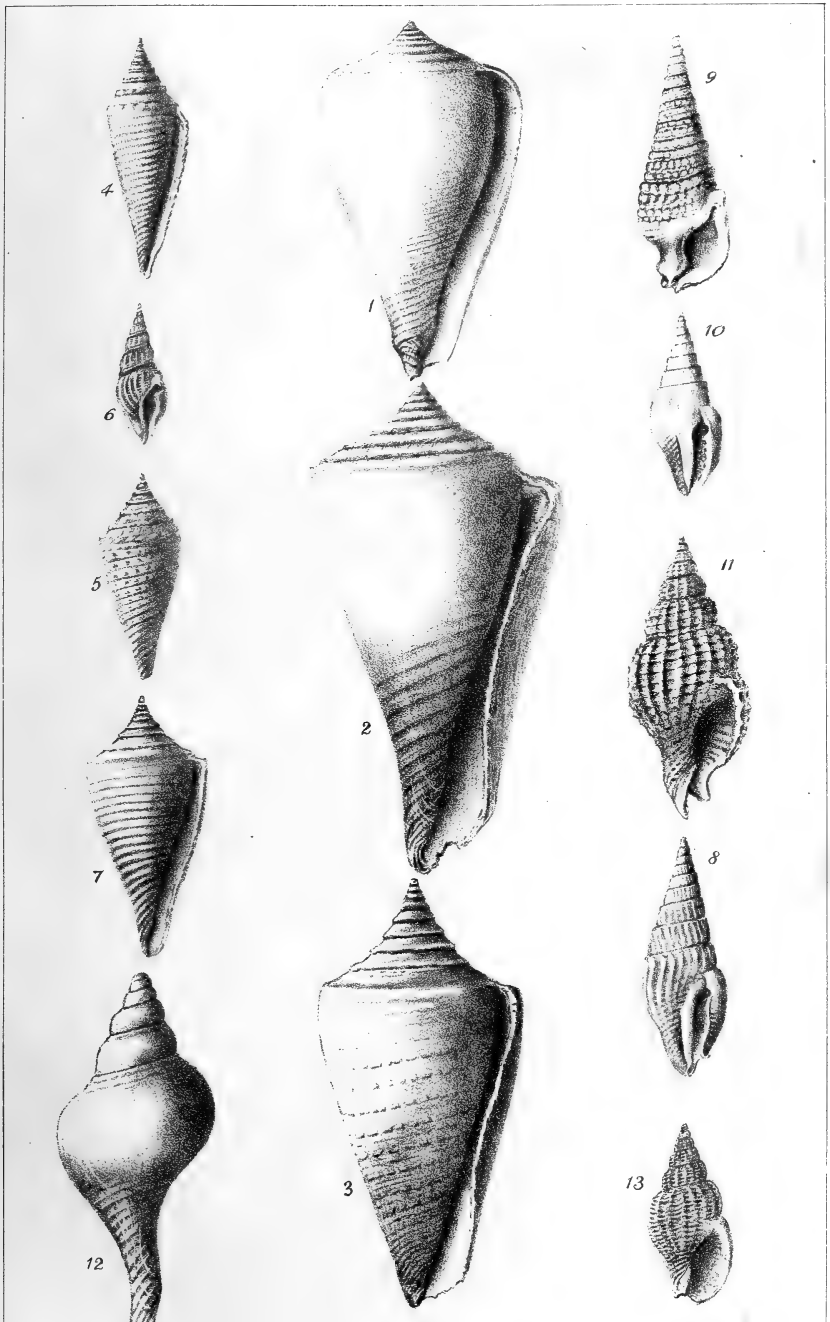
(*Illustrative of Tertiary Shells from Jamaica*).

### Plate XVI.

Fig. 1. *Conus solidus*, Sow.
2. —— *stenostoma*, Sow.
3. —— *interstinctus*, Guppy.
4. —— *gracilissimus*, Guppy.
5. —— *granozonatus*, Guppy.
6. *Pleurotoma Jamaicense*, Guppy.
7. *Conus planiliratus*, Sow.
8. *Columbella ambigua*, Guppy.
9. *Cerithium plebeium*, Sow.
10. *Columbella gradata*, Guppy.
11. *Phos Moorei*, Guppy.
12. *Fasciolaria semistriata*, Sow.
13. *Phos elegans*, Guppy.

### Plate XVII.

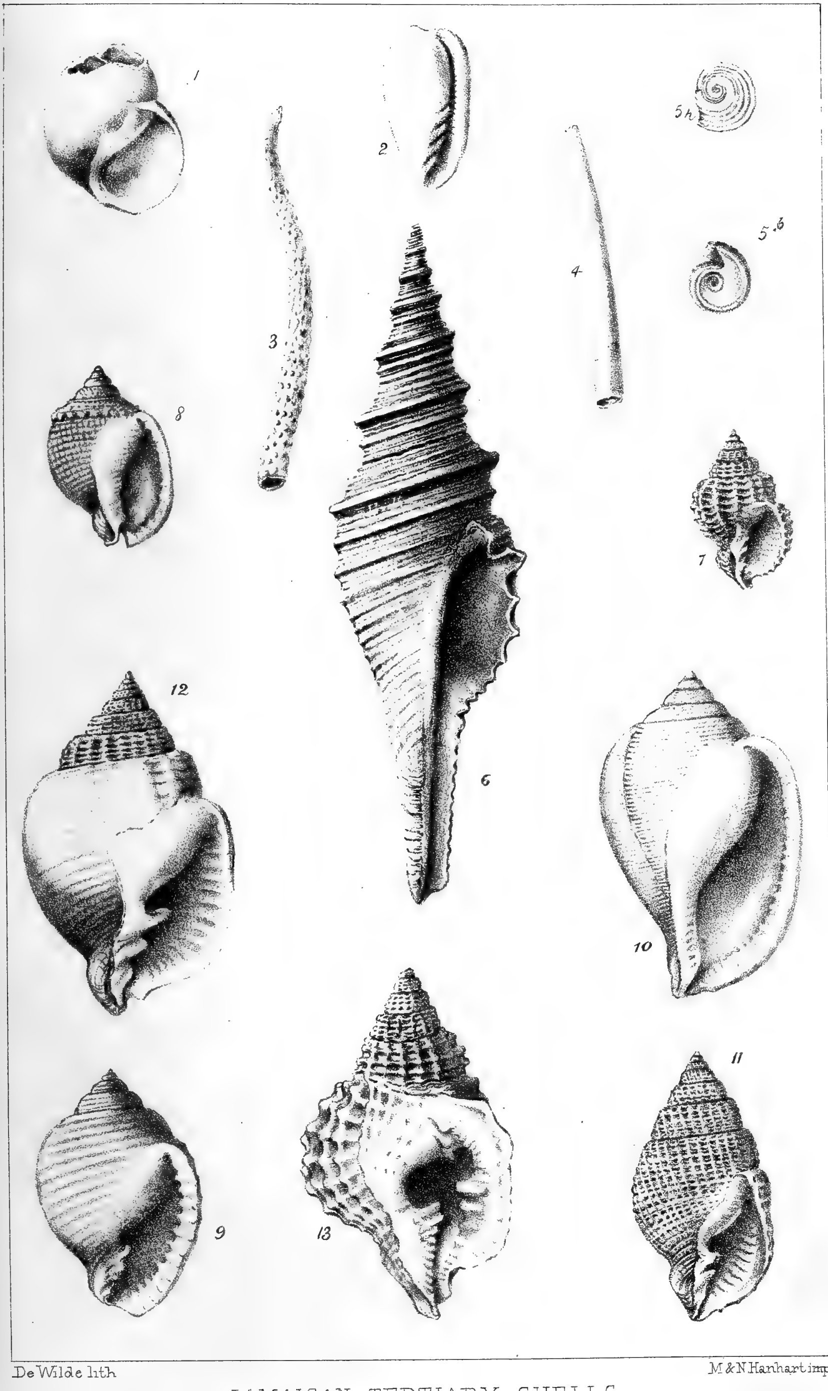
Fig. *Natica phasianelloides*, d'Orb.
*Marginella coniformis*, Sow.
*Vermetus papulosus*, Guppy.
4. *Dentalium dissimile*, Guppy.
5 *a*, 5 *b*. *Cyclostrema bicarinatum*, Guppy.
6. *Pleurotoma Barretti*, Guppy.
7. *Cancellaria Moorei*, Guppy.
8. *Cassis monilifera*, Guppy.
9. *Malea camura*, Guppy.
10. *Cassidaria sublævigata*, Guppy.
11. *Cancellaria Barretti*, Guppy.
12. —— *lævescens*, Guppy.
13. *Persona simillima*, Guppy.




De Wilde lith.

M & N. Hanhart imp.

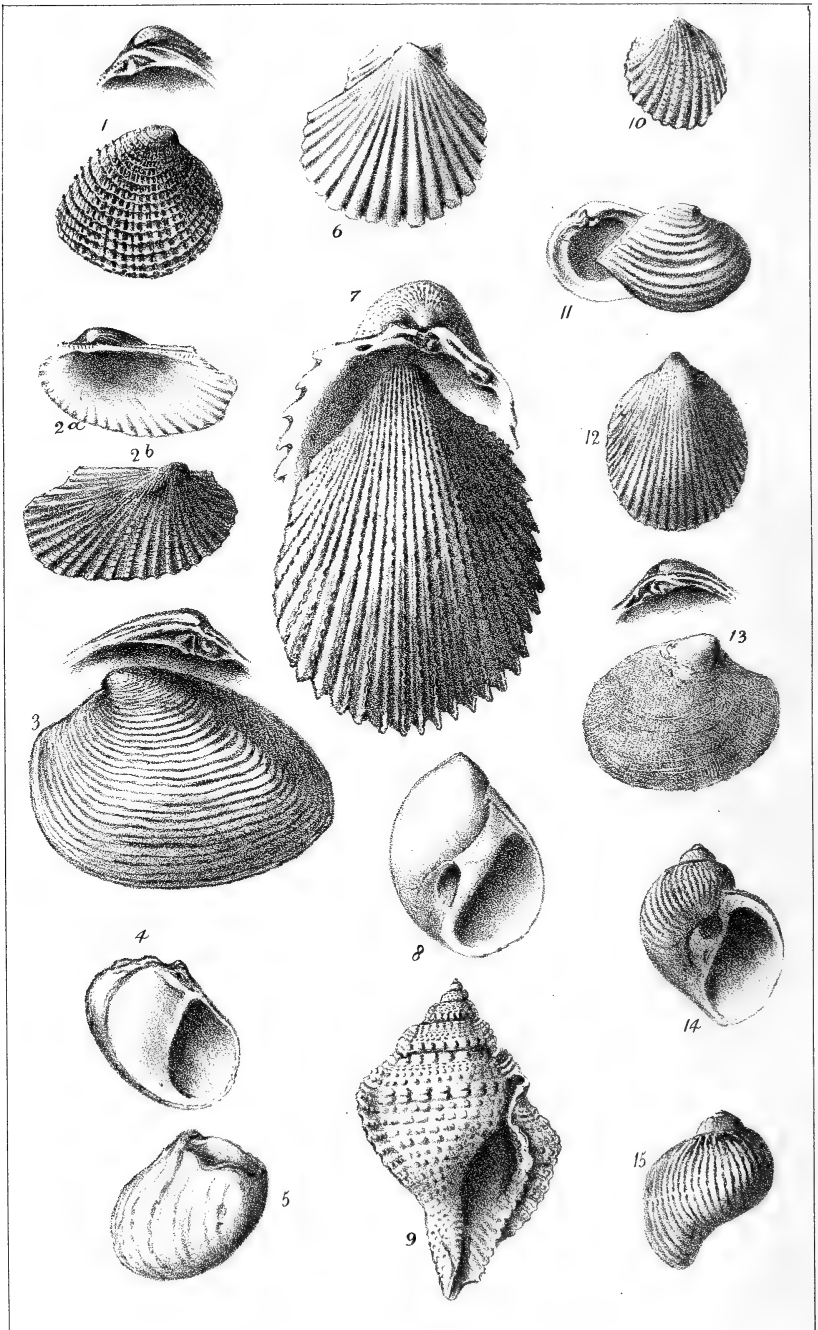
JAMAICAN TERTIARY SHELLS.




De Wilde lith.

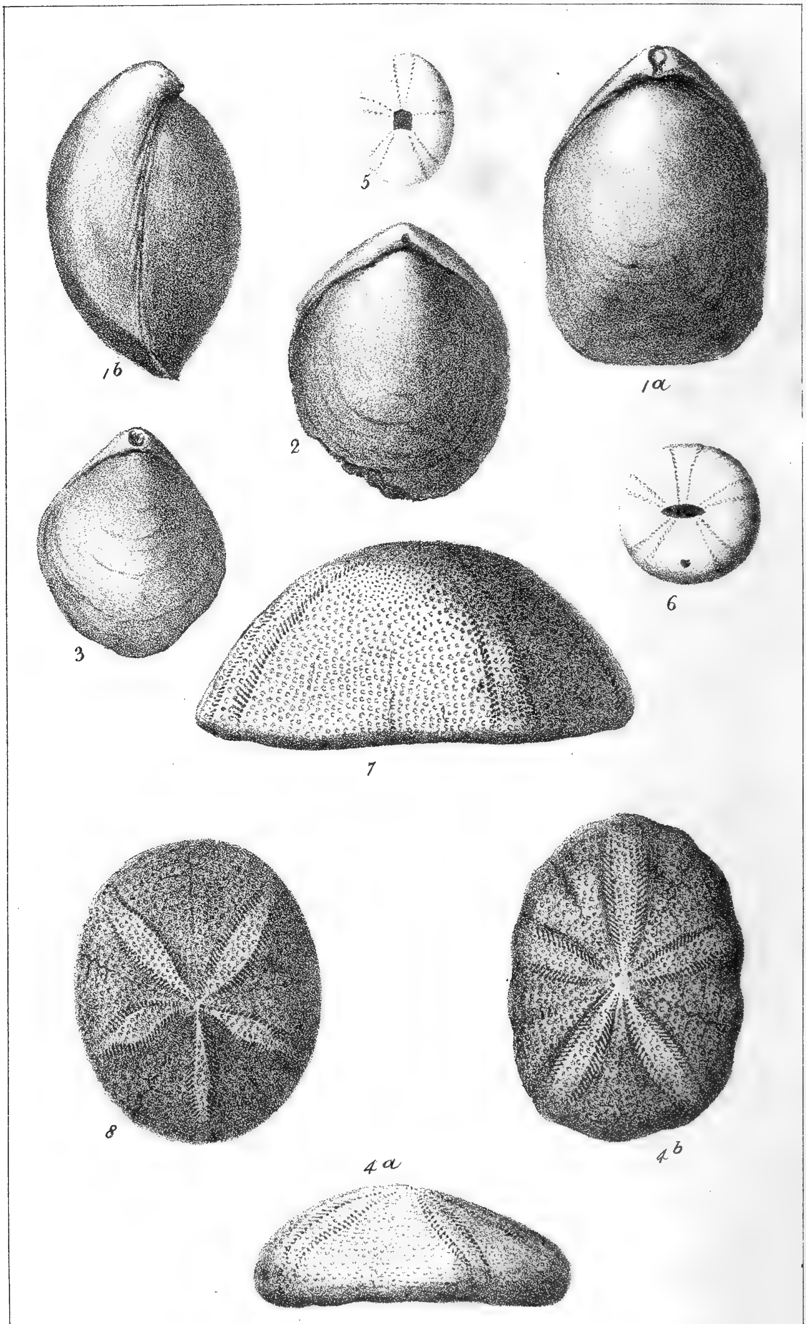
M & N Hanhart imp.

JAMAICAN TERTIARY SHELLS.




De Wilde lith. M & N Hanhart imp.

JAMAICAN TERTIARY SHELLS




De Wilde lith. M & N Hanhart imp.

WEST INDIAN TERTIARY SHELLS.

PLATE XVIII.

Fig. 1. *Venus Woodwardi*, Guppy.
2. *Arca inæquilateralis*, Guppy.
3. *Cytherea* (*Callista*) *planivieta*, Guppy.
4. }
5. } *Neritina Woodwardi*, Guppy.
6. *Pecten inæqualis*, Sow.
7. *Cardium lingua-leonis*, Guppy.
8. *Natica subclausa*, Sow.
9. *Ranella crassa*, Reeve.
10. *Cardita scabricostata*, Guppy.
11. *Corbula viminea*, Guppy.
12. *Cardium inconspicuum*, Guppy.
13. *Cytherea* (*Circe*) *carbasea*, Guppy.
14 & 15. *Natica sulcata*, Desh.

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## 2. *On* TERTIARY BRACHIOPODA *from* TRINIDAD. By R. J. LECHMERE GUPPY, Esq., Civil Service, Trinidad.

(Communicated by the Assistant-Secretary).

[PLATE XIX., Figs. 1–3.]

THE three species of Brachiopoda which form the subject of the present communication, were obtained from the gypseous marls containing *Orbitoides Mantelli* and *Nummulina*, exposed near the town of San Fernando in Trinidad*. I have alluded to these beds in my papers on the Mollusca of Jamaica and on the Echinodermata of the West Indies. The Gasteropoda and Conchifera contained in these deposits, are for the most part in bad condition, and generally specifically indeterminable; but in the papers alluded to I have given the names of such species as I have been able to determine. I have not found any form which could be referred with any degree of probability to recent species; and this circumstance combined with the stratigraphical position of the beds, the occurrence of *Echinolampas ovum-serpentis*, the great development of *Orbitoides Mantelli*, &c. have led me to believe that these strata belong to a lower horizon in the Miocene series than the deposits in Jamaica, Cumana, and Cuba. The evidence furnished by the Brachiopoda now described, can hardly be considered to throw much new light upon the question. They seem, indeed, to be suggestive of Cretaceous affinities; their resemblances to known Tertiary and recent forms not being very pronounced.

It has been suggested to me that, considering the apparent Mesozoic type of these Brachiopoda, they may be derivative fossils, but I see no ground for this supposition. The specimens are not in condition to warrant such a presumption; they do not occur near the base of the series exposed at San Fernando; they are referable to a genus still existing, and represented in Tertiary rocks. Besides which, Mr. Barrett has discovered similar Brachiopoda in the Mio-

* See 'Geologist,' vol. VII., p. 159.

cene deposits of Jamaica, as stated in a letter of that naturalist quoted by Dr. Woodward, an extract from which will be found in a note to my paper on the Jamaica fossils (p. 281). It is even possible that one of Mr. Barrett's fossils may be identical with one of the species now described. At any rate these fossils are interesting as being, as I believe they are, the first Brachiopoda described from Miocene beds in the West Indies.

None of the fossils now under consideration at all resemble Maltese forms; and herein they differ remarkably from many of the other organic remains from the Caribean Miocene beds, especially the Echinodermata and the Corals.

All the species have been ascertained to be punctate.

1. Terebratula trinitatensis, spec. nov. Pl. XIX. figs. 1*a*, 1*b*.

Shell smooth, gibbous, irregularly pentagonal, somewhat longer than wide, marked by wide shallow and obscure sulci of growth, which become finer and more distinct towards the margins; front-edge nearly straight; ventral valve convex and rounded towards the beak, flattened towards the front edge; dorsal valve convex, with an obscure carination radiating to each angle of the front edge; beak large, scarcely incurved over the dorsal valve, truncate by a rather large subcircular foramen, from which a wide and shallow sulcus extends forwards.

2. Terebratula carneoides spec. nov. Pl. XIX. fig. 2.

Shell suboval or suborbicular, smooth, striated by fine lines of growth; ventral valve convex with a tendency to carination along its mesial portion from the beak to the front margin; dorsal valve rather evenly convex, with an obscure slightly raised mesial fold; front margin rounded or somewhat produced; beak small, scarcely curved over the umbo of the dorsal valve, pierced by a very small foramen.

The front margin of the example figured is imperfect, but in another less perfect specimen it is more folded and produced, giving a suboval shape to the shell. The first-mentioned example resembles in some respects *T. carnea* from the chalk.

3. Terebratula lecta, spec. nov. Pl. XIX. fig. 3.

Shell suboval, smooth, sulcated by lines of growth which are strong and well marked towards the margins, and which are crossed by obsolete radiating grooves; front edge plicate and sinuate; ventral valve somewhat compressed, especially towards the front margin; dorsal valve convex, with a slightly raised mesial fold; beak scarcely incurved, truncated by a large circular foramen.

## Note *on the* Foregoing Paper. By T. Davidson, Esq., F.R.S., F.G.S.

The subject relating to Tertiary Brachiopoda is one of considerable importance, since the fossils of this period, taken under the 'homotaxeous' view, connect the Cretaceous with the Recent fauna. A general monograph of Tertiary Brachiopoda is consequently a great desideratum.

With regard to the special subject of Mr. Guppy's paper, the author is quite correct while observing "that the evidence furnished by the Brachiopoda now described can hardly be considered to throw much new light upon the question, as they seem indeed, to be suggestive of Cretaceous affinities;" but I might add that their shapes are not, however, inconsistent with what we might likewise expect to find in Tertiary formations.

*Terebratula Trinitatensis* and *T. lecta* of Guppy are not known to me as Miocene shells, and may be new; but it must be confessed that *T. carneoides*, Guppy, strongly recalls to my mind the Cretaceous *T. carnea*, as well as the recent *T. vitrea*. Indeed the shell now termed *T. carneoides* seemed to me identical in shape and foramen with that of many Cretaceous specimens of *T. carnea*, as well as of the recent *T. vitrea*; and it may be asked whether *T. vitrea* and *T. carnea* are really distinct species. Their shapes are very often identical and undistinguishable, their interiors so likewise; and we find similar shells, identified as *T. vitrea* by Philippi and Sequenza, from the Miocene, Pliocene, and Pleistocene beds of Sicily.

I may here suggest the hope that further researches may be made in connexion with the beds and fossils in question, as it is always hazardous to describe so-called new species from the study of a few specimens, and especially so when the forms are undescribed.

### EXPLANATION OF PLATE XIX. figs. 1–3.

(*Illustrative of Tertiary Brachiopoda from Trinidad.*)

Figs. 1 *a*, 1 *b*. *Terebratula Trinitatensis*, Guppy.
2. —— *carpeoides*, Guppy.
3. —— *lecta*, Guppy.

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## 3. *On* Tertiary Echinoderms *from the* West Indies.

By R. J. Lechmere Guppy, Esq., Civil Service, Trinidad.

(Communicated by the Assistant-Secretary.)

[Plate XIX. figs. 4–8.]

### § 1. General Remarks.

The Corals of the Miocene formations of the West Indies having been made known by the researches of Mr. Lonsdale and Dr. Duncan, the Shells having been in part described by Messrs. Carrick, Moore, and Sowerby, and a notice of the Foraminifera having been given by Professor Rupert Jones, I propose to bring under the notice of the Geological Society the Echinoderms belonging to the same fauna.

The Echinoderms about to be noticed are found in the island of Anguilla, and in Trinidad, associated with remains which leave little doubt of their Miocene age. Two of them are identical with Maltese species, and three more are found living in the West Indian seas.

Three others seem to be new, and I have therefore appended descriptions of them.

In Anguilla the fossil Echinoderms occur in a white marly limestone, in which are found numerous remains of mollusca, chiefly as casts. Several of the mollusca are identical with species found in San Domingo, Jamaica, and other West Indian Miocene localities. The most noteworthy are *Natica phasianelloides*, d'Orb., *Solarium quadriseriatum*, Sow., and species of *Turritella* and *Pecten*. Teeth of Pycnodont fishes also occur in the beds, as in Malta, and among them is one apparently very closely allied to *Sphærodus gigas*. Several of the other mollusca are probably identical with those of the West Indian localities mentioned; but it would be hazardous to speak precisely, where the only materials are imperfect casts.

In Trinidad the fossil Echinoderms are found in highly inclined gypseous marls, often impregnated with asphalte, and with occasional partial dark-blue limestones exposed in a cliff section at San Fernando. The mollusca are numerous, but most frequently in a very imperfect condition; the metamorphism induced by the change of the gypsum into selenite, having frequently obliterated and destroyed their shape and characters. Of those that are recognizable we have the *Natica phasianelloides*, d'Orb., found in San Domingo, Jamaica, Cuba, and Anguilla, and an unnamed *Turritella*, found in Jamaica, San Domingo, and Cumana. Among the Foraminifera we have *Nummulina*, *Orbitoides Mantelli*, and *Heterostegina*. The two former occur in great numbers*, and the *Orbitoides* are well developed. *Echinolampas ovum-serpentis* is the most common Echinoderm here, and it seems to have been a remarkably variable species. The only other Echinoderms found at San Fernando, are a small species of *Echinus* (?), and some stems of *Crinoids*, all too imperfect for determination. Two or three species of *Terebratula* are also associated with these fossils.

At Anguilla remains of a large star-fish are found, which may have belonged to an Astropecten.

In addition to the Echinoderms now made known, several have been previously published, some of which may be from Miocene strata. D'Orbigny has described a fossil, from beds in Cuba which I take to be Miocene, under the name of *Periastes Cubensis*, while Michelin and Duchassaigne have published some species from Jamaica and Guadeloupe. I am not, however, acquainted with those species.

Out of the nine echinoderms which I have determined, three only are new, while two occur in the Maltese beds and in other Miocene localities in Europe. Three more which occur rarely in the fossil state are still existing in West-Indian seas. Though the test of numerical proportion can scarcely be applied to so small a number of species, there is enough evidence to justify us, taking the associated mollusca and foraminifera into consideration, in concluding that the formations in Anguilla and Trinidad, whence these fossils are derived,

* Geologist, vol. vii. p. 159.

are of Miocene age. And it is not surprising, after the researches of Dr. Duncan and Professor Rupert Jones, to find so remarkable an alliance with the Maltese beds. From the evidence furnished by the organic remains, I have been led to consider the Anguilla and San Fernando beds as probably somewhat older than the middle Tertiaries of Jamaica, Cumana, and San Domingo, and I have mentioned this part of the subject in my paper "On the Tertiary Mollusca of Jamaica." Only two or three species appear, as far as my researches have gone, to pass through the entire Miocene; nevertheless the whole fauna is so closely connected throughout by intermediate links, that the separation of the West Indian Miocene into upper and lower, can only be effected in a general way.

## § 2. Description of the Species.

1. Cidaris melitensis (Forbes), Wright.

Wright, Ann. & Mag. Nat. Hist. 2nd ser. vol. xv. p. 107, pl. 4. fig. 1.

Locality, Anguilla.

2. Echinometra acufera, Blainville.

The fossils only differ from the recent examples in that the former are smaller; but they agree perfectly with living examples of the same size.

Anguilla.

3. Clypeaster ellipticus, Michelin.

Michelin, Monogr. des Clypeastres fossiles (Mém. Soc. Géol. de France, 2nd ser. tome 7), p. 109, pl. 12.

"This species, near to *C. rosaceus*, differs from it in that it is less elevated, has no marginal sinuosities, and that its ambulacra are rather elongate than rounded towards the base" (Michelin, *l. c.*). It appears to me to be more nearly related to *C. australasia*, Gray, than to *C. rosaceus*, and I have had some doubt whether it ought to be accounted distinct or not. It agrees with *C. australasia*, in having the base concave from the margins, and in others respects in which these species differ from *C. rosaceus*.

This is a common species at Anguilla. I am not aware of the age of the deposit from which Michelin obtained his fossil.

4. Echinolampas semiorbis, spec. nov. Pl. XIX. fig. 7.

Test large, discoidal, nearly circular, very slightly wider behind than before, subconical; ambulacral summit nearly central; ambulacra not petaloid, extending nearly to the margins; single ambulacrum scarcely narrower than the others; poriferous avenues about one-fourth the width of the interporiferous areas; base somewhat concave, slightly swollen in the interambulacral spaces; oral aperture large, transverse, nearly central, with deep notches opposite the terminations of the rows of pores. Anus large, transverse, close beneath the margin.

Secondary granules none or indistinct; primary tubercles simple, deeply sunk, and very numerous and close-set towards the margins, becoming more dispersed towards the peristome. The ambulacra are somewhat raised above the general upper surface of the test; the pairs of pores are connected by oblique grooves; the inner pores are round, the outer ones slit. The general form is nearly hemispherical, the antero-posterior but slightly exceeding the transverse diameter, and the test being only slightly wider behind. The height is about equal to half the transverse diameter.

This species is closely allied to *E. hœmisphœricus*, Lam., and it differs from that species chiefly in having more numerous and closer primary tubercles, in the more open and less petaloid ambulacra, and in having a large transverse vent. *E. hemisphœricus* is found in the miocene of Malta, and other localities. *E. semiorbis* occurs at Anguilla, and it is used as a pound weight by the inhabitants.

5. Echinolampas lycopersicus, spec. nov. Pl. XIX. fig. 8.

Test oval, wider behind than before; upper surface convex, margins tumid; ambulacral summit subcentral; ambulacra raised, petaloid, extending nearly to the margins, base concave towards the subpentagonal mouth; tubercles small, numerous, and very closely set, becoming large and somewhat more scattered towards the mouth, which is subexcentrical and slightly notched by the termination of the rows of pores continued from the ends of the ambulacral petals; anus large, transverse, oval, closely submarginal.

The nearest species to this is *E. scutiformis*, Leske, found in Malta and elsewhere. The present species is constantly smaller, and the ambulacra appear to be longer and the summit more median. The dorsum is more equally inflated, and there is no tendency to a subconical form.

Anguilla.

6. Echinolampas ovum-serpentis, spec. nov. Pl. XIX. figs. 4–6.

Test oval, subcylindrical or nearly circular, wider behind than before, slightly rostrated anteriorly and truncate posteriorly, sometimes having a tendency to become polygonal; ambulacra raised, petaloid, open at the ends, extending nearly to the tumid margins, the pores connected by an oblique groove; base convex, except towards the mouth, where it becomes somewhat concave; dorsum rather evenly convex; ambulacral summit subcentral; anus small, circular, situate between the peristome and the margin, much nearer to the latter than to the former.

This seems to be an extremely variable species, both as to general shape and as to the form of the mouth. It is distinguished from the preceding by its small circular vent and wider ambulacra. The mouth is usually subpentagonal, but occasionally becomes transversely oval. Some examples which approach the circular form have a tendency to become subconical.

San Fernando, Trinidad.

7. ECHINONEUS CYCLOSTOMUS, Leske.

The very wide geographical distribution of this echinoderm prepares us to expect to find it in a fossil state. It seems, however, to have been rare in the Miocene period, compared with *Echinolampas lycopersicus* and *Schizaster Scillæ.*

Anguilla. The single example I obtained is very small.

8. SCHIZASTER SCILLÆ, Desmoulins.

Anguilla. Rather common. It is also found in the Maltese beds.

9. BRISSUS DIMIDIATUS, Agassiz.

Found in Anguilla. The fossil is, if I have correctly determined it, identical with the species living in the adjoining seas. It is very rare as a fossil at Anguilla.

### EXPLANATION OF PLATE XIX. figs. 4–8.

(*Illustrative of West-Indian Tertiary Echinoderms.*)

Figs. 4*a*, 4*b*. *Echinolampas ovum-serpentis*, Guppy. Natural size.
5. —— ——. A small example, showing the position of the vent and pentagonal mouth. Natural size.
6. —— ——. A circular form with ovate transverse mouth. Natural size.
7. —— *semiorbis*, Guppy. One-half the natural size.
8. —— *lycopersicus*, Guppy. Natural size.

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## 4. *On the* AFFINITIES *of* PLATYSOMUS *and* ALLIED GENERA. By JOHN YOUNG, M.D., F.G.S., of the Geological Survey of Great Britain.

(Communicated by Professor Huxley.)

[PLATES XX. & XXI.]

THE genus *Platysomus*, as defined by Agassiz, and placed by him among the heterocercal Lepidoids with flat broad bodies, contains forms which cannot be included under the definition he has given. The imperfect materials from which his descriptions were drawn up have since been supplemented by abundant well-preserved specimens, whence it is comparatively easy to fill up the masterly outline he has sketched in the 'Poissons Fossiles.'

The first change in the classification of the group to which *Platysomus* belongs was proposed by Sir P. G. Egerton (Quart. Journ. Geol. Soc. v.). The occurrence in a mandible of *Pl. macrurus*, Ag., of teeth with a blunt conical crown and constricted neck, and the discovery of the true nature of the apophyses (compared by Agassiz to the V-shaped bones of *Clupea*), suggested the affinity of that species to the Pycnodonts, to which family, therefore, Sir Philip referred the whole genus, and along with it *Globulodus*, Münst., whose relation to *Platysomus*, Agassiz had previously suspected. This change Agassiz accepted. But the "dents en brosse" mentioned in the generic definition (Poiss. Foss. ii. p. 6) and in the description of *Pl. gibbosus* (ibid. ii. p. 165) are not Pycnodont but Lepidoid (=Lepidosteid). The former family was thus made to include two distinct types of dentition, associated, as will appear, with equally distinct osteological characters. Thiollière in a remarkable paper "On the Jurassic Fossil Fish of Bougey" (Bull. Soc. Géol. France, 1858, xv. p. 372) alludes to the vagueness of the definition of the Pycnodont family, whence, he thinks, should be excluded *Platysomus, Tetragonolepis, Phyllodus*, &c., whose reference to that natural group is based, he says, "on insufficient or deceptive analogies." Cocchi has since (Nuova Famiglia di Pesci Labroidei, 1865) given good reasons for removing *Phyllodus* to the *Labroidei*. The place of *Tetragonolepis* is undoubtedly among the *Lepidosteidæ*.

Professor Huxley having kindly given me access to the specimens under his care, specimens obtained for the most part by Mr. Molyneux of Burton-on-Trent, I have had very favourable opportunities for studying the genus *Platysomus*. I am also indebted to Mr. Ward of Longton, and Mr. Garner of Stoke-on-Trent for the liberality with which they lent for examination many nearly perfect specimens from their cabinets, and to Mr. Davis for his assistance when examining those in the National collection.

The Pycnodont family is characterized by teeth adapted for crushing, which consist of a circular or transversely oval crown, flattened above, and sessile on the bone to which it is attached; or of an obtusely conical crown which is broader than its peduncle of support.

The teeth in the Carboniferous genera which form the subject of this paper present three types; 1st, the sharply conical tapering teeth common to most Lepidosteids; 2nd, the blunted cones with constricted necks; and 3rd, a series of dental tubercles of peculiar ultimate structure.

To the species presenting the former type of dentition, I propose to restrict the generic name *Platysomus*. The genera presenting the second type are, equally with the former, but in a different direction, transitional to the *Lepidosteidæ*; while the genus *Amphicentrum, mihi*, in which the dental tubercles occur, is distinct from the Lepidosteids on the one hand, and, on the other, from the Pycnodonts properly so called.

Platysomus, Agassiz, *partim*.

Body flat, broad. Head triangular, higher than long; snout sharply angular. Premaxilla small; maxilla in a single piece; mandible slender, spatulate; all three bones armed with fine, conical, sharp teeth. Branchiostegal rays few, enamelled. Interopercular wanting. No ventral fins. Dorsal and anal fins opposite; their bases extended, and nearly equal in length. Tail heterocercal, equilobate. Scales oblong, vertically striated, with moderately strong lepidopleura. The marginal scales anterior to the opposite fins, more or less modified. Notochord persistent; arches ossified.

The genus thus defined includes *Pl. gibbosus, rhombus, striatus* (?), and *parvulus*. *Pl. parvus* has been merged by King (Permian Fossils) in *Pl. striatus*; *Pl. intermedius*, Münst., by Geinitz in *Pl. gibbosus*; and *Pl. Fuldai*, Münst., by the same author, in *Pl. macrurus*.

PLATYSOMUS PARVULUS, Ag.

Body with a gentle ventral convexity; the dorsal highest point angular, anterior to the middle of the back. The nuchal margin nearly in a line with the slope of the face. Head triangular; its length equal to one-fourth of that of the body. Orbits of moderate size and close to the upper margin of the head. Jaws armed with slender conical teeth, those in the lower slightly larger and more distant than those in the upper jaw. Facial and opercular bones vertically striated; cranial bones and mandibles finely tuberculated. Pectoral arch moderately strong; fin with narrow base, and expanded rounded extremity. The dorsal commences at or behind the middle of the back, slightly in front of the anal, and terminates opposite the latter at the caudal root; the anterior rays are, in both, the longest, the others abruptly shorten and maintain nearly the same length backwards; the former bifurcate only at their extremities, the latter divide repeatedly, forming a fine fringe. Tail heterocercal, equilobate. The anterior margins of all the fins are protected by fine fulcral scales; the nearly square articles of the rays are covered by striated scales. The scales are oblong, higher than broad, they diminish in size towards either margin of the body and towards the tail. They are ornamented by parallel vertical striæ, which are rather more than their own breadth apart, and have their crests finely tuberculated. The lepidopleura continue distinct as far as the root of the tail, whose upper lobe is covered by a single series of large pointed ridge-scales. The upper and lower edges of the body, anterior to the opposite fins, are also protected each by a single row of small scales, modified into smooth tubercles, which support small, usually recurved, denticles: of these there are generally four on each ventral, and three on each dorsal tubercle. With these tubercles the lepidopleura are connected above and below. The lateral line is nearest the dorsum, towards which it is gently arched in front, terminating at the upper angle of the operculum.

PLATYSOMUS PARVULUS, var.

The body is more oval than in the typical form above described, its greatest depth is marked by no angular dorsal peak. The caudal pedicle is longer. The striæ on the scales are finer, barely their own width apart, and their crests are smooth.

The species was founded by Agassiz on specimens at Leeds, but was not described by its author. My reference to it of the numerous specimens from the North Staffordshire Coal-field is confirmed by Prof. W. C. Williamson, who, in his valuable memoir "On the structure of Scales and Teeth," communicated to the Royal Society in 1849, describes the scales of *Pl. parvulus* as "covered with deep grooves and intervening ridges running nearly parallel with the long axis of the scale which, as in *Gyrodus*, really represents its breadth;

[=height?], and is at right angles to the direction of the lateral line of the fish."

Figs. 1–4.—*Diagrammatic restorations of the heads of* (1.) Amphicentrum, (2.) Platysomus, (3.) Æchmodus, *and* (4.) Pycnodus (*after Thiollière*).

Fig. 1.

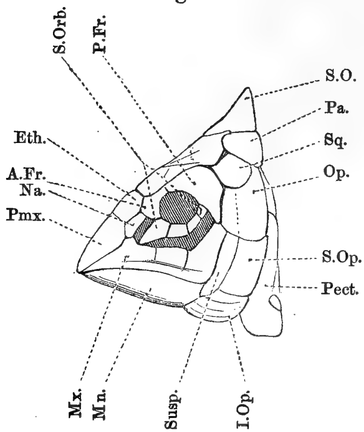


Fig. 3.

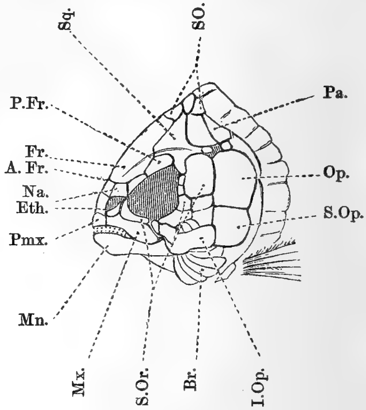


Fig. 2.

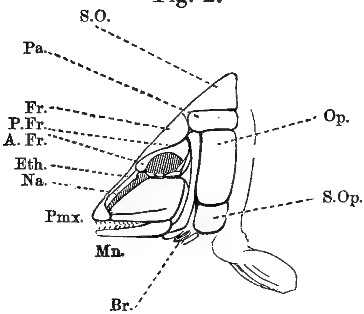


Fig. 4.

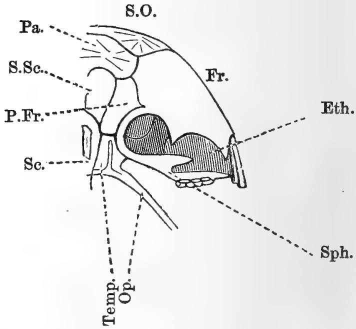


Figure 2 is a diagrammatic restoration of the structure of the head of *Platysomus*. The occipital crest rises from a narrow bone (*S.O.*), lodged between the square parietals (*Pa.*), and connected in front with the frontals (*Fr.*), which, broader behind, narrows in front, receiving in its outer excavated margin two bones, which complete the orbital circle superiorly. The posterior of these (*P.Fr.*) extends to the parietals and thus represents a united postfrontal and squamosal (mastoid, Cuv.). The anterior frontal (*A. Fr.*) dips down, and gives insertion to the narrow suborbital chain which is attached behind to the *P. Fr.* The anterior frontals of opposite sides are separated for great part of their length by the frontals, the remaining space being occupied by the ethmoid, a small bone (*Eth.*) which separates the upper ends of the nasals (*Na.*), two narrow elongate bones, in contact for great part of their length, and received into notches of the ascending premaxillary processes. The upper end of each nasal is dilated into a process separated by a notch from the *A. Fr.*, and forming the inner wall of the nasal aperture, whose outer boundary was either a suborbital bone, or was formed by the vertical portion of the maxilla. The narrow premaxillaries (*Pmx.*) give off ascending plates of considerable relative breadth and height, receiving superiorly the lower end of the nasal bones. The maxillary overlaps the upper mandibular margin behind, and rises above to a right-angled triangle, whose apex is at the premaxilla. The spatulate mandible (*Mn.*) is shorter and stouter than that of *Palæoniscus*, which it much resembles. The teeth are perfectly smooth. The suspensorium forms a solid bar, never shares in the dislocations which have made clear the other head-bones. It consists seemingly of a hyomandibular (*Hy.*), preopercular (*Pr.O.*), and quadrate (*Qu.*). If a symplectic were distinct, its structure would coincide with that of living *Teleostei.* At a point corresponding to the upper edge of the quadrate, traces of the hyoid articulation are frequently seen. Along the anterior margin of this bar two triangular plates are applied, the lower is evidently the slightly expanded quadrate; the upper, part of the palato-pterygoid arch. It is overlapped and apparently in close union with the maxillary vertical plate, by which the other members of the arch are concealed, but above whose margin a long irregular plate appears, which, coming as it does into relation with the anterior frontal, is doubtless the edentulous palate-bone (*Pl.*). The operculum (*Op.*), shorter but as broad as the suboperculum (*S.Op.*), is attached to the hyomandibular, and the latter to the posterior frontal, thus proving the squamosal nature of that bone. No remains are preserved of the inferior cranial bones, which were probably cartilaginous. A bar of bone answers in position to the basisphenoid, but is very imperfect, and wants any sphenoidal expansions. The vomer is rarely seen, but, in a specimen of *Pl. gibbosus* (Brit. Mus. 28279.), is provided with a fine brush of teeth. As many as four similar tufts occur in the Staffordshire specimens, so as to suggest their pharyngeal position, but the branchial arches are invariably wanting. The numerous occipital plates of *Lepidosteus* are not represented unless by some large scale-like plates, which are probably nuchal, not cranial. The small suprascapular (*S.Sc.*) is distinct.

The rest of the body presents no points in addition to those already noted by Agassiz, save that there is no evidence for the existence of a ventral fin. Indeed, perfect specimens demonstrate its absence, and thus furnish a valuable diagnosis from the Pycnodonts which have it.

The range of the genus is from the Coal-measures to the top of the Permian. *Pl. striatus* is the only species common to both periods and to England and Germany, a specimen from Derbyshire being in the Jermyn Street Collection.

Amphicentrum, nov. gen. Pl. XX.

Body flat, broad, prolonged into peaks, a dorsal and ventral protected by indurated scales: the depth of the trunk thus exceeds its length. The prolongation into the upper caudal lobe is short, and tapers rapidly. Head triangular, nearly equilateral. Premaxilla very large, edentulous. Maxillæ and mandibles very strong: the opposed surface of each presents two ridges, on which are inserted dental plates raised into distant tubercles; their substance is traversed by large medullary canals, which reach the surface of the tooth, terminating there in fine pores. The palato-vomerine area is occupied by a pair of plates bearing, each, three longitudinal rows of alternating dental tubercles like those of the jaws. Branchiostegal rays few, enamelled, not projecting below mandible, covered by an interopercular. No ventral fin: dorsal opposite, and longer than anal. Tail heterocercal, equilobate. Scales oblong, ornamented, like head-bones, with tubercles. Lepidopleura very strong, terminating inferiorly in modified marginal tubercles; notochord persistent, arches well ossified.

A. granulosum, Huxley.

This genus is founded on a large number of specimens, all from the North Staffordshire Coalfield.

The general arrangement of the head-bones (fig. 1) resembles that of *Platysomus*, the distinctions in detail are, however, well marked. The occipital crest is bounded by two parietals. The frontal is very broad: the anterior and posterior frontals are massive, and project well over the orbit. Behind the latter, separating it from the parietal, is a strong plate (*Sq.*), the true squamosal, giving attachment to the suspensorium. The posterior frontal thus receives only the hinder end of the suborbital arch. The frontal and anterior frontal, are both received on the broad end of the hour-glass bone (*Eth.*) which abuts against the premaxillæ, a pair of massive elongated edentulous bones forming a strong beak: its outer surface is tuberculate above, but near the tip covered with compact and smooth ganoin. The nasals are thrust out laterally, and applied against the ethmoid, the nasal apertures being completed externally by a plate from the suborbital ring, which is analogous to a lachrymal in many Teleosteans. The vertical upper portion of the maxillary (Pl. XX. fig. 2) bulges below into an abruptly projecting labial mass, whose oral margin forms a ridge separated by a shallow groove from an inner ridge. Seen from below, this groove terminates sharply behind by the approximation of the outer and inner ridges: but is closed in front by the premaxilla. On the outer ridge the dental tubercles are few: on the inner, which is more prominent, they are more numerous, less so however than on the mandible (Pl. XX. fig. 4.), which is the converse of the maxilla, in that the ridges approximate in front (the tubercles ceasing before their coalescence), while the groove is open posteriorly: the outer ridge is also the more prominent.

To the naked eye, and even under the lens, no line can be detected between the substance of the tubercles and that of the jaw. Under the microscope*, however, transverse slices of the jaws show that the two ridges are made up of dentine, and are connected by a thin layer of the same substance which floors the intervening groove. The whole plate thus constituted is lodged in an alveolus, whose thin margins overlap the base of the dental plate, covering the pseudo-enamel or cement layer which invests that portion of the plate. The dentine is very finely granular, and traversed by medullary canals, which are most divergent in the centre of the tubercles. These canals bifurcate once, seldom twice, and never anastomose. The branches reach the surface of the dentine, and there terminate in funnel-shaped pits, similar to those by which they open into the pulp-cavity. Each canal is surrounded by an areola of darker colour than the intervening clear dentinal space. This areola is narrow inferiorly, but its area soon exceeds that of the canal, and maintains this proportion to the surface. The areola is made of tubes which come off at right angles to the canals, form a fine network, and, at the margin of the areola, give off finer tubes, which traverse the dentine in an obliquely upward direction, anastomosing, without intervening dilatations, with the similar tubes from adjacent canals, so as to form a network, whose interspaces are diamond-shaped. In consequence of this upward direction of these fine tubes, a triangular space is left between the bases of the canals, which is traversed by vertical tubes springing directly from the pulp-cavity. The canals of the dentine which floors the median groove are only half the diameter of those in the tubercles: they are close-set, and connected either directly, or by the intervention of branches which pass for the most part at a low angle from the canals. The areola is narrow: the tubules of the clear space are larger than in the tubercles, and form a less angular network. These differences in the proportions of the parts, differences rather of degree than kind of structure, commence abruptly on either side of a vertical line which may be drawn from the point where the tubercle begins to rise above the plane of the groove. At the outer inferior angle of the base of the dental plate, but not encroaching on the surface which is turned towards the substance of the jaw, a layer of bony tissue commences as a thin investment, which rapidly thickens upwards, and appears above the alveolar margin, it also occupies a part of the surface of the median groove. Its further extension towards the apex of the tubercles, or its replacement by a thin enamel layer, of which only fragments survive, cannot be ascertained; the extreme brittleness of the specimens prepared for the microscope having rendered the process of grinding unusually difficult. The pseudo-enamel, or cement, is divisible into three lamellæ, a clearer separating two dark layers; all these are more granular than the dentine. The under surface is projected into conical processes, which fit into the terminal infundibula of the medullary canals. The tubes given off from these canals enter the deepest layer of the cement in which they form a network of equal-sized tubes: this network invades part of the clear

* The details of this interesting dentitional type are reserved for fuller description and illustration.

layer, in whose upper portion it breaks up into a series of fine tapering, anastomotic tubules, which seem to open on the outer surface. The bone on which this dental plate rests presents the usual laminated structure in its deeper portions. Towards its alveolar surface the lacunæ enlarge, and become more spherical: medullary canals make their appearance, and increase both in number and size upwards, the bone occupying a progressively smaller area as compared with that of the canals. Into each of these canals seldom more than one of those of the dental plate open, the intervening dentine resting on, but not being continuous with, the osseous septa. The same modification of structure as may be traced from above downwards in the jaw, is found to occur towards either alveolar margin: the medullary canals disappear, the lacunæ become fusiform, and at length merely separate laminæ of compact bone, which slightly overlaps the lower lateral angle of the base of the plate.

The osseous matrix is thin in proportion to the height of the tooth. The surface vertically opposite the intertubercular groove is very irregular, while the imperfect section of the maxillary vertical plate shows that it did not increase in thickness inferiorly. The maxilla was therefore L-shaped. It is evident that a dental plate so constructed is unequal to the crushing indicated by the tubercular teeth. The palato-vomerine plates are also weak for the work for which they are adapted. It can scarcely be held that the thinness of the jaws is due to the loss of an articular plate in the mandible, or of any part of the maxilla. It seems more probable that, as the incompleteness of the basicranial structures points to their cartilaginous condition during life, so the three tooth-bearing bones are incomplete by the loss of the cartilaginous cushions on which they rested. That the premaxilla also received some similar support, is probable from its fracture showing a thick outer case of bone, inclosing an interior hollow.

This whole masticatory apparatus is very complex in its morphological relation. The jaw-plates bear some resemblance to those of Chimæroid fishes, especially *Edaphodon*, in which the tooth is socketed in a jaw of ordinary osseous tissue; but the medullary canals of that genus are much larger, and become closed superiorly by calcification. In *Cestracion* the calcigerous tubes come off as in *Amphicentrum*, but are lost in the superficial dense layer. From Pycnodonts, the socketing of the teeth of *Amphicentrum*, the thinness of the enamel layer, the presence of a cement layer, and of medullary canals are sufficient distinctions. To *Psammodus* and *Ptychodus* the resemblance of the dental plates is closer. In both these genera, however, the canals are smaller, more numerous, branch more freely, and terminate by breaking up into tufts of calcigerous tubes, whereas in *Amphicentrum* no such breaking up occurs. In the latter, again, the ossified dentine is separated from the osseous matrix; in the former the two structures are continuous. The pharyngeal teeth of *Sargus* and the teeth of *Sargodon* also offer, in their mode of attachment and in their minute structure, resemblances to the genus under description, which are further made interesting by the jaw-teeth of the living genera having some common characters with those of *Pycnodus*. The pharyngeal denticles are implanted in a matrix of widely cancellated bone, which becomes dense and lunular towards its alveolar borders. The ossified dentine is distinct from the matrix, and is not divided into enamel and dentine, the outer layer being simply a portion of the tooth-substance, in which the calcigerous tubes form a fine reticulation. If several of these denticles were continuous in place of contiguous, the dental plates of *Amphicentrum* would be reproduced.

Lying in the wide gape of the large specimen figured are two narrow plates, the one in cast only, the other the plate itself (Pl. XX. fig. 7). On the latter are three longitudinal rows of alternate teeth, those of the lateral rows not opposite each other, but alternate, hence giving the transverse series a spiral aspect. The plate is not entire, its limits, therefore, are indeterminable. It is slightly curved anteriorly, the straight posterior part containing the larger teeth. These are longitudinally oval, evenly curved in both axes, the smaller teeth are spherical. Their surface is studded with fine granular pits, as in *Psammodus*. Under a lens the tubercles are structurally identical, and seemingly continuous with the intervening plate, than which they have a more vitreous aspect, as if a denser enamelloid layer invested their surface. They are, in fact, to outward appearance the counterparts of the maxillary and mandibular apparatus: it is to be regretted that of this structure no microscopic section can be obtained. The plate, whence the tubercles spring, is very thin, $\frac{1}{8}$th of an inch in thickness; the under surface is set with fine, distant, conical pits, to judge by the cast exposed on the shale. The resemblance to the jaws is therefore considerable, in the thinness of the osseous layer and irregularity of its under surface. The anatomical value of this plate is not quite clear. As no bone corresponding to the edentulous plate in *Platysomus* is found, these two curved dental plates may, with great probability, be taken to represent the palato-vomerine mass. As there seems no reason for considering the curvature accidental, they differ from the same parts in *Pycnodus*, in that their inner margins were not in contact; the arch of the palate was, therefore, incomplete, or closed by membranes only; at least there is at present no evidence of a central series of crushing teeth, or of an unarmed bony plate closing the gap. A specimen in Mr. Ward's possession shows that the transverse breadth of the head is in agreement with the supposition that the two rami were apart.

The suspensorium is very strong, descending nearly vertically from the squamosal. The close union of the bones forbids any attempt to say what were the components of the bar. A pterygoid plate is attached to it anteriorly and superiorly; but the other constituents of the palato-pterygoid arch are concealed beneath the maxillary vertical plate. There is an indication on one specimen, of facial plates overlying this vertical portion, as in *Tetragonolepis* and its allies, parts in fact of the so-called outer orbital ring; but, if the surmise is correct, they are in less close relation to the true suborbital ring, and contrast very strongly in shape and size with it. The subopercular is the largest of the three bones; the opercular and interopercular are nearly equal; the latter overlaps the branchiostegals, which are nevertheless enamelled externally. The suprascapular is well developed; the pectoral arch very strong, the so-called coracoid expanding into a wide oval process. The pectoral fins are higher than usual above the ventral margin; but, relatively to the opercular bones, they hold the same place as in the majority of the rhombic fish, namely, opposite the inferior margin of the subopercular.

The peaks into which both margins of the body are produced are not opposite: the dorsal being slightly in advance of the ventral. They are formed by a set of gradually narrowing scales, seemingly denser than the rest, and ending in tolerably sharp recurved points. From these the posterior slopes are rapid, with feebly convex outlines, the anterior more gradual, straight. The scales are very high in proportion to their breadth on the flanks, and diminish both towards the margins and the tail; never, however, becoming equilateral, save on the upper caudal lobe. The series are nearly vertical, thus leaving, anteriorly to that row skirting the opercular bones, a triangular space, whose upper boundary is the mandible. In this area the scales are smaller, but longer than broad, and radiate from the upper posterior corner of the space to the margin of the body. The ornament consists of a thick ganoin layer, raised into partly confluent tubercles, after the fashion of Pl. XX. fig. 5. In only one specimen is the evidence distinct of a modification of the marginal scales; in it those of the ventral edge anterior to the peak have their lower ends denticulate, but as those denticles are attached to high scales, there is no single row, those of opposite surfaces alike contributing to the outline of the trunk. The lepidopleura are very strong, and are of the structure already so well described by Sir P. Egerton (*loc. cit.*). The fins are made up of rays, slender for the bulk of the animal; the articles are short, and covered with ornamented scales. They bifurcate successively near their extremities into a fine fringe. The anterior rays of the dorsal and anal are longer than the rest, as in *Platysomus*. The anterior rays in all the fins (except the pectorals, whose defective state leaves this point undecided) are fringed with a fine series of fulcral scales. Those on the upper caudal lobe are a single row of strong, triangular, peaked scales, with a notched posterior margin. The lateral line is straight, and passes obliquely upwards from the tail to the lower opercular margin.

Of the internal skeleton little can be said, save that the processes are well ossified, and their vertebral ends expanded so as to approach the half vertebræ of the Pycnodonts. The pelvic bones figured by Agassiz have not been preserved in any specimens I have seen; and as they are placed by him in front of the anal fin, it seems likely that they are in reality suggested by the frequent distortions of the dorso-ventral scale-rows in that region.

Fragments of this genus are frequent in the North Staffordshire coal-fields: they also occur, though more sparingly, in the Scottish coal-fields, especially in that of Lanarkshire.

Eurysomus = Platysomus. Ag. *partim.*

This name is proposed provisionally for *Pl. macrurus,* since the character of its dentition removes it from *Platysomus* and *Amphicentrum,* with which it shares the common want of a ventral fin. The scale-character allies it somewhat to the latter genus. Not having seen, however, the characteristic dentition, I refrain from offering any generic definition*.

The relations of these three to each other and to other genera are somewhat complicated. The structure of the head is, in all three, strikingly like that of many osseous fishes, and illustrates the inexactness of the group of Ganoids, especially when internal anatomy is not available for purposes of classification. The palato-pterygoid arch, whose details seem so well brought out in the head of *Platysomus,* is not a little remarkable for the share it takes in the outer configuration of the head. In fact, if the large cheek-plates of *Trigla* are removed, the head of *Platysomus* is presented, with the single exception of the maxilla, which is a narrow bar in place of the expanded triangular plate of the fossil. If this plate is regarded as a facial plate, and the maxilla restricted to the slender spatulate piece marked off by a line near its lower margin, the peculiarity is not less, since a suborbital attached to the maxilla and premaxilla (for these two are closely united) is equally remarkable. The articulation of the maxilla with the pterygoid plates is not quite certain—they overlap and are closely related at least; but even their articulation could not be regarded as wholly exceptional, since it only differs from the similar arrangement in *Crocodilia* by the absence of an os transversum. To *Trigla* a further physiological resemblance may be noted. The great size of the buccal cavity is obtained in both by the same means, namely, the lateral extension of the palatine arcade, and in both doubtless has reference to the predatory habits of the animal. The head of *Platysomus* is narrow, but every available space is secured for the mouth by the tenuity of the pterygoid apparatus; in fact, only the thickness of these bones is to be subtracted from the transverse measurement to give the entire space available for food. In *Amphicentrum,* on the other hand, the hard food, to whose attrition the tubercle-teeth are adapted, required less space; or, more correctly, required closer approximation of the crushing surfaces. Hence the broader jaws, low-set palate and contracted cavity, though the gape is wider than in *Platysomus*. In this genus, therefore, the palato-pterygoid arcade recedes from the surface of the head, and is concealed by a covering of skin, or possibly by the development of membrane-bones. In no point is the difference of the two genera more striking than in the maxilla; and the light which that bone in *Amphicentrum* throws upon the anatomy of *Pycnodus,* gives it peculiar interest. In *Platysomus* it is as in *Palæoniscus* and other Lepidosteids—a single thin bone with small laniary teeth,

* The scale-ornament of *Pl. striatus* manifests, in many specimens, a tendency to the granular form. The figure substituted for that of this species in the 'Poiss. Fossiles,' pl. 17, is accompanied by no description of the conical teeth figured. In the meantime, therefore, it must remain among the *Platysomi*.

contrasting, therefore, with the crushing-plates of *Amphicentrum*. In *Pycnodus*, Thiollière denies the existence of a maxillary, and finds the analogue of the upper jaw in the palato-vomerine rows of crushing teeth. Wagner had figured, but not identified, a triangular plate whose forward attachment is in the premaxillary region. This, Thiollière regards as a suborbital only, it would seem, on the ground that its overlapping the prominent lateral mandibular teeth presents difficulties; in his view, therefore, the palato-vomerines were naked. Heckel* describes a specimen in which he finds a fragment of a maxilla. It is to be supposed, therefore, that he regards this as distinct from the bones bearing the superior mass of tritors. *Amphicentrum* gives the explanation of the arrangement: the outer crest of the mandible is the higher of the two, and is external to the inner maxillary crest, that, namely, which supports the denticles. Doubtless the palatal plates were attached to the maxilla, the latter having no free motion, as in most fish. Here, therefore, the same difficulty is present as in *Pycnodus*; but the overlap of the mandible by the labial flap of the maxilla is unquestionable. The triangular plate in *Pycnodus* becomes, then, the simplest form of maxilla, an edentulous mobile plate covering in the oral cavity laterally. In *Amphicentrum*, therefore, the overlap is greater in degree than, but similar in kind to, that partially developed in *Aechmodus*, *Dapedius*, and *Tetragonolepis*. From the Pycnodonts *Amphicentrum* is separated by the absence of teeth in the premaxillary and premandibular regions, which rather resemble beaks than the same parts in ordinary fishes†. The smaller gape and coincident change in place and direction of the opercular apparatus further separate them, as will be seen from Thiollière's restoration (fig. 4), which I believe to be correct, so far as the less perfect specimens in this country enable me to judge. If to this be added the absence of a ventral fin in *Amphicentrum*, and the less development of its vertebral arches, the data seem sufficient to justify the reference of this genus to a family distinct from, yet allied to, the Pycnodonts, and linking it with the Lepidosteids.

Comparison with *Æchmodus*, as the type of that group whose association with the Pycnodonts Thiollière justly condemns, shows a divergence even more considerable than from *Pycnodus*, as will appear from the restoration (fig. 3), and from the characters of the teeth (Quart. Journ. Geol. Soc. vol. ix. p. 274, vol. x. p. 367). For not only are the number and arrangement of the head-bones different, but the structure and mode of articulation of the scales separate this and allied genera from *Pycnodus* further than the latter is removed in these points from *Amphicentrum*.

The Pycnodont affinities of *Pl. macrurus*=*Eurysomus*, *mihi*, being

* Sitzungsberichte der k.-k. Akad. der Wissenschaften, Math.-nat. Classe, vol. xii. 1854, p. 433.

† The great height of the premaxillary ascending processes, relied on as evidence of the mobility of the muzzle, is here associated with rigidity of the whole oral structures, and even in *Platysomus* the constant connexion of premaxillaries and maxillaries in dislocated examples suggests that in that genus also the protrusion of these parts was very limited.

accepted on the authority of Sir. P. Egerton, enough has been said to prove, as I think, not only the distinctness of that genus from any of the flat fishes of the Coal, but also that, as yet at least, the family to which it belongs has no true representative in the Carboniferous series.

Mesolepis, nov. gen. (Pl. XXI.)

Among a number of specimens marked *Platysomi*, three were found on closer inspection to belong to a new genus. They are characterized by the presence of a small ventral fin, a longer anal, and a dorsal which extends from opposite the anterior border of the former to the posterior margin of the latter. The scales are broader in proportion to their height than in *Platysomus* or *Amphicentrum*, while the lepidopleura, weaker than in those genera, approach somewhat to the kind of articulation present in *Amblypterus* and *Eurynotus*. The imperfection of the head prevents anything being said of it, save that the suprascapular is larger than in the above genera, both it and the operculars rather resembling those of *Eurynotus*, especially in the presence of concentric growth-lines. Fortunately, however, one specimen shows three teeth, and these are closely similar to those described by Sir P. Egerton in *Pl. macrurus*, presenting a bluntly conical, minié-bullet-shaped crown with a constricted neck, much like the *Globulodus* of Münster.

From the characters of the scales I propose the name *Mesolepis* for this genus, and give the following definition:—

Body oval, or arched in the anterior dorsal region, terminating by a blunt prolongation in the upper caudal lobe. Pectoral fin large, its extremity rounded. Ventral small, narrow, at, or slightly in front of, the middle of the body, equidistant between pectoral and anal. Dorsal commencing opposite the ventral, and extending to the tail-root, terminating opposite the posterior margin of the anal, which is rather more than one-half its length. Caudal root strong; upper lobe larger than lower. The anterior rays of all the fins are the longest, and bifurcated only at their extremities; the following rays are slender and divided so as to form a delicate fringe. Orbit large, well forward, close to the facial line. Teeth stalked, with a constricted neck and smooth bluntly conical crown. Scales quadrilateral, those on the flanks higher than broad; the others more equilateral. Ornament on them, and on head-bones, tuberculo-linear.

Two species are distinguished by the following characters:—

M. Wardi (Pl. xxi. figs. 1, 3).

Body ovate; the posterior dorsal slope more rapid than that of the anal region. Length of trunk, from pectoral to tail-root, nearly twice its greatest depth. Caudal root thick, elongate. Scales ornamented with tubercles, more or less confluent into approximately vertical ridges.

M. scalaris.

Body more arched dorsally. Tail-peduncle very short and slender.

The tubercles on the scales arranged in transverse close-set ridges over the middle two-thirds of the scale; above and below the ridges, irregular tubercles; and towards the posterior margin, sinuous tubercular lines. The anterior border of the scale traversed by two or three fine vertical striæ.

In general form of body this genus comes nearest to *Amblypterus*, from which the size of the dorsal and anal fins, the character of the ornament, and the proportional size of the scales, distinguish it. From *Eurynotus*, the relatively larger head and scales, and the tubercular ornament are equally marked grounds of separation, while the teeth are in strong contrast with the small conical Lepidoid armature of the jaw in that genus.

Both species have, as yet, occurred only in North Staffordshire; but the appearance of several fragments from other districts renders it probable that the genus is not confined to the English coal-fields.

Eurynotus, Agassiz.

I have received, through the kindness of Sir P. G. Egerton, the following remarks on this genus, in the form of extracts from letters addressed to him by the late Hugh Miller, and gladly comply with his wish for their publication:—

Edinburough, Feb. 3, 1849.

"My Dear Sir, . . . . . . I found, only a few weeks ago, a group of palatal teeth of a rounded form, with a slight dimple in the centre of each (which I used to set down as belonging to some Placoid), existing as the palatal teeth of the *Eurynotus crenatus* of the Coal-measures . . . . . .

"Hugh Miller.

Edinburough, Feb. 17, 1849.

. . . . . . "I was desirous that in replying to your favour of the 6th inst. I should be able to send you with my communication a cast of the specimen of *Eurynotus crenatus*, in which I detected the palatal teeth referred to in my last. The cast which I now enclose is a good one, and exhibits the rounded granules of the creature scarce less distinctly than the original, one of the finest of this species of Ichthyolite which I have yet seen, and which belongs to our Free Church College Museum. The straightness of the line along the back from the head to the point of the dorsal fin seems a striking characteristic, and has, I think, in the general outline a rather pleasing effect. At least, it would not be easy to construct a fish of a breadth so great in proportion to its length, that would be equally handsome, were this line different. Of the teeth, you will find some eight or nine remaining immediately over what seems to be the under jaw, and the rest represented by the little pit-like sockets which they occupied. The original specimen is from a limestone in the neighbourhood of Crail, in Fife, identical in appearance and character with the limestone of Burdie House.

"I am, my dear Sir,

"Very respectfully yours,

"Hugh Miller.

Sir Philip de M. Grey Egerton.

Many specimens of this genus from the Fifeshire Carboniferous rocks are in the Museum of St. Andrews, but the head in all these specimens is imperfect. In the British Museum there is a specimen which, in all save "the dimple," might be that from which Miller's description was taken. The tritores and their sockets are well seen; not all are of equal breadth, some seeming of smaller diameter and thinner root, a difference comparable to that seen among the teeth of Pycnodonts. The teeth seem, as Miller has stated, undoubtedly palatal, and, as such, disposed in several rows. The small opportunity I have had of studying *Eurynotus*, prevents me from doing more than expressing my belief that the structure of the head agrees with that of *Mesolepis*, the operculars being narrow and the suprascapulars elongate, as in that genus. The form and position of the dorsal, ventral, and anal fins are also similar, while the nuchal line to which Miller draws attention has the same characters in both genera, and in others which are included under *Lepidopleuridæ*. The external ornament of the scales differs wholly in kind; but to this less weight is due than to the absence of the back-stays, which linger in reduced dimensions on the anterior scales of *Mesolepis*. That name was selected to express the transitional character of the genus, and *Eurynotus* supplies the next step in the departure from the Lepidopleurid type. Wherever, therefore, *Mesolepis* is placed, there *Eurynotus* must also go. The cranial structure, traced through the other genera of the suborder, cannot be demonstrated in these two forms, but complete specimens would probably not depart far from it. The dental characters seem decisive, and warrant the juxtaposition of *Mesolepis* and *Eurynotus* as aberrant forms of the *Lepidopleuridæ*. *Amblypterus*, the genus they approach nearest in shape, is widely separated from them by its dentitional characters, which, as well as its cranial anatomy, place it among the *Lepidosteidæ*, not far from *Oxygnathus*. Nor is *Lepidotus* less distinct, as appears from Quenstedt's valuable memoir.

The five genera just described form, with the family of Pycnodonts, a natural group by which the Ganoid affinities of the latter are increased, its Teleostean relations being at the same time brought into greater prominence. The least variable common feature is the structure of the scales, whence the name *Lepidopleuridæ* may be given to the group, whose definition is as follows:—

Suborder LEPIDOPLEURIDÆ*.

Ganoids with heterocercal equilobate tails. Body rhomboidal,

* The word "pleurolepida," applied by Sir P. Egerton to the articular backrib of Pycnodont scales, has been altered to "lepidopleura," partly to render the term more descriptive, partly to secure euphony in the subordinal title. The solid advantage which excuses the change is, that confusion is thereby avoided between *Lepidopleuridæ* as above defined, and *Pleurolepidæ* as used by Quenstedt (Handb. der Petrefactenkunde, p. 209). The latter name includes the Pycnodonts, and along with them *Placodus*, the group being stated to be intermediate between Chondrostean and Holostean Ganoids, *i. e.* those on the one hand in which scales and head-bones are the chief fossil remains, and those on the other

covered with rhombic scales, articulated by strong ribs traversing their anterior margin internally. Dorsal fin equal to half the length of the trunk. Anal fin also with an elongate base. Ventrals, when present, small. Paired fins non-lobate. Branchiostegal rays not taking the form of broad plates. Notochord persistent. Arches well ossified.

I. Ventral fin wanting.

PLATYSOMIDÆ.

Teeth uniserial, conical, sharp. Palate-bones edentulous.—*Platysomus*, Agassiz, *partim*.

AMPHICENTRIDÆ.

Dorsal and ventral margins sharply acuminated. Teeth in the form of tuberculated plates on the maxillary, mandibular, and palato-vomerine bones. Premaxillary edentulous.—*Amphicentrum*, n. g.

EURYSOMIDÆ.

Teeth in the form of blunted cones, on a peduncle with a constricted neck.—*Eurysomus* (=*Platysomus*, Agassiz, *partim*.).

II. Ventral fin present.

MESOLEPIDÆ.

Teeth similar to those of *Eurysomus*.—*Mesolepis*, n. g.; *Eurynotus*, Agassiz.

PYCNODONTIDÆ.

Teeth oval, hemispherical, or, if elongate, blunted cones.—*Pycnodus*, *Mesodon*, *Gyrodus*, &c., (except the Labroid forms of Cocchi).

The arrangement here sketched does not affect the question which further research may raise as to the true position of the genera included under it. The group is transitional between the Ganoids and Teleosteans, and is equivalent to the suborders, 1. Amiadæ, 2. Lepidosteidæ, 3. Crossopterygidæ, 4. Chondrosteidæ, and 5. Acanthodidæ. By *Platysomus* it approaches *Palæoniscus* and its allies, while *Pycnodus* and *Amphicentrum* conduct to the *Labroidei* and *Sparoidei*. From the Pycnodonts the above definition excludes *Tetragonolepis* and its allies by the negative character of absence of lepidopleura, and by the important positive differences of cranial structure already illustrated.

The restoration of ventral fins by Agassiz in the genus *Platysomus* was a matter of inference, which perfect specimens have disproved. His generalization as to the non-appearance of apodal fish prior to

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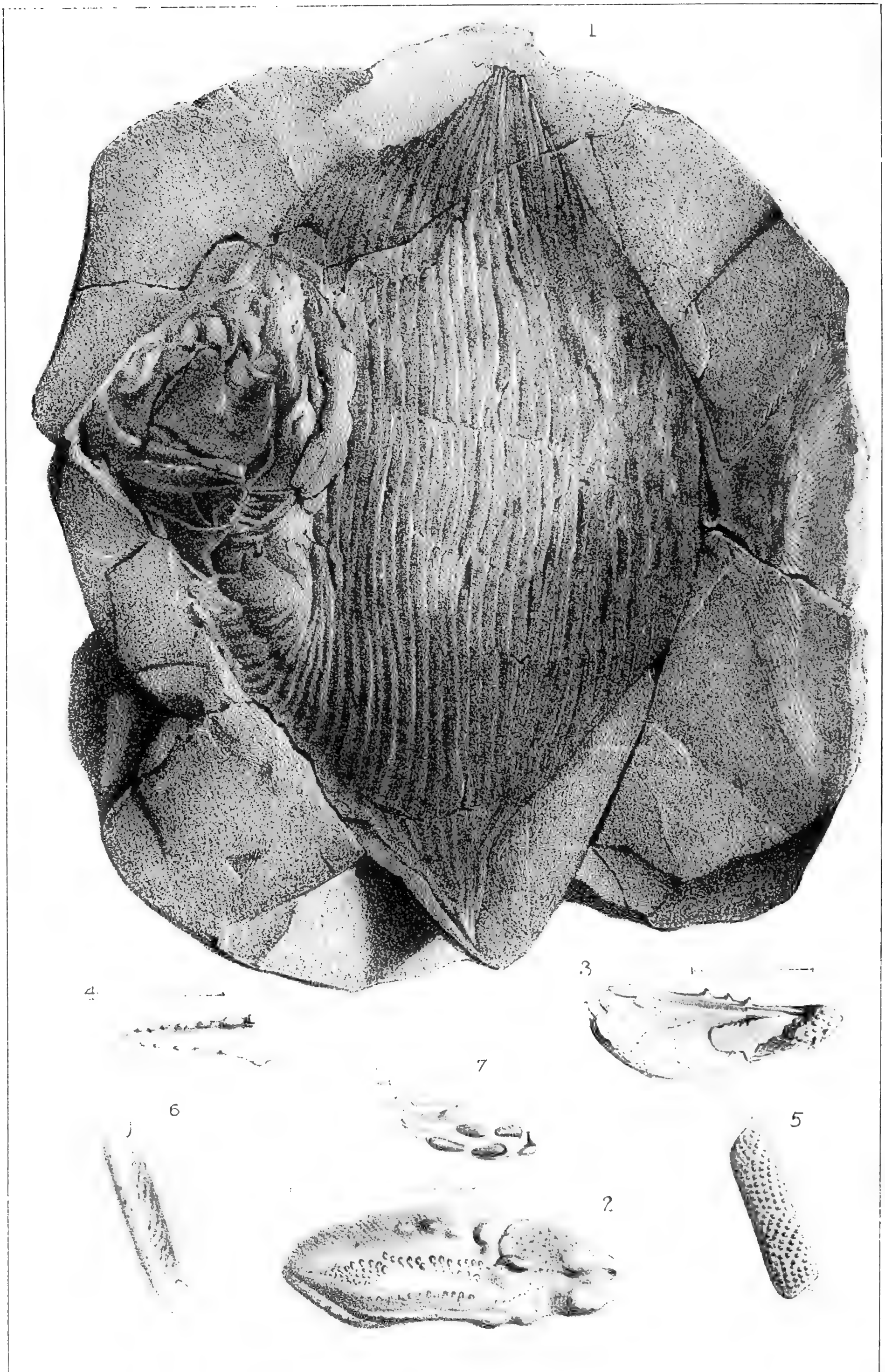
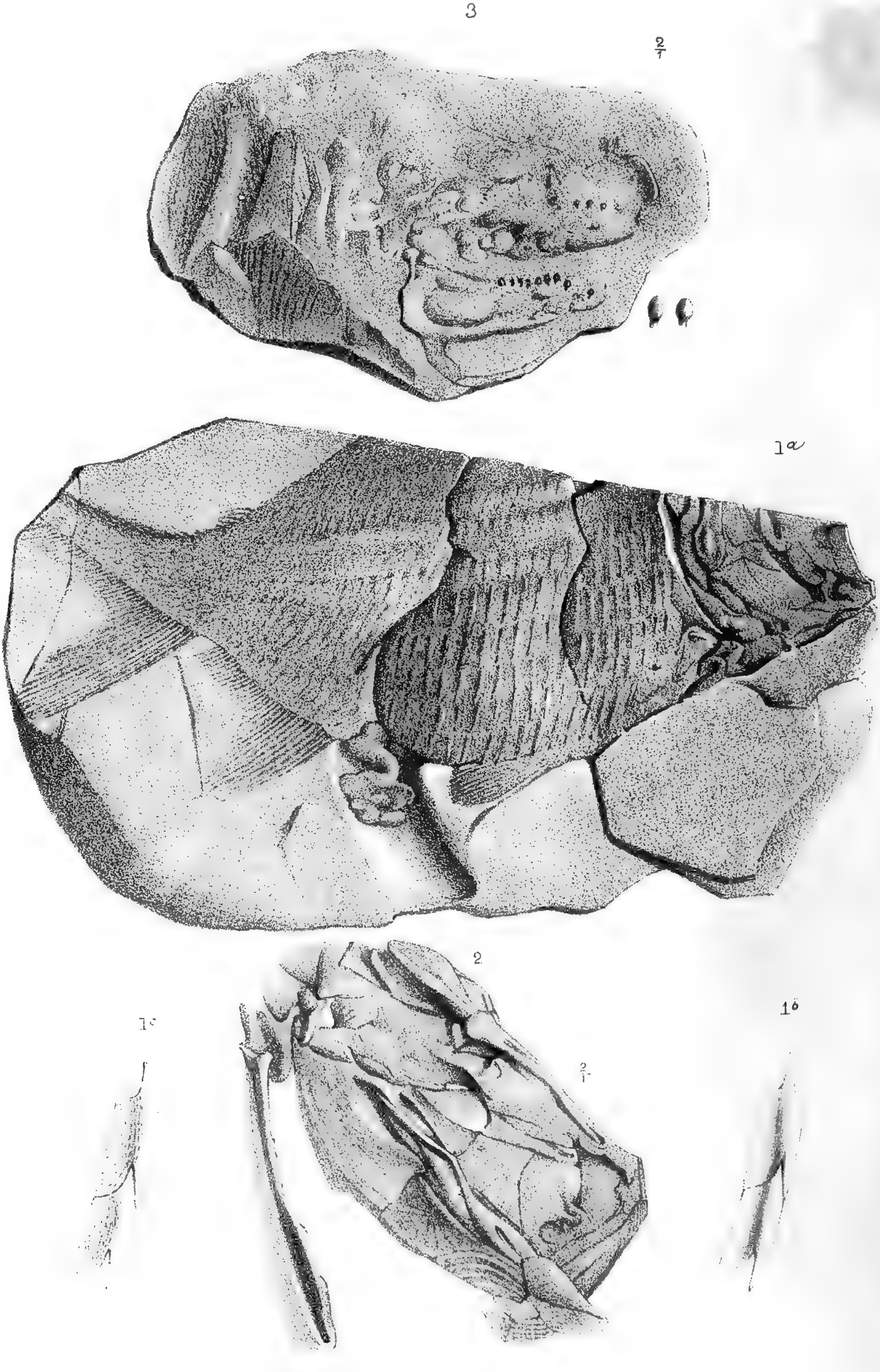
in which parts of an osseous skeleton are more distinctly preserved. To the former belong the Lepidoids, to the latter *Thrissops*, *Macropoma*, *Leptolepis*,—a miscellaneous assemblage. This classification is artificial and inaccurate, its basis—the amount of surviving structures—being only in appearance a zoological one. The character selected to define and designate the subfamily occurs in more genera than those included by Quenstedt under it.




C. R. Bone del. et lith.

M & N Hanhart imp.

AMPHICENTRUM.




C. R. Bone. del. et lith.

M. & N. Hanhart imp.

MESOLEPIS & PLATYSOMUS.

the Chalk, thus also falls to the ground. The absence of this member cuts off *Eurysomus* from the Pycnodonts proper, which are thus restricted to Mesozoic times; for that family is clearly separated from *Eurynotus* and *Mesolepis* by the form of the suprascapular bones, as well as by the different position of the opercular plates, by the structure of the scales, and by the absence of fulcra on the upper caudal lobe.

## EXPLANATION OF PLATES XX. & XXI.

### Plate XX.

Fig. 1. *Amphicentrum granulosum*, one-half the natural size.
2. Maxilla of *A. granulosum*, natural size.
3. Mandible of *A. granulosum*, seen from without.
4. The same seen from above.
5. Outer surface of a scale of *A. granulosum*, natural size.
6. Inner surface of a scale of *A. granulosum*, natural size.
7. Palatine armature of *A. granulosum*, magnified.

### Plate XXI.

Fig. 1 *a*. *Mesolepis Wardi*, natural size.
1 *b*. Outer surface of scales of *M. Wardi*, magnified.
1 *c*. Inner surface of scales of *M. Wardi*, magnified.
2. Head of *Platysomus parvulus*, twice the natural size.
3. Teeth of *Mesolepis Wardi*, twice the natural size.

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## 5. *Note on the* Scales *of* Rhizodus, *Owen.*

By John Young, M.D., F.G.S.

[This paper was withdrawn by permission of the Council.]

[Abstract.]

Attention was drawn to the fact that, on a slab in the collection of the Royal Society at Edinburgh, the characteristic *Rhizodus* teeth occur along with thick bony scales, whose exposed area is ornamented with coarse tubercles, usually irregularly disposed, while the overlapped anterior area is concentrically striated. These characters confirm the generic distinctness of *Rhizodus* from *Holoptychius*, whose smooth anterior and rugose free surfaces contrast with those described.

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## March 7, 1866.

Edward Filliter, Esq., Leeds; Myles Kennedy, Esq., Hill House, Ulverston; and Lieut. Charles Warren, R.E., Gibraltar, were elected Fellows.

Dr. Joseph Leidy of Philadelphia was elected a Foreign Member.

Prof. J. P. Lesley, of Philadelphia; and Prof. Reuss, of Vienna, were elected Foreign Correspondents.

The following communications were read:—

1. DOCUMENTS *relating to the* RECENT VOLCANIC DISTURBANCES *in the* NEIGHBOURHOOD *of* SANTORINO*.

[Abstracts.]

THE document first received is a letter from Consul St. Vincent Lloyd to the Rt. Hon. the Earl of Clarendon, dated Syra, February 8, 1866, in which he states that on or about the 1st of that month, the sea in the neighbourhood of the Kaimeni islands, in the centre of the great ancient crater forming the harbour of Santorino, began to show signs of volcanic action; the result was the formation of a new island, which at the date of his report had become nearly joined to the southern extremity of the island Nea Kaimeni. Consul Lloyd also gave an account of the eruption, mentioning that it was accompanied by loud subterranean noises, flames of fire, and ebullition of the sea. Slight shocks of earthquakes had been felt at Santorino, where the inhabitants were much alarmed.

In a second letter to the Earl of Clarendon Mr. Lloyd encloses a letter which he had received from Mr. A. Delenda, H.M. Consular agent at Santorino, in which was given an account of the phenomena attending the eruption as they were observed day by day at Nea Kaimeni, from February 1st to February 7th inclusive. Mr. Delenda particularly describes the boiling of the sea and the scattering through it of coloured matter, as well as the appearance of flames, the formation of pools of fresh water on Nea Kaimeni, the upheaval of a new island, and the subsidence of some of the houses.

In a letter dated February 16th addressed to the Earl of Clarendon, Mr. Erskine, British Minister at Athens, enclosed a copy of 'La Grèce' newspaper of February 15th, containing letters from M. Decigala dated 23rd, 24th, 25th and 26th, of January. From these letters it appears that signs of volcanic action were observed at a place called Voulcano as early as January 18th, and that the new

* These documents consist of the following Reports, the abstracts of which are here printed together by Order of the Council:—

1. Report from St. Vincent Lloyd, Esq., H.M. Consul at Syra, to the Rt. Hon. the Earl of Clarendon. Communicated by the Secretary of State for Foreign Affairs. Read March 7, 1866.

2. Report from St. Vincent Lloyd, Esq., H.M. Consul at Syra, to the Rt. Hon. the Earl of Clarendon, enclosing letters from A. Delenda, Esq., H.M. Consular Agent at Santorino. Communicated by the Secretary of State for Foreign Affairs. Read March 7, 1866.

3. Report from Morris Erskine, Esq., British Minister at Athens, to the Rt. Hon. the Earl of Clarendon, enclosing letters from M. Décigala. Communicated by the Secretary of State for Foreign Affairs. Read March 7, 1866.

4. Report from Commander G. Tryon, of H.M.S. 'Surprise,' to Vice-Admiral Sir Robert Smart, K.C.B. Communicated by the Lords Commissioners of the Admiralty. Read March 21, 1866.

5. Report from Commander L. Brine, of H.M. Steam-sloop 'Racer,' to Vice-Admiral Sir Robert Smart, K.C.B. Communicated by the Lords Commissioners of the Admiralty. Read April 25, 1866.

6. Report from M. Fouqué to the Eparch of Santorino. Communicated by Sir R. I. Murchison, Bart., K.C.B., &c. Read April 25, 1866.

island first appeared in the form of a reef on the night of January 22nd. M. Decigala describes at length the same phenomena as Mr. Delenda, especially mentioning that the sea was coloured white, like milk, and the formation of several lakes of very pure fresh water. He gave to the new island the name of 'George the first,' and he minutely describes the manner in which it was gradually enlarged, until on January 25th it formed a promontory of the island Nea Kaimeni,

Two letters dated Malta, February 22nd, from Commander G. Tryon, of H.M.S. 'Surprise,' to Vice-Admiral Sir Robert Smart, K.C.B., contain that officer's report. The 'Surprise' reached Santorino on February 16th, and on opening the island of Nea Kaimeni a new island, named Aphroessa by the Greek Commissioners, was observed to have arisen from a new crater situated about 150 fathoms from the south point of Nea Kaimeni. This new island was upheaved from a depth of 14 fathoms, and at that time was 100 yards long and 50 wide; but it was daily increasing in size. Its appearance was very gradual; it first appeared above water on February 13th, but for two days previous it was only one fathom under water. The small bay in Nea Kaimeni, known as Mineral Creek, had also been the scene of volcanic action, and at the time of Comm. Tryon's visit, the creek was not only filled up, but a pile of lava was formed, 300 yards long by 200 broad, which had completely buried the houses which were in its way; and this new hill was then gradually increasing at the rate of from 6 to 8 feet per diem each way. At that time these two localities—Mineral Creek and the new island Aphroessa,—about two-fifths of a mile apart, formed the vents of the volcanic action. The south-eastern portion of Nea Kaimeni had, however, sunk considerably, and was still sinking. No fluid lava had appeared, the new formations having been apparently pushed up from below and extended laterally as they got to the surface. Commander Tryon was unable to discover that any circumstances connected with the eruption, or that any of the materials upheaved, differed from what had been observed in other parts of the world.

Commander Lindesay Brine, of H.M. Steam-sloop 'Racer,' in a letter to Sir Robert Smart, dated Malta, March 13th, reports that active volcanic action is confined to two vents, except that the ancient crater of Nea Kaimeni, by the rents at its summit, and the steam escaping at its sides, appears to be in communication with them. The active volcano forming part of Nea Kaimeni had been raised from 70 to 130 feet above the sea, and consists of an irregular mass of scoriæ, pumice, clinker, and solid basaltic lava, and was slowly increasing in all directions by the addition of matter thrown from the crater. Commander Brine also gives a detailed account of the commencement and progress of the disturbances; but it does not differ materially from other records, except that it draws a distinction between the first-formed vents, from which there had been true eruptions, and the new island, from which there had been no eruption, but incessant noise (caused by the detachment of blocks from the sides), much steam, and clouds of smoke.

Sir Roderick Murchison communicated the contents of a report made by M. Fouqué, the envoy to Santorino of the Academy of Sciences of Paris, to the eparch of Santorino. M. Fouqué states that a fissure had opened between the George Promontory and the new island Aphroessa, and that the points of eruption are simply the sites of the deepest holes in the line of rupture, and that the non-existence of a true crater is owing to the small quantity of ejected matter and the feebleness of the eruption. Owing to the recent progress made in the study of volcanos, M. Fouqué is enabled to state that the eruption of Nea Kaimeni never presented more than a very moderate degree of intensity. M. St. Claire Deville has shown that there exists a constant and certain relation between the degree of intensity of a volcano in action and the nature of the volatile elements vomited at its mouth; thus, in an eruption of maximum intensity, the predominant volatile product is chloride of sodium, accompanied by salts of soda and potash; an eruption of the second order gives off hydrochloric acid and chloride of iron; one of the third degree, sulphuric acid and salts of ammonia; and of the fourth, or most feeble phase, steam only, with carbonic acid and the combustible gases. Applying this principle to Nea Kaimeni, it appears that the eruption never exceeded the third degree of intensity; and when it created the greatest alarm it gave off only sulphuric acid, steam, and combustible gases, or products of the third and fourth orders of volcanic activity. M. Fouqué therefore agrees with other observers in believing that the fears of the inhabitants of the islands were very nearly unfounded.

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## 2. *On the* Carboniferous Slate (*or* Devonian Rocks) *and the* Old Red Sandstone *of* South Ireland *and* North Devon. By J. Beete Jukes, Esq., M.A., F.R.S., F.G.S.

Contents.

## I. Introduction.

Having been able during the last summer to extend a little my knowledge of North Devon, especially in the neighbourhood of Lynton, and having, as the result of my observations, become quite convinced that the rocks of North Devon belong partly to the group called *Carboniferous Slate* in Ireland, and partly to the Old Red Sandstone, I propose to lay before the Society the grounds of that conviction.

As I shall have to maintain that all the first geologists of the day, including Professor Sedgwick, Sir R. I. Murchison, Mr. Weaver, Sir H. De la Beche and Professor Phillips have misunderstood the structure of the country, let me hasten to avow my belief that nobody whose observations were confined to Devon and Somerset, could have arrived at any other than their conclusions. I fully admit that the rocks near Lynton appear to be the lowest, and that there appears to be a regular ascending succession of rock-groups from Lynton to the latitude of Barnstaple. I am, however, compelled to dispute the reality of this apparent order of succession, and to suppose that there is, either a concealed anticlinal with an inversion to the north, or, what I believe to be much more probable, a concealed fault running nearly east and west through the centre of North Devon with a large downthrow to the north, and that the Lynton beds are on the same general horizon as those of Baggy Point and Marwood. As my reasons for this supposition are derived from the experience acquired during many years' labour in the south-west of Ireland, I must in the first instance endeavour to state the result of those labours in as brief a form as possible.

It was at the close of the year 1850 that I succeeded my friend, Dr. Oldham, in the Local Directorship of the Irish branch of H.M. Geological Survey, when it was just entering on the examination of the district alluded to. During many succeeding years the rocks were patiently laid down on the six-inch Ordnance Maps by my colleagues, Mr. W. L. Willson (now of the Indian Survey), Mr. Andrew Wyley (who afterwards undertook the Geological Survey of the Cape Colony), and Mr. G. V. Du Noyer (now the senior Geologist in Ireland). Sir H. De la Beche and Professor Edward Forbes frequently gave their assistance to the work during those years. Subsequently our force was strengthened by the addition of Messrs. G. H. Kinahan, F. J. Foot, and Jos. O'Kelly, who still remain with us, and Mr. A. B. Wynne, who afterwards left us for India. All those gentlemen assisted in the examination of the district, and Mr. Salter (after the death of Professor Ed. Forbes) spent part of one summer in examining our fossils and visiting with me the principal fossil localities. The fossils were collected by the late James Flanagan in the first instance, and additions have been made by our present collectors Charles Galvan and Alexander McHenry; and some of the localities have been visited by Mr. W. H. Baily, who since the year 1857 has acted as Palæontologist to the Irish branch of the Survey. When I speak of the labours of the Survey, then, it is to those of the gentlemen named I more particularly refer; my own share being limited to general inspection of the work and comparison of the structure of different parts of the district, together with laying down the rocks of two or three small areas which happened to be typical localities.

I must not omit to mention that in our examination of this district we had of course been preceded by Sir R. I. Griffith, and that our more exhaustive operations only confirmed the general conclusions which he had previously arrived at, as shown in the later editions of his map. His name "Carboniferous Slate" is perfectly applicable to the grey slates and grits of the south-west of Cork, and has accordingly been adopted by us; and his boundaries agree generally with ours, except in one area where he takes a different base for the Old Red Sandstone, and so far as the imperfect map on which his results are published can be compared with the new ordnance one-inch sheets.

I will now give a sketch of the Old Red Sandstone and Carboniferous formations of the south of Ireland, commencing with the County Wexford and following them to the western bays and headlands of County Cork*.

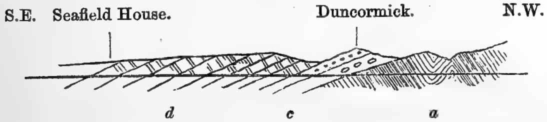
## II. Sketch of the Upper Palæozoic Rocks of the Southern portion of Ireland.

1. *Wexford.*—The Forth Mountain district, in the county of Wexford, shows green and purple slates and grits, with large bands of quartz-rock, which are believed to be part of the Cambrian formation. The town of Wexford is built on these rocks. About a mile to the north of it, however, there are several quarries in a red sandstone and conglomerate just like some of the Old Red Sandstone of South Wales, dipping gently to the east and south-east, in which direction a few exposures of Carboniferous Limestone were obscurely seen. About a mile to the south of Wexford there are several considerable quarries in dark-grey, compact or crystalline limestone, with beds of black shale, from which a number of common Carboniferous fossils were collected. In the townland of Kerloge, near the old church, and not far from St. James's Well, the lowest beds visible of this limestone are full of pebbles of quartz-rock, a crag of which, *in situ* (a part of the Cambrian formation), rises on

* Although much of the matter of this sketch may have been published before in separate forms, I am not aware of any previously published connected sketch of the gradual but great change which takes place in these rocks as they are traced across the south of Ireland.

the other side of the road. This Cambrian crag evidently stood as a rock in the Carboniferous sea, and pebbles derived from it were embedded in the limestone formed in that sea, and if there be any Old Red Sandstone about it, it is overlapped and concealed by the limestone. A mile farther to the south-west, however, about Latimers Town, there appears to be a district of red and yellow sandstone and conglomerate interposed between the Cambrian ground and that in which the limestone is found. A little farther on, quarries in red and yellow sandstone occur, and a regular band of red and yellow sandstone and conglomerate then runs to the south-west until it terminates on the sea-coast. The best section may be seen at Duncormick, about twelve miles south-west of Wexford, of which fig. 1

Fig. 1.—*Section at Duncormick.*




Length of Section, three-quarters of a mile.

Carboniferous Limestone. *c.* Old Red Sandstone. *a.* Cambrian rocks.

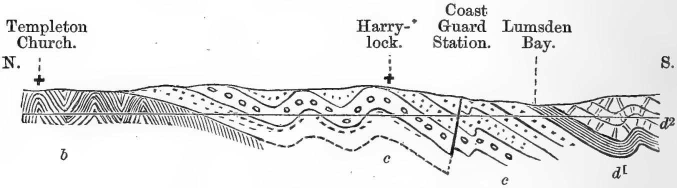
is a sketch. Several quarries were opened here in a dark-grey flaggy and shaly limestone, very fossiliferous and highly fetid, which dipped to the south-east at 25°. These lay between Seafield and Duncormick, which latter village stands on red flaggy sandstones and red shales, underneath which are yellow sandstones and conglomerates, all dipping south-east at 25°. These beds are well exposed in the village and road. North-west of the village, on the other side of the road, green grits and slates, such as are seen everywhere in the Cambrian rocks of the Forth Barony, rise to the surface, undulating in different directions and at various angles. The thickness of the yellow and red rocks here is about 200 feet, while the limestone beds must have a total thickness of 600 or 700 feet, if the dip of the beds is the same in the concealed parts between the quarries, as it is where they are open. We have taken the beds of red and yellow sandstone and conglomerate thus described, for Old Red Sandstone. There are, however, other beds of similar red sandstones and conglomerates to be found to the south-east of this band, interstratified with the Carboniferous Limestone, and therefore certainly not true Old Red Sandstone. This is a circumstance which occurs also in the northern portion of Ireland, as also I believe in parts of England, so that the mere occurence of red sandstones and conglomerates beneath some beds of Carboniferous Limestone is not sufficient to entitle them to be considered really Old Red Sandstone.

a. *Red Sandstones and Conglomerates in the Lower Silurian Rocks.*—Thick masses of red shale and red sandstones and conglomerates are interstratified also with the Lower Silurian rocks of Wexford near Tagoat, and Waterford near Bunmahon. Those of Bunmahon were at first presumed to be Old Red Sandstone let in by faults against the Lower Silurian rocks; but having seen those near Tagoat to be certainly in the Lower Silurian formation, I doubted the correctness of the supposition adopted at Bunmahon, and a recent reexamination of the county by Mr. Du Noyer has shown these also to be really Lower Silurian red sandstones and conglomerates. (See Explanation of sheets 167 &c., of Irish Maps.)

2. *Hook Head.*—The Upper Palæozoic rocks which strike into the sea south of Duncormick reappear on the coast, in the promontory of Hook Head, partly in consequence of a change in the strike of the beds, which there dip nearly due south, and partly from the land projecting farther to the south, as we proceed westwards. Fig. 2 will give an idea of the lie and position of the Carboniferous Limestone and undoubted Old Red Sandstone here; the latter reposing on slates and grits which belong to the Lower Silurian group, as is evidenced by their fossil contents at Duncannon Fort and elsewhere*. These Lower Silurian beds are greatly contorted, as is shown in the cliffs of Waterford Harbour for several miles.

The Old Red Sandstone rests on the edges of these contorted beds quite unconformably, as is shown in section fig. 2, and dips from

Fig. 2.—*Section of part of Hook Head.*




| | | |
|---|---|---|
| *d.* Carboniferous limestone. | $d^2$. Grey often flaggy limestone. | |
| | $d^1$. Black shale highly fossiliferous. | |
| *c.* Old Red Sandstone. | Red and yellow sandstones and shales above. | |
| | Red sandstones and conglomerates below. | |
| *b.* Lower Silurian. | Indurated shales, slates, and fine-grained grey grits. | |

them to the south, as a whole, but is itself undulated at slight angles and broken by faults probably of small throws. It is well shown in cliffs about 40 feet high for about a mile and a quarter along the shore of Waterford Harbour and for nearly two miles along the eastern shore of the promontory, which does not cut so directly across the strike of the beds as the western shore does.

The thickness of the Old Red Sandstone here is not exactly determinable, owing to its disturbed "lie," but it must be at least six or seven hundred feet. The lower beds consist of red sandstones and red shales, with beds of red conglomerate occasionally. Higher up the conglomerates become more massive, and beds of white conglomerate occasionally appear among the red. About the middle of

* See the list of Fossils and the Palæontological Notes by Mr. W. H. Baily in the "Explanation of sheets 169 &c. of the Irish Maps in the Memoirs of the Geological Survey."

the mass fragments of plant-stems occur, either as impressions on the sandstones, or as flattened stems with a thin coating of coaly matter. Little seams also of carbonaceous matter sometimes appear between the beds.

Beds of greenish shale set in near the top of the Old Red Sandstone, the uppermost one being capped by a bed of grey "fucoid" shale, which is taken as the base of the Lower Limestone Shale. There are, however, here not more than from 10 to 20 feet of actual black shale before we come up to the compact grey limestone. The limestone beds are well shown in the low cliff on both sides of the promontory as far as the extremity of the Head, a distance of two miles and a half. They are much bent and broken, dipping in various directions, although never at angles exceeding 30°, and rarely above 10° or 15°. There is a belt of magnesian limestone (one of the many places in which the Carboniferous Limestone is dolomitised) about 400 yards wide, crossing the promontory before reaching the extremity of the Head; but except in that space, the cliffs are crowded with fossils, all of them of species which are known to occur in the Carboniferous limestone elsewhere, as will be seen on referring to the lists by Mr. W. H. Baily, given in the Explanation of the Sheet 167, &c., of the Maps of the Geological Survey of Ireland.

3. *Waterford.*—Opposite the Hook Point, on the western coast of Waterford Harbour about Dunmore, the Old Red Sandstone spreads in a nearly horizontal position over an isolated area six or seven miles long by about two broad, resting unconformably on Lower Silurian rocks, which rise steeply out from underneath it on the west and north.

Two or three other isolated patches of similar size lie, like cakes of Old Red, on the highly inclined Silurians on both sides of the harbour further north, and in the southern angle of County Kilkenny, between the rivers Suir and Barrow.

These isolated patches are obviously pieces spared by the denudation that has removed the rest, and uncovered the Silurian rocks around them. They serve to connect the Old Red Sandstone of Hook with the persistent mass of it which takes the ground north of the city of Waterford.

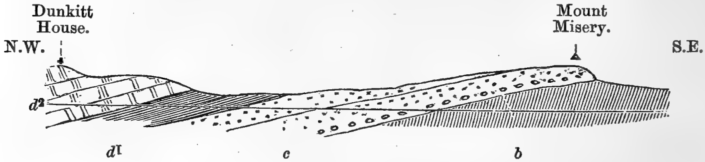
Immediately to the north-west of the city of Waterford, on the south side of the river Suir, are some black slates, in which *Diplograpsus pristis* and *Graptolithus tenuis* are abundant. They dip north-west at 60° and 70°. On the northern side of the river the slates and grits of the Lower Silurian formation are of a greener hue and more siliceous appearance, and are unfossiliferous, but dip in the same direction, at 70° or 80°.

These beds are well shown in the cuttings in the cliffs at the back of the houses by the railway station; and on their upturned edges lie great beds of brown and red quartzose conglomerate, dipping north-west at 10° or 15°.

These are the basal beds of the Old Red Sandstone; which may be followed in one direction to the river-bank, on the other side of which they reappear striking to the west into County Waterford; while in the other direction they may be followed up the cliff to Mount Misery, and for some miles to the north-east in County Kilkenny.

Above the conglomerates come red sandstones often flaggy and and sometimes traversed by a rude slaty cleavage. These beds all dip north or north-west at low angles towards some lower ground, where a few scattered quarries show beds of yellow sandstone and flag with yellowish or greenish shaly or slaty partings.

Fig 3. *Section from Dunkitt House to Mount Misery, Waterford.*




Length of Section, about 2 miles.

| | | |
|---|---|---|
| *d.* Carboniferous limestone. | $d^2$. Grey crinoidal limestone in thick beds. | |
| | $d^1$. Dark-grey fossiliferous shales with flaggy limestones above and flaggy sandstones below. | |
| *c.* Old Red Sandstone. | Yellow and red sandstone above, red sandstones and slates and red conglomerates below. | |
| *b.* Lower Silurian. | Grey, black, and greenish-grey slates and grits. | |

On Mount Misery there is not such a good exhibition of slaty cleavage in the Old Red Sandstone as occurs in the finer sandstones two miles to the west of Waterford, in the townland of Knockhouse Upper. The red sandstones which lie there between the coarse conglomerates, all dipping north-west at 20°, are traversed by a cleavage which, according to Mr. Du Noyer's notes, dips north-north-west at an angle of 50°, making them a rough sandy slate.

North of the slope of Mount Misery the ground is very low and flat and little rock is shown in it except on the shores of the river Suir at low water, where, immediately above the topmost bed of fine-grained yellow sandstone are seen beds of grey earthy and sandy shale, hard but brittle, weathering to a light-brown colour, with partings of clayey shale in which marine fossils are abundant.

Mr. Salter, when he visited this locality with me, noted the occurrence of stems and other fragments of *Rhodocrinus*, and shells of the genus *Nucula* (*Ctenodonta*) and *Aviculopecten* in the beds immediately above the yellow sandstones. Over these come light-yellowish earthy friable shales, with seams of hard dark-grey calcareo-ferruginous shale, and, above these, dark-grey shales with hard thin nodular crystalline limestones all full of fossils. Above these are dark-grey thin-bedded limestones, getting thicker, lighter in colour, and more crystalline as we ascend. Large quarries are opened at Granny and Dunkitt in these thicker crinoidal limestones; and nothing but limestone, sometimes becoming suddenly magnesian, is seen for three or four miles to the north of the quarries. (See section, fig. 3.) In the shales which intervene between the massive limestones and the yellow sandstones which form the top of the Old Red, Mr. Salter noted the following fossils when with me on the occasion above referred to, *Poteriocrinus crassus, Actinocrinus polydactylus*, a species of *Platycrinus* and *Pentremites*; Corals of the genera *Michelinia, Zaphrentis*, and *Syringopora*; and the following shells; *Orthis filiaria, O. crenistria, Spirifera disjuncta, S. glabra, Athyris squamosa, Strophomena analoga, Producta Martini*, and a species of *Pileopsis* (*Acroculia*).

4. *Extent of the Old Red Sandstone, north and west of Waterford.*—The Old Red Sandstone of Waterford just described extends continuously northwards into Kilkenny, and westwards through the counties Waterford and Tipperary into Cork and Kerry. Following it northwards to Kiltorcan and Thomastown it retains the same general character as near Waterford, but a few miles north of Thomastown, it gradually thins out, and finally dies away near Goresbridge (see Explanation of sheets 147 and 157 of Irish Maps); and the Carboniferous Limestone then reposes directly on the Lower Silurian slates and the Granite of the County Carlow.

a. *The Kiltorcan Section.*—At Kiltorcan, near Ballyhale, which is a village about five miles south by west of Thomastown, in the Parish of Knocktopher, are the quarries which have become celebrated for the fossils discovered in them. For a full account of the geology of the neighbourhood I must refer to the Explanation of sheets 147 and 157 of the Irish Maps in the Memoirs of the survey; but will give here the following brief summary of it:—

The Old Red Sandstone lies at a very low angle, the lower beds gradually rising towards the east into some brown arid moorlands, one of the highest points of which is in the townland of Coolroe-beg, 785 feet above the sea. This conglomerate forms a little escarpment there overlooking the valley of the Arrigle brook, which runs northwards into the Nore below Thomastown.

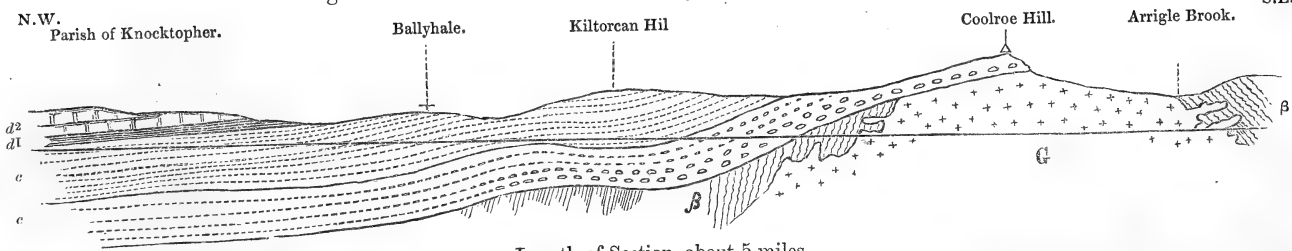
Lower Silurian slates and grits, partly altered into mica-schist, and Granite with highly crystalline greenstone, also probably of Lower Silurian age and altered by the Granite, appear from under the base of this Old Red Sandstone on the east, while towards the west it dips gently to the village of Ballyhale, where it is covered by black shales, and those again by grey limestone, as near Waterford *.

About half-way between Coolroe and Ballyhale some quarries were opened at Kiltorcan in a greenish grey flag, interstratified with brown sandstones and bright red slates. This greenish flag was luckily not affected by the slaty cleavage, and when our fossil-collector, the late James Flanagan, was assisting Mr. Wyley in the examination of the district, he discovered some large ferns and bivalve shells there. This was in the year 1851, when the late Professor Edward Forbes was with me near Cork, and we immediately inspected the district together. Forbes afterwards named the shell *Anodonta Jukesii* † and the fern *Cyclopteris Hibernica*; but M. Adolphe

* The north-west boundary of the Granite under the Old Red cannot be seen in this locality, and its place therefore is a little uncertain.

† There is much inconvenience attending this practice of affixing personal appellations to species of fossils. I can never speak or write of this shell without feeling guilty of egotism, and conscious of the appearance of a wish to thrust it into importance, because it has my own name attached to it.

Fig. 4. *Section across Kiltorcan Hill, from Knocktopher to Arrigle Brook.*




Length of Section, about 5 miles.

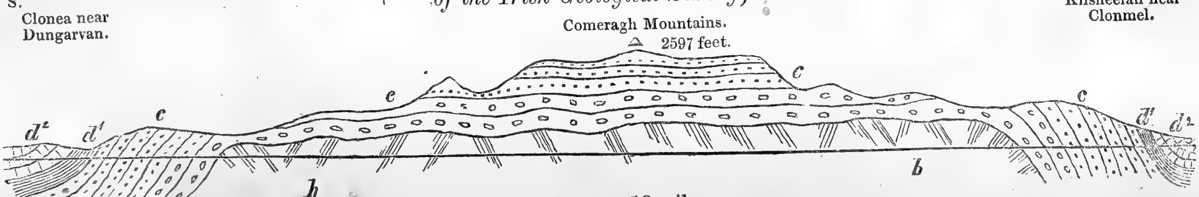
*d.* Carboniferous limestone. { $d^2$ Grey thick limestone, often magnesian. $d^1$ Dark-grey shales, fossiliferous.

*c.* Old Red Sandstone. { Yellow, green, and red sandstone and slates above, red sandstones and conglomerates below.

*b.* Lower Silurian. { Grey slates altered into a kind of mica-schist near the granite.

G. Granite.

Fig. 5. *Section across the Comeragh Mountains (reduced from Section I. sheet 13, of the longitudinal sections of the Irish Geological Survey).*




Length of Section, 18 miles.

*d.* Carboniferous limestone. { $d^2$. Grey limestone. $d^1$. Black shale and flaggy limestone. Lower limestone shale.

*c.* Old Red Sandstone. { Yellow, red, and green sandstone and slates above, red sandstones and conglomerates below.

*b.* Lower Silurian { Grey slates and grits seen in water-courses, &c., east of escarpment of mountains.

Brongniart has since referred the latter to the genus *Adiantites.* This quarry has been repeatedly visited since, especially by Mr. W. H. Baily, and our present fossil-collectors C. Galvan and Alexander McHenry, and, among other things, numerous scales and some teeth of fish have been found. Many of these scales were decided by Mr. W. H. Baily to be those of *Coccosteus*, a determination in which Professor Huxley, when he examined them, fully agreed; others, respecting which the latter gentleman felt some doubt, are believed by Mr. W. H. Baily to belong to the genera *Asterolepis*, *Bothriolepis*, *Glyptolepis*, and *Pterichthys*, or certainly to be identical with those figured by Agassiz under those names (see for figures Explanation of sheets 147 and 157 of Irish Geological Survey Maps). There is also part of the shell with a piece of the claw of a crustacean, apparently a *Eurypterus*, among the fossils from these beds. We have found the Anodon and the fern at other localities in Ireland, as near Cork and at Toe Head on the south coast, in places where the rocks were not so luckily preserved from cleavage as at Kiltorcan, so that only a few fragments could be collected in a sufficient state for transmission to the Museum*.

b. *The Comeragh Mountains.*—It was just now said that the Old Red Sandstone of Waterford was not only continuous northwards to Kiltorcan but westwards through Waterford and Tipperary.

The ridge of Old Red Sandstone, shown in fig. 3. p. 326, may be followed along the south side of the valley of the Suir for 25 miles to the westward, as far as the neighbourhood of Clonmel, the height of the ridge increasing to an altitude of 600 and 800 feet, and the dip of the beds to 50° and 60°, and occasionally more.

The Old Red Sandstone rests unconformably on Lower Silurian rocks, which for the first 20 miles are exposed in the country to the south of it, and dips northwards conformably under the Lower Limestone shale and Carboniferous Limestone, as it does at Waterford. About five miles, however, before coming to Clonmel the Old Red Sandstone, after rising steeply out from underneath the limestone valley in order to form this ridge, is no longer denuded towards the south so as to expose the Lower Silurian base on which it rests, but has been left as a cover to those beds. Doubtless this cover formerly extended over the whole of the Lower Silurian area. In the part where it is still preserved, the lower conglomerate of the Old Red, after rising up at angles of 50° or 60°, gradually flattens towards the south, and ultimately becones horizontal, or undulating gently at angles of 10° or 15° for a space of about twelve miles, and forms the base of a mass of high ground called the Comeragh Mountains. These are upwards of 2000 feet high, the highest point being 2597 feet above the sea. They end in steep indented escarpments towards the east, in which the beds are thoroughly exposed. One precipice over Lough Coumshingaun is itself 1250 feet in height, exposing horizontal beds of Old Red Sandstone through the whole height. To the south of the Comeraghs the beds dip steeply again

* Mr. Doran, the fossil-collector, also discovered a fine specimen of the Anodon in the Old Red Sandstone near Clonmel.

to the south, and the surface of the ground also falls again in that direction, but much more gently. The Old Red then passes beneath the Lower Limestone shale and Carboniferous limestone of the valley of Dungarvan, as shown in Fig. 5.

The thickness of this Old Red Sandstone is, according to Mr. Du Noyer, not less than 1700 feet near the Suir valley, increasing towards the south-west until it becomes upwards of 3000 feet north of Dungarvan (see Explanation of sheets 167 &c. of the Irish Survey Maps, and the Longitudinal section, sheet 13). The Lower Limestone shale also is materially thicker on the south of the Comeraghs than it is on the north. The black shales and the flaggy limestones near Clonea Castle, about four miles east of Dungarvan, seem, from their exposure on the shore, to have a thickness of 600 or 700 feet. They, however, as well as the limestones immediately above them, are so much affected by slaty cleavage that the bedding is often greatly obscured by it. This fact is observed by Sir H. De la Beche in the 'Memoirs of the Geological Survey,' vol. i. p. 76.

The gently undulating arch of Old Red Sandstone which forms the Comeragh Mountains, is continuous as a ridge of lofty ground for thirty-five miles to the westward, first sinking to 650 feet in the pass of Ballynamult, then rising to 2600 feet in the peaked hills called the Knockmeildown Mountains, and then dying away in the much lower Kilworth Hills south of Mitchellstown. The gentle undulations in the beds in the Comeraghs become more pronounced farther west, and the beds are folded into sharp anticlinal and synclinal curves, which let in a little trough of shale and limestone in the very centre of the hills between the Knockmeildowns and the Kilworth Hills.

The axes* of these curves then gradually sink towards the west, and the Old Red Sandstone dissappears in that direction beneath the plain of Carboniferous Limestone that extends from Mitchellstown to Mallow. The undulations in the beds, however, do not cease, the limestone beneath the plain being bent into curves like the Old Red Sandstone of the hills.

This Carboniferous Limestone, after wrapping round the extremities of the Kilworth Hills, runs down the valley of the Blackwater past Lismore and Cappoquin, and is continuous out to Dungarvan Harbour and Clonea. Between Fermoy and Dungarvan the Limestone lies in a long narrow trough, the Old Red Sandstone, which dips underneath it from the hills on the north, quickly rising out again towards the south into a persistent ridge, which stretches east and west right across this part of Ireland from Dungarvan Harbour to Doulus Head in Dingle Bay, a distance of 120 miles.

5. *Old Red Sandstone of North Cork, South Waterford, and South Kerry.*—This continuous ridge forms the northern margin of a tract of Old Red Sandstone, having a mean length of 100 miles. It is 18 miles broad at the eastern end, measuring from a little south of

* By the axis of a curve I understand the purely imaginary line about which the beds may be supposed to be bent, and not any particular mass of rock that appears at the surface.

Lismore to Knockadoon Head on the south side of Youghal Bay, and spreads to a breadth of 36 miles towards its western extremity, measuring from Rossbehy in Dingle Bay to Sheeps Head on the south side of Bantry Bay. Its southern as well as its northern margin is formed by a continuous ridge of Old Red Sandstone, stretching across Ireland from sea to sea, forming Sheeps Head on the west and Knockadoon Head on the east, the distance between them being nearly 90 miles. This large area of Old Red Sandstone is puckered into numerous anticlinal and synclinal curves, the axes of which run nearly east and west in its eastern portion, but bend to west-south-west and east-north-east on its western side. These axes also rise and fall frequently along their course, the lower beds rising out to the surface where each axis rises, the higher beds taking the ground where the axis falls. Not only do different beds of Old Red Sandstone crop up, then, as we trace the summit of an anticlinal curve, or take the ground as we follow the hollow of a synclinal trough, but in the latter case the Carboniferous Limestone is often brought in below the present surface of the ground, and preserved as a limestone trough. These limestone troughs run sometimes for many miles, until the gradual rise of the axis of each synclinal brings the lowest limestone beds to the surface, and in its prolongation the synclinal curve is traceable only in the Old Red Sandstone.

Towards the East we have first the limestone trough of *Rathcormack, Tallow*, and *Aglish*, about 24 miles long; secondly the small trough of *Clashmore*, only two miles long. Both these seem to terminate eastwardly in faults which jump the Old Red Sandstone up above the level of the limestone in the same line of strike. Thirdly we have the trough of *Youghal and Ardmore*, about 10 miles long; fourthly comes the long trough of *Midleton and Cork*, which runs westwardly from Youghal Bay to Cookstown, a distance of 55 miles*. North of the extremity of this are the minor Carboniferous troughs of *Riverstown, Blarney, Ardrum, Coachford*, and *Annaghallagh* (the latter a little south-west of the town of Macroom), all nearly on the strike of the *Ardmore and Youghal* trough. To the west of the Annahgallagh trough the undulations do not bring in any beds superior to the Old Red Sandstone itself, for a length and width of upwards of 20 miles between Dunmanway and Millstreet. A great thickness of Old Red Sandstone is exposed in this tract, as the beds in some places dip steadily north or south at angles of 50° or 60° for two or three miles continuously, clear exposures of them being observable on the sides of barren hills bare of drift. These sections show a thickness of 5000 or 6000 feet in the body of the formation, without reaching either the uppermost or the lowermost beds, and such sections are of no unfrequent

* In a hasty traverse of the country about Pembroke and Tenby, I was struck by the great similarity both in the physical geography and geology of that country to that of the Cork and Youghal district. Mr. Salter, in his paper "On the Upper Old Red Sandstone and Upper Devonian rocks," notices the identity of the beds of Pembrokeshire and South Ireland (Quart. Journ. Geol. Soc. vol. xix. p. 474 *et seq*).

occurrence. Farther west we again get Carboniferous beds in the hollows of two of the synclinals, making first the *Trough of Kenmare* with ordinary Carboniferous Limestone for about 10 miles, and Carboniferous Slate only for about 12 or 15 more. This is nearly in the strike of the *Tallow trough.* Secondly comes the *Bantry Trough,* which contains Carboniferous Slate only, and is about 40 miles long, being extended 4 or 5 miles farther to the east than it otherwise would be, in consequence of the ground rising in Shehy Mountain to a greater height than it usually does when it is formed of Carboniferous rocks. This is in the strike of the *Cork and Midleton trough.*

The two Carboniferous troughs of Kenmare and Bantry have been eroded on the west into two beautiful bays, separated from each other by a lofty Old Red Sandstone ridge, of which the highest point (Hungry Hill) is 2250 feet above the sea.

Kenmare Bay is separated from Dingle Bay by another broader and loftier promontory—that of Iveragh and Dunkerron, in which Carrantuohill (3414 feet) and Macgillicuddy's Reeks lie.

The rocks are well shown in both these promontories in numerous glens and ravines as well as upon bare hill-sides, and while they often undulate in sharp and frequent curves, especially near the centres of the districts, there are also numerous places where a steady dip of 60° either to the north or south may be observed for two or three miles; and this in places where the majority of the rocks are hard massive sandstones with thin interstratified slates, so that no mistake can be made of cleavage, or oblique lamination, for true bedding. Notwithstanding the great depths to which we can thus penetrate into those beds, there is no appearance of any change in the nature or "lie" of the rocks which would enable us to draw a lower boundary to them, or allow us to suppose that we have reached another lower formation.

The rocks consist of red, purple, brown, and greenish sandstones, sometimes becoming purplish-grey, but never black or dark-grey, and they are variously interstratified with bright-red, purple, lilac, greenish, and yellowish clay-slates. The slates occasionally predominate to such an extent as to cause the mass to assume the character of a great *clay-slate formation,* the transverse cleavage cutting across the beds generally at a high angle and with a steady strike of west-south-west and east-north-east, but dipping sometimes to one side and sometimes to the other side of their strike. Thin bands of slate between thick grits are often perfectly cleaved, the cleavage affecting the grits to such an extent as to make them break into sharp dog-toothed indentations at top and bottom, and sometimes to split readily into thin flags at right angles to the bedding.

Although the districts formed of this Old Red Sandstone have been twice diligently searched by our fossil-collectors (James Flanagan and Charles Galvan) as well as by the gentlemen who laid down the rocks upon our maps, and have been examined by many other independent observers, no trace of a fossil has, as yet, rewarded the search in either of these two promontories, except some fragments of plants in the uppermost beds, and some very obscure impressions that might be those of plants lower down in the beds near the Lakes of Killarney.

A curious track, also, in some purple slates near Valencia Island, was discovered by Mr. Kinahan. It seems to be such a row of minute indentations as might be made by the claws of some Crustacean. (See Explanation of Sheet 182, &c., p. 11.)

The uppermost part of this great series of reddish and brownish rocks is more brightly and variously coloured than the lower portion; lilac-coloured slates occurring there more frequently than elsewhere, while the peculiar kind of massive sandstone, which acquired the name of Glengarriff Grit with us, is more abundant lower down. The yellow sandstones and greenish slates which characterize the top of the Old Red in Waterford pass into harder and slatier grits further west, and purple slates make a greater figure among them; though these are by no means absent to the eastward, as may be seen in the hills south of Clonmel. Throughout the whole region, from the south side of Dungarvan Harbour to the extremities of the peninsulas south of Dingle Bay, there is hardly a trace of conglomerate in this Old Red Sandstone, the whole being essentially a clay-slate formation, with great groups of sandstone distributed through it.

6. *The Lower Limestone Shale of the Youghal and Ardmore, and the Cork and Midleton Troughs.*—In fig. 5 and its explanation it is shown that the lowest margin of the Carboniferous Limestone and the top of the Old Red Sandstone are thicker at Clonea than at Waterford. A still greater development of these shales and the sandstones associated with them is apparent in the sections about Ardmore* and Whiting Bay, and near Youghal.

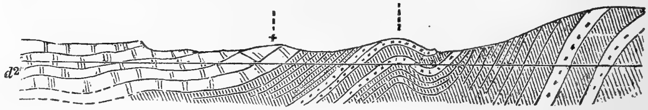
In the quarries immediately north of the latter town the thick dark-grey and brown sandstones are well shown, some of them having rippled surfaces, others showing impressions of large plants several inches across. Many of these beds were originally calcareous, and now are externally converted into rotten-stone. The dip in this locality is 70° north, and the group of shales and sandstones between the red beds and the limestone appears to be 500 yards wide, which would give a thickness of 1400 feet if the

* While going first through this district I made the mistake of looking on the uppermost thick bed of coarse sandstone as the top of the Old Red Sandstone, and thus assigned too high a position to the base of the Carboniferous shale group. The sandstones are often very similar in character through a great thickness, but by disregarding them and looking solely to the characters of the shales and slates interstratified with them, we hit on a natural boundary. As long as, in descending from the limestone, these shales or slates preserve their grey or black colours, marine fossils will often be found both in slates and sandstones; on the other hand, as long as, in ascending in the Old Red Sandstone, the shales or slates show bright-red colours, no marine fossils will be found in either. The instances of any alternation of red and grey slates are very few, even if they really exist at all, so that in an ascending section the first black slates, in a descending one the first red or purple slates, will give the boundary between the Carboniferous series and the Old Red Sandstone with great approximate exactness.

dip were steady for the whole distance. Possibly 900 feet would not be far from the real thickness.

Proceeding up the Cork and Midleton trough to the westward, the next most instructive section will be one drawn north and south through Carrickshane, near the town of Midleton, to the Old Red Sandstone hills on the north.

Fig. 6.—*Section across Bilberry Hill.*




Length of Section, $3\frac{1}{2}$ miles.

| | | |
|---|---|---|
| *d.* Carboniferous Limestone. | $d^2$. Thick-bedded grey limestone with fossils. | |
| | $d^1$. Dark-grey slates with white and brown sandstones. | |
| *c.* Old Red Sandstone ...... | Red slates with red and brown sandstones. | |

The thickness of the slates here is not exactly determinable, as the exposures are few and scattered, and one of them gives a dip of 10° to the north, indicating an anticlinal curve. The quarries and cuttings, however, which were opened at Bilberry Hill in the year 1851, when the late Edward Forbes visited this locality with me, were crowded with the little cases of Crustacea which were then called Cypris, since Cypridina, and are now known as Leperditia. Forbes was greatly struck with these "Cypris-slates," as we then called them, comparing them with those known on the continent as *Cypridina-schiefer*.

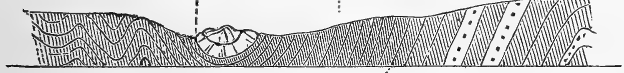
The width of the tract at Bilberry Hill, in which grey and blue slates and brownish and whitish sandstones are interposed between the massive Carboniferous Limestones and the bright-red slates and red and green sandstones of the Old Red Sandstone, is about a mile and a half, but reference to our maps will show that there is a fault as well as a curve in this tract. A list of the fossils collected in the Carboniferous Limestone near Midleton, and those found in the grey slates and grits of Bilberry Hill, drawn up by Mr. Baily, will be found in the Explanation to sheet 187 of the Irish maps. The limestone fossils include more than seventy species of Corals, Shells, &c., such as are most abundant throughout the Carboniferous Limestone of the British Islands. The fossils from the slates are fewer, and I will therefore quote the list here:—*Fenestella antiqua, Orthis Michelini, Producta Martini, Rhynchonella pleurodon, Spirifera lineata, S. striata, S. Verneuillii* (or *disjuncta*, with the variety called *Mosquensis*), *Aviculopecten nexilis, Cypricardia Phillipsii, Modiola MacAdami, Orthoceras undulatum, Leperditia* (*Cypridina*) *subrecta.*

The black slates and dark-grey grits strike steadily along the south side of the Old Red Sandstone ridge from Bilberry Hill, through the city of Cork, and on to Cookstown, everywhere dipping south at a high angle under the Carboniferous Limestone. They are, however, often concealed by the alluvial flats which are formed on them by the river Lee and the branches of Cork Harbour, but may be seen in many places about Cork; for the details of which I must refer to the Explanation of sheet 187 of the Irish Survey maps.

7. *The Knockadoon and Sheeps Head Anticlinal, and the country to the south of it, around Queenstown, Kinsale, Bandon, Skibbereen, and Carrigboy.*—The southern margin of the North Cork Old Red Sandstone district is formed by a narrow anticlinal ridge of Old Red, which, as mentioned at p. 330, stretches across Ireland from Knockadoon Head to Sheeps Head. Along the south side of this ridge the dark slates and grits which interpose between the Old Red Sandstone and Carboniferous Limestone are equally continuous, and may be followed in the first instance from the north shore of Ballycottin Bay to Queenstown, and thence by Monkstown, and Myrtle Hill near Ballea, to Ballinhassig, which is 24 miles west of Ballycottin Bay. From Ballinhassig, both the Old Red Sandstone ridge and the dark slates and grits on the south of it, may be followed for still another 26 miles to Dunmanway, and still farther west, without any break (except an occasional glen coming through the ridge) past Dromdaleague to Carrigboy, and down the north side of Dunmanus Bay, until we come to the lofty vertical cliffs of Sheeps Head itself.

For the first 20 miles, starting from Knockadoon Head on the east, the dark slates and grits dip under beds of Carboniferous Limestone on the south side of the ridge, as they do on the north side of it; but the slates and grits on the south side become materially thicker as we follow them towards the west, until about Five Mile Bridge and Ballinhassig there is no longer any Carboniferous Limestone above them.

Fig. 7.—*Section from Ballea across Myrtle Hill.*




Length of Section, about 3 miles.

| | |
|---|---|
| *d.* Carboniferous Limestone | $d^2$. Thick-bedded grey crinoidal limestone.<br>$d^1$. Dark-grey slates with grey and brown grits. |
| *c.* Old Red Sandstone ...... | Purple and green slates, and red and brown sandstones. |

In fig. 7 we get a diagrammatic section across the valley of the Owenboy River, a mile or so west of Ballea Castle. This runs by a house called Myrtle Hill, and up to one called Fir Hill, which is about 580 feet above the sea.

Some road-cuttings, and a little glen which brings a lateral brook down to the Owenboy, show the rocks well upon the sides of this hill.

The lowest beds crop out near the hill top, and consist of green and red slates, apparently horizontal or nearly so; a little farther south red slates and sandstones dip south at 40° and 50°, greenish flags and slates are occasionally interstratified with the red slates, and the dip increases as we go south up to 60° and 70°. Brown sandstones then come in, with red slates between them at first, but very soon with grey slates. Bluish or blackish grey slates lie above these, with occasional bands of brown sandstones and grey grit, the dip being steady at 50° and 60° to the south. The cleavage in the slates is also very steady dipping N. 20° W. at 80° or 85°. Grey slates are seen down to the road, a little south of which, crags of grey crinoidal limestone appear. This limestone itself is also much cleaved, so that the bedding is not determinable with any certainty.

Immediately south of this the grey slates rise out again at an angle of 30°, and are then much contorted, as may be seen in several small quarries and cuttings, but still better in the little ravine which the river has cut near Ballea Castle, on its way from this patch of limestone to the western termination of that of Carrigaline. The cleavage here also dips steadily north-north-west at 80°, through all the numerous contortions of the beds.

The thickness of the Carboniferous Limestone here cannot be very great, perhaps 200 feet at a maximum. That of the Carboniferous slate and grit is apparently about 1500 feet, while the Old Red Sandstone is exposed to a depth of 4000 or 5000 feet, the lowest beds being bright-red slates.

The fossils found in the Limestone near Ballea comprise *Amplexus coralloides*, *Spirifera pinguis*, *S. striata*, *Streptorhynchus crenistria*, *Actinocrinus variabilis*, and other common Carboniferous fossils. There are several fossil localities in the Carboniferous slate of this neighbourhood, from one or other of which the following species have been collected, the specific determinations being made by Mr. W. H. Baily.

PLANTS. *Filicites lineatus* ("linear plants").

CŒLENTERATA. *Cyathophyllum* (*Petraia*) *celticum*; *Pleurodictyum problematicum**.

POLYZOA. *Ceriopora rhombifera*; *Fenestella antiqua*.

BRACHIOPODA. *Athyris ambigua*; *Orthis Michelini*; *Producta scabricula*; *Rensselæria stringiceps*?; *Rhynchonella pleurodon*; *Spirifera cuspidata*, *S. striata*, *S. Verneuillii* (*S. disjuncta*); *Spiriferina cristata*, var., *octoplicata*; *Terebratula hastata*.

CONCHIFERA. *Avicula Damnoniensis*; *Cucullæa Hardingii*, (including the varieties *amygdalina* and *trapezium*); *Curtonotus elegans*

* This was long familiarly known to us on the Survey under the name of the "Belgooly Coral." Its identification with *Pleurodictyum problematicum* depends on Mr. W. H. Baily's authority. Doubts of the correctness of that identification having been expressed by Mr. Salter and others, Mr. Baily has re-investigated it, and still holds by his opinion that it is either that identical form, or one very closely allied to it. As it is now believed to be the mere cast of another coral, minor variations in the form are to be expected. Whatever it be, it is beyond all doubt identical with specimens from Braunton in North Devonshire.

(and the varieties *elongatus* and *rotundatus*); *Modiola MacAdami*; *Nucula*, sp.; *Sanguinolites*, sp.

GASTEROPODA. *Acroculia striata*; *Pleurotomaria*, sp.; *Turbo*, sp.

HETEROPODA. *Bellerophon subglobatus.*

CEPHALOPODA. *Orthoceras undulatum*, and others.

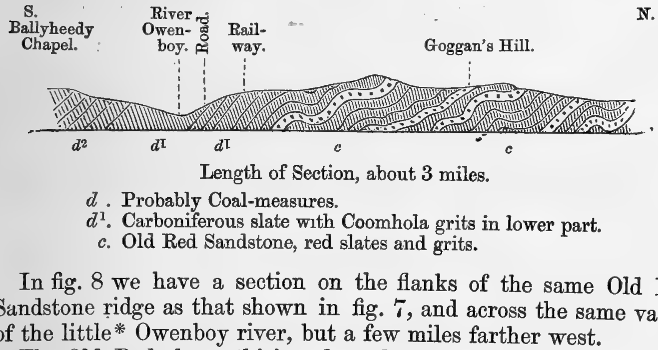
ECHINODERMATA. *Actinocrinus polydactylus*; *Cyathocrinus pinnatus*, and (? *Actinocrinus*) *variabilis*; *Platycrinus*, sp.

CRUSTACEA. *Leperditia* (*Cypridina*) *subrecta.*

Specimens of *Cucullœa* and *Curtonotus* were found at several localities (see Explanation of Sheet 187, p. 17, of the Irish Survey Maps), but always in grits, the situation of which showed them to be low down in the Carboniferous Slate. One very good locality for those shells is in a small quarry on the south side of the lane leading westwards to Coolkirky House, near the hill top. The fossils occur as casts in a band of brown sandstone, about 4 inches thick, which is almost made up of them, though similar beds both above and below do not show a single shell. Those sandstones are interstratified with beds of grey slate, all dipping north at 65° (*Ib.*, pp. 54, 55).

This occurrence of these Conchifers in vast abundance in some thin bands, and their total absence through great thicknesses of rock, is what takes place also in Devonshire, as I saw in the quarries near Braunton.

Fig. 8.—*Section near Ballinhassig.*




Length of Section, about 3 miles.

*d* . Probably Coal-measures.
$d^1$. Carboniferous slate with Coomhola grits in lower part.
*c*. Old Red Sandstone, red slates and grits.

In fig. 8 we have a section on the flanks of the same Old Red Sandstone ridge as that shown in fig. 7, and across the same valley of the little* Owenboy river, but a few miles farther west.

The Old Red shows thick red sandstones and purple slates undulating in various directions, but chiefly to north and south, and finally dipping south at a high angle, the upper beds having much green slate interstratified with the red.

South of these, strong yellowish-brown sandstones and greenish-grey and yellow flagstones and shales show themselves in the railway-cutting, and elsewhere, dipping south at 70°, and still farther south, about the railway tunnel, greenish-grey grits and grey slates undulating in many regular arches and troughs, but on the whole dipping south. Interstratified with these sandstones are dark-grey slates, which increase in number as we pass through the railway-tunnel to its southern termination, where soft dark-grey shining

* Owenbue, or Yellow River.

slates, with thin grit bands dip south at 45° or 55°. These are occasionally very fossiliferous, the species being some of those given above. Over these are bluish-black smooth lustrous slates with occasional nodules, about the size of walnuts, or larger, called "Bulls' Eyes" by the quarrymen. Down in the road, near the river, they dip south at 60°. These bluish-black slates become much paler by exposure to the weather, and might then be described as pale greenish-grey chloritic-looking slate, with a soapy feel.

On the south side of the valley, in the lane going up to Ballyheedy Chapel, we meet first with shining slate similar to that just described; but higher up, near the top of the ridge on which the Chapel stands, the slates become more earthy and blacker, and weather to a rusty brown. These are more like the shales or slates which occur in the Irish Coal-measures above the Carboniferous Limestone than ordinary Carboniferous slate; and having some reason, from the fossils contained in them, to suspect that they really were Coal-measures, I visited the district again two years ago, to search for other exposures in them, but was not successful in finding any, except one little quarry a mile and a half west-south-west of Ballyheedy at a place called Rag Bridge.

The shales or slates here dipped at 10° only, to the east, and had precisely the banded iron-stained appearance, characteristic of the Lower Coal-measure shales in Ireland. Their surfaces were covered also with small *Posidonomya**, as is so often the case with the Coal-measure shales.

The most remarkable evidence for the Coal-measure age of these shales, however, is the presence of certain small skeletons of fish, found many years ago at Ballyheedy, which, by the advice of the late Prof. E. Forbes, I submitted to Sir Philip de M. G. Egerton. He referred them to the genus *Cœlacanthus*, a genus which he informed me he had never known to occur below the Coal-measures. Mr. A. M'Henry, one of our fossil-collectors, has found during the past year some specimens very similar to these, and in precisely the same sort of black slate, in the Coal-measures of the coast of Kerry near Ballybunnion. These latter specimens occurred near the top of the cliff, a quarter of a mile north of the last exposure of Carboniferous Limestone, in beds which lie about 800 or 900 feet above the top of that Limestone.

Professor Huxley has examined both sets of specimens, and will shortly figure and describe them; he refers them to his restricted genus *Cœlacanthus*, which he also does not know as occurring below the Coal-measures.

I believe, therefore, that I am fully justified in referring these black slates of Ballyheedy to the true Coal-measures, and that we have in the section, of which fig. 9 is a sketch, the whole series from the bottom part of the Coal-measures, deep into the Old Red Sandstone, all conformably deposited. Comparing it with the section at Ballea, (fig. 7) 5 miles farther east, I believe the Carboniferous Limestone

* They would well deserve the name of *Posidonomya-schist*, the name given to beds which I believe to be the same beds in the Rhine country.

there to be merely the topmost beds of that formation, and that if the denudation had spared the rocks a little more, they would still be covered by the Coal-measures. Coming to the west, that limestone is evidently becoming debased and dying away, for in the farthest quarry to the west, while there is one good mass of Crinoidal Limestone, the chief part of it is gritty and earthy-looking, and so impure that they have ceased to quarry it for burning into lime. Black shales lie in the ground half a mile farther west, in the lane leading from Old Five Mile Bridge, and on the hill to the north of it, where impressions of *Posidonomya* are abundant.

If those black shales, and those of Ballyheedy, are really Coal-measures, it will show another analogy with Devon, where the Culm-measures (which are exactly like the Irish Coal-measures) rest on the Carboniferous slate without the possibility of drawing any decided line between the two*.

The most obvious conclusion, on comparing the sections of Waterford and Kilkenny with those of Midleton, Ballea, and Ballinhassig (figs. 2 to 8), is doubtless that the Lower Limestone shale has expanded to the south-west, independently of any change in the Carboniferous Limestone, and that the beds which form the base of the Limestone at Ballea are the same beds which are the base of the Limestone at Waterford, for instance. This, however, is not a necessary conclusion, and I now believe that the limestones die away from below upwards in proportion as the shales or slates become thicker; so that what appear to be the lowest beds of Carboniferous Limestone in the south-west, are on the same geological horizon as the upper beds of the limestone to the east and north.

Owing to the want of continuous sections, and the frequent undulations of the beds, it is impossible to assign very accurate thicknesses to the several rock-groups in the Ballinhassig section, fig. 8. Perhaps we might calculate the Ballyheedy Coal-measures at 500 or 600 feet thick; the thickness of exposed Old Red Sandstone as 1500 feet; and the Carboniferous Slate, between the two, as showing a thickness, which may be as little as 3000 feet, but may be as much as 5000 feet, or more.

8. *Old Head of Kinsale.*—The greater estimate is certainly not too great for the thickness of the Carboniferous slate a little farther south, about Kinsale for instance. The narrow promontory which is known as the Old Head of Kinsale stretches out to the south for 3 miles, with vertical cliffs on each side of it. The beds strike east and west from one cliff to the other, and can be examined on both sides from a boat, and are occasionally accessible on land. Their general dip is north, at angles varying from 40° to 80° or 90°.

* Mr. Godwin-Austen describes the limestone of Ugbrook Park, near Newton Bushel, in South Devon, as Carboniferous Limestone with Devonian (or *Stringocephalus* Limestone) below it. Although I have not yet been able to visit the locality, I have no doubt of its being accurately described by Mr. Godwin-Austen, and that the Ugbrook Park Limestone is like that of Ballea, just the uppermost beds of the true Carboniferous Limestone, with the Carboniferous Slate lying under it, enclosing inliers of *Stringocephalus* Limestone, and some of the peculiar forms of fossils to which the name "Devonian" has been assigned.

At the extreme southern point of the head they consist of hard greenish-grey grits, which we at first took for the upper part of the Old Red Sandstone, but which are the same as those afterwards called the Coomhola grits.

These undulate in very regular troughs and saddles, dipping north and south respectively at angles of 40° or 50°. Over them comes a great series of grey slates and grey and greenish grits, the dip being steady to the north at 60°, for a distance of a mile and a half. The beds then become more purely argillaceous, black shining slates, with occasional bands of nodules, and grey slate weathering to a light-green tint with a soapy feel. The cleavage is often vertical, but in Holeopen Bay was noted by Mr. Du Noyer as dipping to south-south-east at 60°, and again in another place to north-north-west, at 80°. To the northward of Ringalusky point and Black Head, undulations occur again in beds of grey slate, but still with a general dip to the north, until we reach Ballymackean on the east coast, and Lispatrick Lower on the west, where the promontory unites with the main outline of the coast. The slates here are black, and carbonaceous, and on the Lispatrick side there occur numerous specimens of *Posidonomya Becheri*, *Goniatites*, and small *Orthoceratites*, making it probable that we here again have some of the basal shales of the Coal-measures brought in on the top of the Carboniferous Slate. Immediately to the north of this the beds rise again to the north for a long way, as may be seen by following the cliffs, eastwards towards Kinsale Harbour, or westwards along the shores of Courtmacsherry Bay.

Mr. Du Noyer, after making all allowance for the undulations of the beds, calculated that the thickness exposed in the cliffs of the Old Head promontory cannot be less than 6500 feet (see Explanation of sheet 194, &c. p. 23).

9. *Cape Clear and Mizen Head Anticlinals.*—Between Ballinhassig and the Old Head of Kinsale, a distance of 15 miles from north to south, no Old Red Sandstone reaches the surface from underneath the Carboniferous slate, notwithstanding the numerous anticlinal and synclinal curves which run through the country. Proceeding towards the west, however, two main anticlinal ridges of Old Red rise gradually from underneath the Carboniferous slate, increasing in width and importance as we proceed further west, and terminating, the southern one in Cape Clear Island, and the other in the Mizen Head. Minor undulations also bring up the Red Rocks on both sides of Clonakilty Bay, forming the headlands called the Seven Heads and Galley Head, and also in Roaring Water Bay, continually sub-dividing and narrowing the area of Carboniferous Slate.

The Old Red of the Mizen Head anticlinal makes its first appearance in the hill of Knockawadra, 5 miles south of Dunmanway *, stretching thence to the Mizen Head. It was on the south side of

* In our published maps, this anticlinal is marked as showing Old Red Sandstone several miles farther to the eastward; but I now believe that the strong green grits and slates which were at first supposed to indicate the top of the Old Red Sandstone, belong in reality to the Coomhola grits in the Carboniferous Slate.

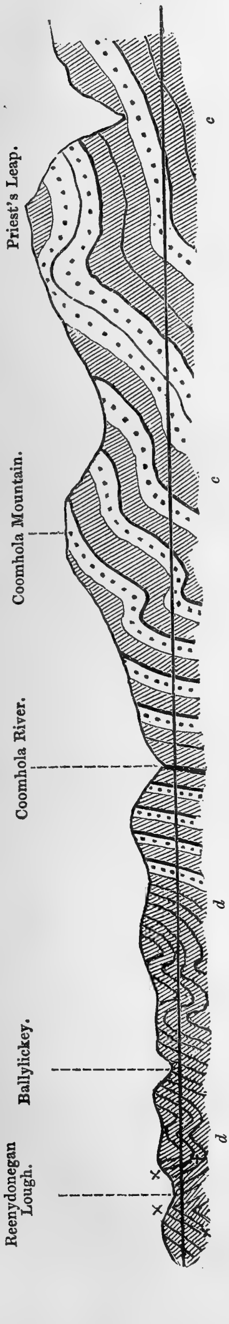



Fig. 9.—*Section from Reenydonegan Lough across Coomhola Mountain to Priest's Leap.*

Length of Section, about 7 miles.

*d.* Carboniferous Slate ...... { Black glossy slates with (XX) calcareous bands in the upper part, and hard siliceous greenish-grey grits (Coomhola grits) in the lower part.

*c.* Old Red Sandstone ...... { Alternations of purple and green clay-slates, and purple and green grits; some of a peculiar type, called "Glengariff Grits."

this anticlinal, 2 miles north-west of the town of Skibbereen, in a lane running by the R. C. Chapel of Abbeystrowry, in the townland of Mohanagh (just under the name Clasheenagnaw, as engraved on the one-inch map), that Mr. Salter and the late James Flanagan and I met with the large casts of *Cucullæa*, and other fossils mentioned in a paper by Mr. Salter and myself, published in the 'Journal of the Dublin Geological Society,' vol. vii.,—"rounded, sharply keeled, and trilobated species of *Bellerophon*" were found here, as well as a large *Lingula*, the large *Cucullæa*, called afterwards by Mr. Salter *Cucullæa Griffithii*, abundance of *Avicula Damnoniensis* and *Rhynchonella pleurodon*, and other shells.

10. *The Bantry Bay Trough.*—On the northern side of the Mizen Head anticlinal lies the trough of Carboniferous Slate, the western extension of which runs down Dunmanus Bay. On the northern side of that trough we again come back to the ridge of Old Red mentioned before as stretching from Knockadoon Head to Sheeps Head, and forming the southern margin of the North Cork Old Red Sandstone district. The exposure of Old Red Sandstone in this ridge is very narrow just south of the town of Bantry, the beds being nearly vertical, with almost vertical beds of Carboniferous Slate (containing Coomhola Grits) on each side of it. The intervening space of red slates and grits is barely a mile wide in one part.

To the northward of this lies

the Bantry Bay trough of Carboniferous Slate, which is five miles in width. The beds are admirably exposed in the cliffs on both sides of the Bay and in the various hill-sides and brook-channels, as far into the country as the eastern base of Shehy Mountain (See Explanation of Sheets 192, &c., of 193, of 197, &c., and of 198; also Sections, sheets 19, &c.). Fig. 9 is a section on the north side of this trough in the neighbourhood of Coomhola.

The beds may be thoroughly examined here, either on the sides of the Coomhola River above Snave Bridge, or on the shores of the Bay from Reenagough Point into Glengariff Harbour. Fossils may be got from the shores about Reenagough and Ardaturrish Points pretty plentifully, but only with much labour and breaking-up of the rocks by strong and heavy hammers.

The dip here is steady to the south by east at 75° or 80° for a mile and a half at least, with scarcely an interval in which rock is not observable.

If we take the distance across the edges of the beds at 8000 feet, and allow a dip of 75°, this gives us a thickness of 7760 feet. Of this thickness we may assign 4000 feet to the Old Red Sandstone, taking the uppermost bed of purple slate as its upper boundary. This boundary may be seen at a little cove on the northern part of Ardaturrish townland, where the shore bends to the westward in one direction, and southwards in the other. South of that there are no red rocks, the grits being all greenish-grey, and interstratified with dark-grey or black slates. The beds of grit are 2 or 3 feet thick, and they occur in groups 200 or 300 feet in thickness, with bands of grey slate of similar thickness between them. They strike steadily from this shore through the Coomhola Glen and along the hill-sides for ten miles to the eastward, and are frequently and largely exposed through the whole distance. They must have an aggregate thickness of at least 3000 feet. Above them is a great thickness of black shining slate, probably 2000 or 3000 feet more, in the upper part of which are calcareous bands, becoming in some places crystalline limestone in beds of 2 feet in thickness.

Mr. Salter and I, with James Flanagan, collected the following fossils when examining the Ardaturrish shore several years ago:—*Linear Plants*, both in the uppermost red rocks and the lowest grey beds; and a stem of the plant called *Knorria* (? *Sagenaria*) in the grey grits*; *Avicula Damnoniensis*, *Cucullæa trapezium*, *Curtonotus elegans*; species of *Lingula*, *Modiola*, *Pileopsis*, *Cythere* (*Leperditia*), besides *Rhynchonella pleurodon* and other Carboniferous Brachiopoda. In the more purely argillaceous parts of the Carboniferous slate, and especially in the calcareous portions of it, Encrinites and Brachiopods abound, the principal of the latter belonging,

* In the fine work lately published by the Société des Sciences Naturelles, of Strasburg, entitled 'Le Terrain de Transition des Vosges,' by J. Kœchlin-Schlumberger and Prof. W. Ph. Schimper, the latter learned gentleman has described and figured several fine specimens of these plants, which seem to be precisely identical with those which are so abundant in the upper part of the Old Red and the lower part of the Carboniferous Slate of Ireland.

according to Mr. Baily's determinations and Mr. Davidson's confirmation of them, to *Athyris Royssii* or *A. concentrica*, *Chonetes Hardrensis*, *Cyrtina heteroclita?*, *Producta scabricula*, *P. semireticulata*, *Rhynchonella pleurodon*, *Streptorhynchus crenistria*, *Spirifera laminosa*, *S. striata S. Verneuillii* (*disjuncta*), and *Spiriferina cristata*, var. *octoplicata*.

These are especially numerous at Reenydonegan point, which is made of about the highest beds of the district, where *Phillipsia pustulata* was to be got in great abundance, and where, in addition to the above-enumerated species, the following were also procured:—

*Alveolites depressa*, *Chœtetes tumidus*, *Cyathophyllum* (*Petraia*) *celticum*, *Fenestella antiqua*, *Glauconome pluma*, *Polypora laxa*, *Pullastra bistriata*, *Acroculia vetusta*, *Bellerophon subglobatus*, and *Cyathocrinus variabilis*.

Although the highest in the district now, and 5000 or 6000 feet, at least, above the top of the Old Red Sandstone, it must be recollected that we have no proof of these being originally the highest beds of the Carboniferous slate.

11. *The Berehaven Promontory and that of Iveragh and Dunkerron.*—We can penetrate in many directions to a depth of many thousand feet into the Old Red Sandstone by means of the numerous glens and ravines in the Glengariff country and throughout the mountainous ground between the valleys of Bantry and Kenmare, or in that between Kenmare and Dingle Bay. In some of these deep recesses, which cut directly across highly inclined beds dipping steadily in one direction for a mile or two at a time, we must come down to beds which are 8000 or 10,000 feet below the base of the Carboniferous Slate. In no one instance, however, either there or elsewhere throughout Ireland, did we find any dark-grey slate or any marine organic remains in or below the Old Red Sandstone, until we came down to Silurian rocks and fossils. The prevailing colours of the rocks are red of different tints, alternating with different shades of green. Massive sets of grits (of a kind called by us Glengariff Grits) and thick bands of slate occur of both these hues; but no change, either lithological, palæontological, or stratigraphical, which would enable us to draw a lower boundary to the Old Red Sandstone, and say that we had got into any other formation lying below it, is to be found south of Dingle Bay.

Sir R. I. Griffith does indeed draw a boundary in the middle of these red rocks, and considers their upper part only to be Old Red Sandstone, and the lower to be Uppermost Silurian. I believe, however, that this has been done in order to make the divisions south of Dingle Bay analogous to those in the promontory immediately to the north of it. We were unable to discover any characters which would enable us independently to make such a subdivision to the south of that Bay. That the upper portion, at least, of this great mass is really Old Red Sandstone is beyond a doubt, since it is physically continuous with those masses in the eastern part of Cork, and in the counties of Waterford and Wexford, to which no English geologist could refuse that name.

12. *Dingle Beds.*—Although it has no direct bearing on the subject of this paper, it may still be pointed out that in the promontory north of Dingle Bay, the Old Red Sandstone differs somewhat from that just described, both in lithological character and in the thickness and lie of the beds.

In the Dingle Promontory the Old Red Sandstone contains much more conglomerate than it does south of Dingle Bay. It has large masses of quartzose conglomerate, and also a very singular local mass containing chiefly angular fragments of granite, gneiss, mica-schist, felstone, and gritstone. This is sometimes as much as 400 feet thick, but thins out rapidly in each direction. We have spoken of it as the "Inch Conglomerate" (see Mr. Du Noyer's descriptions in Explanation of Sheet 160, &c., pp. 6, 14, and 41).

This Old Red Sandstone rises conformably from under the base of the Carboniferous Limestone and has a thickness of 3,000 or 4,000 feet, but it rests quite unconformably on some highly inclined red rocks,—slates, sandstones, and conglomerates,—which have a much greater thickness and a rather different lithological character. These seem to repose conformably on Ludlow and Wenlock rocks at Dunquin and Ferriter's Cove. We have provisionally designated them as the DINGLE BEDS. They are at least 10,000 feet thick. Their conglomerates differ both from the Inch and the quartzose conglomerates of the Old Red Sandstone, their pebbles being chiefly rounded and angular pieces of brown sandstone, in some of which Llandovery fossils were found. The Dingle beds also contain beds of blood-red slates of a brighter colour than any usual in the Old Red Sandstone of Cork or Kerry. On the other hand, their sandstones and gritstones are very much the same as those found in the rocks of the Iveragh and Dunkerron Promontory, south of Dingle Bay, especially some peculiar-looking sandstones lithologically identical with the "Glengariff Grits."

While, then, I cannot by any means feel sure that some of the lowest rocks seen in the country south of Dingle Bay are not the DINGLE BEDS, it was thought best not to assert that as a fact without further proof, and each district has therefore been coloured in our maps according to its own evidence. In the Dingle Promontory the beds on which the Old Red Sandstone rests unconformably are separated from it as "Dingle Beds." In the maps of the other district the colour used to distinguish the uppermost beds, which are undoubtedly Old Red Sandstone, is continued over the lower ones because we failed to discover any characters which would enable us to draw a lower boundary to them.

13. *Gradual Changes in Lithological Character.*—It must not be forgotten that in thus tracing these continuous masses of rock across such large portions of Ireland there occur gradual lithological changes in them, which might easily mislead an observer who saw them only at distant intervals. Any one who visited only the Old Red Sandstone of Waterford, and then went at once to Glengariff in Bantry Bay, without examining the intermediate district, might decline to believe that the Old Red Sandstone there was part of the

same formation as that of Waterford. In like manner any one who studied only the Carboniferous Slate about Cork Harbour, or even about Kinsale, might look upon the Coomhola Grit portion of that group in Bantry Bay, and in the western Headlands of Cork, as something wholly different.

I can speak from personal experience on this point, as I myself made mistakes when first mapping the rocks of Bantry Bay, trusting to the ideas gained about Cork Harbour. The identity of the rather dissimilar rocks in different parts of the country came out as the final result only of the Survey, when the beds had been patiently laid down on the six-inch maps (in the course of several years' labour), entering on those maps merely the data shown in each locality as it was passed through. The monotony of this task can scarcely be understood by amateur geologists, who are at liberty to select their localities and pick out the more interesting and important bits. Its value, however, becomes understood on its completion, when the results are gathered from a mass of data collected by different observers working independently without any foregone conclusions to vitiate their observations.

14. *General Conclusions on the Rocks of the South-west of Ireland.*—One general conclusion may be briefly stated as the result of the examination of the western part of the county Cork, namely, that there are two great formations in it, the Old Red Sandstone below, and the Carboniferous Slate above; the Old Red Sandstone containing no marine fossils and scarcely any fossils at all, except plants in its upper portion; the Carboniferous Slate containing some of these plants, but also marine fossils, sometimes in great profusion. The Old Red Sandstone has a prevailing red tinge throughout, with no beds of black or bluish-grey slate; the Carboniferous Slate has a prevailing black or bluish-grey colour, with no beds of a red tinge. Both are greatly affected by slaty cleavage.

It may also be stated that where the Carboniferous Slate and Carboniferous Limestone are both present together, the Carboniferous Limestone is uppermost; but that where the Carboniferous Limestone has a thickness of 2000 feet, or upwards, the dark slates between it and the Old Red Sandstone are very thin, rarely more than 200 feet in thickness; while where these dark slates thicken out to more than 2000 feet, there is no great thickness of Carboniferous Limestone over them. Where the Carboniferous Slate attains a still greater thickness, and swells out to three, four, or five thousand feet, it has never any Carboniferous Limestone over it at all, but there appear here and there patches of black slate upon it, which both lithologically and palæontologically resemble the Coal-measures. If so, the Carboniferous Slate occupies, there, the whole interval between the top of the Old Red Sandstone and the base of the Coal-measures, with a perfectly conformable and continuous series of beds to the exclusion of the Carboniferous Limestone; and therefore replaces that Limestone. Dark grey mud and sand were at first deposited over the whole area, but were subsequently restricted to a part of it, where they continued to be deposited in great quantity; while in the rest of the area clear water prevailed, in which limestone was formed from the Crinoids and other animals that flourished in that part.

15. *Sudden Changes from thick Limestone to Mechanically formed Rocks.*—Many persons may feel a difficulty in supposing it possible that a sudden change can take place from thick limestones to mere slates and sandstones. My own experience among coral-reefs, however, relieves me from any such difficulty. The barrier-reefs of the north-east coast of Australia, for instance, are continuous for about 1200 statute miles, and have a steep edge throughout that course, which in one part at least is upwards of 1800 feet in depth. They end against the coast of New Guinea, on the north side of Torres Straits, in a massive reef, called the Warrior Reef, which is itself thirty miles long and as massive, and *steep too,* though by no means so deep, as any other reef to the southward. Immediately east of it, however, the coast of New Guinea is fronted by extensive mud-flats; and shoal water, with a muddy and sandy bottom, stretches off the coast for sixty miles from the shore; and the land consists of mangrove-swamps for an unknown distance into the interior, and this for a space of 150 or 200 miles along the coast. There must then be as abrupt a change here as we can imagine, from a widely spread and continuous calcareous mass, to one consisting principally or entirely of a mechanically formed deposit.

No one can study the Carboniferous Limestone minutely without seeing that it is essentially composed of crinoidal fragments. Even in the compact parts of the limestone, examination with the lens will disclose many little shining faces of crystalline Calcite with a dot in the middle, which Professor John Phillips long ago pointed out to me as a sure indication of a crinoidal joint. The limestone has been formed by the growth of submarine forests of Encrinites; the débris of each successive generation being ground down or decomposed into calcareous mud. So far as the circumstances of depth and bottom favoured the growth of these animals, they flourished; where there occurred a sudden change in those circumstances, they ceased to grow. The very incoming of quantities of mud and sand would be one of the circumstances most likely to arrest their growth. The animals inhabiting seas with a sandy or muddy bottom would naturally be somewhat different from those living in the clear water among the forests of Crinoids. Neither would it appear to me at all surprising if, when circumstances favourable to the growth and formation of local banks of limestone occurred within the muddy and sandy area, some animals should live there of a different species or genus from those in the other part of the sea where the crinoidal forests grew.

## III. Geological Structure of North Devon.

1. *Baggy Point to Dulverton.*—In a paper read before the Dublin Geological Society* on May 10th, 1865, and published in their

* The name of this Society has lately been altered by Her Majesty's permission into that of the Royal Geological Society of Ireland, the members being empowered to call themselves Fellows thereof.

Journal, I went at length into the reasons which induced me to identify the beds about Barnstaple, Pilton, Marwood, Braunton, and Baggy Point with the Carboniferous Slate of Cork, and the red beds of Vention in Morte Bay with the top of the Old Red Sandstone of Cork.

The greenish and brownish grits, containing large *Cucullææ*, &c., known as "Marwood Sandstone," are represented in Ireland by similar sandstones with the same fossils as mentioned at pp. 336, 337. These sandstones expand in Bantry Bay into the great mass which there acquired the name of "Coomhola Grits." I believe, however, that any attempt to separate these beds, either in Devon or Ireland, as a distinct group from the Carboniferous Slate in which they lie, will merely mislead us. Both the sandstones, and the peculiar fossils which they contain, are local occurrences, either, or both of which may be present in, or absent from, the same formation in different districts. I satisfied myself during the excursion in 1861, of which the paper mentioned above gives an account, that the Old Red Sandstone which crops up in the south corner of Morte Bay, is continuous into the country at least as far as the moor called Span Head on the Ordnance Map*, a distance of about twenty miles; and that the Carboniferous Slate continues that far to the south of it. The time at my disposal did not allow me, on that occasion, to do more than take one walk from Barnstaple across to Ilfracombe and back, and what I saw during that traverse merely bewildered me. There was apparently a prevailing dip to the south all across the country, nevertheless the rocks about Ilfracombe were very unlike any that I knew of in the Old Red Sandstone of Ireland, and had a certain resemblance to parts of the Carboniferous Slate. Not finding any fossils, however, I hesitated to do more than hint at a doubt whether "the Ilfracombe beds were really below the red beds of Morte Bay," and to suggest a suspicion that they "may belong to the Carboniferous Slate rolled in to the north by contortions, and somewhat different lithologically from those farther south" (*loc. cit.* pp. 10 & 11).

After the meeting of the British Association in Birmingham last year, I hoped I had secured an opportunity of satisfying myself on this point. I had carefully re-read and made an abstract of the paper by Professor Sedgwick and Sir R. I. Murchison in the fifth volume of this Society's Transactions, and had in consequence dismissed from my mind the suspicion mentioned above, and set out with the full conviction that the rocks of the north coast, about Lynton and Ilfracombe, could not be in any way the same as those near Barnstaple, and was accordingly prepared to find a series of rocks wholly new to me.

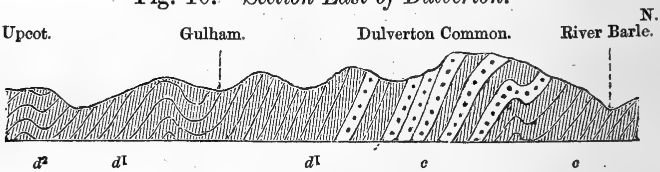
2. *Dulverton.*—I made first for Dulverton, some ten miles farther east than any ground I had yet seen. I found, as I expected from the published descriptions †, that the Carboniferous Slate and Old

* The people of the country give the name of Span Head to another hill two or three miles farther to the east.

† See especially the fossils mentioned by Phillips as occurring at Brushford, near Dulverton, in his 'Palæozoic Fossils.' I collected *Orthis interlineata* in a quarry there.

Red Sandstone of the Barnstaple district continued steady in their strike to the eastwards to at least some miles east of Dulverton. The Carboniferous Slate, however, appeared to me to be getting thinner to the eastward, apparently by reason of the dying away of the sandstones contained in it. That the Marwood Sandstones were still represented was evident from the abundance of subangular blocks and angular fragments of their peculiar kind of stone, in the lanes and ditches and fields along the strike of the lower part of the Carboniferous Slate; but they did not appear to be quarried, neither did I succeed in finding any fragments containing fossils. In the lanes near a place called Crewsball * in the Ordnance map, a mile west of Dulverton, the rocks shown in the ditches were exactly like those in similar ditches near Marwood. A mile to the east of Dulverton, too, by the lane-side going over the hill to Burry, there is one little disused quarry in which these sandstones can be partially observed, and they appeared to be perpendicular, striking E. 10° north. The cleavage in all the slate beds about Dulverton strikes about east-north-east and west-south-west, dipping either north or south at high angles. The beds also dip occasionally to the northward, showing that they are either undulated or inverted in places.

Fig. 10.—*Section East of Dulverton.*




Length of section about three miles.

*d.* Carboniferous ...... { $d^2$. Coal-measures.
{ $d^1$. Carboniferous Slate with Marwood Sandstone in lower part.

*c.* Old Red Sandstone.. { Red, yellow, and greenish sandstones interstratified with greenish and reddish slates.

The sections most interesting to me, however, near Dulverton, were those in the Old Red Sandstone, on the sides of the valleys of the rivers Barle and Exe. Just north of Dulverton, in the valley of the Barle, there are large quarries in rocks precisely identical with those seen in so many places in the south-west of Ireland at the top of the Old Red Sandstone. Hard, massive, fine-grained grits of various tints of yellowish white, pinkish red, greenish yellow, and dark-red, and purple, interstratified with bands of green and purple clay-slate, dip south or south-south-east at angles varying from 40° to 70°, with occasional short rolls to the northward. The cleavage sometimes imparts a sort of grain even to the sandstones, at right angles to the bedding. In one mass of bright-red slate, where the

* No such name as "Crewsball" was known to the people, the place being called "Willway." In like manner "Old Hollom," a neighbouring farm, ought to be "Old Burry."

beds were perpendicular, the cleavage certainly dipped north-north-west at 65°.

Higher up the valley of the Barle, the rocks and the scenery were precisely those of many valleys about Glengariff and Killarney. In the lane going up from Ashwick Bridge (a mere foot-bridge called "a clammer" over the Barle) to Dulverton common and thereabouts, there were many small exposures of rock, of which the following notes occur in my note-book:—"purple sandy slate with grit-bands, strike east-north-east, perpendicular, genuine Old Red Sandstone of Ireland." "Cleaved red sandstone, or sandy slate, precisely like Old Red Sandstone of Ireland, dip south-south-east at 40°."

Fig. 10 will give a general idea of the facts to be observed near Dulverton.

3. *Dulverton to Dunster.*—Having thus satisfied myself that the Old Red Sandstone below, and the Carboniferous Slate above, were continued thus far to the east without any material change in their characters from those that they possess in the Barnstaple country, I proceeded to explore the country to the north, and took the road to Dunster. I was disappointed in the sections on the sides of the Exe, north of Chilly Bridge. There are only occasional small road-cuttings, showing pale greenish-grey soapy slate, in which I was unable to determine the bedding with anything like certainty.

These rocks are evidently the "Green * Chlorite Schist with quartz veins" of Sedgwick and Murchison, appearing to dip under the "schists and thick sandstones, red and variegated," which are as obviously the rocks which I have just spoken of as Old Red Sandstone. The two kinds of rock were nowhere exposed in any close proximity to each other.

Respecting some cuttings a little S. of Exton, I find in my note-book a remark to the effect that "it is not easy to distinguish these from some parts of the Carboniferous Slate;" though when I wrote that, I was under the thorough conviction that I was deep in the Old Red Sandstone, or in some still lower formation. The cleavage hereabouts dipped to the south at 40°, and the beds at first sight seemed to coincide with it; though patient hammering disclosed in some places what appeared to be the lamination of deposit dipping northwards. At Eyeson Hill, between Exton and Wheddon's Cross, an iron-mine was opened on a green hill-side, from which a considerable quantity of hæmatite had been extracted. Reaching Wheddon's Cross, which stands on the crest of the watershed between the basin of the Exe and that of the Dunster brooks (and appeared by my aneroid barometer to be about 830 feet above the sea), I went to examine some old lime-quarries there. In these there were beds of grey slate, becoming in some places very calcareous, and also inclosing

* The green colour in sandstones and slates was formerly attributed to the presence of chlorite, without hesitation. It is probably quite as often due to the presence of the silicate of protoxide of iron. With respect to these slates I believe that the green colour only appears on the weathered surfaces, and that when quarried they yield dark-grey or black slates. In each case they have often a peculiar lustrous surface and soapy feel.

some beds, six or eight feet thick, of pale-grey crystalline limestone. Both beds and cleavage dipped south at 60°. I did not see any fossils, except nests of what I concluded was *Favosites polymorpha* occurring in branching clusters, somewhat as *Fenestella* does sometimes in the Carboniferous Limestone. It is probably to the growth of this coral that the limestone is due.

These calcareous bands are described by Sedgwick and Murchison as stretching from Combe-Martin to this place, and then sweeping round Croydon Hill.

4. *Dunster to Lynton.*—On the road from Dunster to Lynton, there were no good exposures of rock; though a detailed search in the beds of the brooks and the cliffs of the sea-shore would doubtless disclose sufficient to enable a hard-working geologist to make out the structure of the country. Speaking generally for Exmoor and the neighbourhood, the absence of any good continuous sections is remarkable. High, wide, gently undulating moorlands, covered with short heather, or lower cultivated ground with the same gently undulating surface, are the prevailing features of the country. It is only where the brooks cut deep into the ground on their way to the sea, or where the sea itself has cut back into the land and formed cliffs, that any rock is seen, except in a few small, widely scattered quarries and little road-cuttings.

The rocks thus shown on Porlock Hill seemed to me not unlike parts of the Irish Old Red Sandstone.

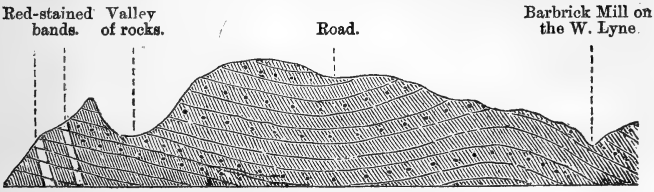
5. *Lynton* and its neighbourhood.*—My very first walk, however, after arriving at Lynton, through the Valley of Rocks and along the footpath over the cliffs, showed me, to my no small astonishment, that I was again among rocks belonging to the Carboniferous Slate.

The picturesque crags, so well known to tourists, and the cliffs, from the pebble beach on the shore to the top of the hill south of the Valley of Rocks, all showed beds which were as familiar to me as Chalk is to an inhabitant of Dover, or Oolite to the dweller in Bath or Cheltenham. The blue-grey slate with little lighter-coloured bands of grit, giving a stripe to the slates, the beds of hard grit often highly calcareous, and crowded with fragments of crinoids, and others more purely siliceous and destitute of organic remains, were all precisely identical with those which stretch for so many miles along the shores of the bays of the deeply indented coast of Cork, or sweep into the interior of that country round so many anticlinal ridges of Old Red Sandstone. The numerous fragments of Brachiopoda and all the other fossils seemed to my eyes also to be the same as those of Ireland. The colour and aspects of the weathered rocks were also exactly similar.

As the hill-tops south of the Valley of Rocks appeared from my pocket aneroid to rise to a height of 1300 feet above the sea, and the rocks dipped south at 10° or 15°, there could hardly be a less thickness seen in them than 1500 feet, and they are so well exposed that almost every bed might be seen somewhere or other (see fig. 11).

* In almost all geological works this name is spelt Linton. In the place itself, however, it is always written Lynton, and the river is called the Lyne.

Fig. 11.—*Section across the Valley of Rocks.*




Length of section about $1\frac{1}{2}$ mile.

Dark bluish-grey slate with calcareous and quartzose grit bands, the lower or Coomhola-grit part of the Carboniferous Slate.

Along the coast, and in parts of the interior, the grey rocks are stained externally of a bright red in parallel bands.

Subsequent explorations along the coast by Woodabay to Heddons Mouth and round by Parracombe, up the glens of the East and West Lyne, and across the country to Simonsbath, only confirmed me in the conviction that the whole, or nearly the whole, of the district consisted of Carboniferous Slate. Whether the upper part of the Old Red Sandstone rises from beneath it in a narrow anticlinal curve, or even more than one, anywhere between the coast and the watershed of the Exmoor ridge *, or whether the brown sandstones and thick green grits which I saw in the bed of the brook near Sparhanger, and in a little quarry on Farley Down, were in the Carboniferous Slate (a part of the Coomhola Grit), I could not exactly decide.

There was also a band of rock at Lynton, in the Carboniferous Slate, rather different from any I know in Ireland. This is a mass of greenish, close-grained, siliceous grit, with liver-coloured blotches, which is perhaps 200 feet thick, and from its hardness often makes a conspicuous feature. It is shown in the cuttings of the upper part of the road from Lynemouth to Lynton, and the Castle Hotel at the latter place stands on it. In some places there are small beds or still smaller patches of grey clay-slate in it. In the road-cutting it sometimes assumed the appearance of a bright-red grit, but diligent hammering showed that this red colour was an external stain derived from the peroxidation of some ferruginous vein-stuff, which had filtered into all the joints and crevices of the rock. All along the cliffs, from Lynton to Heddons Mouth, the grey rocks are similarly stained by one or two parallel bands of bright-

* Just as I was sending in this paper to the Society, I received the February number of the Journal (No. 85), and in the paper by Mr. Godwin-Austen on the submerged forest of Porlock, I perceive the rocks about Porlock, and thence to the valley of the East Lyne, described as "hard, splintery sandstones, grits, and pebble beds, with partings of compact shale, the whole series being of various shades of red," and "very distinct from the grey slaty rocks with calcareous bands" and marine fossils which extend southwards from Lynton. This confirms the suspicion I had formed that the Old Red Sandstone, which must lie at no very great depth under the Lynton rocks, rises to the surface towards the east, perhaps in one low anticlinal, perhaps in more than one, the axes of which strike nearly east and west, with a slight rise towards the east.

red ferruginous matter, 20 or 30 feet in width, striking steadily with the strike of the rocks, but dipping south at much higher angles. The rocks dip south at angles gradually increasing from 5° to 30°, but the red ferruginous bands are inclined at angles of 50° or 60°. The rock thus stained red externally, is dark grey when first broken open, but the red ochre is in such quantities, and so readily stains the hammer and the fingers, that even a fresh fracture is apt to get raddled soon after it is broken, if precautions are not taken to prevent it.

These red ferruginous bands are very deceptive when viewed from a little distance, and especially when seen from a boat, as they look precisely like beds of red rock, and have, I believe, been taken for such beds by some previous observers.

I believe I detected the origin of the ochre, at the cove of Heddons Mouth, in little plates and strings of hæmatite in the quartz veins there. These quartz veins traversed certain beds of rock in great quantity without penetrating beyond them, either above or below; and the hæmitite occurring as nests in their cavities would when weathered be naturally converted into red ochre.

I also observed at Heddons Mouth a mass of grey grit, curiously marked on the surface with wavy interrupted lines or narrow bands, like the edges of compressed cups of *Fenestella* in the Carboniferous Limestone*, and on breaking open the rock, I found them to be similarly due to undulating sheets of *Fenestella,* or of some closely allied form.

The cleavage of the rocks from Lynton to Heddons Mouth dips everywhere south or south-south-east, usually at an angle of 50° or 60°; but in two places, where the beds were horizontal, I find it recorded in my note-book as dipping at as low an angle as 15°. The beds at Heddons Mouth dip south at 20°; east of Woodabay the angle increases to 30°, but as the shore bends to the north, the angle flattens to 15° and 5°, and just west of Lynmouth the beds are horizontal. I did not visit the headland east of this, under Countesbury, but from the deck of the steamer the beds seemed certainly to dip at a high angle to the north, as drawn in Sir H. De la Beche's sketch-section in the Report on Cornwall, Devon, and West Somersetshire.

Proceeding inland the beds undulate at gentle angles, as may be seen in the valley of the East Lyne and elsewhere. A little farther south, however, there appears to be a higher northern dip. Greenish-grey grits and gritty slates dip north-west at 45° in the bed of the brook near Sparhanger, and bluish grey slate and brown grits dip north-north-west at 20° in some quarries near Brendon. If the rocks rise to the south persistently for any distance south of this, the top of the Old Red Sandstone will probably reach the surface. I did not see any rock for some miles to the southward, except one small quarry near Farley Common, where a brownish sandstone dipped south-west at 30°.

* Mr. A. B. Wynne, now of the Indian Survey, first called my attention in Ireland to the fact that these wavy markings were the edges of undulating sheets and cups of *Fenestella.*

Fig. 12.—*Section Lynmouth to Simonsbath.*


Length of the section about seven miles.

The rocks near the coast at the north end of the section as far as Brendon are dark-grey slates and grits (lower part of the Carboniferous Slate). Those about the heads of the rivers Exe and Barle are dark-grey slates without grits (higher parts of the Carboniferous Slate). The sandstone near Farley is doubtful. In the other parts nothing was seen.

This sandstone might be either part of the Old Red Sandstone or a Coomhola grit. No rock was to be seen for three miles south of this, on or near to the road to Simonsbath, until I came to a place where the road crossed a little rocky ravine with a small brook, which the driver declared was the head of the Exe*.

The rock shown here was a bluish-grey, shining, clay-slate, precisely like some parts of the Carboniferous Slate of Ireland, which appeared to dip south at 10°. Near Simonsbath similar slate, but paler, appeared to dip south at 30°. At both places the cleavage dips south at 70° or 75°, and as there were no decided grit bands, and no layers of fossils, or any appearance of fossils at all, it was with some doubt that I decided on the dip of the beds.

The section in fig. 12 will show the above facts in a diagrammatic form, starting from a point a mile east of Lymmouth and crossing the country to Simonsbath.

The green little open valley of Simonsbath was very similar in aspect to valleys in the Carboniferous Slate in Ireland, and I greatly regret that I was unfortunately prevented from returning here, as I intended, to trace the Barle down to the part where it runs in a deeper and wilder glen through the Old Red Sandstone north of Dulverton; for it is there that I should most hope to find sufficient exposures

* The people at Simonsbath assured me that this was the place called Prayway, which, on the Ordnance map, is placed at the head of another stream. The map was, indeed, nearly useless here, as neither the roads, rivers, nor features of ground marked on it agreed with the existing ones.

of rock to enable one to observe directly the relations of the rock-groups to each other.

Returning to Lynton I collected a few fossils in the grey calcareous grits on each side of the Valley of Rocks, and *snatched* rather than *collected* some blocks full of fossils from a set of fragments that had slipped from the cliffs above into the valley of the East Lyne. I believe the fossiliferous beds near the hill-tops of the valley of East Lyne to be very nearly on the same horizon with those of the Valley of Rocks, and to be above the hard siliceous grit-band mentioned above as exposed in the road cuttings down from Lynton to Lynmouth; so that fossils may probably be found almost everywhere in the upper part of these hill-sides. I found them certainly at several places in the lanes and fields above Lynton, south of the Valley of Rocks, in grits that weathered to a reddish brown.

These fossils were examined by Mr. W. H. Baily, and Mr. Davidson was also kind enough to look at the Brachiopoda for me. On the authority of those gentlemen they contained the following species:—

Fenestella antiqua.
Athyris concentrica.
Chonetes sordida*.
Rhynchonella, sp.?
Spirifera aperturata†? *or* caudifera.
—— hysterica?
—— lævicosta (ostiolata, *Schlot.*).
Spirifera speciosa, *var.* paradoxa.
Streptorhynchus crenistria? *or* umbraculum.
Pleurotomaria aspera.
Actinocrinus (*or* Cyathocrinus) variabilis.
Cyathocrinus ellipticus.
Phacops latifrons.

There is one little quarry on the hill-top, south of the Valley of Rocks, near where a small tumulus‡ is marked on the Ordnance map, in a grey and reddish mottled calcareous-looking rock, which is full of fossils, especially *Fenestella* and a small *Orthis* or *Chonetes*. The beds in this quarry dip south at 30°.

6. *Lynton to Ilfracombe.*—Proceeding from Lynton to Ilfracombe, I was again disappointed in my expectations of seeing new quarries or cuttings on or near the road, which keeps as much as possible on the high ground. As before, near Exmoor, this high ground shows a gently undulating dreary-looking expanse, rising into continuous moorlands towards the interior, and ending in lofty cliffs along the coast. The unbroken outline of the moorland watershed, and the gradual increase in the number and depth of the gullies and ravines that run off on either side of it, attest the influence of the rain, and its resulting rivers, in carving out all the picturesque features of the

* Mr. Davidson seems to be of opinion that this is only a variety of the Carboniferous species, *Hardrensis* (Devonian Brach. p. 94).

† [Fragments and imperfect casts of a large *Spirifera*, with irregular and wide ribs, beautifully covered with very fine, close, concentric lines, which Mr. Davidson says he could not determine to his satisfaction; adding that it is probably to a fragment of this shell that Phillips applied Schlotheim's term *Spirifera aperturata* (Pal. Foss. Cornwall, &c. p. 77. pl. xxx. fig. 133). See also Mr. Davidson's remarks, at pp. 26 & 116 of his "Devonian Fossils" in Mem. Pal. Soc.).] Note by Mr. Baily.

‡ Curiously enough I found this tumulus to be, not a regular conical mound or *cairn*, like those which are common in Wales and in many parts of England, but a circular rampart, exactly like the "Raths" scattered over the south of Ireland.

country. Had the ravines been in any way due to internal disturbances and dislocations (a belief which still seems to linger in the minds of some geologists of eminence), why did not some of them cause at least one ravine to cross the present watershed? The rocks must be as much disturbed about the watershed as anywhere else, according to any hypothesis as to the internal structure of the country; but the surface is an unbroken, gently undulating, upland plain or moor.

There is one quarry on the left of the road, about a mile south-west of Parracombe, near the hill-top before reaching the turnpike, which showed a glossy-black slate with some dove-coloured sandstones, over which were some black, earthy, carbonaceous-looking slates, all dipping south at 30°. I was half inclined at first to look upon these as possibly the base of the Coal-measures rolled in, as a small basin, but was unable to find any fossils in them. Subsequently I saw beds like the grits near Ilfracombe.

Going down the hill into Ilfracombe I again examined the quarries which had formerly puzzled me; but was again baffled, and unable to come to any decided opinion as to the dip of the beds. A very strong cleavage dipping south at a high angle, obliterates the stratification.

Walking to the east, however, from Ilfracombe as far as the bathing place called Rapparee Cove, and thence over the hill to Helesborough, I met with rocks of unmistakeable characters. The dark slates with occasional grit-bands are precisely those of Kinsale Harbour, for instance, or of so many other places in County Cork. These slates lie higher in the series than those in which the Coomhola grits occur. The grits they do contain are usually in single beds and are unfossiliferous. The slates, too, are often unfossiliferous in Ireland through a thickness of one or two thousand feet and an extent of many miles. The general dip of these rocks, east of Ilfracombe, is certainly to the south, at angles varying from 30° to 60°, but this dip is by no means so persistent as it at first appears.

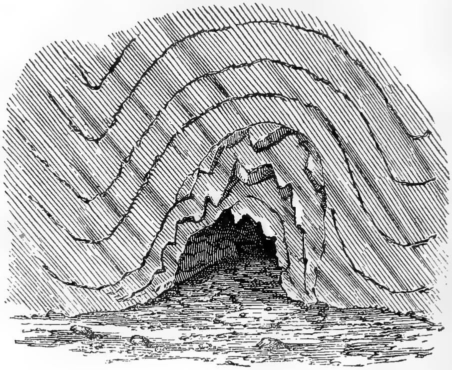
As it is possible that some young geologist, unaccustomed to cleavage in rocks, may visit this spot, perhaps I may be pardoned for entering a little into details which may serve to guide his observations.

Keeping along the south side of the harbour towards the bathing-cove, which the boatman called Rapparee Cove, he will see a limekiln, near which there is a little cavernous hole under the cliff.

The arched roof of this little cavern nearly coincides with a curve in the beds, as shown by the narrow bands, differing slightly in colour and grain (the "stripe" of Professor Sedgwick), which indicate the original bedding of the rock. The cleavage, however, dips steadily to the south at 66° (see fig. 13).

A still more striking example presents itself in Rapparee Cove. This is a small pebbly cove, some 50 yards across, surrounded, except at the seaward opening, by vertical cliffs 40 or 50 feet high. The rocks are dark-grey slate, with two single beds of grey grit appearing in the western cliff, both dipping steadily to the south at 50° or thereabouts. This dip is so obvious that an observer might readily be pardoned who entered it in his note-book as the dip of the whole mass of rock, and allowed it to form an element in his calculations for the thickness of the group. I was at first doing so myself; and had there been a path out of the cove to the eastward, might have been satisfied with the observation, and passed on. The only entrance to the cove by land, however, is by some steps cut in the cliff, near the foot of which is a wooden bathing-house; and on returning towards the steps my attention was attracted by a sharp little ridge of gritstone that rose up from among the pebbles on the floor of the cove, and ran towards the northern corner of the bathing house.

Fig. 13.



Small cavity near limekiln, half a mile east of Ilfracombe, showing contorted beds traversed by slaty cleavage.

Fig. 14.

Small Anticlinal ridge in Rapparee Cove, near Ilfracombe.

This little ridge of grit had a steep face to the north, on which was a well-developed "ripple" or "current-mark." As this could have been formed only on the upper surface of the bed, I saw at once that the little ridge was the top of a sharp anticlinal fold, of which no trace appeared in the cliff of slate above it. Neither was this the only one, for some other crumpled grits showed themselves a little farther south, on the floor of the cove.

These undulations greatly reduced the thickness, which the appearance of the two grit-bands on the western cliff, dipping steadily south, and so far apart from each other, would have led me at first to assign to the rocks shown in the cove. Nor was this all, for on looking more attentively I found that the two grit-bands, which seemed to strike so steadily towards the east in the western cliff, did not appear in the eastern cliff of the cove at all, but were cut off by some fault or "trouble" at the south-east corner of the cove.

The western cliff was formed wholly of slate, which might at first sight be supposed to dip south, but did in reality undulate in various directions, and was in some places horizontal. This was shown by the little parallel bands of dark and light-grey colour, about one-tenth of an inch wide, producing what we call "ribboned slate" in Ireland. They were traversed by a well-marked cleavage, which dipped south at 60°, and one set of joints was parallel to this cleavage, producing exactly the appearance of bedding, so that any observer who was not greatly on his guard, might easily have been deceived, by the facts observable in this cove, into assigning a steady persistent southern dip to the whole of the beds.

From what I saw elsewhere about Ilfracombe and Mortehoe, I believe that, while there is a real general dip to the south throughout the district, this dip is by no means so prevalent as it appears to be, and that the total thickness is accordingly much less than would be at first supposed.

In the little cove of Helesborough, about a mile east of Ilfracombe, the slate contained in one place a strong calcareous band, consisting of nodular lumps of white calc-spar, weathering brown, with strings of the same substance ramifying into the grey slates. The dip here is certainly south-south-west at 35°.

7. *Pickwell Down and Mortehoe.*—Proceeding from Ilfracombe to the south-west by Bicklescombe and Score (? Scaur), and thence along the lanes towards Pickwell Down, nothing was to be seen, before reaching Crosscombe, but small quarries and cuttings in dark-grey slate, apparently without any grit-bands. It would have been quite useless, therefore, to waste the little time at my disposal in attempting to determine the dip of the beds. The cleavage still dipped everywhere to the south at 60° or thereabouts. At Crosscombe, however, I came on a little quarry in thick, coarse, brownish-red sandstone, with slaty partings, some of which were a dirty yellow, and some of a bright-red. "Genuine Old Red Sandstone" is the note I find in my note-book as to these beds. They dip S. 10° W. at 45°. From this quarry, for a mile and a half to the southward, over Pickwell Down, there is no rock exposed *in situ*, that I could find, except in shallow little quarries that did not go deep enough to show the "lie" of the rock. The fragments in these quarries, the field-walls that had been built from them, and the angular rubble and pieces covering the ploughed fields and stubbles, consisted chiefly of yellow and red gritstones of various shades, from light yellow to dark brown, and from light pink to deep claret-colour. Some pieces of purple slate, or of yellowish-green slate also occurred.

I walked over the seaward slope of Pickwell Down, hoping to find some natural or artificial excavation that would disclose the rocks, but in vain. The beach is backed by lofty sand-dunes piled against the foot of the Down. Nothing seemed to be shown before reaching the farm called "Vention," where I had previously seen rocks identical in character with the upper part of the Old Red Sandstone of county Cork (see Journ. Dublin. Geol. Soc. vol. x.).

Taking, however, what I did see in connexion with what I had previously seen, north of Braunton, on the road from Barnstaple to Ilfracombe, near Span Head, and north of Dulverton, I can have no hesitation in affirming the existence of a band of Old Red Sandstone striking from Morte Bay, for a distance of about thirty-five miles into the country, with a general dip to the south, at a very high angle.

The surface-width of this band appears to be about two miles; and if we estimate its average dip at 40°, it will give us a thickness of about 7000 feet. It is, however, quite possible that undulations in the beds, if we could see them, would greatly reduce this amount, and that the actual thickness of Old Red Sandstone which reaches the surface may not be more than half that calculated above.

Walking along the beach toward Tracey, I found some crags *in situ* on the beach, and also in a quarry in the side of the lane going up to Pickwell Down. These are, about "Potter's Hill," as marked in the Ordnance map. The crags on the beach are described in my note-book, as "pale-grey grits and slates, dipping south at 70°, cleavage perpendicular, with nodular bands, as if calcareous, but I believe ferruginous (?). Are these Carboniferous Slate or Old Red Sandstone?" The quarry up the lane is described as showing "softish purple and green sandy slate, dip (?) south at 70°." These beds are so very indefinite in character that I must frankly give them up. They might possibly be deep in the Old Red Sandstone, or they might be part of the Carboniferous Slate.

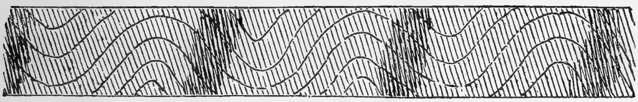
North of Tracey, however, where the rocks are well shown on the coast, and thence to Mortehoe, and down again into Lee Bay, all the rocks are identical in character with parts of the Carboniferous Slate of co. Cork, such as are shown about Bandon and Kinsale, or about Rosscarrberry, or between that and Dunmanway. There are scarcely any grit-bands, the whole mass being a smooth, shining clay-slate, black when fresh and damp, but weathering to a pale greenish-grey. It all seems at first sight to have a steady dip to the south. The cleavage certainly does dip steadily at 50° or 60°, but the more I worked with the hammer at the slate rocks near Mortehoe, the less persistent appeared to be the dip of the beds. Over large spaces I could not succeed in bringing out any structure that could be depended on as the stratification of the rock. On some parts of the low rocky cliffs near Mortehoe, the true bedding of the rocks coincided with the cleavage. In other parts the beds dipped northwards, while the cleavage dipped south. This was certainly the case near a place called "Yard," about a mile north-east of Mortehoe.

While, then, I agree with all previous observers in assigning a general southern dip to the whole of the rocks of North Devon, and believe the Mortehoe, Simonsbath, and Exton slates to be above those of the Lynton district; I believe that it is next to impossible to assign a thickness to the former with anything like the approximation to certainty we might possibly do to the latter, and that their apparent may be vastly in excess of their real thickness.

In making observations on the dip of the beds in a great section of slates, even the most practised observers may be occasionally led astray.

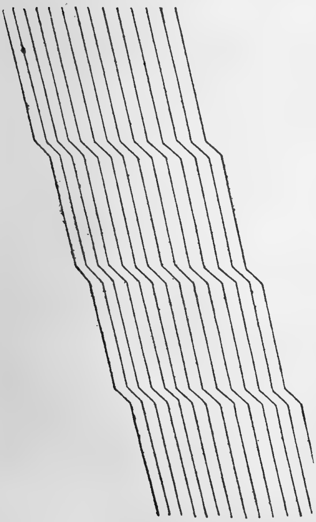
If the beds undulate while the dip of the cleavage is steady, and if the substance of the slate be very homogeneous, it may easily happen that the stratification is only well shown when it has a given relation to the cleavage, when for instance they coincide, or when they are at right angles to each other, or when they cross at some other angle, so that the particular mark of stratification which the kind of slate possesses shall be least obscured by the cleavage. But, when, in observing a long section, a number of these comparatively well-marked "dips" occur at several intervals, all in the same direction, an observer is apt to suppose that the intermediate parts dip also in the same direction, and base his estimate of thickness on the width of the whole mass and its mean angle of inclination. It is possible he may be right, but it is also quite possible that he may be wrong; and that the section may only show the same comparatively small group of beds undulating across it, as suggested in fig. 15, where the parts showing the bedding distinctly are supposed to be those which coincide with the cleavage.

Fig. 15.




*a, b, c, d.* Places where the stratification coincides with the cleavage, and is there observable, while in the intermediate places it is not discernable, or *vice versâ.*

Fig. 16.

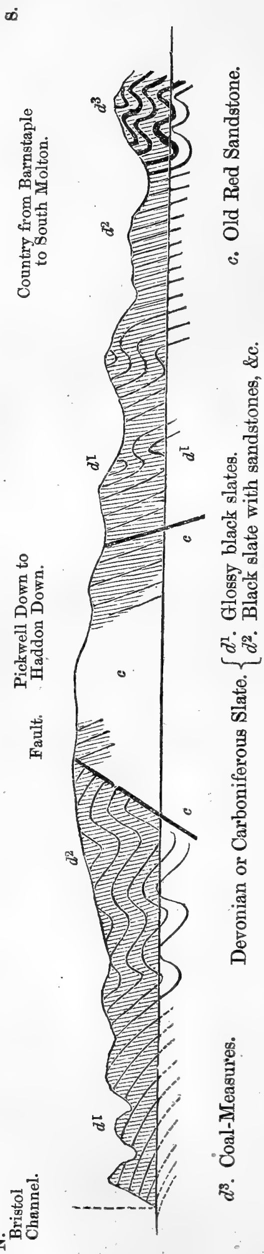


If in such a section the bedding were well seen at *a*, *b*, *c*, and *d*, and not at all observable in the intermediate parts, the whole mass might be supposed to dip south at 45°, and show a continuous succession of beds, instead of a repetition of the same.

While on the subject of cleavage I may perhaps be allowed to mention a structure I observed at Mortehoe, which I took at first for stratification, but had afterwards reason to doubt it; I have often observed it before, and it is sometimes very deceptive, and may accordingly lead to very erroneous conclusions. Along certain parallel bands in the slate, about 1 inch in width, and a foot or two apart, there occurs a shake or crumple in the cleavage-planes. Viewed in section it would be as in fig. 16.

It is, however, when observed on the face of a bed that it is most deceptive, as the change of tint resulting from the difference in the angle of reflection of the light gives to the little bands the appearance of a difference of colour in the substance of the rock, so that they might be taken for the true "stripe" of the slate.

Fig. 17. *Diagrammic Section across North Devon.*




8. *Aspect of the Country.*—In traversing the country between Mortehoe and Lee Bay, I was again struck with the exact similarity of the form of ground and nature of scenery to that so frequent in the Carboniferous Slate country of county Cork. The general surface of the high ground is uniform and monotonous, but it is cut into such numerous little dells, opening out into deeper ravines, and these into steep-sided, flat-bottomed valleys, that it becomes picturesque and beautiful. The tops of the hills, too, left standing between the ravines and valleys, are varied by frequent little brows and ridges of slate, forming small, parallel, escarped terraces, and rocky crags, and furze-covered knolls, while the colour and nature of the soil, and all the minuter features of the scenery are identical in both countries.

I was hastily summoned from Ilfracombe, on private business, before I could examine the calcareous bands and other rocks of Combe-Martin and its neighbourhood. If, however, the Lynton rocks below, and the Ilfracombe and Mortehoe rocks above be determined, the intermediate Combe-Martin beds follow as a matter of course.

9. *Probable Existence of a Great East and West Fault with Downthrow to the Northward.*—Having now laid before the Society the means I have had of examining the rocks and forming an opinion upon them, I have to state my deliberate judgment that the rocks of Lynton, Ilfracombe, and Mortehoe are part of the same group of rocks as those called the Carboniferous Slate in Ireland, and that the rocks which strike from Pickwell Down, through Swinham Down, Garmonds Down, Span Head (of the Ordnance map), and Dulverton Common, to Haddon Down, are the upper part of the Old Red Sandstone of Ireland;

the Irish Old Red Sandstone being the same as that of South Wales, but more indurated and traversed by slaty cleavage. If that judgment be a correct one, it follows, that as the Carboniferous Slate of Ireland is, without doubt, above the Old Red Sandstone, the Old Red Sandstone striking from Pickwell Down to Haddon Down will be below the rocks of Lynton, all appearances to the contrary notwithstanding; and that consequently some great fault, with a downthrow to the north, must run between the two, as suggested in fig. 17. The alternative to the conclusion will be, that there is a band of rocks, from 3000 to 7000 feet in thickness, precisely resembling the Irish Lower Group, but lying in Devonshire in the middle of the Upper Group. If there were any direct evidence in Devonshire that such is the structure of the country, all that could be said would be, that it was a very remarkable, and, as far as I know, unexampled occurrence. There is, however, no direct evidence for it beyond the general southern dip of the country, which is just as compatible with one hypothesis as the other. There is no place that I could find, either by my own search, or described in any published researches of others, where the band of slates stretching from Mortehoe to Exton can actually be seen to pass under the red sandstones and slates that stretch from Pickwell Down to Haddon Down; they can only be seen to dip towards them.

10. *Thickness of the rocks of North Devon on the ordinary hypothesis.*—There is even a strong presumption against the ordinary hypothesis to be deduced from the enormous thickness which it compels us to assign to the rocks of North Devon, and that without arriving at any definite base to them. All observers, from Sedgwick and Murchison, Weaver*, De la Beche and Phillips, down to our own day, when the Rev. M. Mules, of Marwood, and my colleague, Mr. Etheridge, who have constructed rough maps of the country†, and Mr. Townshend M. Hall, of Pilton, who has described it to the Exeter Naturalists' Field Club‡, agree in the opinion that there is a regular succession of rock-groups, dipping one under the other, from Lynton to the latitude of Barnstaple Estuary and South Molton.

Mr. Weaver, the accuracy of whose observations no one has ever disputed, divides the rocks of the country into eight such groups, as follows:—

8. Culmiferous Shales. } Coal strata.
7. Wavellite schistus and limestone. } Coal strata.
6. Trilobite slates.
5. Woollacombe sandstones, flags, and slates.
4. Morte slates.
3. Trentishoe quartzy-slate and sandstone, including the Combe-Martin limestones.
2. Lynton calcareous slates.
1. Foreland sandstones (top of Old Red Sandstone?).

* See Proceedings of Geol. Soc. London, vol. ii. p. 589, Jan. 3rd, 1838.
† I am indebted to both these gentlemen for a sight of these maps.
‡ Reported in the Exeter and Plymouth Gazette, Sept. 29th, 1865.

The two uppermost of these groups, Nos. 7 and 8, belong to the Coal-measures, the other six are the rocks subsequently known as Devonian; and he says, they form "one persistent consecutive series," all dipping generally to the south, with a few occasional undulations. The angle of dip, he says, increases from 20° on the north to 80° on the south, being from 20° to 30° in his 1st and 2nd groups, from 45° to 70° in his 3rd group, and generally 80° in his 4th, 5th, and 6th; a "lower angle being sometimes observable on approaching an undulation"*.

All the published accounts, so far as I am aware, have a general agreement with those statements, and I should myself agree generally with them so far as they profess to be descriptions of observed facts.

Now the distance in a straight line, measured directly across the strike of these beds, from Lynton to South Molton, is about fourteen miles, or 73,920 feet. If we say 70,000 feet, and assign a mean angle of inclination of 45° to the dip of the beds, we get a total thickness of 49,490 (say 50,000) feet for them. But suppose we deduct about a third of the width as an allowance for undulations in the beds, and reduce it to 50,000 feet, and allow the mean angle of inclination to be only 30°, and I think the observable facts will hardly admit of any greater reduction on the hypothesis of a succession of consecutive groups, we must still believe that the beds below the Coal-measures in North Devon have a thickness of 25,000 feet, and that without reaching their base, which is concealed somewhere under the waters of the Bristol channel.

It appears to me that this is a result that requires a comparison with some other district where these same rocks can be measured, either for its correction or its verification.

Comparing them with the south-western part of Ireland, the correction I propose is the inevitable result.

It detaches the true Old Red Sandstone from the grey-slates, which contain marine fossils, and thus divides the thickness, in the first instance, between two distinct formations, while, with respect to the grey slates themselves, it shows those of one district to be a repetition of those of the other, and therefore that the thickness of one is not to be added to that of the other.

The structure of North Devon, then, will be represented by the figure 17, in which the facts observed in different parts of the country are grouped together and condensed. It does not, then, represent any particular line of country, but offers a key to the structure of the whole.

The structure is that of a broken anticlinal, the northern arm of which has sunk in against the southern arm; the line of fracture running along the crest of the curve. It is by no means an uncommon structure. There is an excellent example of it in the hill of Slievnamuck, in the county Tipperary, where in like manner the northern arm of one of a series of parallel anticlinal ridges has fallen in against the southern arm. In that place a thickness of 700 or 800 feet of Coal-measures is brought in direct apposition with

* Proceedings Geol. Soc. London, vol. ii. p. 589.

the Lower Silurian Rocks. There are places there, where in an open ditch, it is possible to stand with one foot on Lower Silurian slates, and the other on a bed 700 or 800 feet above the base of the Coal-measures. To the north of the fault several beds of Coal-measures may be seen, in many places, cropping out on the slope of the ground; while still farther north a great tract of Carboniferous Limestone rises out from below them, across which it is necessary to travel for some miles before the Old Red Sandstone rises up in the ridge, near Emly. To the south of the fault, on the other hand, the base of this Old Red Sandstone may be seen reposing on the highly inclined Silurian slates; and the hill above shows several hundred feet of it, the beds dipping south, under another Carboniferous Limestone valley, the beautiful Vale of Aherlow. The Slievnamuck fault, then, must have a downthrow to the north of at least 4000, and possibly 5000 feet. (See Explan. of Sh. 155, Geol. Surv. Ireland, or 'Student's Manual,' p. 286.)

A similar throw in the supposed fault in North Devon would account for all the observed facts.

11. *Objections considered.*—The arguments against the hypothesis I propose, may be arranged under three heads, (*a*) stratigraphical, (*b*) lithological, and (*c*) palæontological.

*a.* The stratigraphical objections have already been sufficiently considered, and it has been shown that while the observable stratigraphical facts would not of themselves lead to the hypothesis, there are none which are conclusive against it. I may also state my belief that it would inevitably have occurred to any one who had examined North Devon, after having made himself acquainted with the structure of the south-west of Ireland. Had it so happened, for instance, that my old teacher, Professor Sedgwick, and my present chief, Sir R. I. Murchison, had been familiar with the rocks of the county Cork before entering on Devonshire, I believe they would have announced the existence of this great fault as a matter of course.

*b.* The lithological arguments against the hypothesis seem at first to be stronger. The aspect of the beds about Baggy Point, Barnstaple, and Dulverton is not exactly the same as that of the Lynton, Ilfracombe, and Mortehoe beds; and the limestones of Combe-Martin, &c., appear from published accounts to be stronger than the thin bands of calcareous slates in the Barnstaple district.

In reply I would urge that the Carboniferous slate of Ireland varies in character in different districts to such an extent that its parts might not be recognized as belonging to the same formation, if their physical continuity could not be traced, and their different graduations followed across the country.

In Devonshire itself the beds which dip under the Coal-measures on the north, differ in aspect from those which rise from under those same Coal-measures on the south, although they must be on the same general horizon. The limestones which prevail near Combe-Martin, and in South Devon, are local banks of limestone, which did not happen to be formed in the beds about Barnstaple and Dulverton, though the calcareous matter is not totally absent there.

The sandstones, both in Ireland and in North Devon, which are interstratified with the grey-slates, vary greatly in thickness. Near Bantry the Coomhola Grits are 3000 feet in thickness; in many places near Cork 20 or 30 feet is the maximum that could be assigned to them, and they have no greater thickness at Kenmare, which is not more than ten or twelve miles from Bantry Bay. That similar variations in the thickness of the sandstone beds, and their mode of interstratification with the slates should occur in Devon is only what is to be expected. I would also remark, that though there is not a minute lithological identity between the beds of the Baggy Point country and those of the Lynton district, there is after all no very great difference between them; alternations of greenish and greyish grits, with grey slates, prevail in both cases; and if the "lie of the beds," and their circumstances of exposure were alike, I believe their similarity of aspect would appear greater.

The objections, then, arising from variations in lithological character in different localities a few miles apart cannot be accepted as valid against the supposition that they belong to the same group of beds.

*c.* The palæontological resemble the lithological objections, and allow of a similar answer.

There are fossils in the Lynton and Combe-Martin district which are not known in the Baggy Point and Barnstaple district, and *vice versâ*; but there are also fossils which are common to the two districts. If the lithological variations are admitted, some palæontological difference may be expected to follow as a matter of course.

In Ireland, where the Carboniferous Slate forms one physically continuous area, and where its lithological structure is simpler than in Devonshire, many fossils are peculiar to parts of that area, some species only occurring in one or two localities. (See Mems. of Geol. Survey, Explanations of sheets 187, &c., and 192, &c. of the Irish maps.)

It may, then, be reasonably expected, even when all the species are collected, that different species will occur in the same beds in different parts of Devonshire. I refrain from entering into a discussion respecting species of fossils in which my own knowledge would not allow me to take any part except at second-hand, but I may be allowed to mention the following list of species which I find given by palæontological authorities as common to the districts north and south of the central band of Old Red Sandstone in North Devon.

| Species. | South. | North. | Authority. |
|---|---|---|---|
| Cyathophyllum (*Turbinolopsis, Petraia*) pluriradiale | Brushford | Lynton | Phillips. |
| Fenestella antiqua | Pilton<br>Croyde<br>Brushford | Lynton<br>Lee<br>Woodabay | " |
| Actinocrinus tenuistriatus | Pilton | Lynton | " |
| Cyathocrinus variabilis | Pilton | Lynton | " |
| Pleurotomaria aspera | Pilton | Woodabay | " |

| Species. | South. | North. | Authority. |
|---|---|---|---|
| Bellerophon globatus............ | Pilton ........ Brushford ... Marwood...... | Woodabay .. | Phillips. |
| Athyris concentrica ............ | Pilton............ | Ilfracombe..... | Davidson. |
| Chonetes Hardrensis ........... | Barnstaple, Braunton Marwood | Lynton ..... | " |
| Orthis interlineata............... | Barnstaple ... Croyde ..... Marwood..... | Haggington Hill, near Ilfracombe .. | " |
| —— striatula...................... | Pilton............ | Ilfracombe..... | " |
| Rhynchonella pugnus ......... | Pilton (?) ...... | Ilfracombe..... | " |
| —— pleurodon .................. | Pilton............ | Ilfracombe...... | " |
| Spirifera lævicosta *vel* ostiolata | Pilton............ | Lynton ......... | " |
| Spiriferina cristata, *var.* octoplicata .......................... | Pilton ........ | Ilfracombe...... | " |
| Strophomena rhomboidalis * | Barnstaple .. Braunton .. Marwood...... | Haggington Hill, near Ilfracombe ... | " |
| Streptorhynchus crenistria ... | Pilton ........ Barnstaple ... | Ilfracombe..... | " |
| Phacops latifrons† ......... | Braunton ...... | Lynton ......... | Baily. |

I may be pardoned, perhaps, for anticipating a considerable accession to this list when a thoroughly exhaustive search has been applied to the country ‡.

12. *Considerations on the Devonian Fossils.*—As many persons will be inclined to place great reliance on the Devonian fossils as fixing the place, or the age, of the Devonian rocks, it is advisable to determine the precise value of this evidence.

In the first place, I would remark that the problem to be solved is restricted within narrow limits. The question is, to which of the two conformable groups of beds—the Carboniferous Limestone or the Old Red Sandstone—do the Devonian beds belong?

* *Strophomena depressa* (formerly *Leptæna* and *Producta depressa*), and *S. rugosa* and *analoga* are now included under *S. rhomboidalis*, by Mr. Davidson.

† Specimens of this trilobite were procured by me from the late Mr. Symonds of Braunton, and collected by myself at Lynton last year; it occurs also at Pilton and elsewhere.

‡ This anticipation has already been partly verified. In the number of the 'Geological Magazine,' for April last, was a letter from Mr. Spencer George Perceval, of Severn House, Henbury, Bristol, giving an account of some fossils he had found near Witthycombe, a couple of miles south of Dunster. The beds are an extension of the Combe-Martin beds, but not only do they contain, according to Mr. Perceval's determinations, at least fourteen species of Devonian corals, *but a large species of Cucullæa*, together with Terebratulæ, Spiriferæ, &c. It will be interesting to know whether this *Cucullæa* is the same as one from Marwood or Braunton, or is the *Cucullæa Griffithii* of Ireland.

I would also beg leave to take this opportunity of asking Palæontologists whether there is any great difference between the *Myalina* from the Carboniferous rock of Scotland (Carluke and Pitlossie), and that from Hangman Hill, near Combe-Martin. Both specimens are in the Museum of Practical Geology in Jermyn Street. (Note added in July as the paper passed through the press.)

Had the Devonshire slates contained Silurian fossils on the one hand, or Lias fossils on the other, they would, as a matter of course, have been referred to the one or the other of those two formations.

The choice now, however, is limited to the period of the Old Red Sandstone and that of the Carboniferous Limestone, unless we assign to them a hitherto undefined period between those two, or suppose them to be older than the Old Red Sandstone.

We need hardly trouble ourselves, however, with the two latter suppositions.

Now, the Devonian fossils are said to comprise some species which are found also in Silurian rocks *, and are not known in the Carboniferous Limestone. They undoubtedly contain many species found in the Carboniferous Limestone † which are not known in any Silurian rock, as well as a few (such as *Strophomena rhomboidalis*), which range from Silurian into the Carboniferous Limestone.

The Devonian fossils also comprise some peculiar species of Silurian genera, which do not occur as species in Silurian, nor as genera in the Carboniferous Limestone. Some of the Trilobites are conspicuous examples of this case.

They also comprise some peculiar species of Carboniferous genera (*Producta*, for instance) which do not occur as species in Carboniferous Limestone, nor as genera in the Silurian rocks.

Lastly, there are some genera (such as *Stringocephalus* among the *Brachiopoda*, *Megalodon* among the *Conchifera*, and *Calceola*, whatever that may be) which are peculiarly Devonian genera.

Altogether, the Devonian fossils have an intermediate aspect (whether in the specific characters of some, as pointed out first by Mr. Lonsdale, or in their general *facies*) between those of the Upper Silurian rocks and those of the Carboniferous Limestone.

The natural presumption, therefore, was, that the beds containing those fossils were intermediate in age, and therefore contemporaneous with the Old Red Sandstone, which could be observed stratigraphically to hold that intermediate position.

However natural that presumption was, however, I must be permitted to urge that it was a *presumption* only, and *not a proof*.

The intermediate biological character of the Devonian fossils, to whatever extent it may exist, is neither a conclusive proof that they are of the age of the Old Red Sandstone, nor that they were not contemporaneous with those in the Carboniferous Limestone.

The geological age of fossils is proved by the stratigraphical position of the beds containing them. When that age has been established by reference to clear sections in one or two localities, the fossils themselves are admitted as evidence of the age of beds in other localities whose stratigraphical position perhaps is not clear. In all such cases, however, there must be either an avowed

* Mr. Etheridge reckons these as 13, mostly Corals.

† Mr. Etheridge reckons these as 92.

or tacit reference to sections in the first instance, showing the stratigraphical relations of the beds.

It may be reserved for some future palæontologists to treat fossils independently, and show, from their biological relations only, the necessary laws which must have regulated their appearance in time; but I am not aware of any one having even attempted this task as yet.

To take an extreme case at once, the family of the *Graptolitidæ* for instance: if any geologist now find in any rock a fragment of a Graptolite, he refers the age of that rock to one of the Lower Palæozoic periods with the utmost confidence, and in no known instance would he be wrong in so doing. But he does so, not because of anything in the organic structure of the fossil, but because no one ever yet did find a Graptolite in any rock which could be shown stratigraphically to belong to the Upper Palæozoic or any higher part of the series. No palæontologist, so far as I am aware, could show a merely biological reason why the Graptolites might not have existed during the Secondary or Tertiary epochs. Or suppose that no shells belonging to the genus *Producta* had ever yet been seen, could any one on the first discovery of a *Producta* have decided on its age without any reference to the stratigraphical position of the bed in which it was found? Even if he had guessed, from its biological relations to other Palæozoic Brachiopods, that the shell was itself of Palæozoic age, still he must have based his conclusion on the fact that those other Brachiopods had hitherto been found only in beds which were shown to be of Palæozoic age by their stratigraphical position.

The very value of the doctrine of the chronological significance of organic remains, and the constant use made of it by geologists, seem sometimes to have caused them to forget that the significance is a *secondary and derivative one only*, depending, either directly or indirectly, on the stratigraphical succession of the beds in which the fossils are to be found, and upon that alone.

The *peculiar Devonian species and genera* of fossils, therefore, have no definite value in themselves as fixing the exact place in the series of the rocks in which they occur, until the place of those rocks has somewhere been determined by stratigraphical evidence. Those rocks have of late years been held to occupy the same place in the series as the Old Red Sandstone, or to lie between the top of the Upper Silurian and the base of the Carboniferous Limestone; but where, in England or in Western Europe, is the section that shows a distinct stratigraphical succession, with fully developed Upper Silurian rocks below, and fully-developed Carboniferous Limestone above, and a series of Devonian slates and limestones and their peculiar fossils between? There is no such section; but if such had been the order of nature, surely we should by this time have somewhere found a section to prove it.

But the case is even simpler and stronger than that, for not only is there no section exposing the three formations in regular succession, but I have yet to learn the place where a fully-developed set of the marine Devonian rocks are covered by anything like a complete series of Carboniferous Limestone. Where the two things are present, as near Cork, they are neither of them so complete as in adjacent areas where only one is found.

But by the hypothesis which I now propose, the place of these marine Devonian beds will be fixed stratigraphically between the top of the Old Red Sandstone and the base of the Coal-measures, in North Devon as in Ireland.

I cannot yet speak from personal examination of South Devon, but, from the descriptions of Sedgwick and Murchison and others, it appears to have a more complicated structure than North Devon. The occurrence of red sandstones above the Plymouth limestones (Trans. Geol. Soc. vol. v. p. 657) might at first appear to place those limestones below the Old Red Sandstone. On this point I may, by way of caution, refer to the previous remarks at p. 323, that it is not every group of red sandstones, with some beds even of Carboniferous Limestone immediately over them, that is entitled to be called Old Red Sandstone. We have in Ireland beds of red and yellow sandstones and conglomerates *in* the Carboniferous Limestone; there is no reason, therefore, why similar beds may not occur *in* the Devonian beds of Devonshire. In neither case should these red sandstones be identified with the Old Red Sandstone proper.

The true Old Red Sandstone is the conformable base of the great Carboniferous series, and contains no marine fossils; the Devonian beds proper (those containing marine fossils) lie above it, side by side with the Carboniferous Limestone, both being directly covered by the Coal-measures.

The difference in the fossils of the Carboniferous Limestone and the Devonian beds must then be held to be the result of space rather than of time, and to mark the influence of nature of bottom and difference of province, rather than of chronological periods.

This difference will be somewhat analogous to that observable in the case of the Upper Silurian rocks of North Wales and of Siluria proper. The Wenlock rocks of Denbighshire abound with impressions of the various species of *Theca* (Q. J. G. S. vol. ii. pl. 13), so that they might well be called Theca flagstones; but this fossil is either entirely absent from the Wenlock rocks of Siluria proper *, or very rare in them, while the common Wenlock fossils are rare in Denbighshire.

The difference noted by M. Barrande between the Trilobites in the contemporaneous Silurian beds of Bohemia and Scandinavia will occur to every geologist as a still more striking instance.

The influence of geographical distribution, which is so obvious on the existing species of animals and plants, has hardly yet, I think, been sufficiently allowed for by palæontologists. As we trace formations through different countries, we must hold ourselves prepared to find the same species in beds not strictly contemporaneous, and

* *Theca anceps* is mentioned by Mr. Salter as found near Eastnor Castle, Malvern Hills. Mems. Geol. Surv. vol. ii. p. 355.

different species in beds which are so—and this sometimes within very narrow geographical limits.

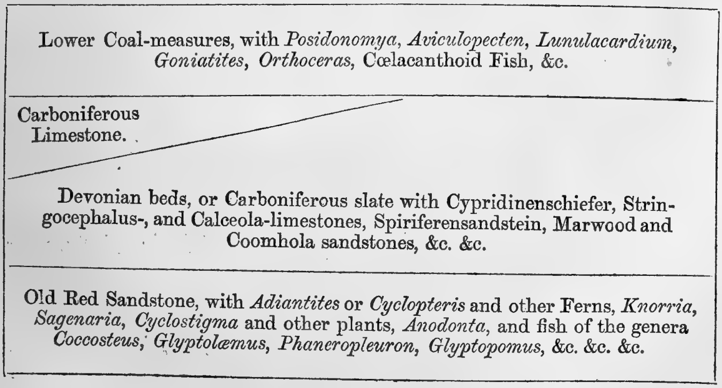
13. *General conclusion.*—I would, then, beg leave to suggest, in the first place, that the identification of the Old Red Sandstone proper with the Devonian beds was an over-hasty conclusion, and that, till the question be finally settled, it would be well to discontinue the use of the term Devonian for all beds which are, or are supposed to be, really Old Red Sandstone. One source of confusion would thus be avoided. The term "Devonian" would then be confined to beds containing those species and genera of Brachiopoda and other marine fossils which are commonly understood when we speak of Devonian fossils. The Old Red Sandstone certainly does not contain any of these fossils. The plants and the Anodonta which it does contain seem to point to a freshwater origin for it, or at all events the neighbourhood of land.

The Devonian beds, when the Old Red Sandstone is detached from them, will still be sufficiently extensive and important. The peculiar genera and species belonging to them seem to have a very wide range over the world in general, quite as wide perhaps as the genera and species peculiar to the Carboniferous Limestone.

I believe, however, that it will ultimately be found that the genera and species which have the widest range of all, are those which are common to the Devonian beds and the Carboniferous Limestone.

It may doubtless be thought a bold, not to say audacious, speculation, but it occurs to me to ask whether we ought not rather to look upon the Devonian beds as the most general type of those which intervene between the Coal-measures and the Old Red Sandstone, and regard the Carboniferous Limestone of the British Islands and Belgium as a local and exceptional peculiarity. It seems to me that good reasons might be urged for such a classification. It would be represented in a condensed form in the subjoined diagram.

Fig. 18.



Where the Old Red Sandstone is absent, the Devonian beds may perhaps repose conformably on the Upper Silurian, or unconformably either on that or some lower formation.

## IV. Appendix.

My colleague, Mr. R. Etheridge, has at my request drawn up a complete catalogue of all the British fossils of the Devonian and Old Red Sandstone formations, so far as they are at present known, with all the recent improvements in their nomenclature introduced by Mr. Davidson and others. He has also shown their distribution, in parallel columns, in the several districts of Cornwall, South Devon, and North Devon, subdividing the beds which occur in those districts into the ordinarily received groups. He has also subdivided the Old Red Sandstone into Upper, Middle, and Lower, according to the prevailing ideas as to the grouping of those beds. He has added columns for Ireland, one showing the fossils which occur only in the Coomhola Grits, the other, including these, in a list which shows the whole fossils hitherto recorded from any part of the Carboniferous Slate of Ireland. He has then shown, in farther columns, the species which also occur in the Carboniferous formations in other parts of the British Islands, taking the commonly received subdivisions of that formation; and, lastly, has given columns which mark the occurrence of any of the species enumerated in the Rhenish Provinces, in Belgium, and in France. Mr. Etheridge, in drawing up this list, has carefully confined himself to the recording of facts from the best authorities, irrespectively of all hypotheses as to the classification of the beds.

He then gives a Table, in which the numbers of species are combined under their respective biological headings. From this it appears that the whole number of species is 529, of which, however, 112 are fish that occur only in the Old Red Sandstone. If we omit these from the total, as not affording any element of comparison, and also omit the 12 species of plants, in order to confine the comparison to undoubtedly marine organisms, we have a total of 405 of such organisms. Of these one only (*Serpula advena*) has been found in the Old Red Sandstone. If we omit this, and also the freshwater Anodon of the Old Red Sandstone, it leaves 403, or in round numbers, 400 species of marine organisms found in the marine Devonian beds for comparison with fossils of the same class in other formations. Of these 400 species, 13 only, chiefly Corals, are said to occur in any Silurian rocks, while 92, or nearly a quarter of the whole, occur in the undoubted Carboniferous rocks of other parts of the British Islands.

It also appears from the Table that the palæontological differences between different areas of the Devonian beds are at least as great, if not greater, than those observable between the Devonian and the Carboniferous Limestone series.

It is also to be recollected that the amount of difference apparent on the comparison of lists of species, is to a certain extent delusive, since a species founded on a single specimen, or a few rarely occurring specimens, counts as much in this comparison as a species of which specimens occur everywhere in the greatest profusion.

The abundance of individuals must be an element of importance towards the establishment of a species, as enabling the palæontologist to include all its varieties; but, even in two equally distinct species, it appears to me that *richness* in individuals and *extent* of diffusion ought to be taken into account by the geologist, when estimating their *potency* in chronological significance.

Tables of percentage in which abundance and diffusion of species are not taken into account are really of no great value. I strongly suspect that the ninety-two carboniferous species mentioned above include those which are at the same time most abundant and most widely diffused in both groups of rock, while the rare and doubtful species will be found entirely among the remainder. Some of the latter, too, will eventually be decided to be mere varieties of the former, and will therefore be not only erased from the one list, but added to the other.

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Notices of Earthquakes, 362.
A. A. Julien.—*Metabrushite, Zeugite, Ornithite,* and other minerals of the Key of Sombrero, 367.
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J. D. Dana.—Discovery of Rhizopods in the Azoic Rocks, 391.
R. E. Owen and E. T. Cox.—Mines of New Mexico, 391.
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## ADDENDUM TO THE ANNIVERSARY ADDRESS OF THE PRESIDENT.

Dr. GEORGE FORCHHAMMER was born at Husum on the 26th July, 1794. After his preliminary studies in Latin and chemistry, he entered the University of Kiel, where he became an assistant in Pfaff's laboratory. In 1818 he went to Copenhagen, where he soon became Oersted's assistant. In 1820 he took his doctor's degree, on which occasion he wrote a treatise 'De Mangano.' After travelling for two years in England, Scotland, the Hebrides, and the Faroe Islands, he was appointed teacher of Mineralogy and Chemistry at the University of Copenhagen. In 1825 he became a Member of the Academy of Sciences there; in 1829 he was named Professor of Chemistry and Mineralogy at the Polytechnical Institute; and in 1831 Professor of Mineralogy at the University. Since 1851 he was Director of the Polytechnical Institute, and Secretary of the Academy of Sciences.

His literary productions were partly chemico-mineralogical, and partly geognostical, chiefly with reference to the Danish Kingdom and the Duchies. An important portion of his investigations refers to the water of the sea and that of springs, wells, streams, and fresh-water lakes. Many of his works refer generally to natural history, while others contain views and representations of objects of natural history.

Dr. Forchhammer was blessed with an unusual capacity for work, which, together with his rich stores of knowledge, enabled him to meet the numerous calls upon his time and labour. The Professorship at the University, the care of the Mineralogical Museum, the Directorship of the Polytechnical Institute, the Secretaryship of the Academy of Sciences, required extraordinary powers from one man. Moreover, as Rector of the University, he had to superintend new buildings of great extent, and to make full reports on many questions referred to him by the Government. He was consulted scientifically, not only for public, but for many private undertakings, where his knowledge, his practical talent, and his extreme good-nature were available. The result was that he was loaded with honours by the Government, and that he enjoyed the friendship and esteem of all who knew him.

[illegible] born [illegible] of the 19th [illegible] [illegible] and [illegible] [illegible] [illegible] [illegible] [illegible] Copenhagen, where he [illegible] [illegible] his doctor's degree [illegible] After the [illegible] in England, Scotland, the Hebrides, and the [illegible] was appointed teacher of Mineralogy and Chemistry [illegible] of Copenhagen. In 18[illegible] he became a Member of [illegible] of Sciences there; in 18[illegible] he was named Professor of Mineralogy at the Polytechnical Institute; and [illegible] of Mineralogy at the University. Since 18[illegible] [illegible] the Polytechnical Institute and Secretary of the Academy [illegible].

[illegible] publications were partly [illegible] mineralogical, and [illegible] with [illegible] the Danish Kingdom [illegible]. An important [illegible] of his investigations [illegible] the sea and that of springs, [illegible], streams, and [illegible]. Many of his works refer generally to natural [illegible] [illegible] objects of [illegible].

[illegible] was blessed with an unusual capacity [illegible] together with his [illegible] of knowledge [illegible] numerous calls upon his time and labour. The [illegible] University, the care of the Mineralogical Museum [illegible] of the Polytechnical Institute, the Secretaryship [illegible] required [illegible] were from [illegible] Rector of the University, he had to superintend [illegible] [illegible] to him by the [illegible]

The result [illegible] that he was [illegible]

THE

# QUARTERLY JOURNAL

OF

# THE GEOLOGICAL SOCIETY OF LONDON.

## PROCEEDINGS

OF

## THE GEOLOGICAL SOCIETY.

March 21, 1866.

The following communications were read:—

### 1. *On the* Fossil British Oxen. Part I. Bos Urus, *Cæsar*. By W. Boyd Dawkins, M.A., F.G.S.

Contents.



#### 1. Introduction.

Since the publication of Professor Owen's great work on the British Fossil Mammalia in the year 1846, no addition has been made to our knowledge of the British Fossil Oxen, while on the continent Professor Nilsson, of Lund, has described with a master's hand those of Scandinavia, and Dr. Rütimeyer, of Basle, those found in the Pile-works of Switzerland. In the meanwhile a large amount of information with reference to them has been obtained from the bone-caves and river-deposits of Britain, and from the peat-bogs and marls below of Britain and Ireland, for the most part unpublished or scattered about in disjointed fragments through the numerous scientific and archæological journals of the day.

The relics of the food of the Roman legions stationed in Britain, and of the Romano-British, and the contents of their tombs, and especially many incidental notices of wild oxen in the historians from the time of Charlemagne down to the end of the 12th century, afford remarkable evidence as to the date down to which the wild oxen lived in continental Europe and in Britain. To collect all these isolated facts together, and to give an outline of the characters of each species or variety, and to define their range, so far as may be, in time, is the object of this essay. The three species which come under our notice are—1. The Great Urus, *Bos urus* of Julius Cæsar; 2. The Small Short-horn, *Bos longifrons* of Professor Owen; 3. The Bison, *Bos bison* of Pliny.

The problem as to the origin of our domestic races of cattle is only to be solved by a careful examination of each of these three European fossil animals. Of the three, we shall begin with the *Bos Urus* of Julius Cæsar.

## 2. Characters.

The *Bos urus*, or the *Bos primigenius* of Bojanus*, is characterized, according to the latter, by the concavity of the forehead, by the prominence of its orbits, which have not such a forward direction as in *Bos taurus*, and by the large size of the neural spines of the dorsal vertebræ. The large horns also have a double curvature, first outwards, and then forwards and upwards. Professor Nilsson†, describing the remains of this animal found in Scania, describes it as characterized by the flatness of forehead, the straightness of "the edge of the neck," and by the horns being very large and long, near the roots directed outward and somewhat backward, in the middle bent forward, and towards the points turned a little upwards. Baron Cuvier, on the other hand, writes, with reference to the skulls of this animal that he had examined‡, "The general contour of the frontal bone, its concavity, and the reentering curve which bounds it above, and which extends as a crest from one horn to the other, the acute angle that the surface of the frontal makes with that of the occipital, the circumference of the latter, the temporal fossa, are absolutely the same in these two skulls as in the common Ox (*Bos taurus*)." In the horn-core of the Urus he can detect no differences of specific value as compared with the former animal, in which almost every variation of curvature is to be found; while at the same time the fact that the horn-core of the Urus, after bending outwards, bends back upon itself a little downwards and forwards, instead of presenting the regular double curvature of that of the common Ox, outwards and more or less upwards or forwards, is well worthy of remark. The common Ox, however, presents every variation in the size of its horns, sometimes being entirely hornless, as in a Welsh, Scotch, and Islandic breed, at others having them most enormously developed, as in the Sanga or Galla Ox of Abyssinia, in which variety, according to Father Lobos (quoted by Zimmerman, Spec. Zool. Geograph. 4to, 1778, p. 110), the horn is sufficiently large to contain more than ten quarts. A walk into a cattle market will convince the most sceptical of observers that the common Ox presents also almost every variation possible in the shape and the direction of the horns. In fine, a very careful comparison of the skulls of *Bos urus* in Britain with those of the various varieties of *Bos taurus* or the common Ox, compels me to believe that there

* Nov. Act. Acad. Nat. Cur. xiii. 2. p. 424, 1. 24.

† Ann. & Mag. Nat. Hist. 1849, vol. iv. ser. 2. p. 257–258.

‡ Oss. Foss. t. iv. p. 150, 3rd edit. 1825.

is no difference of specific value between them, those points of difference noticed by Professors Rütimeyer and Nilsson proving to be peculiar to the individual and not to the species, and therefore useless for classificatory purposes. At the same time, its size, though inferior to that of the Italian or Abyssinian animal, was far greater than that of any variety of *Bos taurus*, which coexisted with it in the forests of France, Germany, or Britain, and affords a ready means of identification; while it is easily differentiated from the smaller contemporary Bison by the double curvature of the horns, their backward position close to the occipital crest, the concavity of the frontal bone, and the acute angle that the occiput makes with the frontal region. The quadrangular outline of the occipital region and the larger size of the bones, the anterior dorsal vertebræ being excepted, are also guides by which to recognize it.

### 3. Synonyms.

The synonymy of the *Bos urus* is in a state of very great confusion, arising from the fact that the two words denoting two distinct species, the Urox and the Aurochs, are derived from the same Sanscrit root, *ur*, *aur*, or *or*, that signifies a forest or stony waste. The root can be traced through many languages, and still survives in the Greek *ὄρος* (a mountain), the Norwegian *ore*, the Islandic *urd* (the stony desert surrounding the base of the mountains), and is preserved without change in the old German *ur* (a forest) and in "Ur of the Chaldees." It appears also in the *Ural* Mountains, and also in the canton of *Uri*, the crest of which is an ox-head. At the annual election of magistrates in the latter place, my friend the historian of 'Federal Republics,' Mr. E. A. Freeman, tells me that two gigantic horns with double curvature are borne in solemn procession to this day. These probably are of considerable antiquity, and were obtained from a gigantic Urus-bull* that fell a victim to the chase, in which the German youth in Cæsar's time prepared themselves for the toils of war, obtaining almost as much honour from the possession of horns of Urus slain by their own hands as from that of trophies won in battle†. The root also occurs in the name applied to the gigantic ox of the tableland of Central India—the *Gaur* (*Bos gaurus*). With reference to this, Mr. W. A. Chatto observes, "The word *Gau* or *Ghoo*, as it is sometimes spelt by European writers, appears to be used both as a generic and specific term in Persia and Hindostan; and as it has the same meaning as the German word *Kuh*, and the English *Cow*, it is highly probable that its origin is the same. As the word *ur* in Hindostan appears to have the meaning of *wild* or *savage*, the name Gaur or Gau-ur literally signifies *wild cow*‡.

* That the Urus's horns were used in the Bronze age, and possibly before, is proved by Professor Nilsson's discovery of a bronze trumpet made in the shape of a horn of Urus, dug from a depth of 6–8 feet out of a turf-bog in Southern Scania. "It is more than probable that the inhabitants of the south of Sweden first used the horns of the Urox for their *war*-horns, and at a later period made themselves horns of bronze in the same form as the former." *Op. cit.* p. 267.

† Cæs. Bell. Gall.

‡ Nat. Hist. of the Ox Tribe. By George Vasey. 8vo. London, 1857: p. 103.

The German Urox, Aurochs, and the Gaur of Hindoostan are therefore etymologically one and the same, and mean primarily *wild* or *forest ox*, but are used to denote three distinct species. To pass over the latter species of Hindostan, with which we have nothing to do in this place, the term *Aurochs* has been restricted to the European Bison by the authority of Buffon, Cuvier, and Professor Owen; the term *Urox*, or *Bos urus*, to the species under consideration by Julius Cæsar, Pliny, the chronicler of 'The Wars of Charlemagne'*, and other writers of the 6th to the 12th centuries; also by Cuvier, Nilsson, and our great naturalist Professor Owen. The Polish "Thur" is simply another form of the root *ur*, and signifies wild ox.

A reference to Dr. Fischer's great work (Synopsis Mammalium, 8vo, Stutgardtiæ, 1829, pp. 497–498) will show the confusion that exists between the *Urox* and *Aurochs* in the works of the older European naturalists, and will obviate the necessity of my giving details in this place.

The large fossil ox of the Pleistocene period, termed *Bos primigenius* by Bojanus and Professor Owen, differs in no respect from the *Bos urus* of the Prehistoric and Historical period.

### 4. Measurements.

The following measurements show that there was a considerable difference in size between the individuals of the *Bos urus*. They are all reduced to inches and tenths, for the sake of ease of comparison. The first skull that Cuvier mentions (*op. cit.* pp. 150–151, pl. iii. figs. 3–8) presents a

| | in. |
|---|---|
| Width between the horn-cores of | 12·8 |
| " " orbits | 12·9 |
| Circumference of horn-core | 12·9 |
| Length of horn-cores following curvature | 27·9 |
| Distance between their tips | 32·5 |

Cuvier observes of this skull that, according to the proportion of the *Bos taurus*, it would belong to an animal 12 feet long and 6·5 feet high at the withers.

The dimensions of a second and more perfect skull, dug from the peat-bog of Saint-Vrain in the canton of Arpajon (*op. cit.* pl. xi. figs. 1, 2, 3), indicate an animal of considerably smaller size than the preceding—

| | in. |
|---|---|
| Extreme length from occipital crest to end of premaxillary | 25·75 |
| Distance between orbits | 11·3 |
| Horn-core to horn-core | 11·0 |
| Diameter of horn-core at base | 5·5 |
| Distance between tips of horn-cores | 24·8 |
| Height of occipital crest from the bottom of the foramen magnum | 8·8 |
| Maximum width of occipital surface between the two mastoid processes | 12·0 |
| Antero-posterior extent of palate | 12·08 |
| Length of skull from the foramen magnum to anterior edge of premaxillaries | 22·05 |

* Monachi Sangallensis Lib. ii. de Rebus Bellicis Caroli Magni, c. xi.

This skull is 4 inches longer than that of the largest *Bos taurus* in the Jardin des Plantes.

The most perfect remains, however, are those derived from the turbaries of Scania, described by Professor Nilsson, of Lund *. They afford the following measurements in inches and tenths:—

| | |
|---|---|
| Occipital crest to premaxillary | 28·33 |
| Horn-cores to anterior edge of premaxillary | 25·41 |
| Lower edge of orbit | 15·33 |
| Outer curve of horn-core | 26·0 |
| Breadth of forehead between base of upper part of horn-cores | 9·08 |
| " " " lower part of " | 12·01 |
| " " between orbits, upper part | 12·01 |
| " " " lower part | 11·33 |
| Distance between tips of horn-cores | 28·0 |
| Circumference of base of horn-core | 14·33 |
| Distance between auditory foramina | 12·33 |
| First cervical to last dorsal vertebra | 91·33 |
| Cervical vertebræ | 23·33 |
| Length of shoulder-blade | 20·0 |
| Breadth of its distal end | 12·0 |
| Length of humerus between articulations | 14·0 |
| " of radius | 14·33 |
| " of ulna and olecranon | 19·5 |
| " of femur | 19·0 |
| " of tibia | 17·5 |
| " of metatarsal | 11·0 |

Professor Nilsson estimates the length of the animal as being from 11·5 to 12 feet, and its height over the withers as about 6 to 6·5—an estimate that coincides remarkably with that given by Baron Cuvier from the examination of the head of a French specimen, which we have already noticed.

To pass, however, to the remains of the *Bos urus* found in our own country, the first and most noteworthy discovery in Britain was that of the frontal portion and horn-cores in the bed of the river Avon at Mellisham, near Bath. The span from tip to tip of the unbroken horn-cores was 39 inches†, their basal circumference 17·5, and their length, following their curvature, 36·5. This last measurement is one-fourth greater than that mentioned by Cuvier as indicating an animal 12 feet long and 6·5 feet high. Mr. Woods also cites an instance of the occurrence of a head of this species of a size little inferior to the head of the preceding, under a tumulus near Calne in Wilts, and associated with remains of the Deer, Boar, and British pottery ornamented with right lines. The measurement from tip to tip of horn-core of 33 inches, and their basal circumference of 15·5, prove that at the time the makers of the tumulus lived in Wiltshire a Urox inhabited the same area of larger size than any of those mentioned by Baron Cuvier in Germany, or by Professor Nilsson in Scania.

Professor Owen figures, in the 'British Fossil Mammals,' a skull fromnear Athol, in Perthshire, derived probably from a turbary. It is

* *Op. cit.* p. 258 *et seq.*

† Descript. of Fossil Skull of Ox. By Henry Woods, A.L.S. 4to. London, 1839: p. 29.

36 inches long, the span of the horn-cores is 42 inches, and the breadth of the forehead between the horn-cores 10·5 inches*. Dr. Fleming notices the large size of the skulls of oxen from the marl-pits underlying the peat of Scotland, and speaks of one in his possession as being 27·5 inches long, with a span of 9 inches between the bases of the horn-cores, and of 11·5 across the orbits. He considers them to have belonged to a species of *Bos taurus* †.

All the cases cited above, with the exception of that found on the banks of the Avon, near Bath, which may perhaps be of the same date as elephantine and leonine remains found in the neighbouring gravels, are of a date posterior to the extinction of the Mammoth, tichorhine Rhinoceros, Cave-bear, and other animals characteristic of the Pleistocene period in Central, Western, and Northern Europe, and are derived from deposits either of peat or of marl beneath it, or from tumuli. They are therefore of Prehistoric age. The few remaining measurements that I shall give are those of the skulls and horn-cores of the same species that boast of a vastly greater antiquity, and which were associated with the remains of the Pleistocene Mammals, both in the caverns and in river-deposits of that early period.

Mr. Brown, of Stanway, to whom we are indebted for the discovery and preservation of the remains of a large number of Pleistocene mammals, describes a skull of this species, along with the molar of a *Elephas primigenius*, in the drift of Clacton in Essex‡. Each of its cores measures 36 inches in length following the outer curvature, and has a basal diameter of 6 × 5 inches. Professor Owen describes a second skull, obtained by Mr. J. Wickham Flower, F.G.S., from the drift of Herne Bay, as possessed of horn-cores measuring along the outer curve 39 inches, with a basal circumference of 18·85. A remarkably fine pair of horn-cores have also been obtained from the brick-earth at Crayford, in Kent, belonging to the low-level series of gravels and brick-earths of Mr. Prestwich. Their basal circumference is 16·6 inches, and their length, following the outer curvature, 35 inches. They are preserved in the collection of Mr. Grantham, to whom I am indebted for their examination. A large number of other cases of the remains of this species having been found in Britain may be cited, as in the river-deposits near Erith, Maidstone, Ilford, Wickham, Brentford, Bielbecks in Yorkshire, and Fisherton in Wilts, and in the caverns of Kent's Hole, Oreston, and many others. As sufficient evidence has been given for the variation in size of the head and of the horn-cores of the species, their measurements would serve no special purpose in this place. The measurements of the long bones and lower jaws will be given in a tabular form in the essay upon the Aurochs, or *Bison priscus* of Professor Owen.

One point is very remarkable with reference to the development of the horn-cores and the size of the animal—that just as the

* *Op. cit.* p. 512.

† British Animals. 8vo. Lond. & Edin. 1828: p. 24.

‡ Mag. Nat. Hist. n. s. 1838, p. 163.

Urus mentioned by Cæsar as "magnitudine paulo infra elephantos," and that found in the peat and in the marl beneath in France, Northern Germany, and Scandinavia, surpassed the average *uncastrated Bos taurus* of Western and Central Europe in size, so were they exceeded in size by those that inhabited the same area in the Pleistocene period. The more abundant food afforded by the vast prairie grounds of the Pleistocene continent would naturally cause the Pleistocene Urus to attain to a higher pitch of development than the more restricted range and food, after the submergence of the Pleistocene lowlands, of the species in Prehistoric and in Historic times, where, moreover, it would have a hard battle to fight for its very existence with the most formidable of the beasts of prey—with man. This is the only hypothesis that I can suggest to account for the larger size of nearly all the Pleistocene Mammalia as compared with those descendants of them now living in the same area.

### 5. Range in Space and Time.

That the *Bos urus* or *Bos primigenius* was a contemporary of the Mammoth, leptorhine, megarhine, and tichorhine Rhinoceros is proved by its occurrence in the brick-fields of Crayford, in Kent, already mentioned. Besides the above, it was associated with

Felis spelæa.
Ursus spelæus.
Ursus arctos.
Bison priscus.
Megaceros Hibernicus.
Cervus elaphus.
Elephas antiquus.
Equus fossilis.
Arvicola amphibia.

In the brick-earths on the opposite side of the Thames it is associated with the *Hippopotamus major* at Grays, in Essex. The associated remains, indeed, from many other localities such as that given above leave no room to doubt that it wandered through the Pleistocene woodlands in France, Germany, and Britain with the other mammalia of the period. A table of the distribution of Pleistocene Mammalia in my possession proves that it was far less numerous in Britain than its smaller contemporary the Bison, or *Bison priscus* of Professor Owen. In Prehistoric times, after the Elephants and Rhinoceroses of the Pleistocene period had passed away, and the Cave-hyenas and Cave-lions had retreated from Western and Central Europe southwards, it still held its ground in France, Germany, and Scandinavia; and from the instances cited of the occurrence of its remains, it seems to have become relatively more numerous than the Bison, which also survived in Europe, but which, so far as I know, has not yet been detected in any Prehistoric deposit in Britain or Ireland. The case of the skull of this species being found under the tumulus at Calne, associated with the remains of the feasts and the fragments of pottery of some ancient British tribe, proves that the Urus was hunted in those early days in Wiltshire. The date of its extinction in Britain is, to say the least, a very vexed question. Professor Owen infers, from the condition of the remains from the Scotch peat-bogs, that it retained its ground longest in Scotland; Nilsson infers, from Cæsar's silence, that it was extinct in his time; but when we take into consideration the small area that he saw of the country, and its physical condition, covered with vast forests and pathless morasses, his silence does not seem to be of any weight either for or against the extinction of the animal at that time. The absence, however, of its remains from the very numerous accumulations of bones of *Bos longifrons*, Red Deer, Wild Boar, and the like animals, which were the food of the people after Britain was interpenetrated by Roman influence, makes it highly probable that it was, to say the least, very scarce. It may perhaps have still lingered on in the wilder parts of the country. To add to the perplexity as to the date of its extinction, William Fitz-Stephens, in his 'Life of Becket,' incidentally mentions the condition of the country immediately to the north of London *. After describing the pleasant gardens that the citizens had out of town, the pastures and hills, he says, "Close by there extends a great wilderness, woodland glades, the lurking-places of wild beasts, Red Deer, Fallow Deer, Wild Boars, and Wild Bulls" (tauri sylvestres). Whether or not "taurus sylvestris" be synonymous with *Bos urus* in this passage may be disputed, as it may be objected that perhaps it may mean only the domestic cattle that were sent out into the woods to get their own living. On the other hand, the fact of their being classed under the head of *feræ*, along with the Red Deer, Fallow Deer, and Wild Boar, read by the light of records of the existence of the Urus on the continent at that time, inclines me to the belief that they were as undoubtedly wild in Britain in the middle of the 12th century as the wild bull hunted by Charlemagne in the forest of Aix-la-Chapelle, to be mentioned subsequently. That the Bison is not meant is rendered almost certain by the absence of its remains from any British formation posterior to the Pleistocene period. The smaller *Bos longifrons* may perhaps be the animal meant in this passage. Probably, however, the Urus lived in Britain to Becket's time in a wild state, modified in size according to its food and the extent of its range, that of the Pleistocene being vastly larger than that of the Prehistoric times, and the latter than those few survivors in the struggle for life when the cultivated lands encroached more and more on their feeding-grounds and the dread of the hunter was upon them. The half-wild oxen of Chillingham Park in Northumberland, and other places in Northern and Central Britain, are probably the last surviving representatives of the gigantic Urus of the Pleistocene period, reduced in size and modified in every respect by their small range and their contact with man.

On the mainland of Europe *Bos urus* was very numerous and had a very extended range, both in Pleistocene and Prehistoric and Historic times; while in our own country, insulated from the con-

* Undique extra domos suburbanorum horti civium arboribus consiti spatiosi et speciosi contigui habentur. Item a borea sunt agri pascuæ, et pratorum grata planities aquis fluvialibus interfluis; ad quas molinarum versatiles rotæ citantur cum murmure jocoso. Proxime patet ingens foresta (not forest, but uncultivated ground), saltus nemorosi, ferarum latebræ, cervorum, damarum, aprorum, et *taurorum sylvestrium*. (Vita sancti Thomæ, auctore Willelmo filio Stephani, vol. i. p. 173). 8vo. Edidit E. A. Giles, Oxoniæ.

tinent, at the close of the Pleistocene it was exposed to exterminating causes that did not obtain in the far larger and wilder area of the European mainland; it was rare in the two latter periods, and probably became extinct as a wild variety several centuries before the species (or variety) on the continent was driven away from the Hercynian Forest and the banks of the Danube. In Pleistocene times it wandered in vast herds over Northern, Central, and Western Europe, and, according to Bojanus, over Southern Russia, and, in company with the Woolly Rhinoceros (*R. tichorinus*) and the Mammoth, frequently fell a prey to the Cave-hyena and the Cave-lion. In the Prehistoric deposits of France, Germany, and Scandinavia its remains are very abundant, and in the latter district prove that it was far more numerous than the contemporary Bison.

That the animal was hunted at this early date in Scania is proved by the discovery by Professor Nilsson of a skeleton which had been pierced with a javelin. It was found at a depth of 10 feet, at the bottom of a peat-bog, and "lay with its head downwards; and one of its horns (horn-cores) had penetrated deep into the blue clay which formed the bottom under the peat"*. The evidence that the animal fell by the hand of man is indeed perfectly incontrovertible.

The dwellers on the Pile-works of the Swiss lakes have also left numerous remains of *Bos urus* among the bones that have been found surrounding the rotten piles, in association with other varieties of oxen, for the discussion of which I must refer to the works of Dr. Rütimeyer, of Basle.

In Historic times the animal has been frequently mentioned, first by Cæsar, as a dweller in the Hercynian Forest along with the Elk and Bison. Its name occurs also in the writings of Pliny, Martial, and Seneca, in passages which must be familiar to those who have studied the works of Professors Nilsson and Owen, and of Mr. Henry Woods, who has described so ably the ox-head found at Melksham, near Bath †. There are, however, other and later notices of the animal scattered through the records of France and Germany from the 6th to the 12th centuries, that have not as yet attracted the attention they merit in this country. The chronicler of the life of St. Karilef, the founder of the Abbey of St. Calais, happens incidentally to mention an interview that the hermit saint had with Childebert, the son of Clovis ‡. It came to pass in this way: the king happened to be out hunting in the Province of Maine about the year A.D. 540, and having started a fine ox—rare game in that district—he chased it with his dogs right into the hermit's cell, where he found it standing behind his back. This passage proves two things—that the Bubalus or Wild Ox occurred sometimes in the Province of Maine, and

* *Op. cit.* p. 264. † *Op. cit.*

‡ Erat spectabile videre bubulum qui in eâ provinciâ difficile est inventu. . . . . Invenimus in quodam tugurio hominem nobis cognitum . . . . . . . . post tergum illius adstantem bubulum. Unde vobis, O incognitæ personæ! tanta presumptionis audacia, ut ausi sitis . . . . . nostræ venationis dignitatem . . . . . mutilare? . . . . . . (Vit. S. Karilefi, c. 4, 14, 20.) This quotation is taken from 'Les Moines d'occident,' par le Comte de Montalembert: Paris, 8vo (1860): vol. ii. p. 362. I have had no opportunity of verifying it.

that this one happened to be *tamed* by the hermit. There may indeed be a doubt as to whether the Bubalus mentioned here be actually the *Bos urus*; but interpreted by the light of what we know in other districts respecting the hunting of *Bos urus*, I think that probably it was the animal mentioned in this passage: at all events, the passage is worthy of note.

In the 'Wars of Charlemagne,' written by a monk of St. Gall, a remarkable anecdote is told of a hunt in the forest near Aix-la-Chapelle, in which the king was attacked by a *Bos urus*, and in which, for the first time in history, "hose" are mentioned*. "On the next day Charles, very tired of the quiet and leisure, prepares to go into the forest to hunt (Bisontium vel Urorum) Bisons or Uri, and to take the Persian ambassadors along with him, who, when they saw these gigantic animals, struck with very great terror, took to their heels; but the hero Charles, unmoved, mounted on a very swift horse, coming up close, drew his sword and attempted to cut off the head of one of them. But when he missed his stroke, the most fierce beast, rending his sandals and gaiters, and grazing his thigh with just the tip of its horn, made him a little more cautious, and then, enraged by the slight wound, took refuge in a most safe retreat, bristling with thickets and stones; and when all his suite, to curry favour with the king, wished to take off their hose (hossas suas vellent extrahere), he forbade them, saying, 'In this plight I must go to Hildegarda (one of his wives).' And Isambardus, the son of Warinus, the persecutor of your patron Otmarus, having followed up the beast when he dared not approach nearer, thrust his lance between its shoulder and throat, pierced its heart, and presented it, still quivering, to the king. This deed he pretended not to notice; and leaving the dead animal to his companions, he returned home, and called the queen (Hildegarda), and showed her his torn hose, and said to her, 'What reward is he worthy of who has delivered me from an enemy inflicting these things upon me?' And when she answered, 'Of every good,' the king told her every particular; and having had the vast (immanissimis cornibus) horns brought forward as a proof that he was telling the truth, moved the queen to tears and groans and beating of her breasts." . . .

It is clear, then, that at this time (the beginning of the 9th century) Bisons and Uri were still to be found in the forests near Aix-la-Chapelle. The description of the horns proves that the animal was one of the latter species, as the size of the horns of the former is not such as to warrant the use of the term "immanissima." In the remarkable collection of MSS. preserved in the Abbey of St. Gall is one by Ekkehard the younger, who lived from A.D. 980 to 1036, and composed a set of graces for the use of the monks, in which we are indebted to the custom of returning thanks after every dish for the preservation of the names of the animals they ate†. Among

* Monachi Sangallensis Lib. ii. de Rebus Bellicis Caroli Magni. Folio. (Du Chesne.) Chap. xi.

† "Benedictiones ad mensas Ekkehardi Monachi Sangallensis," Archæol. Journ. vol. xxi. pp. 117–136. "Dextra Dei veri comes assit carnibus uri" (p. 125).

the wild animals, the list comprises Bear, Wild Boar, Red Deer, Roe Deer, Fallow Deer, Chamois, Wild Horse (*Equus feralis*), the Beaver (which is termed *a fish*, and therefore eatable on fast-days), the Bison, and the Urus. The Bison and the Urus, then, were sufficiently abundant in the wilds of Southern Germany and Switzerland at the close of the 10th century to be used as an article of food, and to be deemed worthy of a special grace by the monks of that day. At the close of the next century (the eleventh) the Urus is mentioned along with the Elk as being met with on the route through Germany taken by the First Crusade, and the large size of their horns is noted*. Posterior to this, in the 12th century, in the "Niebelungen-Lied," Tregfried is said to have killed one Bison and four Uri in the neighbourhood of Worms (p. 3775–6). For four centuries after this no mention is made of the animal; and if not extinct in Germany, it must have become very rare. Gesner, in his 'History of Animals,' published at Frankfort in the year 1622, gives a figure of the Polish "Thur," which corresponds exactly in the curvature of its horns with the wild Urus of Germany, though it is very much inferior to the latter in point of size. The wild Urus, therefore, probably lingered in the wilder parts of continental Europe till at least the 16th century; and having first of all sprung into being in Pleistocene times, survived the larger of its contemporaries, and is indeed superior in point of bulk to any of the Pleistocene mammalia that have come down to the times of history. In Pleistocene, as I have mentioned, it was larger than in Prehistoric times, and in the latter than when it was last met with in Poland. The diminution in size is probably to be accounted for by the gradually diminishing area over which it ranged. The area in Prehistoric and Historic days was gradually lessened by the hand of man and the encroachment of cultivation on its old haunts.

### 6. Relation to Domestic Races.

The question that still remains to be discussed is, whether or not it still lives in any of the domestic races. Professor Nilsson thinks that the larger cattle of the Netherlands and Holstein have sprung from this animal. Baron Cuvier and Professor Bell believe that the Urus was, in part at least, the ancestor of our domestic breeds; while Professor Owen† thinks that the tame ox of Western Europe was probably derived from the already domesticated cattle of the Roman colonists. The evidence, on the whole, inclines me to the belief, as there is no osteological or other difference saving that of size between the Urus and the domestic race of cattle, (to pass over the notice already quoted of the tame "bubalus" being hunted into the hermit's cell in Maine) that the larger cattle of Western Europe at least are the descendants of the former animal, modified in many respects by restricted range, but still more by the domination of man.

* "Uris cornua sunt immensæ concavitatis, ex quibus ampla satis et levia pocula fiunt." (Hist. Gest. Viæ Hierosolymitanæ a Fulcone quodam, Lib. i. [Du Chesne, Hist. Franc.])

† *Op. cit.* p. 500.

2. *Further* Documents *relating to the* Formation *of a* New Island *in the neighbourhood of the* Kaimeni Islands. By Commander G. Tryon.

(Communicated by the Lords Commissioners of the Admiralty.)

[An abstract of this communication was published in Quart. Journ. Geol. Soc. No. 87, p. 319, by order of the Council.]

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3. *Note on the* Junction *of the* Thanet Sand *and the* Chalk, *and of the* Sandgate Beds *and* Kentish Rag. By Thomas McKenny Hughes, B.A., F.G.S., of the Geological Survey of Great Britain.

At the bottom of the Thanet Sand there is always a bed of green-coated flints in a green and rust-brown clayey sand*.

The following observations have led me to infer that this bed is due to the decomposition of the top of the Chalk after the deposition of the Thanet Sand:—

1. The flints never show any traces of having been rolled or worn by the action of water, or broken up and weathered by any subaërial agency, but are, except in colour, exactly similar to those in place in the Chalk.

2. No fossils, except chalk fossils preserved in flint, have been found in it.

3. Where a nearly continuous bed of flints, or a large tabular mass of flint occurs, the base-bed of the Thanet Sand seems to be arrested by it in a manner that would suggest rather the chemical decomposition than the mechanical erosion of the surrounding chalk.

4. Where masses of chalk are imbedded in the base of the Thanet Sand they appear to be due to local undermining of the main mass of the rock, and not to be transported fragments rearranged in a hollow.

Again, to look at the question from another point of view, it is highly improbable that it could be otherwise. As water charged with carbonic acid, soaking through the Thanet Sand, reaches the chalk below, it must decompose the surface to a certain extent; and if the water can pass freely away so that new supplies, not saturated with carbonate of lime, are brought to act upon it, that decomposition must go on *ad infinitum*.

The only difference, therefore, between this action extending over the whole surface of the chalk where covered by Tertiary or later deposits and that which forms pipes is, that in the case of the pipes the water is collected at or near the surface into small streams; whereas in the other case it permeates the whole of the deposit overlying the chalk, and acts more equally on its surface.

There are cases where the surface of the chalk does not appear to have suffered any great amount of decomposition—as, for instance, north-west of Rainham, in Kent, where there is very little of this

* For further description, see Prestwich, Quart. Journ. Geol. Soc. vol. viii. p. 243. See also Whitaker, *infrà*, p. 405.

green bed with flints at the base of the Thanet Sand. The junction may be seen in a chalk-pit in the brick-field north of Moor Street. But there are local circumstances by which this may be explained:—

1st. There is a bed of clay in the Thanet Sand, as may be seen in the road-cutting leading to the brick-field; and

2nd. There is other evidence of a line of upheaval running nearly east and west through this part of the district, which, in conjunction with the bed of clay above mentioned, would have the effect of throwing the drainage off to the north and south, and therefore partly protecting the surface of the chalk here from the action of the carbonated water.

Similar reasoning may be applied to explain the local phenomena of the more westerly part of the Tertiary basin—as, for instance, at Reading and Newbury, where the surface of the chalk is bored by *Lithodomi* to a considerable depth. Here the impervious beds of clay in the overlying Reading series have probably contributed most towards protecting not only the oysters of the lowest part of the Tertiary beds, but also the surface of the chalk from the action of the carbonated water. It is known that the clays of the Woolwich and Reading series allow very little water to pass through them*.

An examination of the junction of the Sandgate Beds and the Kentish Rag leads to a similar conclusion. In the large quarries on the north-west of Maidstone, at the base of the Sandgate Beds, there is a greensand, generally on rubbly Kentish Rag. The thickness of these intermediate beds varies. It is greater in hollows and depressions, where, we have reason to believe, a larger amount of the Rag has been removed.

In the brick-fields close to the town of Maidstone the brick-earth occurs in long furrows of the nature of pipes, in the Kentish Rag. The whole of these furrows are lined with greensand and rubbly limestone, similar to that found at the base of the Sandgate Beds†.

Now, unless we allow that the greensand has been derived from the decomposition of the Rag after the deposition of the brick-earth, and that the rubbly limestone below it is the same in process of decomposition, we have only the improbable alternative left that the irregular denudation which removed the Sandgate Beds previously to the deposition of the brick-earth left the same thin bed at the surface over this large area.

There are several interesting questions raised by this view of the origin of such beds. What do they represent? Do they represent the periods during which the surface of the limestone has been above the sea-level? for, except in some peculiar cases, if it were under the sea, and the water on its surface were at rest, *i. e.* not constantly renewed by fresh infiltration, it would soon become saturated with carbonate of lime, and could remove no more.

How much limestone has been removed since the deposition of the overlying beds? The thickness of the beds formed of its insoluble remainder is not a fair criterion; for, in the case of the chalk, for

* See Prestwich, Quart. Journ. Geol. Soc. vol. x. p. 82, footnote.

† See Messrs. Foster and Topley, Quart. Journ. Geol. Soc. vol. xxi. p. 443.

instance, where a large quantity is washed and run in troughs, as is frequently necessary in the cement-works and brick-fields of North Kent, it is found that the amount of sand left varies considerably in different localities. At the cement-works about one mile and a half south-west of Rochester it is very large; near Sittingbourne, on the other hand, it is comparatively small. (The former is near the junction of the Upper and Lower Chalk, the latter near the top of the highest chalk of that part of the country.)

Mr. Prestwich* has speculated on the origin of the green colour. I would add one note. It seems to occur where carbonate of lime has been dissolved. We find it, as noticed above, on the decomposed surface of limestones; and where lines of greensand or sandy clay occur in the Lower Tertiaries, there we most often find casts of shells†.

The chief deduction from these observations is, however, general—viz., that we cannot safely draw any conclusion as to the conformability or unconformability of a porous formation upon a limestone from an examination of the line of junction only, since that may be very much modified after the deposition of the newer formation.

The unconformity may be inferred from other evidence, as, for instance, in the case of the Thanet Sand, which, it is well known, is not the direct successor of the highest Cretaceous strata found in England.

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## 4. *On the* "Lower London Tertiaries" *of* Kent. By William Whitaker, Esq., B.A. (Lond.), F.G.S., of the Geological Survey of Great Britain.

[Plate XXII.]

Contents.



### § 1. Introduction.

The following paper is meant to give some of the results of the Geological Survey work in the Tertiary District of Kent, and to lay before the Society the conclusions to which that work has led me, in order that they may receive that criticism which is so valuable to every observer.

I give results only, so as not to burden the Society with a description of sections, which would be out of place here for two reasons:—first, because Mr. Prestwich has already described the chief sections of the district, and I can therefore refer to his well-known

* Quart. Journ. Geol. Soc. vol. x. p. 244.

† Perhaps the carbonate of lime neutralizes the effect of the acidulated water, and prevents its acting on the silicate of iron.

papers*; and secondly, because a detailed account of all of them will appear in future Geological Survey Memoirs.

It is also needless to notice earlier authors, as Mr. Prestwich has given a full list of them.

Although the Geological Survey of the district in question is not yet finished, still so little is left undone that there can be no doubt as to the general correctness of the observations on which this paper is founded.

It should be stated that, although the whole of the district is known to me, I have not myself surveyed all of it, Mr. Hughes being answerable for the mapping of the country between Rochester and Faversham, and Mr. Dawkins for some part of the neighbourhood of Faversham. All the rest is my own work, the unfinished parts being on the east of Eltham, in the neighbourhood of Erith, and around Cliffe and Halstow, between the Thames and the Medway.

The more I have learnt of the Tertiary beds, the more have I seen reason to agree with Mr. Prestwich's views; and, indeed, all he has left to do is the filling-in of his outlines, the addition of a few details which seem to have escaped his notice, and a change in nomenclature in a matter that he looked on as doubtful; in fact I only differ from Mr. Prestwich in questions on which he has spoken with doubt.

The beds between the London Clay and the Chalk, of which this paper treats, are of far greater interest in Kent than elsewhere, and for these reasons:—1, that they are there most fully developed; 2, that their structure is there more complex and shows more change than anywhere else; 3, that there are many fine sections; and, 4, that they are almost without fossils in all other districts. These beds might indeed be well called "*the Kentish Tertiaries.*"

## § 2. Thanet Beds.

The indefinite word "Beds" seems to me better than the more definite "Sands" or "Clays," as it is somewhat uncommon for a formation to have everywhere the same lithological composition; and I have therefore used the above name rather than that of "Thanet Sands."

(*a*)† At the base of this set of beds, and resting at once on the Chalk, there is always a clayey greensand, with unworn green-coated flints at the bottom; to this the name of the "Base-bed" may be given. Mr. Prestwich has called the like part of the London Clay the "basement-bed"‡; and I have named that of the Woolwich and Reading Series the "bottom-bed"§. By using a different name for each of these marked layers, one is saved the repetition of the names of the formations to which they belong.

This is the only part of the series which is constantly present,

* Quart. Journ. Geol. Soc. vol. vi. p. 252; vol. viii. p. 235; and vol. x. p. 75.

† The letters *a*, *b*, *α*, *β*, &c., and the numerals 1, 2, &c., refer to those by which the several beds are distinguished in the sections in Pl. XXII.

‡ Quart. Journ. Geol. Soc. vol. vi. p. 255 (1850).

§ Geol. Survey Mem. on Sheet 13, p. 23 (1861).

although it is the thinnest, being often but two or three feet thick, and seldom more than five. For this reason, and from the fact that the green-coated flints are unworn, the question has occurred whether it may not have been formed, in some measure, after the deposition of the beds above, by the slow action of water flowing through the overlying sand, &c., to the Chalk, dissolving away the latter and depositing clayey matter, salts of iron (the green colouring-matter), and sometimes allophane. The occurrence of the last mineral at the junction of the Thanet Beds and the Chalk has been recorded by Prof. Morris*, who says that "it must have been deposited from a fluid or viscid state, not only after the denudation of the Chalk and the deposit of the partially abraded (?) flints, which are coated with it, and after the accumulation of the Thanet Sand, but subsequently to the disturbance of the whole series, whereby the fissures in the Chalk were formed, and in which the allophane is now found." I have since found it at the same junction at Chiselhurst and Faversham; and I believe that it occurs at the bottom of the Reading Beds at Northaw, where they rest on the Chalk†.

Mr. Prestwich has noted "the constant occurrence" of the green-coated flints at the bottom of the Thanet Beds, "just as they occur in the underlying Chalk, from which in fact they appear to have (been) removed comparatively without wear or fracture," but has inferred that a "powerful but transient action" must have been needed "to uproot these flints from the Chalk"‡.

It is remarkable that, whatever rests on the Chalk, there should nearly always be unworn flints at the junction: thus in the western part of the London Basin there are flints at the bottom of the Reading Beds; and in the many places where the Chalk is hidden by the irregular deposit of brick-earth so common in Wiltshire, Berkshire, Oxfordshire, &c., the two are separated by the peculiar "clay with flints," as I have called it§, the origin of which my friend Mr. Codrington, F.G.S., and myself have, independently, referred to the slow dissolving away of the Chalk by water‖. I think it not unlikely that the "argile à silex"¶ of the French geologists (or some part of it) is the same as our clay-with-flints, in which case, strange to say, the same name will have been given to the deposit in two countries and languages. Prof. Hébert's description of the former in France** would in great part serve equally well for the latter in England.

I have before noticed the remarkable conformity between the

* Quart. Journ. Geol. Soc. vol. xiii. p. 13 (1857).

† Geol. Survey Mem. on Sheet 7, p. 30 (1864). It was noticed before by Mr. Prestwich as "hydrate of alumina:" Quart. Journ. Geol. Soc. vol. x. p. 123 (1854).

‡ Quart. Journ. Geol. Soc. vol. viii. pp. 243, 253.

§ Geol. Survey Mem. on Sheet 13, p. 54.

‖ Magazine of the Wilts. Archæol. and Nat. Hist. Soc. vol. ix. p. 167 (1865), and Geol. Survey Mem. on Sheet 7, p. 64 (1864).

¶ I have lately (July) seen some of the "argile à silex" on the coast of Normandy, where it is exactly like the clay so common on our own Chalk.

** Bull. Soc. Géol. France, 2e série, t. xix. p. 445 (1862), and t. xxi. p. 58 (1864).

Thanet Beds and the Chalk in East Kent*. Is it not possible that this also may be owing, to some extent, to the infiltration of water along the line of junction, and that the dissolving away of the chalk by the water may have been stopped, or regulated, by the continuous bed of flint which there occurs directly below the base-bed? I do not mean to say that this can have taken place since the elevation of the country to its present position, but would suggest that such an action would not be impossible when the beds in question were many hundreds of feet lower, and therefore saturated with water throughout, and subjected to great pressure from overlying materials. Should this be true, it will be a case of the same action causing exactly opposite results under different conditions; the infiltration of water through the Tertiary beds to the Chalk now (when comparatively small) causes unevenness (pipes) at the junction, at least where that junction is near the surface, whilst it may have caused evenness when of far greater extent and when the junction was at a great depth.

Since the above was written, I have found that my colleague Mr. Hughes has come to a more decided opinion as to the formation of the bed of green-coated flints after the deposition of the Thanet Beds, and that he has gone into the question in greater detail than I have, as may be seen from his paper (p. 402).

Mr. Codrington, in the essay before noticed, has come to the conclusion "that the origin of the clay-with-flints is to be ascribed to the gradual dissolving away of the chalk-with-flints *under a capping of drift brick-earth.*"

Just after this paper was read, Mr. Dowker published a note on the junction of the Thanet Beds and the Chalk†, in which he suggests that the bed of green-coated flints may be the result of the subaërial dissolution of the Chalk before the deposition of the Thanet Beds. I can hardly agree with this view, but look with more favour on my friend's idea, that the tabular layer of flint at the top of the Chalk may have been formed after the deposition of the overlying beds, and the more so as he has in his collection a specimen of a green-coated flint partly enveloped in a piece of the whitey-brown tabular bed. The same idea occurred also to Mr. J. Evans, F.R.S., who spoke to me (before the publication of Mr. Dowker's note) of the possibility of the layer in question having been thus formed. This flint-layer occurs further west than is stated in my former paper, and may be seen at Grays and Purfleet.

Mr. Prestwich has inferred that the layer of unworn green-coated flints, which nearly everywhere rests on the top of the Chalk where it is covered by Tertiary formations, is everywhere of the same age‡. This may be the case; but it is remarkable that where the Thanet Beds are present, the Chalk never (as far as I know) shows those holes of boring mollusks so common where the Reading Beds lie directly on it, and the occurrence of which at Kembridge, Newbury,

* Quart. Journ. Geol. Soc. vol. xxi. p. 397.
† Geol. Mag. for May 1866, vol. iii. pp. 210, 239.
‡ Quart. Journ. Geol. Soc. vol. viii. pp. 241, 252, 253.

and Reading has been described by Mr. Prestwich*, near Pinner by my colleague the late Mr. Trench, and near Reading, Amersham, Chesham, and Maidenhead by myself†.

(*b*) This bed, which consists of alternations of brown clay and loam, is local, occurring only, I believe, east of Faversham. It may be seen at Pegwell Bay, where it is separated from the Chalk by little more than a foot of the base-bed. No fossils have been found in it.

This is mostly overlain by, and passes up into, the sandy marl (*d*), although another bed sometimes occurs between.

(*c*) In the railway-cutting close to Bekesbourne Station, east of Canterbury, there is a little sand below the sandy marl (*d*), in which the greater part of the cutting is made; and this I take to be the same as the Thanet Sand of London and the western part of Kent. The only other place in that neighbourhood where I saw anything of it was at Selling.

This fine light-buff sand thickens westward, and near Sittingbourne forms a considerable part of the Thanet Beds. Further west it gets still thicker, at the expense of the beds above, until, on the other side of the Medway, it replaces them altogether, and takes up the whole of the space between the Woolwich Beds and the base-bed, some 60 or 70 feet. It thins slightly to the neighbourhood of Woolwich, and then rather more rapidly until it dies out west of London.

No fossils, excepting some casts of *Pholadomya* at Erith (recorded by Mr. Prestwich), have been found in this bed, which is fairly uniform throughout its range. At Charlton and elsewhere its lower part is more clayey, and it passes down into the base-bed.

(*d*) Near and east of Canterbury a grey sandy marl is the most marked member of the Thanet Beds. It is often rather hard, contains green grains, and is of a slate-grey colour, which weathers to a sort of brownish-yellow by exposure, the division between the two colours being sometimes sharp enough to mislead one into thinking that there are two distinct beds.

It often abounds in fossils; and from it have come most of the rarer specimens in the collections of my East Kent friends, such as the parts of Crustacea, a few Echinoids, the *Turritella*, a *Solarium*, and other small univalves, besides many remarkable distorted specimens of *Cyprina Morrisii* and *Pholadomya cuneata*. In the discoloured exposed parts the fossils are nearly all casts, the shell having been dissolved away; whilst in the less exposed part the shells remain, but are very fragile.

This division may be much thicker in some places than is shown in the section (Plate XXII.); for Mr. Dowker found 93 feet of " blue

* Quart. Journ. Geol. Soc. vol. x. pp. 82, 87, 88, 116.

† Geol. Survey Mem. on Sheet 7, pp. 29, 37, 39, 44; and on Sheet 13, pp. 29, 37–39.

clay" above the base-bed in sinking a well at Stourmouth, nearly the whole of which must belong to *d**.

This marl is more sandy towards the top, and passes up into the next division.

(*e*) The uppermost part of the Thanet Beds consists of a fine sharp light-grey sand, of a slightly greenish tinge, often ironshot, and here and there with layers of calcareous sandstone, as at the Reculvers and Pegwell Bay.

It contains fossils, which near Faversham are sometimes silicified, as Mr. Prestwich has observed, though with some doubt whether the bed which contained them belonged to this or to the overlying series†. Mr. Dowker has a large and well-preserved silicified core from a pit in this sand at Canterbury; it is like that figured by Lindley and Hutton‡, which must have come from this formation or from the Woolwich Beds, though described (by some mistake) as from "green sand" near Deal. Mr. John Goodchild, of Sittingbourne, has lately found some Crustacean remains and distorted *Cyprinæ* and *Pholadomyæ* in the brickyards close to that town; these, however, must have come, I think, from low down in the sand, where it passes into the marl below.

From a thickness of 30 or 40 feet near Canterbury, this decreases westward and thins out before we reach Rochester.

## § 3. Woolwich and Reading Beds.

(1) The "bottom bed" does not occur in the most eastern part of the Kentish Tertiary district; and consequently it is there very difficult to divide the sands of this series from those of the underlying Thanet Beds.

At the mouth of the tunnel on the Whitstable Railway at Canterbury, the lowermost part of the Woolwich sand is rather clayey and green, contains a few pebbles, and is more regularly bedded than the higher parts; and this is all that I have seen to represent the bottom bed in the neighbourhood. At Sittingbourne, however, there is a foot or more of pebbly green sand, and at Upnor rather less of the same. Westward this thickens, and from Erith to London the bed consists of from 3 or 4 to 15 or more feet of a rather bright-green sand, with flint-pebbles, both in layers and scattered.

West of London, where the Reading Beds rest on the Chalk, the structure changes, and instead of the pebbly light-green sand, with no fossils but the teeth of *Lamnæ* and sometimes an *Ostrea*, there are grey laminated clays, with green grains and here and there casts of shells§, and dark clayey greensand, with unworn green-coated flints.

(2) Near Canterbury the Woolwich Beds consist almost wholly

* The Geologist, vol. iv. p. 213 (1861).
† Quart. Journ. Geol. Soc. vol. viii. p. 246, and vol. x. p. 109.
‡ The Fossil Flora of Great Britain, vol. ii. pl. 125.
§ Geol. Survey Mem. on Sheet 13, p. 24.

of a pale-grey sand, often of a yellowish or greenish tint, much false-bedded and rather coarse, whilst the underlying sand of the Thanet Beds is fine and not false-bedded. Eastwards, however, the sand of the former gets fine and loses its false-bedding, for which reasons, and from the absence of the pebbly bottom bed, it is almost impossible to divide the two; indeed no one would think of doing so from an examination of that district alone; it is only because they are sharply separated on the west that one is forced to try to divide them in the far east.

The "Corbula-bed" of the coast west of the Reculvers and of the Richborough section is near the bottom of this division. It is this Corbula-bed which has yielded the fossils (except some teeth of *Lamnæ*) that have been found in the Woolwich Beds in the eastern part of Kent, and nearly all of which are silicified. They are marine, except a specimen of *Cyrena cuneiformis*, which Mr. Dowker found at Woodnesborough, near Sandwich.

2 *a* is a bed of flint-pebbles in greenish loam, which overlies the bottom-bed just west of St. Mary's Cray and at Loam Pit Hill, Lewisham.

2 *b* is a mottled clay (green, red, &c.), sometimes like the plastic clays of the west, as in the railway-cutting at Eltham, and sometimes sandy, as on the hills near Cobham. In the latter district I have seen beneath it (in a lane-section) a light-green sand (Section 8, Pl. XXII.), which may belong to 2, but, on the other hand, may be the bottom-bed.

It will be seen that 2, 2 *a*, and 2 *b* all occur in the same position; that is to say, they each fill up the space between the bottom-bed (1) and the estuarine shell-beds (4) [not taking into account the thin bed (3)]; and as we cannot be sure that we ever see any two of them together, it is therefore not unlikely that they simply replace one another; but as I cannot be sure of it, I have thought it better to give each a separate index-mark.

2 *b* thickens under London into the mass of mottled plastic clays and sands which have been found beneath the shell-beds in many wells* (Section 4, Pl. XXII.), and further west joins the other like mass which comes on above the shell-beds.

(3) This bed, though very thin, often indeed no more than three inches thick, is of some importance theoretically, as from its constancy it shows the amount of denudation which the Woolwich Beds of East Kent had suffered before the deposition of the Oldhaven Beds. In that part of the county it is a pale purple-grey sand, often hardened into small lumps of sandstone, which, as Mr. Prestwich has noticed, sometimes show traces of the holes of boring mollusks†. In the neighbourhood of Canterbury the Oldhaven Series comes on at once above this bed; and therefore either none of the higher parts of the Woolwich Series ever existed here, or they have been worn away before the deposition of the Oldhaven Beds;

* See Prestwich in Quart. Journ. Geol. Soc. vol. x. pp. 142, 143, 148–150.

† Quart. Journ. Geol. Soc. vol. x. p. 110.

and it is remarkable that this denudation is quite even, the thin bed of purple sand or sandstone nearly always occurring at the junction. In West Kent, on the other hand, the denudation has been uneven, and the Oldhaven Beds rest on various parts of the underlying series.

I have not seen this bed for some way westward from Shottenden and Boughton-under-Blean, and near Sittingbourne the junction of the Oldhaven and the Woolwich Beds is more irregular. At Upnor, however, there is some sand, whitish at top and purplish below, dividing the shell-beds (4) from the sands (2); and this, I have no doubt, is the same as the like bed at the top of 2, near Canterbury. It occurs also near Cobham (Section 8, Pl. XXII.), and is very likely represented near Woolwich by the "layer of hard concretionary limestone" which sometimes underlies the shell-bed*, and by the clay with calcareous concretions in the same position at Loam Pit Hill, Lewisham.

(4) The most easterly place at which the well-known Woolwich clay with *Cyrenæ, Melaniæ,* and other estuarine shells has been seen is Sittingbourne, where, however, there is no clear section of it. These clays, which are of a dark colour, laminated, with the shells in the lines of bedding, mostly stiff, but sometimes sandy, thicken westward and are well shown at the great Upnor section, where they are about 6 feet thick, and partly without shells. Hence to London they are generally rather thicker, but near Abbey Wood are sometimes cut off altogether by the Oldhaven beds (see section 7, Pl. XXII.) They reach their greatest thickness just south of Chiselhurst, where more than 20 feet of them was shown in the cutting on the London, Chatham, and Dover Railway. West of London this bed soon thins out again. In the neighbourhood of Woolwich the sand below sometimes contains like shells, and may be a distinct bed, coming in between those numbered 2 and the clay shell-bed; though, on the other hand, it may be simply 2 in another condition. Perhaps, too, there is sometimes another and higher set of clay shell-beds, divided from 4 by sand or clay †; but this is a matter of detail, here of no importance, and in the list of fossils any upper set of shell-beds is included under No. 4.

(5) At Sittingbourne there is, next below the Oldhaven Beds, a light-coloured sand with *Cyrenæ, Melaniæ, Ostreæ,* &c., which must thin out eastward, as it occurs nowhere in the Canterbury district; whilst westward it is thicker, as may be seen at Upnor. Further west, however, it has suffered more from denudation, and is sometimes quite cut off by the pebble-beds of the Oldhaven Series.

In the neighbourhood of Lewisham the top part of the Woolwich Beds consists of many feet of alternations of sand and clay, the

* Prestwich, Quart. Journ. Geol. Soc. vol. x. p. 103.

† At the cliff-section on the French coast westward of Dieppe there are two masses of the clay shell-beds, separated by clay; and the cliff at Newhaven, in Sussex, shows a great thickness of the same divided into two by unfossiliferous sand and clay.

lower part of which is generally the more clayey; this bed has been well named "striped sand and loam" by the Rev. H. M. De la Condamine*. As it is in the same position as bed 5 further east, I have classed them together, though possibly they may not be the same.

Under London this part of the Woolwich Beds seems to be often absent. (See Section 4, Pl. XXII.)

(5 *b*) Many of the London wells† have shown that a mass of mottled plastic clays and sand, of the same nature as bed 2 *b*, comes on above the clay shell-beds. This, therefore, may represent 5; although, on the other hand, it may be a separate bed, and I have therefore given it a separate index-mark.

West of London 2 *b* and 5 *b* come together, the beds between having thinned out, and form the well-known plastic clays and sands of Reading, &c., where there is nothing but these and the thin bottom-bed between the London Clay and the Chalk.

## § 4. Oldhaven Beds.

Up to this point my nomenclature has followed that of Mr. Prestwich; but with regard to the sands and pebble-beds next below the London Clay in a great part of Kent, I am obliged to differ from him—the difference, however, being not as to the position of the beds, but only as to their relation to those above and below and as to what they should be called.

Mr. Prestwich has, though with some doubt, classed the greater part of the pebble-beds of Blackheath, &c., and the uppermost sands of Upnor and the Reculvers with his "basement-bed of the London Clay," taking them to represent the pebbly loam which occurs at the bottom of that formation on the west‡. To this I objected in a paper read before this Society about four years ago§, as the layer of pebbles in clay which on the south-east of London occurs at the bottom of the London Clay, and is therefore its basement-bed, overlies the thicker sandy pebble-beds. Moreover in some places the two are separated by a layer of sand.

I thought therefore that the sandy pebble-beds should be classed rather with the Woolwich Series, and inferred that the highest sands of Upnor, &c., would follow the same classification. Since then, however, I have had the means of learning much more of the "Lower London Tertiaries," and am bound to say that the knowledge thus gained has led me to a greater agreement with the views of Mr. Prestwich, as I took the first chance of stating||, and to acknowledge that the classing of these sands and pebble-beds with the

* Quart. Journ. Geol. Soc. vol. vi. p. 441.

† Prestwich, Quart. Journ. Geol. Soc. vol. x. pp. 76, 142–144, 148–151.

‡ Quart. Journ. Geol. Soc. vol. vi. pp. 254, 255, 261–265, and vol. x. pp. 105–107, 110, 111, 130 (note),

§ *Ibid.* vol. xviii. pp. 267–268. The section at Bickley was reopened after my paper was published, in order to get ballast for the railway.

|| Geol. Survey Mem. on sheet 7, p. 24. See also a short account of the Tertiary Beds of Kent in the Geologist, vol. vii. p. 57 (1863).

Woolwich Series in that paper was in some measure a step backwards. This was owing to my want of the detailed knowledge of the subject which I have since been enabled to get, and partly to a misunderstanding of Mr. Prestwich's writings, caused by the sense in which he has used the term "basement-bed." This is the right place to correct my statement that in the railway-cutting north of Sittingbourne there was "nothing like the usual basement-bed to be seen." I first saw that section during a sharp frost and after snow, when, of course, it was neither easy nor pleasant to make a very careful examination, but have since been there under more favourable circumstances, in the company of my colleague Mr. Hughes, who mapped that neighbourhood; and we then found that the lowermost foot or so of the London Clay was often rather sandy, and contained a few pebbles, some teeth of *Lamna*, and a little clayey greensand—that is to say, that it had the characters of the basement-bed in Berkshire, &c. The like thing occurs at the cliff-section west of the Reculvers, and at some other places, as Mr. Prestwich has noticed.

In the neighbourhood of Woolwich, Mr. Prestwich has classed part of the pebble-beds with the Woolwich Series, and part with his basement-bed; but such a division seems to me rather arbitrary, and it would be impossible to map it. I have been led rather to look on the whole as one thing, and to separate the pebble-beds from the Woolwich Series, on which they so often rest unconformably.

It will be seen therefore that, whilst holding to my opinion that the pebble-beds and the uppermost sands do not belong to the basement-bed, I now think (with Mr. Prestwich in great measure) that they do not belong to the Woolwich Series—or, in other words, that they are a separate series, to which, of course, some name must be given. That of "Oldhaven Beds" is a good one, and for two reasons,—first because they are well shown at "Oldhaven Gap" on the coast west of the Reculvers, and secondly because it is not an ugly name—a thing that might perhaps be thought more of in geological nomenclature with some advantage.

In thus separating these beds from those above and below, I do not really differ so much from Mr. Prestwich as seems to be the case at first sight; for he classes his "basement-bed" not with the London Clay or "Upper London Tertiaries," but with the underlying series, to form the "Lower London Tertiaries." Now the term "basement-bed" of a formation means simply a peculiar bed at the bottom of and *belonging to* that formation; and, on the other hand, it cannot rightly be used for the bed *next below*, in which latter sense this author seems sometimes to use it. The "basement-bed of the London Clay" therefore is the characteristic bed at the bottom of that formation and forming a part of it.

The difference between my classification and that of Mr. Prestwich will perhaps be best understood by tabulating the two side by side, as below:—

| Prestwich, 1850–54. | | | Proposed Classification. | |
|---|---|---|---|---|
| | London Clay. | Clay. | | London Clay. |
| Lower London Tertiaries. | Basement-bed of the London Clay. | Thin pebbly loam &c. of the western part of the London Tertiary District. Thin clayey pebble-bed of Lewisham, &c. | Basement-bed. | London Clay. |
| Lower London Tertiaries. | Basement-bed of the London Clay. | Highest sands of Upnor, the Reculvers, &c., with pebbles at the bottom. Part of the sandy pebble-bed of Kent (Blackheath, Abbey Wood, Shottenden Hill, &c.). | Oldhaven Beds. | Lower London (or Kentish) Tertiaries. |
| Lower London Tertiaries. | Woolwich and Reading Series. | Part of the sandy pebble-bed of West Kent (Sunderidge near Bromley, &c.) | Oldhaven Beds. | Lower London (or Kentish) Tertiaries. |
| Lower London Tertiaries. | Woolwich and Reading Series. | Sands, shell-beds, mottled clays, lower pebble-beds (unfossiliferous and local), and pebbly greensands of West Kent and of part of East Kent. Mottled plastic clays, sands, &c. of the western part of the London Tertiary District and sands of East Kent. | Woolwich and Reading Beds. | Lower London (or Kentish) Tertiaries. |
| Lower London Tertiaries. | Thanet Sands. | Sands, sandy marls, &c. | Thanet Beds. | Lower London (or Kentish) Tertiaries. |

Having, I trust, clearly stated what is here meant by "Oldhaven Beds" a short account of the different members of that series will now be given.

(*α*) At the bottom of this series at Upnor there is a thin irregular layer of pale greenish-yellow sand, crowded with shells (*Cyrena*, *Ostrea*, *Cerithium*, *Melania*) and filling small hollows in the underlying sand of the Woolwich Beds. This is not constant, being cut off in many places by the pebble-bed above, the lower parts of the hollows, however, being often left as separate patches. This bed is very local; indeed I do not remember having seen it anywhere else, though it may occur in places at the great Reculvers section. Possibly, too, the thin bed of sand with shells which next underlies the London Clay at the Brockwell Hall Brickyard, Dulwich *, may be the same as the above, which it is not unlike.

(*β*) The characteristic sandy pebble-bed which nearly everywhere occurs at the bottom of this series, varies in thickness from a few inches to rather more than two feet in the Canterbury and Reculvers district. At the former place, and for a few miles to the west, it often undergoes a great change in structure, the pebbles being replaced by a mass of sandy brown iron-ore, sometimes 5 feet thick. Here and there a few pebbles occur below, and scattered through, the stone, which in some places contains many casts of shells. At one pit near Boughton-under-Blean all the fossils are of estuarine

* See Geol. Survey Mem. on Sheet 7, pp. 23, 24.

Woolwich species (*Cyrena cuneiformis, C. cordata, Melania inquinata*, and *Cerithium*) ; whilst in another, less than a mile off, they are for the most part marine (*Cardium, Pectunculus, Aporrhais, Calyptræa, Fusus*), but with a mixture of the freshwater shells.

But a little southwards from these pits another change takes place, there being nothing but some 30 feet of pebble-beds over the Woolwich sand at the outlier of Shottenden Hill, the only place in East Kent where this part of the series thickens in the same way as at Blackheath, Bromley, &c.

Westwards the pebble-bed is thin, and sometimes there are merely a few pebbles in the bottom part of the Oldhaven sand; but on the Cobham hills it swells out again, and from Erith by Plumstead Common to Blackheath is very thick, as also on the south at Bromley and Chiselhurst, the name of which last place, indeed, is derived from the Saxon "Chesil," a pebble.

From Blackheath to Lewisham, a distance of about a mile, the pebble-beds thin away quickly; and in the cutting on the Lewisham and Tunbridge Railway there was to be seen (in 1864) a layer (no more than from a few inches to a foot thick) of pebbles in sand capped by another (of the same thickness) of pebbles in clay, the latter being the true basement-bed of the London Clay.

Although this division of the Oldhaven Series has been here treated as one bed, yet one cannot be sure that the whole of the thick mass of pebbles of West Kent represents, or is the same as, the thin layer of the eastern division of the county; for it is possible that other beds may come on above, and that the sand of East Kent may be replaced westward by pebbles; but I think that it is the safe and right thing to treat of it so until the contrary view can be proved, and the more so as here and there a layer of sand occurs above the pebbles in the neighbourhood of London.

Most observers must be struck with the very great extent to which these pebbles have been worn. The flint-shingle of our coasts nearly always contains flints in many states of wear, from the rough piece that has not long fallen from the chalk-cliffs to the rounded pebble; but here *all are finished*; at least it is very rarely indeed that even anything like a subangular flint is to be seen. It would seem therefore that these old pebble-beds could hardly have been a shingle-beach along a chalk shore, for in that case they ought to contain many flints but partly worn. They must, however, have been derived from the Chalk; and one is led to infer therefore that they must have been deposited as a shingle-bank some way off shore, to which no flints could get until they had been so long exposed to the wearing action of the sea as to be well rounded.

(γ) In East Kent a fine light-buff sand forms nearly the whole of the Oldhaven Beds, excepting at Shottenden Hill, where it is not shown. Near Canterbury and the Reculvers, this is from 15 to 20 feet thick, for the most part finely false-bedded, sometimes with layers of clay or of sandstone, and sometimes with fossils.

Westward, at Sittingbourne and Upnor, it is thinner, and beyond the latter place is not seen, unless it is represented by the sand which, as aforesaid, sometimes occurs above the pebble-beds in West Kent.

A strange form of selenite seems to be characteristic of the Oldhaven sand both at Upnor and the Reculvers; it consists of crystals with grains of sand caught up between the thin plates, which generally cause a peculiar satin-like lustre, but sometimes are in such plenty as to make the mineral look like concretionary sandstone. These crystals are of various sizes; they often lie with their longer axis vertical or oblique to the bedding, most likely from having been formed in cracks; and now and then casts of shells are made up of them.

*Note on the Fossils from the Oldhaven Beds at Grove Ferry.*

I think it right to correct a mistake, of some importance, that has been made with regard to a section in the Oldhaven Beds, and the more so as it is printed in the Society's Journal.

In 1859 a short paper, "On Some Tertiary Fossils found at Grove Ferry" *, was published by the late Mr. J. Brown, F.G.S., who stated therein that "the beds forming the central portion of this hill above Grove Ferry would appear, according to Mr. Prestwich's sections . . . . . to belong to the 'Basement-bed of the London Clay' (Oldhaven Beds) . . . . . but many of the fossils which I collected here . . . . . appear to have an Upper Tertiary character; indeed some cannot be distinguished from Crag species."

Now there can be no doubt whatever as to the age of the sand in question. It belongs, as Mr. Prestwich has always held, to the series called "Oldhaven Beds" in this paper. Its lithological character is quite enough to settle the matter: no field-geologist who had worked at the many sections in the neighbourhood could doubt for a moment which of the Tertiary sands the pit is in, much less could one who had mapped the district and traced the continuous outcrop of each.

As for the fossils, I could never find any but the common shells, &c., of the Oldhaven Beds; nor could Mr. Dowker, who has been there often. The section, however, is small, and parts once open may now be hidden.

Mr. Prestwich having told me that he thought Mr. Brown had by mistake mixed up some Crag fossils with those from Grove Ferry, and that the reported occurrence of Crag species at that place was therefore open to great doubt, I carefully looked through the collection, now in the British Museum. The result of this examination was to convince me that most of the fossils were really from the Oldhaven sand, and that therefore any mistake in the list must have been chiefly owing to the wrong determination of the species. The following remarks show the main points wherein I differ from Mr. Sowerby's identifications.

* Quart. Journ. Geol. Soc. vol. xv. p. 133.

*Remarks on Mr. G. B. Sowerby's List of the Fossils.*

The names are in the order of the original list.

1. *Pyrgoma Anglica*, Sow. I cannot say what this came from.
2. *Balanus Chisletianus* (new sp.). I did not see this.
3. *Mactra*, "a fragment." I did not see this.
4. *Corbula Regulbiensis*, Mor. From Oldhaven sand.
5. —— *Hencklinsiana*, Nyst. From Oldhaven sand.
6. *Nucula tenuis*, Mont. From Oldhaven sand.
7. —— *nucleus*, Linn. From Oldhaven sand.
   Nos. 6 and 7 may be the same; they are much like the common *N. labellata* of the Lower Eocene.
8. *Pectunculus Plumsteadianus*, Sow. From Oldhaven sand. Should be *P. Plumsteadiensis*.
9. *Limopsis aurita*, Wood. From Oldhaven sand. Mr. S. V. Wood has written to me to the effect that, judging from the figure in Mr. Sowerby's plate, this is not the *L. aurita* of the Crag. It looks to me like a small oblique *Pectunculus*.
10. *Lucina*? "fragmentary." From Oldhaven sand. A mere rolled fragment of a bivalve shell, but, I think, not a *Lucina*.
11. *Cyprina Morrisii*, Sow. From Oldhaven sand.
12. *Astarte elevata* (new sp.). From Oldhaven sand.
13. —— *gracilis*, Goldf., var. *multilineata*, Wood. I cannot say what this came from.
14. —— *Burtinii*, Lajonk. This seems to have come from Oldhaven sand, and to be much the same as the foregoing.
15. *Cyrena consobrina*, Caill. A bad specimen of a small bivalve, most likely an *Astarte*, from Oldhaven sand.
16. *Cardium Laytoni*, Mor. From Oldhaven sand.
17. *Rostellaria Sowerbyi*, Mant. From Oldhaven sand (*Aporrhais*).
18. *Trophon subnodosum*, Mor. From Oldhaven sand.
19. *Pleurotoma*, "imperfect." From Oldhaven sand.
20. *Pyrula nodulifera* (new sp.). I did not see this from Grove Ferry; but there are some good specimens from the Oldhaven sand of the cliffs west of the Reculvers in another draw of Mr. Brown's collection.
21. *Purpura tetragona*, Sow. Not from Oldhaven sand; but must have got into the collection by mischance.
22. *Clavatula brachyostoma*, Wood? From Oldhaven sand (in a piece of *Cyprina*).
23. *Buccinum concinnum* (new sp.). From Oldhaven sand. Looks much like a London Clay *Fusus* (unnamed?).
24. *Chemnitzia elegantissima*, Mont. There is in the collection a shell labelled *Chemnitzia* which may have come from Oldhaven sand; but being small and without matrix, it is hard to say. The same remark applies to No. 25.
25. *Odostomia*, "like *O. plicata*, Mont."
26. *Nassa reticosa*, Sow., var. *costata*, Wood. Not from Oldhaven sand. Marked as *Buccinum costatum* in the collection, into which it must have got by mischance.

27. *Natica Hantoniensis*, Sow.? From Oldhaven sand.
28. —— *cantenoides*, Wood? = *N. glaucinoides*, Sow. From Oldhaven sand. This seems to be the common Eocene *N. labellata*, Lam., which also = *N. glaucinoides*, Sow., this last name seeming to have been given both to a Crag and to an Eocene species.
29. *Bulla concinna*, Wood. I did not see this.
30. —— *utricula*, Nyst. From Oldhaven sand.
31. *Dentalium*, new sp.? Perhaps from Oldhaven sand.
32. *Helix*, "adhering to a broken *Fusus*." The latter is from the Oldhaven sand; but the former is a recent species, and clearly came from a modern freshwater deposit, like that of Copford (Essex), or from a valley-drift, like that of Chislet, close to Grove Ferry (see Prestwich in Quart. Journ. Geol. Soc. vol. xi. p. 110), and has stuck on to the Eocene shell by chance.
33. *Ringicula*. I did not see this.
34. *Valvata piscinalis*, Müller, "in sand within a *Cardium Laytoni*." This seems to be nothing but the broken top of a *Natica* from the Oldhaven sand.
35. *Limax*. Source uncertain.

I cannot help doubting others of the determinations in the above list, besides those to which I have therein taken objection. A few of the fossils, however, were new to me.

There are some small *otolithes* in the collection, which seem to have been left out of the list by mistake. I have also got parts of the scutes of a Turtle and the teeth of *Lamna* in the same pit.

### § 5. General Relations of the Divisions of the "Lower London Tertiaries" to one another.

1. *The Thanet Beds* are the most regular of the three series. They steadily thin away westwards; whilst eastwards from their central district, near Rochester, fresh beds come on above, and partly perhaps replace the sand (*c*), giving the whole a more clayey character.

Wherever a good section of the junction with the Chalk is to be seen, that junction is even and does not show unconformity. There is indeed no stratigraphical proof of unconformity between the Thanet Beds and the Chalk.

I must quote some remarks of Mr. Prestwich, which might seem to differ from the above. "Extensive and deep wear of the Chalk evidently took place before the commencement of the lowest Eocene deposits. In the neighbourhood of ......... Pegwell Bay, Upnor, Woolwich, ...... Reading, Newbury, ....., and Alum Bay, the Chalk invariably presents a worn though not very irregular surface, and is strewed over ..... with those peculiar green-coated flints. This mass of flints, although generally not above 1 or 2 feet thick, in itself indicates a wide destruction of the Chalk"*. I think that Mr. Prestwich will now allow that any irregularity that occurs at

* Quart. Journ. Geol. Soc. vol. viii. p. 256 (1852).

the junction, is owing to the formation of pipes after, and not to the wearing away of the Chalk before, the deposition of the beds. Moreover, if Mr. Hughes be right in accounting for the formation of the bed of green-coated flints *, it follows that the destruction of Chalk needful for its production also took place after the deposition of the Thanet Beds. Of course the process which would effect this result would alike efface the signs of conformity; and therefore the evenness of junction *may* be owing to this, and not to conformable deposition, as said before (pp. 406, 407).

2. *The Woolwich and Reading Beds,* though far more constant in their presence, are less so in their structure. In the far east they pass into the sands below, whilst on the west the two are sharply divided, and the pebbly greensand of the bottom-bed sometimes rests irregularly on the light-coloured Thanet sand†. West and north of London the Reading Beds lie immediately on the Chalk, as is also the case in the Hampshire basin. I think, therefore, that we should be prepared to find this series make a like overlap southwards from the mass of the Kentish Tertiaries, and should not be surprised if outliers of it should be found resting on the Chalk of the North Downs. Now on the hills just north-east of Otford there do occur (besides the loamy mottled brick-earth) masses of bright-coloured mottled plastic clay, just like that of Berkshire, &c., associated with the sands which Mr. Prestwich has classed as Crag‡.

3. *The Oldhaven Beds* are the most local, the most uniform in structure, and the most irregular in occurrence of the whole. Mr. Prestwich long since noticed the way in which the pebble-beds rested on a worn surface of the Woolwich Series§, sometimes indeed cutting off almost the whole of the latter (see Sections 6, 7, 8, Pl. XXII.); and near Chiselhurst I have lately seen the former cutting through the clay with shells (4), the pebble-bed (2 *a*), and the bottom-bed (1), until it rested on the Thanet sand (*c*). If, then, we ought not to be surprised at the Woolwich Beds overlapping the underlying series and resting on the Chalk of the North Downs, still less so should we be at finding the Oldhaven Beds in that position. Here, again, Mr. Prestwich is before me; for, from having found some of the peculiar green-coated flints of the "base-bed" in the Oldhaven sand near Herne Bay, he infers that "it is probable that the denuding action acted not only on the . . . . . upper part of the underlying (Woolwich) series, *but that it in places extended to the chalk itself*" ||.

There seems to be another reason why the Oldhaven Beds must have somewhere reached to the Chalk; for else how is one to account for the great mass of flint-pebbles which they contain?—a mass too great to have been derived from any beds between the two, none of which, indeed, contain anything like that amount of flints.

* See above, p. 402.
† See Prestwich, Quart. Journ. Geol. Soc. vol. x. p. 101.
‡ *Ibid.* vol. xvi. pp. 323–324.
§ *Ibid.* vol. x. pp. 106–107.
|| *Ibid.* vol. vi. p. 277.

In the eastern part of Surrey there are some Tertiary outliers on or near the crest of the Chalk escarpment*. These consist chiefly of masses of pebbles, and are not shown on the Geological Survey Map, as, when working in that district some years ago, I was led to take them for Drift, not being then prepared for those overlaps in the Tertiary beds, of which longer study has shown me the existence; and I now think that these sandy pebble-beds belong to the Oldhaven Series. There are a few small outliers of the same in Kent, and also of sand like that associated with the pebble-beds at Shottenden Hill.

A long and close examination of the Tertiary district of Kent has led me to think therefore that its structure tends to show that *there may have been a southerly transgression† of the Woolwich Beds over the underlying Thanet Beds, and still more of the Oldhaven Beds over both.*

The transverse section in Plate XXII. may serve as a diagram of the geological structure implied by the above theory. It does not show an unconformity between the Thanet Beds and the Chalk, but rather one in the midst of the Lower London Tertiaries, by means of which their highest member overlaps the others and rests on the Chalk.

For the sake of simplicity no outlier of the Woolwich Series has been shown, but only the greater irregularity caused by the overlap of the Oldhaven Beds.

## § 6. Fossils.

Although this paper is founded wholly on geological evidence, apart from that of fossils, yet the latter have not been neglected, either in the field or at home; and the accompanying list contains, I believe, the name of every properly recorded fossil from these beds. The authorities from which it has been compiled are as follows:—

(1). The many lists scattered through Mr. Prestwich's papers in vols. vi., viii., and x. of the Quart. Journ. Geol. Soc.

(2). The lists in the Geol. Survey Memoirs on sheets 7, 12, and 13.

‡(3). Prof. Morris's 'Catalogue of British Fossils,' 2nd edit. 1854.

‡(4). The Monographs of the Palæontographical Society, by Mr. F. E. Edwards, Mr. S. V. Wood, &c.

(5). The 'Catalogue of the Fossils in the Museum of Practical Geology,' 1865.

(6). The list given by Mr. G. B. Sowerby in the paper by Mr. J. Brown, Quart. Journ. Geol. Soc. vol. xv. p. 133 (see pp. 416, 417).

(7). The lists by Prof. Forbes and the Rev. H. M. De la Condamine in the paper by the latter in Quart. Journ. Geol. Soc. vol. vi. p. 440.

* See Prestwich in Quart. Journ. Geol. Soc. vol. viii. p. 257, and in the 'Waterbearing Strata around London,' pp. 135–36 (1851).

† This word may perhaps be better here than "unconformity," as our notions of conformity and unconformity are not yet as clear as might be wished.

‡ The names in the list have been corrected according to these works.

(8). Mr. C. Evans's note in the 'Geologist,' vol. vii. p. 34 (1864); and a few other short notices of fossils.

It is not, however, wholly made from the above published works, but has been largely added to from unpublished lists, in my Notebooks, of the collections of Mr. G. Dowker, F.G.S., Mr. J. Reid and the Rev. Dr. Mitchinson (Canterbury), Mr. J. Horsley (given to the British Museum), Mr. J. G. Goodchild (Sittingbourne), given to the Geol. Survey, and Mr. J. Marten (Ensinge), also in part given to the Survey, besides many notices of fossils found whilst working at the Tertiary beds of Kent. Of course I cannot hold myself responsible for the right identification of the species in the published lists; each observer must answer for his own determinations. Some of these, no doubt, are wrong; but that is not my fault, and I shall be glad to have corrections and additions.

Sometimes I have been unable to state in what particular bed a fossil has been found. This, again, is not my fault, but is owing to the fact that authors are somewhat careless in giving information as to the exact position or locality of the fossils they find: thus many specimens are recorded simply as from "Woolwich Beds," whilst of others one can learn no more than that they are "Lower Eocene." I am sorry to say that the last case often occurs, just where it is most to be regretted, in the elaborate monographs of the Palæontographical Society "On Eocene Shells," which, whilst being almost perfect from a zoological point of view, sometimes are of little use to the field-geologist.

The classification of the large groups follows that of Prof. Huxley in the 'Catalogue of Fossils in the Museum of Practical Geology,' 1865, p. lxxv.

## List of Fossils from the Beds between the London Clay and the Chalk, with their Range upwards into the Basement-bed of the London Clay, into the London Clay, and into Beds above the London Clay.

[Those species marked ‡ are so named in the Monographs of the Palæontographical Society, and those names marked † occur in Professor Morris's 'Catalogue of British Fossils,' 2nd edit.].

| Names of Fossils. | Pass up | | Basement-bed of London Clay. | Oldhaven Beds. | | Woolwich and Reading Beds. | | | Thanet Beds (EastKent). | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Above London Clay. | Into London Clay. | | Sand, &c. (Central & East Kent), *a*. | Pebble-bed (West Kent), *β*. | Shell-beds, chiefly clay (W. Kent), 4. | Sand (E. Kent), 2. | Bottom-bed (Berkshire), 1. | Sand, *e*. | Sandy Marl, *d*. |
| Kingdom **ANIMALIA.** | | | | | | | | | | |
| Subkingdom VERTEBRATA. | | | | | | | | | | |
| Class Mammalia. | | | | | | | | | | |
| Coryphodon | | | | | | * | | | | |
| †Didelphys (?) Colchesteri, *Charlesworth* | | | * | | | | | | | |
| †Hyracotherium cuniculus, *Ow.* | | | * | | | | | | | |
| Lophiodon, or Coryphodon | | | | | | | | | | |
| Vespertilio, sp., *Ow.* | | | * | | | | | | | |
| Bones | | | * | | | * | | | | |
| Class Aves. | | | | | | | | | | |
| Bone (phalangeal) | | | | | | * | | | | |
| Class Reptilia. | | | | | | | | | | |
| *Chelonia*. Bones | | | | * | | * | | * | | |
| ——. Fragments of carapace | | | | * | | | | | | |
| *Crocodilia*, remains of (*Ow.*) | | | ? | | | | | | | |
| ——. Scutes | | | | | | * | | | | |
| *Lacertia*, remains of (*Ow.*) | | | ? | | | | | | | |
| †Palæophis longus?, *Ow.* | | | ? | | | | | | | |
| Class Pisces. | | | | | | | | | | |
| Edaphodon | | | | | | | * | | | |
| †Lamna contortidens, *Ag.* | | | ? | | * | * | | | | |
| —— dubia, *Ag.*? | | | | | ? | ? | * | * | | |
| †—— elegans, *Ag.*? | | | | * | | | | | | |
| —— Hopei, *Ag.*? | | | | | ? | ? | * | * | | |
| —— (?sp.) teeth | | | * | * | * | | * | * | * | |
| Lepidosteus (vertebræ), 2 sp.? | | | | | | * | | | | |
| —— scales | | | | | ? | | | | | |
| Lepidotus minor? | | | | | | * | | | | |
| Myliobatis (fragments) | | | | | | | * | | | |
| Otodus. Teeth | | | * | | * | | | | | |
| Fish (broken up). One fairly perfect skeleton got by Mr. J. Marten, at Ensinge, now in the Mus. of Pract. Geol. | | | | | | | | | | * |
| Bones, scales, teeth, or vertebræ | | | * | * | * | * | * | * | * | |
| Otolithes | | | | * | | | | | | |

| Names of Fossils. | Pass up | | Basement-bed of London Clay. | Oldhaven Beds. | | Woolwich and Reading Beds. | | | Thanet Beds. (East Kent). | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Above London Clay. | Into London Clay. | | Sand, &c. (Central & East Kent), γ. | Pebble-bed (West Kent), β. | Shell-beds, chiefly clay (W. Kent), 4. | Sand (E. Kent), 2. | Bottom-bed (Berkshire), 1. | Sand, *e*. | Sandy Marl, *d*. |
| Subkingdom MOLLUSCA. | | | | | | | | | | |
| Class CEPHALOPODA. | | | | | | | | | | |
| Nautilus (2 specimens, one found by Mr. J. Evans, F.R.S., near Reculvers, the other by Mr. J. Marten at Ensinge; both in the Mus. Pract. Geol.) | | | | | | | | | * | * |
| Class GASTEROPODA. | | | | | | | | | | |
| (Including classes Pulmogasteropoda and Branchiogasteropoda of Huxley.) | | | | | | | | | | |
| Actæon | | | * | | * | | | | | * |
| †Aporrhais Sowerbyi | * | * | * | * | | | | | * | * |
| †Auricula pygmæa, *Mor.* | | | | | * | | | | | |
| Buccinum (?) ambiguum, *Desh.*, and "new sp., large and globose" (*Prestw.*, Q. J. G. S. vi. 257) | | | * | | | | | | | |
| —— concinnum, *G. B. Sby.* (Grove Ferry, see p. 417.) | | | | * | | | | | | |
| —— ? | | | | | * | * | | | | |
| ‡Bulla concinna, *Wood?* (Grove Ferry, see p. 418.) | * | | | ? | | | | | | |
| —— utricula, *Nyst* (Grove Ferry, see p. 418.) | | | | * | | | | | | |
| †Calyptræa trochiformis, *Lam.* | * | * | * | * | * | * | * | | * | |
| †Cancellaria læviuscula, *Desh.* (? *Sby.*) | * | * | * | | | | | | | |
| †Cassidaria nodosa, *Brand* | * | * | * | | | | | | | |
| †—— striata, *Sby.* | | * | * | | | | | | | |
| †Cerithium Bowerbankii, *Mor.* | | | | | * | | | | | |
| —— crenatulum, *Desh.* ? | | | | | | * | | | | |
| —— crenulatum, *Desh.* ? | | | | | * | | | | | |
| †—— funatum, *Mant.* (including C. variabile, *Desh.*) | * | | | * | * | * | | | | |
| †—— gracile, *Mor.* | | | | | | * | | | | |
| †—— Lunnii, *Mor.* | | | | | * | * | | ? | | |
| ‡Chemnitzia elegantissima, *Montagu* (Grove Ferry, see p. 417.) | * | | | * | | | | | | |
| ——, or Eulima, "a very small sp." From Thanet Beds, (*Prestwich*, Q. J. G. S. viii. 248. | | | | | | | | | | |
| ‡Clavatula brachystoma, *Phil.* ? (Grove Ferry, see p. 417.) | * | | | * | | | | | | |
| †Dentalium nitens, *Sby.* | * | * | | ? | | | | | * | |
| —— sp. (rather large) | | | | | | | * | | * | * |
| ——, small sp. (?=D. nitens) | | | | | | | | | | * |
| †Eulima ?, or Rissoa ?; see also Chemnitzia | | | | | * | | | | | |

| Names of Fossils. | Pass up | | Basement-bed of London Clay. | Oldhaven Beds. | | Woolwich and Reading Beds. | | | Thanet Beds (E. Kent.) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Above London Clay. | Into London Clay. | | Sand, &c. (Central & East Kent), γ. | Pebble-bed (West Kent), β. | Shell-beds, chiefly clay (W. Kent), 4. | Sand (E. Kent), 2. | Bottom-bed (Berkshire), 1. | Sand, *e*. | Sandy Marl, *d*. |
| †Fusus complanatus, *Sby*. | ..... | * | ..... | * | | | | | | |
| †—— gradatus, *Sby*. | ..... | ..... | ..... | ..... | * | | | | | |
| †—— latus, *Sby*. | ..... | ..... | ..... | ? | * | * | | | | |
| —— planicostatus, *Mell*. | ..... | ..... | ..... | ..... | * | | | | | |
| †—— subnodosus, *Mor*. | ..... | ..... | ..... | * | * | ..... | ..... | ..... | * | |
| †—— tuberosus, *Sby*. | ..... | * | * | * | ? | ..... | ..... | ..... | ..... | * |
| ——, sp. | ..... | ..... | * | * | * | ..... | ..... | ..... | * | * |
| Helix (?!) | ..... | ..... | ..... | * | | | | | | |
| †Hydrobia Parkinsoni, *Mor*. | ..... | ..... | ..... | ..... | * | * | | | | |
| †—— Websteri, *Mor*. | ..... | ..... | ..... | ..... | * | ? | | | | |
| Limax (?!) | ..... | ..... | ..... | * | | | | | | |
| †Melania inquinata, *Defr*. | ..... | ..... | ? | * | * | * | | | | |
| †Melanopsis ancillaroides, *Desh*.? | ..... | ..... | ..... | ..... | * | * | | | | |
| †—— brevis, *Sby*.? | ..... | ..... | ..... | ..... | ..... | * | | | | |
| †—— buccinoides, *Fér*. | ..... | ..... | ..... | ..... | * | * | | | | |
| —— subcarinata? | ..... | ..... | ..... | ..... | ..... | * | | | | |
| —— subfusiformis? | ..... | ..... | ..... | ..... | * | * | | | | |
| Metula juncea, *Sby*. (=Buccinum junceum) | * | * | ..... | * | | | | | | |
| Murex foliaceus, *Mell*.? | ..... | ..... | ..... | ..... | * | | | | | |
| ‡†Natica catenoides, *Wood* (Grove Ferry, see p. 418) | ..... | ..... | ..... | * | | | | | | |
| †—— Hantoniensis, *Linn*. (or *Pilk*.?) | * | * | * | * | | | | | | |
| †—— labellata, *Lam*. | * | * | * | * | * | | | | | |
| †—— patula, *Lam*.? (from the Thanet Beds). | | | | | | | | | | |
| †—— subdepressa, *Mor*. (=Ampullaria) | ..... | ..... | ..... | * | * | ..... | * | ..... | * | ? |
| —— (small, sp.) | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | * | |
| †Neritina concava, *Sby*. | * | ..... | ..... | ..... | * | | | | | |
| †—— consobrina | ..... | ..... | ..... | ..... | * | | | | | |
| †—— globulus, *Defr*. | ..... | ..... | ..... | ..... | * | * | | | | |
| —— pisiformis, *Fér*. | ..... | ..... | ..... | ..... | * | * | | | | |
| —— vicina, *Mell*. | ..... | ..... | ..... | ..... | * | | | | | |
| Odostomia | ..... | ..... | ..... | * | * | | | | | |
| Paludina aspera, *Michaud* (?=P. Desnoyeri, *Desh*.) | ..... | ..... | ..... | ..... | ..... | * | | | | |
| †—— lenta, *Brand*. | * | ..... | ..... | ..... | ..... | * | | | | |
| —— ——, *Brand*. var. β, *Mor*. | ..... | ..... | ..... | ..... | * | * | | | | |
| —— rugosa, *Brand*.? | ..... | ..... | ..... | ..... | ..... | * | | | | |
| Patella, sp. | ..... | ..... | ..... | ..... | * | | | | | |
| Pitharella Rickmanni, *Edw*. | ..... | ..... | ..... | ..... | * | * | | | | |
| ‡†Planorbis hemistoma, *Sby*. | * | ..... | ..... | ..... | * | * | | | | |
| —— lævigatus, *Desh*. | ..... | ..... | ..... | ..... | ..... | * | | | | |
| ‡Pleurotoma acuminata, *Sby*. (Grove Ferry, see p. 417) | ..... | * | ..... | * | | | | | | |
| ‡†—— comma, *Sby*. | * | * | * | * | | | | | | |
| ——, sp. | ..... | ..... | * | * | | | | | | |
| †Pseudoliva fissurata, *Desh*. | ..... | ..... | ..... | ..... | * | | | | | |
| †—— semicostata, *Desh*. | ..... | * | ..... | ..... | * | | | | | |

| Names of Fossils. | Pass up | | Basement-bed of London Clay. | Oldhaven Beds. | | Woolwich and Reading Beds. | | | Thanet Beds. (E. Kent.) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Above London Clay. | Into London Clay. | | Sand, &c. (Central & East Kent), γ. | Pebble-bed (West Kent), β. | Shell-beds, chiefly clay (W. Kent), 4. | Sand (E. Kent), 2. | Bottom-bed (Berkshire), 1. | Sand, *e*. | Sandy Marl, *d*. |
| Pyrula nodulifera (*G. B. Sowerby*, Q. J. G. S. xv. 136) | ...... | ...... | ...... | * | | | | | | |
| †—— Smithii, *Sby.* | ...... | * | * | | | | | | | |
| †—— tricostata, *Desh.* | * | * | * | | | | | | | |
| ——, sp. | ...... | ...... | ...... | * | | | | | | |
| †Ringicula turgida, *Charlesworth* (and from Thanet Beds, *Prestw.* Q. J. G. S. viii. 248) | * | * | ...... | ...... | * | | | | | |
| ——, sp. | ...... | ...... | ...... | * | | | | | | |
| Rissoa, sp. | ...... | ...... | ...... | ...... | ...... | * | | | | |
| —— (see Eulima) | | | | | | | | | | |
| †Rostellaria lucida, *Sby.* (? Aporrhais Sowerbyi, see *Prestwich*, Q. J. G. S. vi. 261) | * | * | * | | | | | | | |
| ——, sp. | ...... | ...... | * | * | ...... | * | | | | |
| ——, or Aporrhais (*Prestwich*, Q. J. G. S. viii. 248) | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | * | |
| †Scalaria Bowerbankii, *Mor* | ...... | ...... | ...... | ...... | ? | ...... | ...... | ...... | * | |
| ——, sp. | ...... | ...... | * | * | * | ...... | ...... | ...... | * | * |
| Solarium | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | * |
| Trochus ? | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | * |
| Turritella | ...... | ...... | * | ...... | * | ...... | ...... | ...... | ...... | * |
| Valvata (?) | ...... | ...... | ...... | ...... | * | | | | | |
| ‡†Voluta denudata, *Sby.* | ...... | * | * | | | | | | | |
| Class Conchifera. | | | | | | | | | | |
| Anomia ? | ...... | ...... | ...... | ...... | * | | | | | |
| ‡†Arca depressa, *Sby.* | ...... | ? | ...... | ...... | * | * | | | | |
| ‡—— Dulwichiensis, *Edw.* | ...... | ...... | ...... | ...... | ...... | * | | | | |
| —— Laekeniana | ...... | ...... | ...... | ...... | * | | | | | |
| ——, sp. | ...... | ...... | ...... | ...... | * | * | ...... | * | * | |
| Astarte Burtini, *Lajonk.* (Grove Ferry, see p. 417) | * | ...... | ...... | * | | | | | | |
| —— donacina, *Sby.* | ...... | ? | | | | | | | | |
| —— elevata (*G. B. Sby.*, see p. ) | ...... | ...... | ...... | * | | | | | | |
| —— gracilis, *Goldf.* (*var.* multilineata, *Wood*). (Grove Ferry, see p. 417) | ...... | ...... | ...... | * | | | | | | |
| —— tenera, *Mor.* | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | * | |
| ——, sp. | ...... | ...... | * | * | | | | | | |
| Avicula ? | ...... | ...... | * | ...... | * | | | | | |
| Byssoarca Cailliaudi, *Bellardi* | ...... | ...... | ...... | ...... | ...... | * | | | | |
| †Cardium Laytoni, *Mor.* | ...... | ...... | * | * | * | ...... | * | * | | |
| †—— nitens, *Sby.* | ...... | * | * | * | | | | | | |
| †—— Plumsteadiense, *Sby.* | ...... | * | * | * | * | ...... | * | | | |
| †—— semigranulatum, *Sby.* | ...... | * | * | | | | | | | |
| ——, sp. (one, or both the last two?) | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | * | ? |
| †Corbula Arnouldii, *Nyst* | ...... | ...... | ...... | ...... | * | ...... | * | ...... | * | |
| †—— globosa ?, *Sby.* | * | * | ...... | ...... | ...... | ...... | ...... | ...... | * | |

| Names of Fossils. | Pass up | | Basement-bed of London Clay. | Oldhaven Beds. | | Woolwich and Reading Beds. | | | Thanet Beds (EastKent). | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Above London Clay. | Into London Clay. | | Sand, &c. (Central & East Kent), *γ*. | Pebble-bed (West Kent), *β*. | Shell-beds, chiefly clay (W. Kent), 4. | Sand (E. Kent), 2. | Bottom-bed (Berkshire), 1. | Sand, *e*. | Sandy Marl, *d*. |
| Corbula Hencklinsiana, *Nyst.* (Grove Ferry, see p. 417.) | | | | * | | | | | | |
| †—— Regulbiensis, *Mor.* | | * | * | * | * | * | * | | * | * |
| Crassatella, sp. (From Thanet Beds, *Prestw.*, Q. J. G. S. viii. 248.) | | | | | | | | | | |
| ‡Cucullæa decussata, *Park.* (=†C. crassatina, *Lam.*) | | | | | | | * | | * | * |
| †Cyprina Morrisi, *Sby.* | | | * | * | | | * | | * | * |
| †—— planata, *Sby.* | | * | | | | | * | | ? | |
| †Cyrena cordata, *Mor.* | | | | * | * | * | | * | | |
| †—— cuneiformis. *Fér.* (and in sand below clay shell-beds, Woolwich, *Prestwich.* Q. J. G. S. x. 101) | | | * | * | * | * | * | | | |
| †—— deperdita, *Sby.* | | | | ? | * | * | | | | |
| —— Dulwichiensis, *Rickman* | | | | | | * | | | | |
| —— Gravesii, *Desh.* | | | | | | * | | | | |
| —— intermedia, *Mell.* | | | | | * | | | | | |
| †—— obovata, *Sby.*? (?=C. cordata) | * | | | * | | | | | | |
| †—— tellinella, *Fér.* | | | | * | * | * | | * | | |
| ——, new sp.?, shape of C. cordata, banded like C. Dulwichiensis. Undescribed (*W. W.*) | | | | | * | | | | | |
| †Cytherea convexa, *Brong.* (Newhaven, Sussex) | | | | | | * | | | | |
| —— lævigata (var. *a*?), *Lam.* (*Prestw.* Q. J. G. S. vi. 257) | | | * | | | | | | | |
| †—— obliqua, *Desh.* | * | * | * | * | | | | | | |
| —— orbicularis, *Edw.* (wrongly taken for C. Bellovacina, *Desh.*) | | | * | * | | | * | | * | * |
| —— ovalis (*var.*?), *Sby.* (*Prestw.* Q. J. G. S. vi. 257, 264) | | | * | * | | | | | | |
| Dreissena serrata, *Mell.* | | | | | | * | | | | |
| †Glycimeris Rutupiensis, *Mor.* | | | | * | | | * | | * | ? |
| ——, sp.? | | | * | | * | | | | | |
| ——, or Panopæa | | | | * | | | | | | |
| ‡Leda substriata, *Mor.* | | | | | | | | | * | |
| ‡Limopsis aurita, *Brocchi* (Grove Ferry, see p. 417.) | * | | | * | | | | | | |
| Lithodomus ? (bores) | | | * | | | | * | | | |
| Lucina (and from Thanet Beds, Pegwell, *Prestw.* Q. J. G. S. viii. 248) | | | | ? | * | | | | | |
| Mactra (a fragment). (Grove Ferry, see p. 417.) | | | | * | | | | | | |
| ‡†Modiola depressa, *Sby.* | | * | * | | | | | | | |
| ‡ —— dorsata, *Mor.* | | | | | * | | | | | |
| ‡†—— elegans, *Sby.* | * | * | * | | | * | | | | |
| ‡†—— Mitchellii, *Mor.* | | | * | | * | * | | | | |
| ‡†—— simplex, *Sby.* | | | | | | | | | | |
| ‡†—— subcarinata, *Lam.* | | * | | | | | | | | |
| ——, sp. | | | * | * | | | | | * | * |

| Names of Fossils. | Pass up | | Basement-bed of London Clay. | Oldhaven Beds. | | Woolwich and Reading Beds. | | | Thanet Beds (East Kent). | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Above London Clay. | Into London Clay. | | Sand, &c. (Central & East Kent), γ. | Pebble-bed (West Kent), β. | Shell-beds, chiefly clay (W. Kent), 4. | Sand (E. Kent), 2. | Bottom-bed (Berkshire), 1. | Sand, *e*. | Sandy Marl, *d*. |
| Mytilus | | | * | | | | | | | |
| ‡†Nucula Bowerbankii, *Sby.* | | * | ? | | | | | | * | |
| ‡—— cardioides, *Edw.* (Thanet Beds, Pegwell). | | | | | | | | | | |
| —— fragilis, *Desh.* | | | | | * | * | | | * | |
| ‡—— gracilenta, *Wood* | | | | | * | | | | | |
| —— margaritacea, *Lam.* (?=N. similis, *Sby.*) | * | * | | * | | | | | * | |
| ‡—— nucleus, *Linn.* (Grove Ferry, see p. 417.) | * | | | * | | | | | | |
| ‡—— proava, *Wood.* (Bishopstone (? what from), Palæont. Soc.) | | | | | | | | | | |
| ‡—— sextans, *Edw.* (Thanet (?) Reculvers, Palæont. Soc., ? from *e* or 2). | | | | | | | | | | |
| ‡—— striatella, *Wood* | | | | * | | | | | | |
| ‡—— tenuis, *Montagu.* (Grove Ferry, see p. 417.) | * | | | * | | | | | | |
| ‡—— Thanatiana, *Edw.* (Thanet Beds, Pegwell, Palæont. Soc., ? from *d* or *e*). | | | | | | | | | | |
| ——, sp. | | | * | * | | * | | * | * | * |
| ‡†Ostrea Bellovacina, *Lam.* (including O. edulina, *Sby.*) | | | * | * | * | * | | * | * | |
| ‡—— cymbuloides, *Wood.* | | | | | | | | | | |
| †—— elegans, *Desh.* | | | | | | * | | | | |
| †—— elephantopus, *Sby.* (Mr. S. V. Wood tells me that he believes this to be the thickened upper valve of O. gigantea) | | * | | | | * | | | | |
| —— lateralis (see *Prestwich*, Q. J. G. S. x. 444) | | | | | | | | | * | |
| ‡†—— flabellula, *Lam.* | ? | * | | | * | * | | * | | |
| ‡—— pulcherrima, *Wood.* (Given simply as from Reading by Mr. S. V. Wood, Palæont. Soc.) | | ? | * | | | | | | | |
| ‡†—— pulchra, *Sby.* | | ? | * | | * | * | | * | | |
| ‡†—— tenera, *Sby.* | ? | | | * | * | * | | * | | |
| ——, sp. | | | * | * | | | | | * | * |
| †Panopæa granulata, *Mor.* | | | | | | | | | * | |
| †—— intermedia, *Sby.* | | * | * | * | | | | | | |
| ‡Pecten contubernalis, *Wood* (noticed simply as from Herne Bay by Mr. S. V. Wood, Palæont. Soc.) | | | | | | | | | | |
| ‡†—— Prestwichii, *Mor.* | | | | | | | | | * | |
| ‡†Pectunculus brevirostris, *Sby.* | | * | * | * | * | | | | | |
| ‡†—— decussatus, *Sby.* | | * | * | | | | | | | |
| ‡†—— Plumsteadiensis, *Sby.* | | | * | * | * | | | | | |
| ‡—— terebratularis, *Lam.* | | | ? | * | * | * | * | | * | |
| †Pholadomya cuneata, *Sby.* | | | | | | | | | | * |

| Names of Fossils. | Pass up: Above London Clay. | Pass up: Into London Clay. | Basement-bed of London Clay. | Oldhaven Beds: Sand, &c. (Central & East Kent), γ. | Oldhaven Beds: Pebble-bed (West Kent), β. | Woolwich and Reading Beds: Shell-beds, chiefly clay (W. Kent), 4. | Woolwich and Reading Beds: Sand (E. Kent), 2. | Woolwich and Reading Beds: Bottom-bed (Berkshire), 1. | Thanet Beds (E. Kent): Sand, *e*. | Thanet Beds (E. Kent): Sandy Marl, *d*. |
|---|---|---|---|---|---|---|---|---|---|---|
| †Pholadomya Koninckii, *Nyst*? | | | | | | | | | * | * |
| —— margaritacea, *Sby.*? | | * | | | | | | | ? | |
| ——, sp. | | | * | | | | | | | |
| Pholas, sp. | | | | | * | | | | | ? |
| Pinna, sp. | | | * | | | | | | * | ? |
| †Psammobia Condamini, *Mor.* | | | | | | * | | | | |
| ——, sp.? | | | | | | | | * | | |
| †Sanguinolaria Edwardsii, *Mor.* | | | | | ? | | * | | * | ? |
| Saxicava compressa, *Edw.* (MS.) (From Thanet Beds, *Prestw.*, Q. J. G. S. viii. 248.) | | | | | | | | | | |
| Solen, sp. | | | * | | | | | | | |
| Tellina? | | | * | | * | | | * | | |
| †Teredina personata, *Desh.* | | * | | | * | | * | | | |
| ——, large and undetermined sp. (? T. personata) | | | | | | * | | | | |
| †Teredo antenautæ, *Sby.* | * | * | | | * | | * | | | |
| ——, sp. | | | | | | * | | | * | * |
| †Thracia oblata, *Sby.* | | * | | | | | * | | * | * |
| ‡Unio Edwardsi, *Wood* | | | | | | * | | | | |
| †—— Solanderi, *Sby.*? | | | | | | * | | | | |
| ‡—— subparallela, *Edw.* (U. Deshayesii, *Prestw.*, Q. J. G. S. x. 118) | | | | | | * | | | | |
| ——, sp.? | | | | | * | * | | | | |
| Venericardia? | | | * | | | | | | | ?? |
| **Class Brachiopoda.** | | | | | | | | | | |
| ‡†Lingula tenuis, *Sby.* | | | * | | | | | | | |
| **Class Polyzoa.** | | | | | | | | | | |
| Flustra | | | | | * | * | * | | * | |
| †Lunulites urceolatus, *Lam.* | * | | | | ? | ? | | | | |
| Polyzoan, undetermined | | | | | * | | | * | * | * |
| **Subkingdom ANNULOSA.** | | | | | | | | | | |
| **Class Crustacea.** | | | | | | | | | | |
| Cancer, sp. | | | | | * | | | | | |
| ‡†Hoploparia Bellii, *M'Coy* | | * | * | | | | | | | |
| ——, sp. | | | | | | | | | | * |
| Palæocorystes | | | | | | | | | | * |
| **Order *Ostracoda* (or *Entomostraca*).** | | | | | | | | | | |
| ‡Candona Richardsoni, *Jones* | | | | | | * | | | | |
| Cypris or Cythere, sp. | | | | | | * | | | | |
| ‡Cythere Kostelensis, *Reuss* | ? | | | | | * | | | | |
| ‡—— (Cythereis), "sp. undetermined" (*Jones*) | | | | | | | | | | ? |
| ‡†—— (Cytheridea) Muelleri, *Münst.* | * | | | | * | * | | * | | |

| Names of Fossils. | Pass up | | Basement-bed of London Clay. | Oldhaven Beds. | | Woolwich and Reading Beds. | | | Thanet Beds (E. Kent). | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Above London Clay. | Into London Clay. | | Sand, &c. (Central & East Kent), γ. | Pebble-bed (West Kent), β. | Shell-beds, chiefly clay (W. Kent), 4. | Sand (E. Kent), 2. | Bottom-bed (Berkshire), 1. | Sand, *e*. | Sandy Marl, *d*. |
| ‡Cythere (Cytheridea) Muelleri, *Münst., var.* torosa, *Jones* | * | | | | * | * | | | | |
| ‡—— (Cytherideis), sp. (*Jones*) | | | | | | ? | | | | |
| ——? | | | | | * | * | | | | |
| [C. angulatopora, *Reuss*, C. plicata, *Münst.*, and C. Wetherellii, *Jones*, have been recorded by mistake as from the Woolwich Beds; they are Upper Eocene species. See Prof. T. R. Jones's "Tertiary Entomostraca" (Palæontograph. Soc.), p. 26.] | | | | | | | | | | |
| Order *Cirripedia.* | | | | | | | | | | |
| †Balanus Chisletianus, *G. B. Sby.* (Grove Ferry, see p. 417.) | | | | * | | | | | | |
| Balanus ? | | | | | * | | | | | |
| Class Annelida. | | | | | | | | | | |
| †Ditrupa plana, *Sby.* | | * | * | | | | | | | |
| Serpula | | | | | * | | | | | |
| Class Echinodermata. | | | | | | | | | | |
| Diadema ? | | | | * | | | | | | |
| Hemiaster Bowerbanki | | | * | | | | | | | |
| ‡Ophiura Wetherelli, *Forb.* | | | | * | | | | | | |
| Schizaster ? | | | | | | | | | | * |
| Spatangus (? Hemiaster Bowerbanki), *Prestw.* | | | * | | | | | | | |
| Spines of Echini | | | | * | | | | | * | |
| Subkingdom CŒLENTERATA. | | | | | | | | | | |
| Class Actinozoa. | | | | | | | | | | |
| Coral, small | | | | *(*a*) | | | | | * | |
| Subkingdom PROTOZOA. | | | | | | | | | | |
| Class Spongida. | | | | | | | | | | |
| Sponge-spicules | | | | | | | * | | * | ? |
| Class Rhizopoda. | | | | | | | | | | |
| Order *Foraminifera.* | | | | | | | | | | |
| †Cristellaria calcar, *Linn., var.* platypleura, *Jones* | * | | | * | | | | | | ? |
| Globigerina, sp. | | | | | | * | | | | |
| †Nodosarina (Cristellaria) Italica, *Defr.* (=C. Wetherelli, *Jones*) | | * | | | | | | | | ? |
| †Nodosarina (Nodosaria) raphanistrum, *Linn.* (=N. bacillum, *Defr.*) | | * | | | | | * | | * | |

(*a*) From the ironstone of Boughton-under-Blean.

| Names of Fossils. | Pass up | | Basement-bed of London Clay. | Oldhaven Beds. | | Woolwich and Reading Beds. | | | Thanet Beds (E. Kent). | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Above London Clay. | Into London Clay. | | Sand, &c. (Central & East Kent), γ | Pebble-bed (West Kent), β. | Shell-beds, chiefly clay (W. Kent), 4. | Sand (E. Kent), 2. | Bottom-bed (Berkshire), 1. | Sand, *e*. | Sandy Marl, *d*. |
| Polymorphina lactea, *W. & J.* (=P. ampulla, *Jones*, and Globulina of authors) | * | | | | | | | * | | ? |
| †Rotalia Beccarii?, *Linn.* | | | | | | | | | | * |
| Textularia | | | | | | * | | | | |
| Truncatulina lobatula, *W. & J.* (=Rosalina Mariæ, *Jones*) | | | | | | * | | | | * |
| *Incertæ Sedis.* | | | | | | | | | | |
| Nidulites (London Clay and Thanet Beds). | | | | | | | | | | |
| Kingdom **PLANTÆ.** | | | | | | | | | | |
| Carpolithes (Rhytidosporum, *Hooker*) ovulum, *Brong.* | | | | | | * | | | | |
| Zamiostrobus macrocephalus, *Lind. & Hut.*, a silicified cone (see p. 409) | | | | | | | | | * | |
| Cone, cast of | | | | | | | * | | | |
| Leaves, impressions of | | | * | | | * | * | | | |
| Seed-vessels | | | | | * | * | | | | |
| Wood | | | * | | * | | * | | * | * |

Besides which, impressions of leaves occur in the "striped sands" (5) at Lewisham, and many plant-remains have been found in the lower part of the plastic clays, &c., at Reading. (See Prestwich, Quart. Journ. Geol. Soc. vol. x. p. 88, pl. 4.) These latter have been more lately named by De la Harpe as follows (in the Geol. Survey Memoir, on sheet 10, pp. 113, 116), although perhaps it would be safer, with Dr. Hooker, to leave them without specific names for the present (note to Mr. Prestwich's paper, p. 163):—

Dryandroides Prestwichii, *Heer.*
Ficus Forbesi, *De la Harpe* (ranges up into the Bagshot Beds).
—— Prestwichii, *De la Harpe.*
Grevillea Heeri, *De la Harpe.*
Laurus Hookeri, *De la Harpe.*
Robinia Readingensis, *De la Harpe.*

*** The above List does not refer to Kent only, but is a record of all the fossils from the basement-bed of the London Clay and the Lower London Tertiaries of all parts of England.

## § 7. On the Outliers of Sand on the North Downs, which have been classed with the Crag.

In 1857 Mr. Prestwich read a paper to this Society "On the Age of some Sands, &c., on the North Downs," in which he inferred that the beds in question are of Lower Crag age *. The following remarks on this subject are made with the view, not of giving a

* Quart. Journ. Geol. Soc. vol. xiv. p. 322.

decided opinion on it, but rather of showing how careful we should be in doing so.

Mr. Prestwich's reasons for classing these sands with the Crag are, that they are different in structure from the neighbouring old Tertiary beds, and that many of their fossils are like those of the Crag. Now it has been shown, in the foregoing part of this paper, that there are irregularities in the Lower London Tertiaries, by means of which outliers of the upper and middle divisions occur resting at once on the chalk, without the presence of the lower division, the Thanet Beds, and also that those divisions often change their structure. May not, therefore, the peculiar features of these outlying sands be explained on the supposition that they are transgressive parts of the Woolwich and Oldhaven Beds?

I should not venture to make this suggestion were the fossil-evidence more trustworthy. In Mr. Wood's list, appended to Mr. Prestwich's paper, the name of every species is followed by a note of interrogation; and, in the words of that palæontologist, "the most that can be said is, that there is a stronger resemblance in these fossils to the shells of Crag than to those of any other formation." Since the publication of the above, fresh fossils have been found by my colleague Mr. Hughes and myself, but they do not throw much light on the question. All are in the state of casts or impressions, and are therefore hard to determine. There are amongst them specimens which many palæontologists would at once refer to Crag species, especially perhaps a large *Tellina* exactly like *T. Benedenii* (?), and a *Panopæa* like *P. Faujasii*; others, however, would do equally well for Eocene species; and some can hardly be classed as of any other age than Eocene—for instance, some specimens of *Phorus* quite like *P. agglutinans*, a *Cyrena cuneiformis*, and some examples of a small *Nucula* (which Mr. J. G. Jeffreys, F.R.S., tells me is quite unlike any that occurs in the Crag, whilst it seems to be rather the Eocene *N. minor*). When discussing this question, I have sometimes been met with the statement that the finding of the large *Terebratula* of the Crag (*T. grandis*) in the Lenham ironstone settles the matter; but against this there is the fact, pointed out to me by Mr. Charlesworth, that this shell has been recorded as occurring in Eocene beds in England, under the synonym of *T. bisinuata*, by no less an authority than Mr. Davidson*. It seems, therefore, that we cannot get much help from the fossils. I would add that our knowledge of those from the Kentish Tertiaries is yet far from perfect; fresh species (both new and recorded before from higher beds only) often turn up; so that some of the anomalies of the Lenham list may perhaps be explained when the fossils of the older Tertiary beds are better known.

Another element of doubt is, that the fossils occur only in the ironstone of some pipes at Lenham, none having been found in the larger masses of these sands at Paddlesworth &c.†—and yet another

* Monogr. Palæont. Soc.

† My colleague, Mr. Topley, has lately found a cast of a bivalve (*Cyprina*?) in a field on the hills above Folkestone.

in the fact that fossils from a bed of sand below the London Clay have been mistaken for Crag species (see pp. 416-418); for if old Tertiary shells in fairly good preservation show such a likeness to those of the Crag as to be mistaken for them, how much more likely are we to be led astray by mere casts and impressions, such as those from Lenham?

Since this paper was read, there have appeared two abstracts of a note by MM. Cornet and Briart "On the Discovery in Hainaut, below the Thanet Sands, of a Limestone with a Tertiary Fauna"*, most of the species being allied to those of our Barton and Bracklesham Beds; in other words, there is a Middle Eocene fauna at the bottom of the Lower Eocenes. Surely this should lead us to be careful in determining the exact position of Tertiary beds by their fossils alone.

Those who agree as to the comparatively modern age of the sands on the North Downs are at issue as to their exact position. Mr. Prestwich refers them to the Lower or Coralline Crag. Sir C. Lyell † has thrown them down into the Miocene; and, last of all, a foreign palæontologist has lifted them up higher than before, as may be seen from the following translation, for which I have to thank Mr. Jenkins, the Assistant-Secretary:—"Moreover the iron-sandstones of Kent, which Lyell misquotes as Miocene, contain no single typical Miocene species, but many which are referable to species characteristic of the Upper Crag—a fact of which I have convinced myself by an inspection of the collections of Mr. Prestwich and of the Geological Survey; these beds must therefore be considered Pliocene ‡.

It seems to me that Dr. von Koenen is somewhat rash in saying that these beds *must* be considered Pliocene; he has seen the fossils only, and not the beds they came from; but he has told me that his opinion was backed by the late Dr. S. P. Woodward, an authority second to none in the determination of recent and Pliocene shells. Mr. S. V. Wood and Mr. Charlesworth, however, say that the fossils cannot be determined with accuracy, as they are only casts.

With regard to the placing of these sands in the Miocene System by Sir C. Lyell, I cannot help remarking how that age seems to be used in England as a sort of harbour of refuge for Tertiary rocks. Wherever there are Tertiary beds of which the age is doubtful (that is to say, which are not capped by any other deposits, or are capped by drift only), those beds have been, at one time or other, called Miocene—for instance, the Bovey Beds of Devonshire, the Hempstead Beds of the Isle of Wight, and the Leaf-beds of Mull. Moreover, when Tertiary formations are classified by their contained plant-remains, the worst of all fossils for such a purpose, the odds are greatly in favour of their being called Miocene. Bovey, Hempstead,

* Geol. Mag. vol. iii. p. 174, and Quart. Journ. Geol. Soc. vol. xxii. part 2. p. 11.

† Elements of Geology, 6th edit., pp. 233, 368 (1865). I believe that Sir Charles Lyell has since given up this opinion, and now looks on these sands as Crag.

‡ "Die Fauna der unter-oligocänen Tertiärschichten von Helmstädt bei Braunschweig," by Dr. A. von Koenen, Zeitschr. der deutsch. geol. Gesellschaft. vol. xvii. p. 461 (1865).

and Mull are also in this list, together with beds in other parts of the world.

It should be understood that I do not venture to assert that the iron-sands of Paddlesworth &c. are Eocene, but only suggest that, in the absence of good palæontological evidence, one might look on them as of that age. The great difficulty in the way of classing them with any of the old Tertiary beds of the neighbourhood seems to be, that their fossils as a group are not like those of the latter, but (as far as the Eocene species are concerned) seem rather to be more allied to those of our Bracklesham beds, or perhaps of some of the Tertiaries of the Continent. I can see no difference in the condition of the fossils which would warrant the inference that some have been derived from older beds: those that have been referred to Crag species are in just the same state as the Eocene forms.

For the present, therefore, it would perhaps be well not to commit ourselves to any theory; but should clearer evidence of the Crag age of the fossils be given, either by the finding of better specimens or by the further examination of those already found, I shall be glad to take Mr. Prestwich's view; and if this note on the subject should be the means of bringing forward such evidence, by drawing further attention to the question, its author will be as well pleased as if he could himself make out the age of the doubtful beds.

I take this chance of putting right a mistake made in a former paper * (where, by the way, I adopted the Crag theory) in saying that Mr. Godwin-Austen classed some outliers of sand on the Chalk-hills of Surrey as Lower Bagshot. He has always looked on them, and on the Kentish outliers too, as Lower Eocene, as also has my colleague Mr. Bristow†.

## § 8. Conclusion.

From what has been said above, and from a study of the sections in Plate XXII., we may gather the following facts amongst others:—

1. That the base-bed (*a*) is the only constant part of the Thanet Beds.

2. That the higher and fossil-bearing parts of that series (*d*, *e*) occur only in the east, which partly explains why it is often very hard to separate the Thanet Beds from the overlying series in the eastern part of Kent, whilst the division is well-marked westward; and that the unfossiliferous sand (*c*) thins out on the east, so that the Thanet Beds near Canterbury may be a different thing from the Thanet Beds between London and Rochester.

3. That the bottom-bed (1) is also constant, except in the far east.

4. That above this last there is always a sand (2), a pebble-bed (2 *a*), or a mottled clay (2 *b*), which replace one another.

5. That one very thin bed (3) in the middle of the Woolwich

* Quart. Journ. Geol. Soc., vol. xviii. p. 273.

† See his note on the subject at p. 553.

Series seems to occur right through Kent, at all events through the eastern division.

6. That the higher and estuarine members (4, 5) of the same series occur only in the western and central parts of the county.

7. That the pebbles ($\beta$) at the bottom of the Oldhaven Beds (except at Upnor, where there is a little sand ($\alpha$) below) are constant, being, however, locally replaced by brown iron-ore in some places near Canterbury.

8. That in West Kent this series lies irregularly on that below, whilst in the greater part of East Kent *the junction of the two shows an accidental conformity, although the higher parts of the Woolwich Beds are absent.*

9. That it is the lowermost part of each of the three sets of beds which is the most constant, whether from the denudation of the higher parts, or from their more local deposition.

10. That the true basement-bed of the London Clay is also constant, though but poorly represented in East Kent, and that *its character depends on that of the underlying beds*: thus, in Berkshire, where the latter consist of clays and sands, it is a loam (mostly with pebbles); on the south-east of London, in the neighbourhood of the thick pebble-beds, it is a clayey pebble-bed; and in East Kent, where the London Clay is underlain by sand, the lowermost foot or so of the former is sandy.

11. That the higher divisions, the Oldhaven and the Woolwich Series, are transgressive over the Thanet Beds, and occur as outliers on the Chalk at or near its escarpment; so that what has been thought to show an unconformity between the Chalk and the Tertiary system would seem rather to be the result of an unconformity in the lower part of the latter. To prove the existence of the first-named unconformity it is needful that the lowest Tertiary bed, the Thanet Series, should be present; and I think it has been shown that where it is present (in Kent) there is as yet no stratigraphical evidence of unconformity between it and the Chalk: palæontologically there is a break, and from the examination of a larger tract of country we may perhaps see some signs of the unconformity which that break leads us to expect.

## EXPLANATION OF PLATE XXII.

(*Illustrative of the "Lower London Tertiaries" of Kent.*)

The vertical sections in the Plate very likely do not show all the changes in the beds; but I believe that they show the most important and the best-marked. Full details cannot be given until various Geol. Survey Memoirs are written.

The small letters and numbers are the same as those of the respective beds in the text.

No. 1 is made up from the many fine sections in the Canterbury and Reculvers district.

No. 2 is meant simply to show the local thickening of the pebble-bed ($\beta$) at Shottenden Hill.

No. 3 is an abstract of a few sections near Sittingbourne, and has been partly drawn with the help of my colleague Mr. Hughes.

No. 4 is a generalization of the great Upnor sections.

No. 5 is made from some road-cuttings and pits on the Cobham hills.


Engraved by J.W. Lowry.

Sections to illustrate a Paper "On the Lower London Tertiaries of Kent" by William Whitaker, B.A. F.G.S.


Drawn by W. Whitaker

Engraved by J. W. Lowry.

No. 6 is also made up from various sections.

No. 7 is a section of the ballast-pits at Charlton.

No. 8 is from the great brickyards at Loam Pit Hill, the beginning of the sandy pebble-bed (β) being introduced from the new railway-cutting just east of Lewisham.

The others have been drawn to show what takes place westward of Kent.

No. 9 is a generalized section from the London wells.

No. 10 is a general section from the London Clay to the Chalk in Berkshire &c.

No. 11 shows the westerly thinning of the London Clay and the Reading Beds, which I have shown to bring the Bagshot Sand within 20 feet of the Chalk in Marlborough Forest. (Quart. Journ. Geol. Soc. vol. xviii. p. 258. In the diagram at p. 263, what are here called Oldhaven Beds are included in the Woolwich Series, see above, p. 414.)

No. 12 is purely imaginary, being meant to show what we might see if the London Tertiary District reached a few miles further west than it does, when, from the thinning of the London Clay and Lower London Tertiaries, it is very likely that the Bagshot Beds would rest at once on the Chalk.

The transverse section is simply a diagram to show the way in which the Oldhaven beds are transgressive over those below, until at last they rest on the Chalk. Of course this section is greatly exaggerated vertically.

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## April 11, 1866.

The following communications were read:—

### 1. *On the Examination of* Brown Cannel, *or* Petroleum, Coal-seams *at* Colley Creek, Liverpool Plains, New South Wales. By W. Keene, Esq., F.G.S., Senior Examiner of Coal-fields of New South Wales.

(In a Report to Michael Fitzpatrick, Esq., Under-Secretary for Lands, Sydney.)

[Communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S.]

Already acquainted with the succession of deposits visible in the various natural sections on the line and in the vicinity of the Great North Road, so far as Aberdeen, I was desirous of working out the geological position of the Brown Cannel Coal (specimens of which had been sent to me from Liverpool Plains), so that I might be able to judge of the probability of success in any search for this coal in the district of the Lower Hunter. I therefore went to Colley Creek, the station of Mr. Loder, and this gentleman at once offered to accompany me and point out the places whence he had taken specimens identical in appearance with the Brown Cannel I had seen from Hartley.

From an examination of the rocks, I was able to determine that the geological position of this Brown Cannel is below the coal-seams worked in the Newcastle field—that, in fact, it forms the very base of our Coal-measures, and in such close contact with the porphyries that these latter are absolutely mixed up with the lower portion of the Cannel. I found two seams of workable thickness, tilted at a high angle, running north and south, not far from, and parallel to, each other, both of the same quality.

I was the more desirous of determining the geological position of this coal, because a large piece from a block of Brown Cannel was given to me a short time ago, which had been brought up by the buckets of the dredge working on the Hunter River, at the shallow known as Eales's Flat, near Morpeth. On my return to Newcastle, and with the knowledge acquired in my examination at Colley Creek, I went to Eales's Flat, and had the place pointed out to me where the dredge had been working; and it is remarkable that I found it to be on the line of upthrow of the porphyries from the Williams River range (which I had long ago traced across the Hunter, near Morpeth), being the extension of the well-known Porphyry Point, the residence of the late Dr. Carmichael. I therefore conclude that the piece brought up by the dredge, although a loose block, must belong to a deposit not far distant from the place where it was found; and research will probably lead to the discovery of the seam.

Geologists have defined that, of Cannel Coals, *jet* is an extreme variety in one direction, as *batt* or carbonaceous shale is in another; and the specimens which I send will show you that we possess these varieties.

I have taken the specific gravities of various specimens; and the richness in oily products will probably be found to decrease with the augmentation in specific gravity, the heaviest leaving the greatest amount of solid residue after distillation. The Hartley stands first as of the lowest specific gravity; that from Lake Macquarie, a coarse jet, is the heaviest (having a specific gravity of 1·5); and that from Colley Creek shows but little difference from the famous Boghead Coal of Scotland, of which I am also able, through the kindness of Mr. Donaldson, to send you a specimen:—

| | |
|---|---|
| Specific gravity of Hartley Cannel | 1·064 |
| ,, ,, Boghead | 1·160 |
| ,, ,, Colley Creek | 1·166 |
| ,, ,, Dredge | 1·190 |
| ,, ,, Stoney Creek | 1·289 |
| ,, ,, Lake Macquarie | 1·560 |
| Chapapote or Mineral Bitumen from the Cretaceous rocks of the south of France | 1·158 |

Our ordinary coals vary from 1·3 to 1·4.

The small excess in the specific gravity of the dredge-specimen over that of Colley Creek may be attributed to long contact with water; it otherwise looks of good promise as a Petroleum Brown Cannel, and, like that of Hartley, ignites readily in the candle-flame.

The specimens, with the exception of the Chapapote, are all true massive Cannel Coals; and to call them "*Shales*" is to misname them.

Besides Colley Creek, I heard of specimens having been picked up in other creeks, at many distant places, particularly on the Warrah Station; and I can have no doubt that Brown Cannel will be found where the porphyries have tilted up the Lower Coal-measures so as to render them accessible to the miner. The Boghead Coal of Scotland is likewise found low down in, if not at the base of, the Carboniferous series; for we are informed that it rests on a bed of fire-clay full of *Stigmaria*, and is surmounted by shale and ironstone with plants and shells (*Anthracosia*). Sir Roderick Murchison likewise states that in the Silurian rocks of Russia there are shales yielding 25 per cent. of bitumen and a considerable portion of inflammable gas, and in America solid bitumen is found in the lowest fossiliferous rocks.

I am looking for, but have as yet seen no signs of, a petroleum-spring. In a geological report to the State of New York, on the Seneca oil-spring the Government geologist observes, "There is no necessary connexion between oil-springs and beds of coal."

Both in proceeding to and in returning from Liverpool Plains, I made some deviations from the road, where objects appeared to offer matters of interest.

Rix's Creek is the most northern colliery in work—opened by my recommendation on my first examination of it. I descended to the workings; and it was satisfactory to me to learn that the coal is much approved of. In every locality as I went onwards, desires were expressed to me that workable seams might be found; and the Rix's Creek Coal is actually carted as far as Aberdeen, a distance of thirty miles. I pointed out that coal may be got near the chain of ponds close to the railway; and at Muswelbrook the cutting near the town has gone through a seam of coal which, though cropping out at a high angle, will no doubt be worked until further discoveries are made.

At Scone, near the Kingdom Ponds, the plain is strewed with fossil wood; and the rooted trunks of large fossil trees rising from the ground look as though they were still in their places of growth; whilst a natural section in the bank of the creek or pond close by, bordering the estate of the Honourable the Secretary for Lands, shows the outcrop of the coal-seam rising from below, and regularly covered by the fossil-bed.

In examining attentively the stratum of these fossil trees, I perceived signs of a marine deposit; and it became a question which of the two was the older, the forest or the sea-bottom. This was soon solved—a block of coral built upon and into the fossil wood proved unmistakeably that the forest and the coal beneath are both more ancient than the marine fossils covering them. This evidence, in conjunction with that which I am obtaining from the workings at Dalwood Creek, will set at rest the controversy as to the age of the Carboniferous deposits of New South Wales.

About seven miles from Scone, on the left bank of the river Page, a limestone is worked, which I followed for a couple of miles, to where the beds are laid bare over a large surface. I procured specimens, which show it to be a rich oolitic limestone. Finding it to be encased as it were in a clay or impure limestone, I am not without hope that some of the beds may be found to be of the proportion of clay and lime which makes cement, and I have given instructions for portions of these rocks to be sent to me for experiment. I found a bed of calcareous rock near Singleton and a band of clay iron-ore of the Coal-measures below it, both beds being above the coal worked at Rix's Creek.

Proceeding onwards from Scone, I visited Mount Wingen, where abundant sulphurous vapours issue from a coal-seam on fire, killing the trees in the direction in which the wind carries the vapours; and, as the coal is exhausted by burning below, the ground falls in, making fresh crevices for the exit of vapour. On the walls of these crevices sulphurous salts are deposited, which are collected by visitors and have much local repute for various uses.

Approaching Mount Murulla, the marine fossiliferous beds are again abundant; and as I heard many different stories of rocks and fossils to be found on the mountain-top, I went to the summit, which is about 2000 feet above Murrurundi, and nearly 4000 feet above the sea-level. For 800 feet of the ascent the mountain is flanked as by a wall of coarse conglomerate, chiefly of quartz pebbles, in some of which I found gold. The summit is a rough black basalt in large angular masses, and in such disorder as to indicate violent upheaval. The range on the opposite side of the narrow valley of Murrurundi is of like character; but there is sandstone in the valley, and coal is reported to be seen cropping out in the creeks on the lower levels. I have reason to believe that the seam which is on fire at Mount Wingen extends into these levels, and will be found where they have not been disturbed by eruption.

I purpose making an early examination of the deposits of Brown Cannel at Hartley for my further instruction. Research will be made in the Lower Hunter District for the same mineral with great probability of success; and meantime the Black Cannel of Stoney Creek, and the rich coals of Anvil Creek, and the seams of the same group which I am successfully opening at Dalwood Creek will probably commence to be distilled. I would also direct attention to the Inganee seam, formerly worked at the Four-Mile Creek, East Maitland, as a good Black Cannel of easy access.

There have been considerable differences in the reports of experiments as to the yield in oil of one and the same coal at the hands of different operators; but the process employed may greatly affect the yield, and by one mode there may be driven off in gas much which may be condensed by another. I know that it is so in the distillation of turpentine from resins; and it may be equally the case in obtaining the products from Cannel Coal. I would recommend that in such experiments the gases be collected and measured as well as the liquids, and then we shall be more correctly informed as to the qualities of the coals experimented upon. The oil in the Boghead Coal is said to be equal to 75 per cent. of its weight. Whatever the yield may be, the Hartley Coal is of less specific gravity than the Boghead, and will, I have no doubt, if operated upon by the same means, give as good results.

## 2. *On the* Occurrence *and* Geological Position *of* Oil-bearing Deposits *in* New South Wales. By the Rev. W. B. Clarke, M.A., F.G.S.

[Abridged.]

Contents.



1. *Introduction.*—The author, after detailing the circumstances connected with the discovery of Cannel Coal at Reedy Creek, at the base of Mount York, and near the line of railway from Sydney to Bathurst, gives a brief summary of the various divisions of the coal-bearing beds of New South Wales; these divisions, with their estimated maximum thicknesses, are represented in the following table:—

| | ft. ft. |
|---|---|
| 1. Wianamatta beds | 700 to 800. |
| 2. Hawkesbury rocks | 800 to 1000. |
| 3. Upper Coal-measures (including Nattai, Wollondilly, Illawarra, and Lower-Hunter beds) | 5000. |
| 4. Upper Marine beds | 3000. |
| 5. Lower Coal-measures | 1000. |
| 6. Lower Marine beds (with *Lepidodendron, Sigillaria, Syringodendron,* &c.) | 4000. |
| 7. Porphyry and granitic rocks rising through slates. | |

Further investigations will probably establish the fact that marine fossils occur in all divisions of the above series; but it has been already determined by indisputable evidence that, notwithstanding the presence of *Glossopteris, Phyllotheca,* &c., in the Coal-measures, both upper and lower, Palæozoic fish range up to and through the Wianamatta beds, and are associated in great abundance with ferns (but without *Glossopteris*) at the junction with the Hawkesbury rocks, in the upper part of which the same fishes are found.

Oil-bearing products have already been found in the *third* and *fifth* divisions. Of these, Black Cannel occurs in the latter at Stony Creek, near Maitland, on the Hunter, Brown Cannel in the former at Reedy Creek, and Shaly Cannel on American Creek, in Illawara, in various creeks running into the Wollondilly and Nattai rivers, in the Grose River, in Burralow Creek, a feeder of the latter, and in the Colo River. The Colley-Creek cannel, which approximates to that of Reedy Creek, I believe will also be found to belong to the Upper Coal-measures.

2. *Stony Creek.*—The cannel coals and associated beds in this section occur in the Lower Coal-measures, and are overlain by nearly 3000 feet of fossiliferous rocks, dipping at the same or a somewhat higher angle. *Glossopteris* occurs very low down in the series, which has, by some geologists, been considered altogether of a much older date than the formations which usually carry that genus; but Mr.

Daintree* has verified and confirmed the views which I have for years been maintaining, and which have been so surprisingly combated.

The cannel from this locality has been subjected to distillation, the produce of 180 tons of it being 400 gallons of crude oil; but as the coke resulting from the operation is considered to be of excellent quality, it is of more value than would at first sight appear. These beds of cannel occur again on the western side of the anticlinal axis, and are, it is supposed, traceable to the north bank of the Hunter, where they also underlie the fossiliferous marine beds, eight or nine miles to the north-east of Stony Creek; and from below them the lower marine beds begin to rise on the slopes of the Tangorin Ranges. The specific gravity of this cannel varies, as does its composition; but 1·281 represents its density in a general way.

3. *Colley Creek.*—On the north side of the Great Liverpool Range, a little to the west of the 151st meridian and 80–90 miles north-west from Stony Creek, occurs Colley Creek, in which have been found two seams of a *Brown Cannel*, of somewhat higher specific gravity than the black cannel of Stony Creek. It is very like that of Reedy Creek, but is full of grains of quartz, which give it, in places, an arenaeous aspect. It occurs in blocks, which are superficially decomposed into a lighter substance, but where unaltered retain a clear dark-yellowish or light-brown hue, and split with a conchoidal fracture, with a hard woody sound, when struck with a sharp axe or other edge tool, the substance being tough and resisting a blow from a round or flat tool. Mr. A. Loder, on whose estate it occurs, sunk a shaft, and passed through a series of layers of black, partly unctuous, clay, which appears to result from the decomposition of basaltic rocks. A seam or mass of the cannel was passed in the midst of these layers, which, like the cannel, contain numerous, distinct, scarcely rounded, grains of quartz; and these give to the clays a porphyritic appearance, so that by sight alone one might be led to consider them a decomposed porphyry. Between the crest of the Liverpool Range, which is, on the Murrureaidi Pass, 2500 feet above the sea, and Colley Creek, where the level is not more than 1600 feet, the whole of the country consists of conglomerates and sandstones, or of basalt and greenstone with trappean alluvial mud or clay.

The Liverpool Plains lie at a higher level than the valley of the Hunter; and the Coal-measures on that flank of the Liverpool Range, at about 1300 feet above the sea, are much disturbed, and also gullied by drainage-channels. And close to the Range a considerable metamorphosis has occurred in the Carboniferous rocks.

It has been asserted that porphyry has intruded into these seams of Brown Cannel; but I confess I did not see any evidence of it; and I doubt whether rocks which exhibit the clearest proof of being in part derivative from it, could be locally upheaved in the way suggested. Nevertheless it is possible that porphyry may be near at hand; yet it is very unlikely that it could have any action in saturating a seam of coal or shale with volatile materials. It is according to experience, on the contrary, that if there be any contact between these

* 'Geological Notes' by R. Daintree, field-geologist, Victorian Survey.

seams and porphyry, the volatile matter should be dispersed, and not accumulated; and the alteration of the combustible into anthracite or graphite would be the most probable effect*. The association of porphyry and cannel coal is therefore merely accidental, and, so far as my experience goes, has no bearing on the condition of the latter. Assuming, even, that the Colley-Creek cannel is in the Lower Coal-measures, the arrangement is not much affected thereby, for they rest upon and are younger than the porphyry. Supposing heat to be necessary to produce the natural distillation required for saturation of deposits *in situ,* there is no need to infer that the supposed (always much exaggerated) heat of granitic rocks at the time of eruption can have had anything to do with it. It is a fact also that the inflammable cannels are limited in area, and oftentimes pass off into an ordinary coal. The most that can be reasonably conjectured on such a change is, that (supposing no objections to arise from other principles) the volatile matters removed by distillation, or in the change to anthracite, from one part of a seam to another part of such a seam, have found a reception where no revolatilization could occur. But there is no evidence to be obtained of any such transfer. The condition of Loder's cannel would imply that it had originally been deposited in a marshy hollow of the Carboniferous period, to which drift quartz and arenaceous sediment had access. The grains of quartz are certainly entangled as they would be in a muddy or viscid substance.

The yield of the Colley-Creek cannel is 60 gallons per ton.

4. *Illawarra Shales.*—Under the escarpment at the head of the Cordeaux River and a little to the west of it, and below Mount Kemble, in the beds intersected by American Creek, a series of shales exist with coal, a portion of which are found to produce oil, but in inconsiderable quantity compared with the Brown Cannels. These schistose beds are arenaceous in appearance, and when taken from the retort, after distillation, are found in lumps of charcoal, not coaked, but with a ligneous character. They will perhaps not be esteemed as a source of oil. With them are also schists that have a half anthracitic or graphitic texture; and a long way below their level, which is from 900 to 930 feet above the sea, the shales of the locally lower coal-seams, not far above the junction with the Upper Marine beds, are altered by basalt, which has also coked and prismatized the coal in the Bollambi seams. Here, then, though there is some evidence of oil-bearing schists, we find that character not prominent in association with igneous rocks, but, on the contrary, the anthracitic and graphitic characteristics are well established.

The Illawarra Coal-measures are nearly the *uppermost* of the New South Wales series of coal-bearing beds, being certainly above the Newcastle series, and they extend for at least fifty miles, passing upwards to the level of the Nattai or Fitz Roy beds in their extension southwards.

Some blocks from American Creek have been taken out, which are cut very easily with the knive, leaving a clay-like surface, and hav-

* See Delesse, Métamorphisme des roches, pp. 305–314.

ing the usual woody sound when struck. They ignite readily by a lighted match. The section exhibits an escarpment of 500 feet of Hawkesbury rocks resting on 800 feet of Coal-measures, which exhibit various distinguishing differences when compared with the Newcastle beds, and are supported by the Upper Marine beds, which rise in a dome-like form, and exhibit an approach rather to the beds immediately below the Muree series than to those of that place, reminding one of the deposits near Harper's Hill, where basalt, as in the neighbourhood of Wollongong, intrudes into and disturbs them, and where they are succeeded by just such beds as mark the base of the Coal-measures under Mount Keira. Certainly the Newcastle coal-seams are not represented in the Illawarra section; but the evidence is perfectly distinct as to the inflammable beds belonging to the upper part of the Upper Coal-measures.

A view has been taken by some observers, of the connexion of the Illawarra and Lower Hunter coal-beds, which would place them in the same angular relation with the axis of the basin. This I believe to be altogether erroneous. A considerable portion of the eastern side of it has been entirely swept away; and traces of former surfaces which must have belonged to a wider area are now apparent on the summit of insulated points along the coast, that can only be accounted for by admitting the destruction of considerable masses. This explanation was offered by myself many years ago, and has been confirmed by more recent observations. Others have adopted this opinion; but they have not coupled it with the fact, which I consider capable of clear establishment, that the Illawarra and Newcastle beds are not in the same plane. The coast-line is not that of the axis of the basin, but cuts it obliquely; so that different portions of the same series of beds are represented in what would otherwise be about the same longitudinal horizon. Looking at the matter in this way, the strike of the Illawarra beds would appear to be full 25 miles to the eastward of Newcastle, which will account for the existence of beds in the former district which are not represented in the latter, but which were once continuous over them. A further deduction from this view is, that parts of the Coal-measures of the Illawarra, the Shoalhaven, the Wollondilly, and the Cox river-basins are unquestionably the uppermost portions of the great eastern coal-field, the middle and lower parts of which are so abundantly developed in the basins of the Page, Goulbourn, and Hunter river-basins.

Were it possible here to enter into a close investigation of this subject, by reference to the evidence of the fossils collected from the different members of the series, it could be shown that the characteristic species of the upper beds are not altogether those of the middle and lower, although, generally speaking, there are the same genera in all.

5. *River Nattai.*—The Upper Coal-measures extend along the heads of the creeks forming the Nattai River; these creeks run in deep ravines, cutting the series from the Hawkesbury rocks down to the Upper Marine beds, which come in (as at the same distance in the Illawarra, ascending Mount Keira) about 250 feet below the lowest

coal-seams. The Coal-measures thence range to the southward as far as the banks of the Shoalhaven and Wollondilly rivers, the older or Hunter-River beds cropping out from under the upper. About the heads of the Nattai the whole series has been disturbed by the intrusion of igneous rocks in the Mittagong (or, rather, Merrigang) Range. Immediately upon the older trachytic diorite of the extremity of the range, where it attains an elevation of nearly 2800 feet, at Bourell or Gibraltar Gap, but altered by more recent basalt, repose the fragmentary patches of the Hawkesbury rocks, covered by the Wianamatta black shales, in which are a profusion of stems and leaves of *Phyllotheca*, *Cyclopteris*, *Sphenopteris*, and a new genus having the venation of *Diplazites*, together with the following generic forms of fish :—*Myriolepis*, *Cleithrolepis*, *Palæoniscus*, and one or two others.

The shales which contain these fishes are precisely those of the fish-beds of Campbelltown, which also occur at the junction of the Wianamatta and Hawkesbury rocks.

The insulated hills in advance of the Merrigang form the fine Mittagong of the aborigines. One of these summits slopes down to the iron-mine to the south, and, at an elevation of 570 feet above the working coal-seam at its base, forms the top of a precipitous escarpment to the north, at the base of which occur four seams of coal, from some of the shales of which I procured *Glossopteris* and M'Coy's new genus *Gangemopteris*. In the ravines to the north-west, about three miles from Fitz Roy, the seam was found to have thickened to 38 feet 6½ inches, and appears to have below it a bed of basaltic greenstone (one of the intrusive dykes of the igneous outburst which exerts so extensive an influence for many miles round Mittagong); and from 250 to 300 feet below all the Coal-measures there occur marine beds with *Trochus*, *Spirifera*, &c.

Above the great seam and at the base of Mittagong is a Cannel-coal.

The Coal-measures of this neighbourhood are treated of because they belong to the upper measures, and contain peculiar beds, which again present themselves on the Wollondilly, where blocks of brown oil-producing Cannel *have been* found. Silicates of alumina, and coals full of small cavernous spots (the latter often filled with hydrated oxide of iron in the form of seeds), mark some peculiarities of these deposits; and these again occur in Burragorang, and occasionally further to the west, about the sources of the Cox.

6. *Burragorang*.—This is a local name for the part of the Wollondilly valley which occurs between the junctions of the Nattai and the Cox with the former river, and the section of which shows completely that the order of deposits is similar to that of the Illawarra and Nattai. The Upper Marine beds, which occupy the bottom of the section, agree in part with those of Maree, near the junction of the Williams and Hunter rivers, passing into the next lower set of beds in that neighbourhood; they support a series of coal-measures which are capped by Hawkesbury rocks, all resting apparently in a nearly

horizontal position on each other. At the junction of the Nattai the lowest beds are seen dipping only slightly to the westward.

Near the junction of Toonalli River a dry creek intersects the beds of a spur from Toonalli Mountain, locally called "The Peak of Teneriffe." In this creek I found in undisturbed position white and blue shales with *Glossopteris*. The bottom and sides of the creek are encumbered with fallen blocks from the upper quartzose sandstones and intermediate beds of similar kind below the Hawkesbury beds; and amidst these blocks occur also others of inflammable shale passing into Brown Cannel. The seam was ascertained to lie between 900 and 1200 feet above the sea, and consequently is not far from the base of the Hawkesbury rocks. There are on the flat at the base of the spur several water-worn blocks of this Cannel lying on the surface of the ploughed ground, which rests upon a red and yellow grit of the Upper Marine beds. These are about 9 inches thick, whereas up the creek the blocks reach a thickness of 12 or 14 inches. Only one conclusion can be drawn as to the blocks upon the flat—namely, that they have been drifted by floods to their present position. It is quite impossible that they could occur actually bedded as a coal-seam with the marine beds without any accompanying shales or clays; and it is equally impossible that they can belong to one seam highly inclined, for the beds have a dip, if any, in a contrary direction to the implied upheaval.

Nearly opposite the mouth of the Nattai, the Upper Marine formation attains an elevation of 500 feet above the valley, so that the three successive groups of beds have nearly equal vertical dimensions. In a recess of the ranges near the head of Lacy's Creek, the Middle or Coal-measure series is generally plainly exposed. The junction of the latter with the Hawkesbury rocks is marked by springs, and the regular stratification of the beds both above and below this junction is remarkable; their fall is about 100 feet in succession, until the white shales are reached, where a similar concealment to that on the Tonalli River takes place, from detached huge blocks of coarse grits and sandstones.

A coal-seam, extremely like one of the Nattai seams, has strewn its fragments on the ledge below the springs; and blue shales and mottled clays mark its position somewhat higher up. The blocks that obscure the beds originate in a system of three-jointed planes cutting up the beds, which are thus rendered capable of supplying materials for a débâcle.

7. *Fluviatile Drift.*—The river-bed and bottom of the Wollondilly valley, for a depth of 40 feet and upwards, is covered by a fluviatile drift of hard pebbles, chiefly porphyritic, with very little granite, (probably because it easily disintegrates), some sandstone, and coal mingled with sand. This drift I have traced along the Warragamba, and the shoulders of the ridges above it, into the Wianamatta region, across the latter in directions corresponding with the Wollondilly and Goose, to Emu and Penrith, and across

the country to Windsor, Wilberforce, and to the river Hawkesbury, where, at a distance of forty miles from its river-sources, this drift is found in solitary pebbles.

At Penrith there is an accumulation of them to the depth of several feet on the river-bank. Emu Plains and the bed of the Hawkesbury are covered by them (and Lapstone Hill takes its name from their presence) as high up as 400 feet.

At Cox's basin, where the Warragamba joins the Nepean, there is also an island formed of drift, in which porphyry, hardened sandstones, and coal occur. But it is remarkable that there is in these accumulations very little, if any, granitic rock besides porphyry, and no basalt or other trap; whilst in the trappean ash which occurs at Cox's basin and in the Kowmery River, a feeder of Cox's River, porphyry and bastard granite are imbedded.

Nothing can so clearly mark the origin of the deep ravines by continual washings and erosions (probably after some dynamical action had fissured the country) as the fallen blocks of the plateau, and the pebbles which cover the surface of the country in the line of drainage.

8. *Reedy Creek.*—On the eastern arm of the fork at Mount York, which is now called Mount Dixon, there exists a bed of very rich iron-ore; and iron also occurs near the head of the Reedy-Creek valley, which extends to the west. Below the ironstone occur sandstones, shales, and coal-beds; but at the level of the valley the Cannel stretches across it, and when I first visited it seemed to consist of blocks of from 6 to 12 inches thick. Now that the seam has been opened and worked into the boundary ranges, it is found much thicker than was anticipated.

The section is as follows :—

| | feet. | inches. |
|---|---|---|
| Ironstone | 0 | 3 |
| Shale | 1 | 0 |
| Rich Cannel | 4 | 0 |
| Cannel Coal, less rich | 0 | 6 |
| | 5 | 9 |

The Cannel dips about east by north at from 1° to 2°, or about 1 in 35; in places it is full of fronds of *Glossopteris*, and a plant branching after the manner of *Asterophyllites*, which lies in perfect unrumpled order; it also puts on a prismatic structure, and has a flat but well-marked conchoidal fracture. The shales are impressed with *Vertebraria*, *Glossopteris*, and *Gangemopteris* (M'Coy). The Cannel passes into true bituminous coal in parts of its course; and the shales in contact are earthy, but very inflammable. The toughness is remarkable. The produce of the rich Cannel is from 150 to 160 gallons of oil (realizing 100 gallons of pure oil) and from 1700 to 1800 cubic feet of gas to the ton. This seam appears, by borings commenced in the vicinity of Mount Victoria and to the east of the first workings, to be extremely variable in dimensions and composition. At the Sugar-Loaf, part of the Mount Victoria range, a seam was pierced which is but 2 feet thick. It is supposed to represent the Reedy-Creek seam; but as it is 300 feet or so above that level, it would rather belong to the coal-seam at the height of 3000 feet on Mount York. A further discovery of Cannel, but not so rich as the original, has been made south of the foot of Mount Victoria, in two spots where the Cannel proved to be from 15 to 18 inches and 21 inches thick respectively. It is, so far as is at present known, quite clear that these seams are in patches, and not of uniform thickness; and consequently it would be premature to build expectations of any kind as to the extent in space occupied by them.

9. *Colo and Grose Rivers.*—The existence of Cannel of the Reedy-Creek kind is not altogether confined to the western side of the plateau; for in the Colo River and in the Grose also, and in the Burralow Creek, which flows to the latter from the Kurrajong, rounded pebbles of Brown Cannel have been found, as I learn from my field-notes made many years ago, and from specimens more recently collected.

Both the Colo and Grose flow through gorges and ravines like those of the Nattai and Wollondilly, but not so accessible as the latter. As there are considerable deposits of coal about Wolgan, Capertu, and Cherry-tree Hill, where there is a seam 10 feet thick, it is not improbable that the Colo-drift Cannel may have come down from the higher parts of the river.

In the places mentioned above, the same genera and species of plants which occur in the Coal-measures of the Nattai and Wollondilly are also found; and these same fossils are abundant in the shales at the head of the Turon, and also at the head of the Cox, and under Hassan's Walls and Mount Clarence; so that the Upper Coal-measures are everywhere distinguished in the area under review.

It is quite clear, therefore, *that the Oil-bearing shales and Cannels are, in the eastern Coal-field of New South Wales, entirely confined to the upper group.*

10. *Turon Drift.*—About Bowerfells, and at Brucedale, on the Winburndale rivulet (near Bathurst), there is a drift of another kind from that of the rivers over the Wianamatta beds. It consists of fragments, much rounded, of yellow sandstone, full of *Spirifera*, *Orthis*, &c. It was not until very recently that I ascertained the source of these fragments. Some distance below the head of the Turon River there is a place called the Gun, which is surrounded by ranges fully 1000 feet high; the bottom of the gulf is formed of slates, from which the gold of Sofala has been derived; and over them occurs a ferruginous conglomerate, which is succeeded by thick beds of the Brachiopod-sandstone, over which come in conglomerates, shales, sandstones, and the coal of Cherry-tree Hill, surmounted by the Hawkesbury rocks. In the drift of the Turon, about Sofala, occur blocks of hardened sandstone impressed with *Lepidodendron.*

In like manner the Brachiopod-bearing sandstone is strewn about in the river-drift of the Moruya to the southward, from which it is to be inferred that the whole of the groups connected with the Carboniferous formation have been broken up and dispersed. Where, however, the Hawkesbury rocks cover them, the Upper Coal-measures are in some degree protected.

The success which appears to have attended the working of the

Reedy-Creek Cannel has excited so much interest that all kinds of substances have been forwarded for examination, and among them black clays from various parts of Manearo, some of which, on analysis, have shown the proportion of ash to volatile and carbonaceous matters to be as 77 to 23.

11. *Bournda.*—There is, however, another kind of deposit which demands notice.

The coast, for many miles to the northward of Cape Howe, is formed of rocks which belong to the Lower Silurian formation, and consist principally of purple schists with quartz veins and with some beds of purple slate and sandstones. Along the shore, as just north of Eden, at Pambula and Meribula, beach-lakes occur, and some of those further to the northward are partly blocked by sand. At Bournda there is a tract of country in which formerly a lake or lagoon existed. It is now not altogether dry; and though not much timber exists there, there is a considerable growth, on the dried surface, of that peculiar vegetation which clings to a soil made up of sand and marsh. The coast-line intersects the deposits which form the base of this tract, and which rest upon the highly inclined purple slates, granite occurring at no great distance. The age of the deposits is probably of the recent period. There is no *evidence* of any Tertiary epoch; yet it has some resemblance to a Brown Coal deposit.

A section of 60 feet of the cliff at Bournda gives the following succession of deposits:—

1. White decomposed granite full of rounded bits of quartz like that of granite.
2. Rather more yellowish decomposed granite, of like kind, with roots of recent plants.
3. Very gritty pale deposit with woody matter.
4. Yellowish, and occasionally reddish, sand (in the condition of *dune* sand), with partly abraded particles of quartz.
5. Greyish-white clay, strongly adherent to the tongue, with recent plant-fragments.
6. White, fine, friable, very slightly gritty clay of a kaolin character, probably useful for fire-clay and pottery.
7. Blackish muddy laminated deposit, full of vegetable patches, much iron-pyrites, and some lignite.
8. Dark yellowish-brown laminated deposit, 1 foot thick—the "Bournda" so-called "lignite," being a clay-bed saturated with volatile matters, resting on—
9. A partly reddish, partly brown, sandy and earthy deposit, with an abundance of small quartz pebbles.

The lower part of the deposit has been entered to the extent of fifteen yards; it is found to be four feet thick, and has been subjected to chemical analysis. It seems to have been a mud saturated with oily ingredients, and is highly inflammable. It is not altogether a true peat, but may be regarded as such, having probably had a similar origin and afterwards been covered by flood-detritus brought down from the ranges. None of the sand- or clay-deposits exhibit any evidence of calcareous matter; the explanation, therefore, of its lacustrine origin on the land is probably the correct one.

A year ago I received from a creek about forty miles north of

Bournda a white waxy mineral, which comes very near "Bog Butter" in appearance and chemical composition. Probably this was a *peaty* product, and, as such, is in correspondence with the Bournda deposit, to which latter it is difficult to assign either the name of peat or lignite. I have called it "bog stuff."

The following results of distillation assign its actual character:—

| | | | | |
|---|---|---|---|---|
| Residue | Clay and sand | | 15·60 | |
| | Other inorganic matter | | 0·68 | |
| | Carbon | | 8·75 | |
| Volatile Products | Liquid | Water | 48·00 | |
| | | Tar-oil | 8·00 | |
| | Gaseous | | 19·00 | 100·03 |

The tar-oil is butter-like and viscid, but it contains a proportion of what is called solar oil, lubricating oil, and paraffin, to the amount of 35 per cent.

The gas was at first bluish at low temperatures, but became afterwards white, and very offensive from sulphuretted and phosphoretted hydrogen.

It may be suggested that, mixed with the better-class coal of New South Wales, it is likely to be valuable for the production of gas. It has been ascertained by actual experiment that three tons of this Bournda deposit are equal, in the manufacture of sulphuric acid, to two tons of coke.

12. *Conclusions.*—The chief conclusions arrived at are:—

1. That, with the exception of the Stony Creek Cannel, all the oil-producing deposits occur in the Upper Coal-measures; and that the Cannel of Stony Creek, on the river Hunter, occurs in the Lower Coal-measures, which are above the Lower Marine beds with Trilobites, below which, again, are numerous fossiliferous beds before the porphyry is reached.

2. That the Cannel belongs to beds in which *Glossopteris* occurs, and therefore may be a slight additional evidence of their antiquity, as it is an analogue of the "Bog Head" Cannel of Scotland.

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## 3. *Remarks on the* Copper-mines *of the* State *of* Michigan.

By Hilary Bauerman, Esq., F.G.S.

Contents.



1. *Introduction.*—The remarks contained in the following pages are the results of a general examination of the mines of Keweenau Point, made during the summer of 1865; and although the subject is not a new one, having been elaborately treated by Professor Whitney in two different works, and having received subsequent notices from Messrs. Rivot, Borie, and others, still the progress of mining enterprise has

opened up some new features which have not as yet received any notice, and may be of interest to the Society.

The copper-mining district of Michigan is situated in the upper peninsula, or north-western portion of that State, forming a narrow belt of country about 140 miles in length, extending in a north-easterly and easterly direction, from the boundary of the State of Wisconsin to the end of Keweenau Point, the promontory of which projects into Lake Superior on the southern shore, about midway between Fond du Lac and the outlet of the lake at Sault S. Marie.

2. *Structure of the District.*—The rocks of the district consist of coarse sandstones and conglomerates, occupying either shore, with a central mass of trappean rocks, which forms the mineral range proper. The sandstones on the eastern side have a south-easterly dip, while the traps, which are well stratified, and include several conformable beds of conglomerate, together with the overlying sandstones and conglomerates of the western and northern shores of Keweenau Point, dip towards the north and north-west, or generally at right angles to the trend of the land.

The surface of the country is for the most part covered with a dense forest, interspersed with small lakes and swamps. In the drier ground maple is the prevailing timber, with spruce, pine, and oak, in less quantity. Cedar is common in the swamps, which are also remarkable for their profuse growth of enormous plants of *Osmunda cinnamomea* and other large ferns characteristic of wet ground.

In the northern district, and as far west as Eagle River, the rocks are free from cover, the sandstones and conglomerates on the north shore forming a steeply-scarped cliff, surmounted by gently sloping inclines on the upper surface of the beds. At Copper Harbour the face of the escarpment of one of the conglomerates is so very regular that, owing to the wood having been burnt off, it may be traced, forming a perfect wall without break, for several miles. Further to the westward, however, the geology becomes very obscure on account of the drift, which extends from near Eagle River to the extreme point of the district beyond the Ontonagon, and, in greater or less thickness, effectively covers up the rocks below. This drift is composed of a stiff blue or reddish clay, passing up into sands or gravels, and in places is full of angular or scratched stones. It is of great thickness in some places—as, for instance, at the Naumkey mine, on the south side of Portage lake, where a shaft was abandoned from excessive influx of water, after 100 feet of sand had been sunk through without reaching the rock. Sections of contorted drift are seen in considerable numbers in the drift plateau which forms the belt of country below the Minnesota hills and the lake-shore near Ontonagon. The surfaces of the rocks immediately below the drift are often scored and striated by ice, the furrows being sometimes of extraordinary size—for instance, at the Concord mine, on Portage Lake, where they are nearly semicircular and about $1\frac{1}{2}$ inch deep. The general direction of the glacial striations is about north and south; and the drift occasionally contains Upper Silurian fossils, which have been derived from the country between the north shore of Lake Superior and Hudson's Bay.

From the preceding remarks on the nature of the surface, it may be understood that the order of sequence of the rocks is not as yet quite conclusively determined, and that therefore there may be some doubt as to the proper age to be assigned to them, fossils being absent on Keweenau Point. Where the rocks are bare, the section has been well made from shore to shore by Mr. W. H. Stevens; and they are shown to be in conformable sequence from east to west. At Portage Lake the lower boundary of the trap is hidden; and, indeed, researches subsequent to those of Messrs. Foster and Whitney have shown that more ground is included within the trappean range than is laid down on their map. In the original survey of Messrs. Foster and Whitney, these beds were assigned to the Potsdam or Lowest Silurian group; but subsequent investigations have led Prof. Hall and Sir W. E. Logan to refer them to a somewhat higher level, or in the Quebec group—the former geologist having determined that the mass of the sandstones of the Sault S. Marie and the south-eastern shore of the lake are equivalent to the Saint Peter's sandstones of Minnesota, forming probably part of the Chazy formation*. On the Canadian side of the lake, the traps are penetrated by intrusive dykes which do not affect the overlying sandstones; but there is no good evidence of a similar unconformity in the upper beds of Keweenau Point, as no transverse dykes are seen. I have examined the junction of the traps and sandstones at three different points—namely, at Portage Lake, Copper Harbour, and Eagle River. In the latter case the junction-surface was perfectly smooth, without any indication of intrusion; while in the two former a few small irregular veins, filled with a red jaspery substance, are given off from the traps, and penetrate the sandstones and conglomerates to the depth of a few inches; but this evidence is too inconsiderable to have much weight, in view of the abundant proofs of conformable stratification derived from the regular alternation of the conglomerates with the igneous rocks.

The central trappean belt, forming the mineral range proper, varies in width from 2 to 3 miles, and extends throughout the whole length of 140 miles, passing into the neighbouring State of Wisconsin. The prevailing rock is mineralogically a dolerite, or mixture of felspar (labradorite), hornblende, and augite, with chlorite, epidote, calcite, and magnetite as occasional constituents. It is usually of a dark-brownish-red or chocolate colour, mottled with green or black by the chloritic material, but occasionally becomes bright green, or even sulphur-yellow when epidote prevails, as is the case in the Ontonagon district.

More important, however, than the mineralogical constitution of the traps is their physical structure, which varies considerably, the commonest condition being compact, with finely granular fracture,

* Geology of Canada, pp. 84–85, Atlas, p. 19.

with only a few small empty vesicles, the joints being irregularly disposed, giving fragments of no defined forms. Near Eagle Harbour a well-marked columnar bed is seen, which has been traced for several miles. Another more important bed of a crystalline character occurs a little lower down. This is the so-called "greenstone," a finely crystalline rock without vesicles, which appears to be nearly homogeneous, and of a dark green colour on a freshly fractured surface; but a concretionary structure is brought out by weathering, the exposed surface presenting a finely mammillated appearance. The thickness of this bed is from 500 to 800 feet, according to Whitney; and where present in force it forms a well-marked feature in the scenery, the escarpment being in fact the "cliff" after which the oldest and most successful of Lake Superior mines is named. It has been traced from the Point eastward for about 40 miles, and is used to divide the mass of the trap into the northern and southern ranges—a distinction that cannot be established in the Portage Lake district, where the greenstone is absent, or covered up with drift.

Scattered through the massive trap are beds of amygdaloidal character, containing cavities that have been subsequently filled, by infiltration, with foreign minerals, usually zeolite and calcspar, with chlorite, epidote, and native copper in the mineral range; whereas chalcedonic amygdules, agates, and similar siliceous substances characterize the amygdaloids of the higher or Lake-shore traps at Eagle Harbour, Copper Harbour, and Agate Harbour, &c.

3. *Metallic Minerals of the District.*—In addition to the native metal, other copper-bearing minerals have been observed, but only in small quantity: these include a rare substance called Whitneyite (which is the most basic of the known components of copper and arsenic, its composition being represented by the formula, Cu 18, As, with 88·36 per cent. of copper, and 11·64 per cent. of arsenic), copper glance, and the various oxidized ores, such as chrysocolla, malachite, azurite, cuprite, and melaconite. The latter mineral, although not of present importance, is of interest as having laid the foundation of mining industry in the country, the first operations of the Cliff Company in 1847 having been upon a vein in the upper conglomerates of Copper Harbour, which produced about 25 tons of mixed silicates and black oxide of copper, being the only instance in which a deposit of any extent has been found in the top beds. Copper glance has been found in small quantities in a vein at the Huron mine on Portage Lake, and more abundantly at the Mendola mine near Lac la Belle, in the lower or southern portion of the mineral range, which is now being explored in a regular manner. The arsenide occurs in a quartz vein at the Shelden Columbian mine, and in an unworked deposit on the Lexington location south of Portage Lake, where it has been got in masses of several hundred-weights. This mineral, although rare, is of interest, as it also occurs in the copper-mines of Chili.

4. *Mode of Occurrence of the Copper.*—In addition to its presence in the amygdaloids, copper is found in one of the conglomerates associated with the trap rocks, finely interspersed in the more epi-

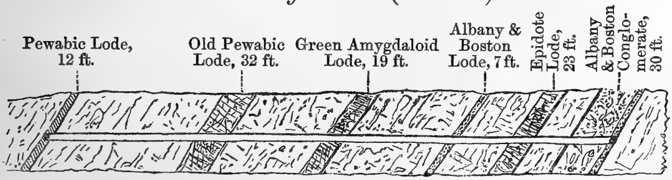

Fig. 1.—*Section of the Trappean Belt of the Mineral Range.*

dotic portions of the latter, and in two classes of true lodes,—one of which crosses the strata at right angles to their strike, forming the so-called fissure-veins of the Keweenau Point and Eagle River districts; while the other includes such veins as run with the formation, and are found in the Ontonagon district. These are very irregular in character; and the fact of their being veins can only be made out by their relations to the containing rocks as developed in deep working, the surface appearance being that of irregular masses of epidote-breccia, continually varying in thickness, although capable of being traced for considerable distances. In the fissure-veins the metal occurs in comparatively smooth platy masses, of all sizes, and comparatively free from intermixed rock; while in the Ontonagon lodes the masses are rough and on a very large scale, arborescent in form, and usually contain large adherent and included fragments of the vein-stone—a breccia of epidotic rock and quartz; but in either case they may attain a great size, and at times a weight of several hundred tons. In the cupriferous amygdaloids of Portage Lake, masses of great size are not found, the largest being that discovered about two years since in the Mesnard location, which weighed about 18 tons, and lay loose on the drift covering the rock. In addition to the masses, thin sheets of metal are common wherever narrow transverse cracks occur in the rock, either forming masses of tangled crystals with a serrated edge, or, when of large size, being more compact and not unlike worn-out copper sheathing. The metallic kernels of the amygdaloids are rarely solid, but form thin shells moulded to the wall of the cavity, or to the crystals of some mineral previously deposited, usually carbonate of lime. In the conglomerates, in like manner, the metal usually incrusts the pebbles, sometimes completely investing, but never entirely replacing them. When crystallized in its own form, the copper has also a great tendency to appear in hollow crystals, the simplest solid forms being formed in the hollows of the larger masses. A fine example of this has been recently furnished by the great mass of the central mine, which on one of the cuts disclosed a druse full of nearly perfect crystals of tetrahedral form, without any secondary planes. The finest crystallized varieties are, as a rule, obtained from the Ontonagon district, and generally are more abundant in newly opened mines than in those which are worked at greater depths.

In the Porcupine Mountains, to the west of the Ontonagon River, a compact epidote rock is found containing copper in such a very finely divided state, that it has hitherto been impossible to work it advantageously. Native silver is found to a small extent, either crystallized in arborescent forms, or irregularly spotted through the copper, the line of separation between the two metals being well marked in polished specimens. The Cliff and Minnesota mines have produced the largest amount of the precious metal, the absolute production, however, being but small; and scarcely any portion of what is found comes into the hands of the mining adventurers, except a few pounds which are annually got by hard picking from the coarser sizes of the dressed mineral. The larger pieces find their way into the hands of dealers and collectors, the earlier miners having appropriated them to their own use, and the precedent has been persistently followed ever since.

5. *Distribution and Association of the Copper.*—Among the three classes of deposits in which the mines are worked, the most important are the stratified amygdaloids, which will therefore be first considered. They are confined to the district of which Portage Lake (an inlet which nearly cuts the Peninsula into two parts) is the centre. The oldest mines are on the southern or Houghton side of the lake, so called from the town or village named after the geologist who examined the country; while the newer and more important ones are on the northern side, above the village of Hancock. The banks of the lake on either side rise steeply from the water to a height of from 400 to 600 feet; the dressing-flows, being placed close to the water, receive the ores from the mines (which are located on the high tablelands above) by means of railways and inclined planes. Taking the extreme north and south mines as limits, the district has a length, measured along the strike of the trappean belt, of about 9 miles, and a breadth of from 3 to 5 miles. The general section, showing the position of the copper-bearing beds, is as shown in Fig. 1. The series of beds indicated are amygdalous traps, which contain more or less copper in the cavities, and are regularly mined under

Fig. 2.—*Section from the Pewabic Lode to the Albany and Boston Conglomerate* (530 feet).

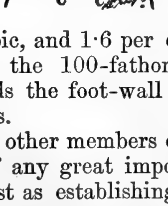



the name of "lodes." In the uppermost or Hancock series, only one mine is opened, bearing the same name. The ground is more irregular than is usual in the lower beds, three different belts of metalliferous rock being known. The principal one is 24 feet thick, without any defined walls; and about one-half of it is workable: the drivage is done on the upper or hanging wall, which often presents a laminated appearance from the occurrence of strings of calcspar, testing cross-cuts being driven into the vein below at intervals; the copper mass is chiefly on the lower or foot-wall side, the upper part being a hard compact trap. The yield of the rock sent to the stamps in 1864 was about 272 lbs. per cubic fathom, equal to 15 lbs. per ton, or about $\frac{3}{4}$ per cent.

The second or Pewabic group is more important than the preceding, and includes several belts or lodes, whose thicknesses and positions are given in Fig. 2, which represents the section obtained in a cross cut made at the 70 fathom-level of the Pewabic mine.

The most important members of this series are the highest, or Pewabic lode, and the lowest, or Albany and Boston conglomerate. The former has been systematically mined by the Quincy, Pewabic and Franklin Companies for a length of about $1\frac{1}{2}$ mile in a north-easterly direction from the Hancock shore of the lake. North of the Franklin it has been traced, but not worked, for a further length of about $3\frac{1}{2}$ miles, up to the Albany and Boston mine. It is a dark brownish-red amygdaloid, filled with small vesicles containing chlorite and native copper; the thickness varies from 6 to 30 feet, the average being 9 feet in the Pewabic, and 10 feet in the Quincy mine; the hanging wall is a compact greenstone-like trap; while the foot-wall is a dark-coloured amygdaloid, with very small kernels of chlorite. Fig. 3 shows the character of the lode at the 130-fathom level of the Pewabic mine. Copper is well sprinkled through the whole mass, with a few small masses near the foot-wall, and with irregular calcspar strings in the upper side. Although not producing any very large masses, the yield is tolerably uniform, the produce being at the rate of 1·5 per cent. in the Pewabic, and 1·6 per cent. in the Quincy mine: the latter is sunk below the 100-fathom level. The concentration of the copper towards the foot-wall is characteristic of the whole of the amygdaloids.

Fig. 3.—*Section of Pewabic Lode in the end of the* 130-*fm. level, Pewabic Mine.*




The other members of the group, below the Pewabic lode, although not of any great importance as regards produce of copper, are of interest as establishing the regular succession of the amygdaloids over areas of a certain extent, the section being substantially the same in the Pewabic cross cut as it is in the Albany and Boston line about $3\frac{1}{2}$ miles further north. It is not necessary to go further into the characteristics of these belts or lodes; but it may be incidentally remarked that the epidote lode is filled with a purplish rock, containing a great deal of bright-green epidote, and that the Albany and

Boston lode is also very epidotic, and in the hollows carries large quartz crystals and masses of prehnite.

The Albany and Boston conglomerate is a deposit of considerable interest, as it forms a well-marked horizon in the rocks of the Portage district, and carries in places a very considerable amount of copper. It is about 30 or 32 feet in thickness, and is included between a soft argillaceous sandstone floor, 4 feet thick, and a clay roof of 9 inches in thickness. The latter contains at times parallel sheets of copper, and is locally known as the "flucan lode." The pebbles are chiefly of red jaspideous porphyry, and are for the most part well-rounded, varying in size from about half an inch up to six or eight inches in greatest diameter. The cementing material varies considerably, being mainly calcareous at the Pewabic, and a compact epidote at Rhode Island mine. The more usual character, however, is a granular mixture of epidote, quartz, and finely divided rock-matter with small specks of copper.

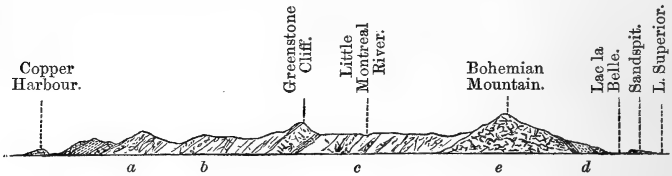
More remarkable conditions, however, have been observed in some portions of this rock at the Albany and Boston mine, where the cement is in places entirely metallic, the copper forming closely-fitting shells over the pebbles, and at times permeating them to such an extent as to form, with the siliceous mass, a kind of copper-concrete, which of course is extraordinarily tough, such pebbles being capable of passing almost unaltered in form through the jaws of the powerful rock-breakers employed in the dressing-floors. In places, however, the copper in the cement of the coarse conglomerate has been changed to chrysocolla and red copper ore, both of the octahedral and fibrous forms, associated with which are calcspar, prehnite, and, probably, cupreous allophane. Out of the total thickness of 32 feet, only the lower portion of the bed, from 10 to 15 feet in thickness, is cupriferous; so that in this respect the conglomerate resembles the amygdaloids.

The lower metalliferous, or Isle Royale series, is a belt of amygdaloids similar in general particulars to those of the Pewabic group. It includes two great lodes:—the grand Portage, worked in the mine of the same name on the south shore of Portage Lake; and the Isle Royale, which is opened on the Huron mine, also on the south side, but has also been traced for several miles on the north shore. It is a pale-green amygdaloid containing quartz, steatite, chlorite, epidote, and copper in small quantity, from 24 to 33 feet in thickness, yielding about 1 per cent. of copper when dressed. Below the Isle Royale is another lode called Mabbs lode, which has recently been discovered; and it is not quite certain whether it be a parallel belt or an actual fissure-vein, as its dip is much steeper, being 75° instead of from 52° to 60°, which is the amount of inclination of the higher belts.

6. *Mines of the Northern District.*—In the district of Keweenau Point the cupriferous amygdaloids occupy but a subordinate position, the whole of the produce being derived, with a very few exceptions, from true lodes, or, as they are called in the district, fissure-veins, which, as a rule, are nearly vertical, and cross the trappean formation

at right angles to its strike, the greater number being included between the directions N.W. & S.E., and N. & S. The relation of the rocks is shown in the sketch-section, Fig. 4, from which it will be seen that the trappean series is divided into two parts by the great greenstone bed, the upper portion being known as the northern, and the lower as the southern mineral range. Now although lodes in many cases pass through both ranges, yet, as a rule, up to the present time they have rarely proved to be of value for copper in both, the most important deposits being confined to the southern side, and at no great distance from the greenstone, the principal mines being the Cliff near Eagle River, the Amygdaloid, Delaware, and Pennsylvania near Eagle Harbour*.

Fig. 4.—*Section from Copper Harbour to Lac la Belle* (after Foster & Whitney).




*a.* Upper sandstones and traps. *b.* Upper metalliferous traps. *c.* Lower metalliferous traps. *d.* Chlorite rock and sandstone. *e.* Porphyry ?

The lode worked at the Cliff mine has been traced for about $2\frac{1}{2}$ miles, but the main workings are below the greenstone, and extend southward for about 1400 yards. It is a nearly vertical fissure, varying in breadth from a mere line to six feet, filled with broken rock and zeolitic minerals, with native copper, both in fine particles and large masses, the latter being common in the wider portions, which alternate with barren strings made up of laumonite and decomposed trap. The containing rock is a hard trap, with interstratified beds or "flows" of amygdaloid, which have been laid down in the plans to the number of 12 or 13. These are occasionally

* The total yield of copper from the mines of Lake Superior in 1864 was as follows:—

| | | | | | |
|---|---|---|---|---|---|
| From 13 mines in | Portage Lake | district, | 4293 | tons of 70 per cent. | mineral. |
| ,, 16 ,, | Keweenau | ,, | 2548 | ,, | ,, |
| ,, 19 ,, | Ontonagon | ,, | 1722 | ,, | ,, |
| | | | 8563 tons. | | |

These quantities are in American customary tons of 2000 lbs. The above total is equal to about 5609 statute tons of fine copper.

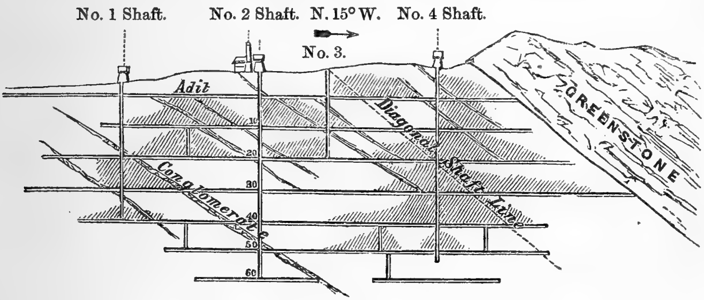
The largest individual production was, in dressed mineral (70 per cent):—

| | | | | | |
|---|---|---|---|---|---|
| 1485 tons | 13 cwts., | American | weight, | from | Quincy Mine. |
| 1133 ,, | 19 | ,, | ,, | ,, | Cliff Mine. |
| 932 ,, | 8 | ,, | ,, | ,, | Pewabic Mine. |
| 609 ,, | 3 | ,, | ,, | ,, | Central Mine. |
| 525 ,, | 10 | ,, | ,, | ,, | National Mine. |

impregnated with copper to a depth of about 20 feet from the lodes. The mine is 156 fathoms deep, and produces from 35 to 65 masses weighing about a ton each per month, and about an equal weight from stamp-rock, containing about 1·9 per cent. The copper-ground, as a rule, appears to follow the greenstone in depth, dipping about 27° north-westerly. The North and South Cliff mines, opened on the prolongations of the same lode, are not now at work.

The Central mine, about 14 miles east of the Cliff, is opened upon a similar lode, consisting of a series of alternations of red laumonite strings, with large lenticular expansions containing copper. The original discovery of this lode was made in an old Indian working at the No. 2 shaft, out of which a mass of copper, weighing 50 tons, was taken. Only a small amount of metal has been found immediately below this point in sinking; but further north, below the greenstone, under similar conditions to those observed in the Cliff mine, a very rich run of ground has been discovered. There is a good deal of calcspar in the vein, and the finer copper appears rather in sheets than in shots. At the 50-fathom level, on the No. 4 shaft, the largest mass that has as yet been discovered on the lake was struck; it measured 50 feet in length, 30 in height, and about 4½ feet in greatest thickness, and yielded somewhat over 500 tons of copper.

Fig. 5.—*Longitudinal Section of the Central Mine.*




The mines in the range north of the greenstone are the Petherick, Copper Falls, and Phœnix, which derive their produce almost entirely from a remarkable bed of very much decomposed finely vesicular trap, filled with small shots of copper, known locally as the "ash-bed." Associated with this is a compact trap, containing elongated cavities at its contact with the more vesicular portions. These cavities are usually filled with copper in ramifying forms resembling eagles' claws. The ash-bed, according to its discoverer, Mr. Hill, has been traced for about 8 miles, and by its position probably represents some of the upper beds of Portage Lake. Although extensively worked, it is too poor to yield any great profit, the produce at Copper Falls being 1 per cent., and at the Phœnix only ¾ per cent., of the rock treated.

7. *Ontonagon District.*—The mines of this district are all opened in the same class of deposits—namely, very irregularly defined lodes which follow the strike of the trappean belt, commencing on the Minnesota Hills, at the southern end of the district, which rise abruptly from a drift-covered plateau, about 12 miles in length, lying to the south of the town of Ontonagon. They extend in a north-easterly direction for about 16 miles to the Wynona mine, the last explorations in the direction of Portage Lake. The Minnesota mine has been worked to a depth of about 200 fathoms, on a lode dipping about 46° northerly, and included between a roof of compact grey trap and a floor of conglomerate. A northern branch, dipping at a higher angle, falls into it at the fifth level below the adit; between these is another branch, more nearly parallel with the main lode, in which the great mass of 400 tons was found in the year 1856, about 20 fathoms below the surface. This mine has shown a decided decrease of richness in depth, the produce having diminished from 2058 tons in 1857, derived from ground yielding 1267 lbs. per fathom, to $387\frac{1}{4}$ tons in 1864, the amount per fathom being reduced in the latter year to 186 lbs. The lower workings are now completely abandoned, and an attempt is being made to develope the northern lodes. As seen in the adjoining National mine, the Minnesota lode is filled with a mass of epidote and quartz, apparently of a brecciiform structure, with rough particles of copper scattered irregularly through it. The hanging wall is full of small slipped pieces of rock and clay, and is covered with longitudinal striations.

The sandstone below the conglomerate on the underside of the lode occasionally contains a little copper, when it assumes a laminated appearance, in thin stripes of red jasper and yellow epidote grains, interspersed with bright metallic leaflets, the arrangement being similar to the cement of the Albany and Boston conglomerate and the compact epidote-rock of the Porcupine Mountains.

The lode at the Indian mine is an epidotic mass, apparently a concretion in the hornblendic trap. It is remarkable for carrying large quantities of analcime, with small masses of copper in solid crystals. A very decided concretionary structure is seen in the trap at the Bohemian and Toltee mines, which are on the same run of ground; the deposit worked is a course of trap, filled with epidote about 8 feet thick, the rock containing spheroidal masses which in section present alternately light- and dark-green rings, the former being due to epidote, and the latter to the prevalence of hornblende and chlorite, the two colours being divided by intermediate rings of calcspar: the largest of these concretions are about 15 inches in diameter. The lode is an epidotic amygdaloid, about 8 feet in thickness, with a N.W. dip of 35°. It is spotted through with small strings of calcspar and quartz; the copper occurs either in pseudomorphs or in crystallized masses of no great size, or in leaf-like plates in the bright-green epidote: similar conditions prevail in the Wisconsin mines further to the N.E.; but as yet none of these mines are distinguished by any great production. Several heavy masses have recently been taken out of the shallow workings at the Flint-Steel mine, which is opened upon an epidote-breccia lode divided into two branches by a horse or rib of barren trap. Very extensive traces of aboriginal mining have been discovered at this place, the old miners having sunk their pits on both branches of the lode, avoiding the barren ground between them. It is very remarkable that almost all the valuable mining locations on the lake show traces of Indian or Aztec work; and recent discovery has shown that they not only worked on the mass lodes, but also—in one instance at least—on the conglomerates. If the country were less wooded, these old workings might be of considerable service in indicating the position of deposits of value; but they are, in almost all instances, filled up and covered by vegetation, the trees being as large as any of those of the surrounding forest, thus giving proof of the remote antiquity of these workings.

8. *Paragenesis.*—The following are a few of the chief alternations of minerals observed in the Lake Superior mines: others will be found in the works of Professor Whitney:—

1. Chlorite, calcite, copper—Pewabic lode.
2. Chlorite, quartz, copper—Isle Royale lode.
3. Chalcedony, quartz, apophyllite, calcite—Bay State mine.
4. Laumonite, quartz, green-earth—Phœnix mine.
5. Prehnite, quartz, copper, laumonite—Bay State mine.
6. Natrolite, laumonite, analcime—Copper Falls mine.
7. Calcite, copper, analcime, orthoclase—Copper Falls mine.
8. Apophyllite, copper, orthoclase—Copper Falls mine.
9. Datholite, copper, calcite—Copper Falls mine.
10. Analcime, copper, orthoclase—Bohemian mine.
11. Quartz, prehnite, copper, calcite, clay—Albany and Boston lode.
12. Quartz, epidote, laumonite—Isle Royale lode.
13. Quartz, epidote, copper, orthoclase, calcite, melaconite—National mine.
14. Calcite, prehnite, copper, cuprite, chalcotrichite, chryosocolla, allophane, silver—Albany and Boston conglomerate.
15. Calcite, chrysocolla, malachite, cuprite, silver—Albany and Boston conglomerate.
16. Quartz, Whitneyite—Shelden and Lexington mines.
17. Copper-glance, calcite—Mendola mine.

From the above list it will be seen that the copper is sometimes older and sometimes newer than the associated minerals. In the Ontonagon district it occurs very generally as incrusting pseudomorphs upon opaque rhombohedra of calcite, but is also itself enclosed in transparent complex scalenohedral forms of the same mineral, but of later formation. Similar encrusting pseudomorphs of quartz are also common, the original mineral having at times been removed, leaving an empty six-sided tube. The best examples of this class are to be found at the Huron and Bohemian mines. Silver occurs, both in massive lumps included in the copper and in crystallized arborescent forms. The two metals have probably been deposited simultaneously.

9. *Origin of the Copper.*—The occurrence of native copper in the cavities of amygdaloid traps has been observed under circumstances similar to those seen on Lake Superior, in the agate-bearing melaphyre of Oberstein in Rhenish Prussia, in Nova Scotia, and in the Faroe Islands. Thin sheets encrusting the walls of cracks in similar rocks

have been found in several places near Glasgow. In the whole of the above localities, however, it is a comparatively rare phenomenon, and might be accounted for by the reduction of dichloride of copper sublimed from a volcanic vent—a process of which we have indications in the occurrence of oxychloride of copper in the lavas of Vesuvius. It is difficult, however, to consider this an adequate cause for the metallization of a mass of rocks which, from their appearance on Isle Royale, Michipecoton, and other points on the northern and eastern shores of the lake, must cover an area of many thousands of square miles. Another hypothesis, suggested by Müller, supposes the copper to have formed part of the felspathic component of the trap rock when in the unaltered state—a view that is supported by the occasional occurrence of protoxide of copper in small quantities, usually less than 1 per cent., in several anhydrous silicates, such as felspar, orthoclase from Schemnitz, and Amazon-stone from Siberia, epidote from S. Marcel in Piedmont, idocrase in the Norwegian variety called cyprine, and olivine*. This hypothesis may be modified by supposing the copper to have existed in the trap as sulphide, mechanically interspersed in minute quantities, in the same way that it is found in the coarse metal slags of copper-furnaces. On the other hand, we have the recorded statement of Whitney†, who, in an analysis of the trap from Isle Royale, found it to contain no copper, although it was specially sought for; but traces were found in the sandstones overlying the trappean series. This piece of negative evidence, however, must not be overestimated, as it would in any case be very difficult, if not impossible, to determine the original composition of the traps as they exist at present. They have undoubtedly undergone considerable change, as is shown by the presence of hydrated minerals, such as chlorite and zeolites, as well as calcspar.

Rammelsberg has found as much as 0·56 per cent. of protoxide of copper in a lava from Vesuvius from the eruption of 1811—a rock not very dissimilar in composition from the Lake Superior trap; and although we have great masses of copper concentrated at single points, it must be remembered that the percentage contents of the deposits selected as rich enough for working are included between the narrow limits of one-half and two per cent.; and supposing the contents of these deposits to be uniformly distributed through the whole mass of the traps, the state of division would be so great as to render the copper difficult of detection. The presence of copper in the sandstones suggests another origin—namely, that it may have originally been deposited with the quartz-ore sediment as a finely divided sulphide from sea-water under the influence of organic matter, and by subsequent oxidation and solution have been removed and collected in the rocks below. Cupriferous sandstones and other sedimentary rocks are comparatively common, as, for example, the Carboniferous Sandstones of Nova Scotia and the Kupfer Schiefer, which contain sulphides of copper in an unaltered form, partly on account of the state of aggregation of the deposited mineral, and partly from the texture

* Bischof, Geol. vol. ii. pt. 3. p. 189.

† Geology of Lake Superior, pt. 2. p. 87.

of the rock and the presence of organic matter, which prevents oxidation. In coarser and more easily permeable rocks, however, not containing organic matter, it is easy to see how the finely divided sulphide would be readily oxidized by infiltrated atmospheric water, giving rise to sulphates, carbonates, and other oxidized minerals—a condition which is exemplified by the cupriferous Triassic Sandstones of Cheshire, which contain only oxidized compounds of copper.

The size of the accumulated masses of metal appears to be mainly dependent upon the size of the cavities in which they are deposited, whether in the amygdaloids or in the main fissures; and their absence in the compact traps is probably only due to the non-occurrence of such cavities. In almost all cases the introduction of the metal has been preceded by the deposit of minerals produced from the decomposition of the rock, such as quartz, calcite, chlorite, and zeolite; and in the larger cavities it is often followed by transparent crystals of calcite, which are formed over branching masses of copper, or even show signs of simultaneous deposition, being filled with fire-spangles of metal arranged parallel to the diagonal striations or lines of growth on the rhombohedra. Similar alternations in the formation of zeolites, more particularly analcime, have been described by Whitney.

Bischoff * has shown that hydrated silicates of copper, both artificially prepared and the natural mineral dioptase, are sensibly soluble in pure water, but much more readily so when carbonic acid is present, the solution in the latter case being attended with a partial decomposition and separation of silica. A reaction of this kind is suggested by the occurrence of chalcedonic and quartzose kernels in the amygdaloids of the higher portion of the trappean series, while copper is found lower down. As regards the reduction of the metal from solution, it is probable that the chief agents have been substances containing protoxide of iron derived from the decomposition of the trap itself. Professor Andrews, of Belfast †, has suggested a more potent reducing-medium in the presence of metallic iron in certain varieties of basalt in Ireland, and other crystalline rocks from other localities; but it does not appear to be very likely that such an agency can have been at work on Lake Superior, as it is difficult to suppose that an eminently oxidizable substance like finely divided iron could have remained unaltered after the changes produced by infiltration of water had once been set up; and these changes appear to have preceded the deposition of the copper.

A point of considerable interest, but which we have at present no means of determining precisely, is, whether the copper in the fissure-veins is of the same age, newer, or older than that of the amygdaloids of Portage Lake. I am inclined to think that the latter are the older class of deposits, and that they have served as feeders for the fissure-veins, for the following reasons:—

1. The lodes carry more copper between amygdaloid walls than they do when encased in compact trap.

2. The transverse joints and fissures of the amygdaloids on

* Vol. ii. pt. 3. p. 1887. † Brit. Assoc. Report.

Portage Lake carry masses and sheets of copper analogous to, but much smaller than, the masses of the northern mines.

3. The amygdaloids adjoining the bearing portions of the veins are often found to contain considerable quantities of copper for some distance from either wall.

The last of the above reasons may no doubt be made available in support of the opposite hypothesis of the permeation of the cellular rock by materials introduced from the lodes; but in order to prove this, it would be necessary to show that the rock was barren, except within the distances explored. This is, however, by no means certain, as the miner stops at the limit of profitable working without carrying on systematic researches along the strike of the bed, as is done in the Portage district.

Bischoff * showed, as far back as the year 1825, that copper may be deposited from solution in a massive condition in a comparatively short time, by the action of organic matter upon solutions containing sulphate of copper partly in the state of a salt of the suboxide. This was observed at Linz, on the Rhine, where a solid malleable mass of copper, weighing $2\frac{3}{4}$ lbs., was deposited in a wooden vat, used in the concentration of blue vitriol leys obtained from the lixiviation of poor copper ores after roasting.

Where the amygdaloids are compact, and tolerably free from cracks and joints, the metallic kernels have undergone no change, and appear as clean brilliant masses on a freshly fractured surface. It is different, however, at the outcrops, where the cavities are usually empty, and their former contents, converted into malachite, have been absorbed by the crystalline base of the rock, which is stained green for a considerable distance round. Similarly in the conglomerates atmospheric agencies have been largely at work, producing malachite, red copper ores, chrysocolla, and similar secondary products; and another instance of the same kind may be adduced in the old vein in the sandstones of Copper Harbour, which yielded melaconite and chrysocolla in considerable quantities, but not metallic copper. The mines, as a rule, are very dry, the deepest requiring only a small amount of pumping-machinery of no great power, and that only employed at intervals, in order to keep the workings free from water. This comparative impermeability of the rock is probably the cause that has preserved its metallic contents with such a small amount of change, as it is well known that metallic copper is rapidly oxidized when exposed to ordinary atmospheric vicissitudes. This is well seen in the "floats," or small masses, that have been removed from the rock by denudation, and are found in the drift covering the backs of the lodes. These are often incrusted with a coating of earthy malachite nearly half an inch in thickness.

Perhaps the most interesting fact in connexion with the mineralogy of the Lake Superior mines is the prominent occurrence of orthoclase among the newest minerals in the lodes, and in succession to zeolites;

* Pogg. Ann. iii. p. 195.

and as it is found deposited upon the faces of crystals of analcime and apophyllite, it is evident that it must have been formed at a very moderate temperature*.

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April 25, 1866.

The following communications were read:—

1. Additional Documents *relating to the* Volcanic Eruptions *at the* Kaimeni Islands. By Commander Brine, of H.M.S. 'Racer.'

[Communicated by the Lords Commissioners of the Admiralty.]

(An abstract of this communication was published in Quart. Journ. Geol. Soc. No. 87, p. 319, by order of the Council.)

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2. Report *to the* Eparch *of* Santorino *on the* Eruptions *at the* Kaimeni Islands. By M. Fouqué.

[Communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S., &c.

(An abstract of this communication was published in Quart. Journ. Geol. Soc. No. 87, p. 320, by order of the Council.)

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3. Remarks *upon the* Interval *of* Time *which has passed between the Formation of the* Upper *and* Lower Valley-gravels *of part of* England *and* France; *with Notes on the Character of the* Holes *bored in* Rocks *by* Mollusca. By A. Tylor, Esq., F.G.S.

The elaborate examination of the Quaternary deposits made by Mr. Prestwich has induced that geologist to divide the valley-gravels into upper and lower, which are supposed to be separated from each other by a considerable interval of time.

There is much similarity in these deposits, although separated for purposes of classification by Mr. Prestwich; for the organic remains are nearly identical, and the human implements found in both (made of roughly chipped flint) are of the same general character. Mr. Prestwich argues that although the upper valley-gravels are at a

* The following are the chief works on Lake Superior Mine:—

Foster and Whitney, 'Report on the Lake Superior Land District, Washington,' 1845.

J. D. Whitney 'The metallic weight of the United States.'

Rivot, "Voyage au Lac Supérieur," Ann. des Mines, 5e sér. vol. vii. p. 175; "Notice sur le Lac Supérieur," Ann. des Mines, 5e sér. vol. x.

Jules Borie, 'Bulletin de la Société de l'Industrie Minérale,' vols. vi. vii., viii.

Alb. Müller, 'Verhandlungen der naturf. Gesellschaft zu Basel,' vol. iii.

higher relative level than the lower, yet the higher series are always the older, and the lower the more modern; and we have thus the ordinary superposition of new over old strata supposed to be reversed. This difficulty is considered by most geologists to have been surmounted by Mr. Prestwich's arguments, and his classification of the gravels has been generally accepted. My own opinion is, that the evidence on which Mr. Prestwich's theory is based is insufficient; at the same time, I fully admit the careful and accurate manner in which he has stated his views.

Present inquirers have the great advantage of having before them the accurate sections prepared by Mr. Prestwich with great skill and labour. Mr. Prestwich describes the drift-beds of the valley of the Somme as the opposite extremities of a series of gravels deposited in a period of time so vast that during its continuance extensive valleys were formed and excavated out of solid strata, and the gravel-beds afterwards deposited on their flanks and on their bottoms.

The lower valley-gravels are more continuous than the upper; and their lower extremities touch the alluvium of the present rivers, often on the same horizon.

They contain organic remains resembling those found in the well-known bone-caverns, including the bones of extinct Mammalia, associated with flint weapons of rude workmanship. The upper beds contain nearly the same organic remains and human implements as the lower, and are occasionally capped by thick beds of loess of freshwater origin. Both upper and lower valley-gravels contain materials brought from a distance and deposited irregularly, as if they were the feeble successors of the great diluvial deposits of the glacial period which immediately preceded them, but which in its typical form left no remains south of the Thames.

Mr. Prestwich has described the present valley of the Somme as having a transverse section of five hundred times the area of the present water-channel, and other valleys of similar character as possessing still greater proportionate size when compared with their present water-channels.

He supposes that during the elevation of the land the action of torrents, ice, and snow removed large masses of stratified rock from the valleys; and in writing of the duration of the period of time in which the upper and lower gravels might have been accumulated, he observes:—"The next possible standard to measure the duration of the period of time in which the upper and lower gravels were accumulated is the time required for the excavation of the valleys themselves." I do not see that this supposition is confirmed by sufficient evidence; for, supposing the excavation of the valleys to have occurred between the dates of the upper and lower valley-gravels, we are obliged to allow not only a vast, but an apparently unnecessary amount of time for the accumulation of such incoherent and often unstratified deposits. The lower valley-gravels at Grays, Ilford, Menchecourt, &c. &c., are thick, and must be the accumulation of a long period; for they contain remains in great abundance of the large extinct Mammalia, deposited among fragile shells of many Mollusca now living in tranquil water in the neighbourhood and on the same horizon, and also of three species of Mollusca which have disappeared from the country, one species not being met with now at any nearer point than the Nile. To suppose that man was living throughout the period of the lower valley-gravels at the same time as the great extinct Mammalia, obliges us to carry back his presence on the earth not only to a very distant date, but to a period when physical circumstances must have differed very much from those we experience. We therefore wonder that there are so few indications of his presence or works left behind; for we cannot realize the lapse of time without fixing on some events by which to measure it. If man existed prior to so great and distant an event as that of the excavation of the valleys, the problem becomes still more difficult to understand.

The opinion of Mr. Prestwich as to the age of the Somme valley is not at present confirmed, as far as I am aware, by any other geologist. Sir H. T. De la Beche thought the valleys of Devon and Cornwall opening into the English Channel might have been excavated not later than in early post-Cretaceous times, but that their forms may have been modified more recently. Mr. Godwin-Austen thinks the German Ocean and English Channel were not united at the period of the Coralline and Red Crag, so that the easterly part of the Channel would have been formed in the Pleistocene period—a view now generally adopted.

Also Mr. Pengelly considers that the valleys of the south-east of Devonshire were excavated in post-Cretaceous times, and were subsequently filled from base to hill-top—a point also discussed by Sir H. T. De la Beche without his arriving at a definite conclusion*.

Mr. Pengelly distinctly refers the reopening of the valleys to a subsequent denudation, and remarks, "A remnant of the gravel remains to line the slope and preserve a record of the operations"†. He does not give any sections; but, having visited some of the localities, I concur entirely in his opinions. Mr. Pengelly asserts that he has also discovered perforations made by a marine boring-animal at considerable elevations above the sea and above raised sea-beaches, in many localities in the Torbay district; and I give the following sections of valleys, that the position of these bored holes may be clearly understood.

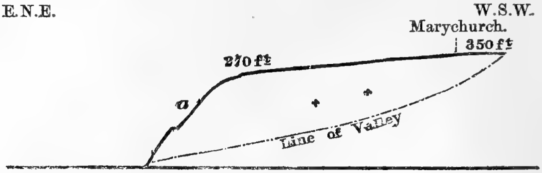
In the valley leading to Kent's Hole Cavern (fig. 1) there is red drift on the plateau, and the same material in the cavern and on the bottom of the valley; this is usually the case in the district. If the borings in the limestone forming the face of the cliff in which the openings into Kent's Hole Cavern occur, at a height of 180 feet above the sea, have been made by a marine animal (*Pholas*, or any other borer) then it is good evidence that the drift has been removed from the narrow and short valley below the cave, leaving no marks of denudation on the valley itself. We have therefore no evidence in Kent's

* I may add that the fringes of gravel along the Devonshire valleys were noticed by Mr. Godwin-Austen in an early paper.

† 'Denudation of Rocks in Devonshire,' 1864, p. 19.

Hole valley of such a great denudation as Mr. Prestwich supposes to have occurred in the valley of the Somme, although we have in both places drift associated with the bones of extinct Mammalia, and with rude flint implements at very high levels above the sea.

Fig. 1.—*Longitudinal Section of Marychurch Valley.*




* Pholas markings.

The raised beaches fringing the coast-line in the south-east of England, north-east of France, and south-east of Devonshire, as well as the gravels, &c., fronting at similar heights the transverse valleys which open in both districts into the English Channel, place all these localities in close geological relationship.

The presence of calcareous deposits on the sides of the chalk valleys in France, described by Mr. Prestwich, is matched in Devonshire by a calcareous deposit which has cemented loose blocks of limestone on the solid rock.

At Watcombe, figs. 2 & 3, one mile north-east of Kent's Hole Cavern, the analogy is still more complete, if I am correct in the suggestion that this may be a thick bed of freshwater loess covering the angular drift below it, and that both drift and loess are derived from the ruins of the Triassic rocks close by. The clay in question is extremely fine, and must have been deposited from a most tranquil lake†; and yet it is now raised more than 200 feet above the present sea-level.

Fig. 2.—*Longitudinal Section along the Valley of Watcombe.*

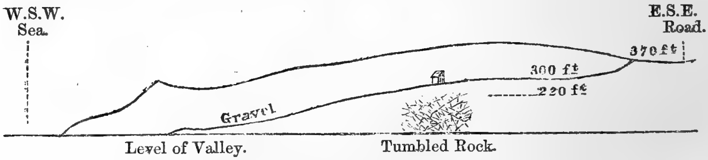



Fig. 3.—*Coast-section from Babbacombe to Watcombe.*


× Borings.

Reasoning on so many parallel circumstances, we must admit a close analogy between the former condition of the Devonshire and Somme valleys during the gravel-period, and may consider that the surface of the Devonian limestone has been so little affected by the

† This loess clay is about to be used for terra-cotta figures.

action of weather during the removal of the gravel in the valley above and below it that the interval must be comparatively small since the event in question took place, viz., since the valley previously filled with gravel, sand, or mud was denuded, leaving what may be called high- and low-level gravel in a remanié state on the flanks and the bottom.

Having repeatedly visited the valley of the Somme without being able to satisfy myself as to the correctness of the views entertained by geologists regarding the extreme antiquity of the upper gravels, I wish to state that I attach great importance to the views so long ago put forward, as to the valleys of post-Cretaceous age having been filled with gravel in one geological period and cleared out and partially refilled in a subsequent and, perhaps, very recent date*.

The theory of the excavation of the French valleys between the periods of the deposition of the upper and lower gravels was proposed by Mr. Prestwich as the most probable explanation of the phenomena, the impossibility of obtaining absolute proof of his hypothesis being obvious†.

All the evidence, on the contrary, which is forthcoming, I contend, should rather cause us to admit the identification of the ages of the Devonshire and Somme valleys; for both sets of valleys are ancient, they were afterwards wholly or partially filled with gravel, and the gravel on the slopes and bottoms in each is remanié recently, the levels of the new drift-deposits are similar, the character of the mammalian remains in each is strikingly alike, and raised sea-beaches occur on the coast not very distant from the mouths of the valleys in question. If the perforations of marine boring-shells could be proved to occur in the valley of the Somme, the analogy would be still clearer (but of this there is no evidence at the present time), as it would then appear as if the deposition of these drift-beds might have occurred almost within the historical period.

It is, however, certain that both the low- and high-level gravels with human implements and mammalian remains are more recent than the Boulder-clay, for this is proved in the Hoxne section; and reasoning by analogy, all the other gravels in valleys and caves, containing the same kind of organic remains associated with the tools of uncivilized man, belong to an interval between the Boulder-clay and historical periods.

The raised sea-beaches containing only organic remains of species of mollusca now living in their neighbourhood are the equivalents in time of a portion, or the whole, of this period—as their subaerial heads shade into modern deposits, while the base may, from other reasons, be of much older date. Godwin-Austen separated the lower portion of the Brighton beach from the upper, many years since, in this manner.

The conclusions at which I arrive are:—

1st. That the valleys of the south-east of Devonshire and of the north-east of France were excavated in remote geological periods,

* Pengelly, Denudation of Rocks in Devonshire, p. 13.

† Prestwich, Phil. Trans. p. 253, 1864.

and filled up with marine or fluviatile gravel, and reexcavated prior to the epoch of the high- and low-level valley-gravels.

2nd. That all these gravels are reconstructed of drift and gravel of the Glacial period, or of its equivalent south of the Thames, mixed with a certain amount of local materials.

3rd. That the high- and low-level gravels are of one formation, closely connected in age, and dating from a time immediately preceding the historical period.

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May 9, 1866.

The following communications were read:—

1. *On a* New Species *of* Acanthodes *from the* Coal-shales *of* Longton. By Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S., &c.

[Plate XXIII.]

Owing to the kindness of Mr. Ward, of Longton (who has for some time past devoted his time and attention to collecting the fossil remains of the coal-pits in his vicinity), I have had the opportunity of examining a considerable collection of specimens of the Acanthodian fishes of the North Staffordshire Coal-measures. Numerically speaking, the collection is a large one, but the specimens themselves are all imperfect. The anterior parts of the fish are rarely preserved; and even when present, the dislocations and crushed condition of the component bones are so extensive that the form and structural details of the head and thorax are difficult to decipher. Most of the best-preserved specimens contain the middle and hinder portions of the body, from the ventral spines to the bifurcation of the tail; and all have the scales well shown, and most of the spines supporting the fins. Although it might perhaps be desirable to wait for more perfect specimens before undertaking a complete determination of the specific forms, yet the evidence already procured is so decisive as to the distinctness of at least one species, that a brief description of this form may be given without prejudice to future investigation.

The generic characters of *Acanthodes* have been so thoroughly worked out in previous publications * that it is needless to recapitulate them here, the more so since no important anatomical points are supplemented by the specimens under consideration.

Selecting for description those individuals of a medium size, the length of the body, from the snout to the point where the vertebral axis trends upwards to form the upper lobe of the tail, seems to have been about $5\frac{1}{2}$ inches. Of this total the anterior third comprises from the nose to the point of insertion of the ventral spines, the middle third from the ventral spine to the anal spines, and the posterior third from the anal spine to the point above mentioned. Estimating

* Agass. Poiss. vol. ii. p. 9. Herr Fred. Römer, Ueber *Acanthodes gracilis*: Breslau, 1857. Memoirs of Geological Survey, Decade 10. pp. 37 & 57.

the length of the tail beyond that point at $1\frac{1}{2}$ inch, we arrive at a total length of 7 inches for the perfect fish. The depth of the body is greatest between the pectoral and ventral fins, where it measures $1\frac{1}{10}$ inch. The anterior contour of the head is obtusely oval; and the trunk tapers gradually from the thoracic region to the spring of the tail. On comparing these dimensions with those of the known species of the genus, it appears that this fish was far less bulky, and more elongated, than *Acanthodes Bronni* from the coal of the neighbourhood of Saarbrück, but not so slender as *Acanthodes gracilis*, from the Permian beds of Klein Neudorf.

In one or other of the specimens the curious plates encircling the orbit, the pair of slender ossicles representing the lower jaw, and the branchial apparatus are well preserved. The orbital plates are four in number on either side, and are prettily ornamented with minute tubercles or granules. They are very similar in character to the analogous parts in *Acanthodes gracilis*. The styliform bones forming the rami of the lower jaw are slender and rounded, and about $\frac{3}{4}$ of an inch in length. The branchial apparatus is composed of six arches (as seen in one specimen), whereas Römer has only represented four in his restoration of *Acanthodes gracilis*. They are arranged more longitudinally, *i. e.* more parallel to the outlines of the back and belly, than in that species. They seem to have been unprotected by any opercular flap. The pectoral spines are long, broad, and scimitar-shaped, the distal end being flattened out and rather blunt; a deep groove runs parallel to the anterior margin, and a few obsolete depressions traverse the spine obliquely from the inner pectoral margin towards the outer distal extremity: these are not so prominent as the grooves on the pectoral spines of *Acanthodes gracilis*. The spines are articulated to two strong T-shaped coracoids, a structural peculiarity common to all the Acanthodidæ, and affording, according to Professor Huxley, one of the strongest arguments against the placoid affinities of the family. The spines support fins of large size, the full extent of which is not shown in any of the specimens. The ventral spines are situated, as before stated, at one-third of the antero-posterior length of the fish. They are short, sharp, and recurved. A distinct furrow runs along the front of each. They bear small triangular fins. The anal spine is (next to the pectoral spines) the most powerful of these defensive weapons. It is long, thick, and nearly straight, and is traversed by a deep groove. It is furnished with a large fin extending to within one-third of its point. The dorsal spine is inserted over and behind the anal spine. It is rather weaker than that spine, and is slightly recurved, but resembles it in all other respects. The tail is strikingly heterocercal. The upper lobe tapers off to a fine point; the inferior lobe commences below with strong fin-rays, which diminish in length and strength as they ascend along the upper margin of the lower lobe. They appear to be composed entirely of ganoin; in fact each segment has the character and appearance of a thick scale. There is nothing remarkable in the dermal investment; the scales are smooth externally, and have their under surfaces produced into small circular eminences. They increase in size as they recede from the head, and are largest on the posterior part of the trunk. A well-defined lateral line traverses the flank about mid-distance between the back and belly, and an auxiliary mucous duct runs along the abdominal parietes as far as the anal spine.

I am desirous of giving my testimony to the zeal and liberality which Mr. Ward has shown in advancing the knowledge of the organic remains of his district, and therefore have much pleasure in naming this rare species *Acanthodes Wardi*.

Accompanying the specimens from the coal-shale are some ironstone nodules containing remains of Acanthodian fishes, indicating a species of much larger size than the one above described.

One of these contains the head and anterior parts of a fish which must have measured at least 2 feet 6 inches in length. Two other nodules contain portions of the head of (probably) the same species, a fourth specimen shows a pectoral spine $3\frac{1}{2}$ inches in length, which may also have belonged to the same species.

The only other distinctive character shown by these specimens is the small size of the scales, they not being so large as those of *Acanthodes Wardi*, which species measured only 7 inches in length.

### Explanation of Plate XXIII.

(Illustrative of *Acanthodes Wardi.*)

Fig. 1.—*Acanthodes Wardi.* Natural size. In Mr. Ward's collection.

Fig. 2.—Part of another specimen showing the branchial apparatus. Natural size. In Mr. Ward's collection.

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## 2. A Sketch *of the* Gravels *and* Drift *of the* Fenland. By Harry Seeley, Esq, F.G.S., of the Woodwardian Museum in the University of Cambridge.

### Part I.—Descriptive.

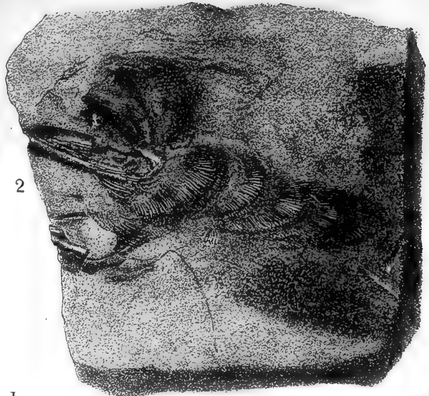
[Abridged.]

By the Fenland is here understood the great flat country west of the Chalk-hills of Norfolk, from Hunstanton to Cambridge, thence to Bedford, and so north to Peterborough.

Such an area offers many conditions favourable for a consideration of the subject of this paper, being bounded by Cretaceous rocks east and south, and the outcrop of the Oolites flanking the west, while the sea opens to much of the north; and the included country, being nearly flat, presents a minimum of complications.

This tract slopes gradually to the sea, which it resembles in its dreary uniformity. Every village and town, however, indicates a patch of higher land than that around it; and from Chatteris, round by Haddenham and Ely, to Littleport the level is relatively by no means low. South of this, too, by Denny Abbey, Cottenham, Rampton, Over, and St. Ives, towards Huntingdon, there is a line of higher ground. And south of this, to the east of Cambridge, are low Chalk-hills, and to the west of Cambridge an undulating country of Cretaceous outliers and hills of Boulder-clay and Oxford Clay. All the higher land north-east of Cambridge is capped with Shanklin Sand (?).

2



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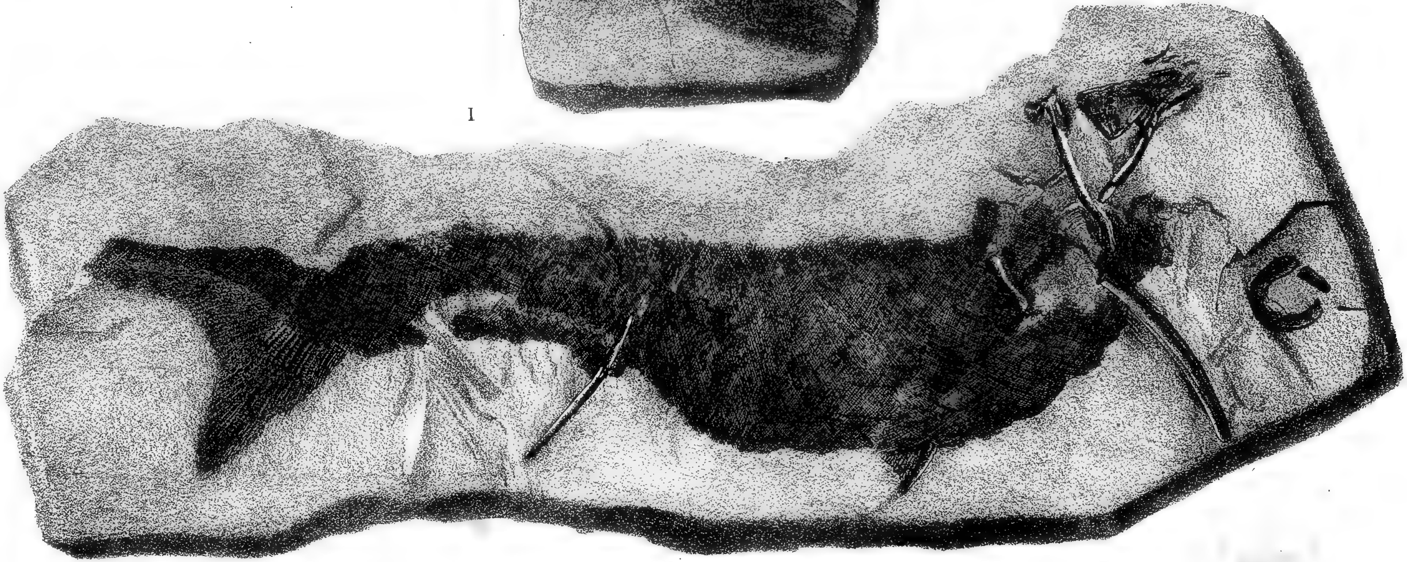


W. Dinkel, lith. M. & N. Hanhart, imp.

ACANTHODES WARDI. *Egerton.*

And the great level itself is the Fen-clay, in which are a few isolated reefs of Coral-rag, and some stone-bands in its Oxford-Clay member, which clay covers nearly the entire area.

There are in this region three kinds of drift—namely, a Boulder-clay covering the high land, a coarse gravel which caps the hills, and the fine gravel of the plains.

The Boulder-clay is widely spread to the west of Cambridge. It rarely, if ever, forms hills, though frequently capping them. Yet it is thick; for, near Caxton and Longstow, wells in it have been sunk 160 to 180 feet: and the clay seems sometimes to fill up valleys; for a well in the village of Caxton, half a mile north of the deep sinkings, found the drift reduced to a thickness of 14 feet.

From March to Longstowe it is generally a dark-blue deposit wholly unstratified, and more or less abundantly charged with fragments of Chalk and Septaria and Limestone-rock of the ? Kimmeridge Clay; while fragments may be found of almost any other rock, though not everywhere. They abound at Longstowe; but a little north, scarcely anything is found in it but chalk; while at March the clay is almost free from fragments, and largely used for brickmaking.

In this district, as elsewhere, it is rare to find gravel over the Boulder-clay, though at a lower level gravel abounds. Thus the high land of Elsworth, Papworth, and Abbotsley, is Boulder-clay; and the high land north of St. Ives, at Bluntisham &c., is Boulder-clay; yet all the valley between, as at Fenstanton, St. Ives, Hemingford Abbot, &c., is filled with a fine flint-gravel. Where the Boulder-clay ceases, at Elsworth, there the gravel begins, and thickens as it joins the valley of the Ouse.

At Bluntisham the Boulder-drift presents the usual feature—capping a hill. From it I obtained:—

Ammonites serpentinus.
—— bifrons.
—— Mariæ.
—— cordatus.
—— biplex.
—— Achilles.
—— Lamberti.
—— serratus.
—— fimbriatus.
—— oxynotus.
Pleurotomaria, sp.
Gryphæa incurva.
Gryphæa cymbium.
—— dilatata.
——, sp.
Ostrea deltoidea.
—— læviuscula.
Cardinia Listeri.
Belemnites tornatilis.
—— abbreviatus.
——, Liassic sp.
Belemnitella mucronata.
Terebratula subimpressa.

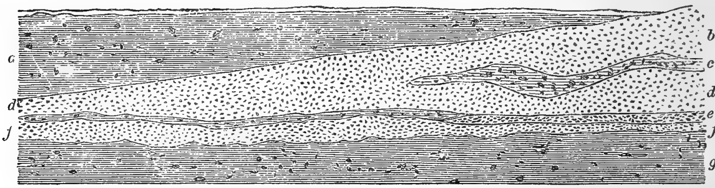
these species being characteristic of the Lias, Oxford Clay and Kimmeridge Clay, and Upper Chalk.

The Boulder-clay at Ely is brown, and remarkable for showing, in places, regular courses of curved lines making a rough stratification. But the chief importance of the section is in the fact that, while the country above is level, the Boulder-clay has been let down some 30 feet by a fault, thus evidencing considerable denudation since the Boulder-clay was deposited. It is also worth stating that many of the rocks of the north of England occur here*, and among them great boulders of Mountain-limestone, such as are met with at Elsworth and Wimpole. Boulder-clay also occurs on the south side of the city, and on the landward side of most of the hills in the Fens.

In the Museum of the Geological Society are a few shells from March, *Tellina solidula* and *Ostrea edulis*, which were presented in 1846 by H. M. Lee, Esq. They are marked "Raised beach."

The deposit at March was subsequently examined by Professor Liveing and the Rev. O. Fisher, who collected many fossils, and presented them to the Woodwardian Museum. These also were marked "Raised beach." But on visiting March in 1860, I found a section 150 yards long, displaying a gravel included in the Boulder-clay. The gravel was thin, a foot or so, though thicker east and

Fig. 1.—*Section at March, in Easter* 1860.




*a.* Boulder-clay, not very characteristic. *b.* Gravel.
*c.* Many shells, but few species.
*d.* Gravel. *d'.* Fine gravel.
*e.* Boulder-clay.
*f.* Gravel. *f'.* Sand.
*g.* Substriated Boulder-clay. Few boulders.

west, and overlain, as shown in the section, by clay containing characteristic specimens of Septaria striated by drifting, hard chalk, often deeply grooved as though by ice, and one bough of a tree some 3 inches in diameter, converted into imperfect lignite. The gravel, which was largely made up of small pieces of flint and of sand, contains an abundance of comminuted shells and many whole ones, *Tellina* and *Turritella* being commonest. The Boulder-clay, where seen underneath, has the usual characters. In the middle of the pit the gravel, which was deeply ferruginous, and consisted largely of small flint-fragments, came to the surface; and under this was a layer much more sandy, with some rounded pebbles and few flints, and half made up of shells. *Buccinum, Trophon, Litorina, Cardium, Tellina,* and *Ostrea* were most abundant; and the greater part were resting in natural positions. The deposit much resembled the Norwich Crag of Thorpe, or of the Thorpe near Aldborough.

* The monks appear to have observed the peculiar character of the Boulder-clay as early as the time of Henry the Sixth; for in Lonelich's translation of the Sank Ryal, a copy of which is in the library of Corpus Christi College, Cambridge, the description of a wound where the flesh had been burnt away to the bone, is illustrated by the lines,

"And the bon as whit it lay,
Lik as doth chalk in the clay."

Under the shell-bed was a very fine sand, which was cut-down-into 4 feet. It is grey-brown at the top, but darker lower down, becoming argillaceous, and at a greater depth changing to a blue-black clay clearly stratified, which is dug for bricks. Out of this clay were got Septarian concretions, and fragments of a large-grained Oolite and other rocks. The pits are very extensive about the March railway-station; and everywhere the gravel contains shells, though they differ from pit to pit.

Tracing this gravel south to Wimblingdon, near the railway-station, the deposit, quite at the surface, and only a foot or two thick, rests on one of those thin stonebands so common between the Oxford and Kimmeridge Clays. It is a fine sandy gravel with the usual shells; but the argillaceous-limestone rock was drilled with the burrows of *Pholades*, the shells still being in the holes.

To the south the gravels are somewhat continuously spread along by Chatteris, Somersham, Earith, St. Ives, Willingham, to Swaversey. And in the spring of 1861, walking up the railway between Over and Swaversey, I found the line had been made with gravel dug on the spot, which was full of shells similar to those of March, *Tellina solidula* and *Turritella communis* being very common, and *Cardium edule* not rare. The pits, which were just beyond Drayton Gate-house are, unfortunately, filled in. North of March the gravel is continuous nearly to Wisbeach.

*Marine Shells from March.*

| | |
|---|---|
| Rhynchonella psittacea. | Scalaria communis. |
| Corbula nucleus. | Trophon clathratus. |
| Astarte crebricostata. | —— scalaris. |
| Mactra elliptica. | Buccinum undatum. |
| Tellina proxima. | Bela turricula. |
| Mya truncata. | Turritella communis. |
| —— arenaria. | Litorina litorea. |
| Tellina solidula. | —— rudis. |
| Ostrea edulis. | Natica helicoides. |
| Cardium edule. | Natica, sp. |
| Purpura lapillus. | |

I will here notice a deposit at Hunstanton, as belonging to the same geographical district. There are many pits between Hunstanton and Brancaster where the gravel is thick and coarse; but south of the railway-station a hill has been cut into for ballast, exhibiting ash-coloured sands and gravels 30 feet thick without reaching the bottom. The cross stratification is very marked, and the beds differ much in different parts of the pit. In some of the bands pebbles were almost as well rounded as on a pebble-shore like Dunwich. Shells occur in several distinct bands of gravel, and at various heights, but are most numerous and best preserved in the coarse layers.

This deposit is remarkable for the absence of local fragments (the Red Rock occurs but rarely, and then only in small pieces which may have come from the north); for the included fragments comprise every kind of rock, numerous granites, syenites, traps, Cambrian, Carboniferous, Lias, Middle Oolites, Kimmeridge Clay, Shanklin Sands, Speeton Clay, chalk and flint, and lignite, and these in such proportion that it can hardly be called a flint-gravel. Besides these are numerous balls, rough and round, formed of pieces of clay which had rolled on a shore and so acquired a coating of pebbles.

At the top is an earthy gravel with *Ostrea edulis*, *Mytilus edulis*, *Cardium edule*, &c., very recent; for the *Mytilus* still preserved its epidermis.

The large shells were broken, and all showed marks of drifting, in breakage, wear, or separation of the valves. Among others were:—

| | |
|---|---|
| Buccinum undatum. | Mytilus edulis. |
| Nassa reticosa. | Mya truncata. |
| —— reticulata. | Scrobicularia piperata. |
| Fusus antiquus. | Ostrea edulis. |
| Tellina obliqua. | Cyprina islandica. |
| Cardium edule. | Corbula nucleus. |

Associated with these were a *Crioceras* from the Speeton Clay, *Millericrinus* probably from the Coral Rag, pieces of shelly Oolite, *Ammonites communis*, *A. annularis*, and *A. Bucklandii*, a Lias Belemnite, *Gryphæa incurva*, *Carbonicolæ*, and Palæozoic *Rhynchonellæ*.

Southward to Lynn there is on the west a flat of Kimmeridge Clay, and over this on the east is Carstone and sands, but so abrupt, and so beautifully worked into chines, that one continually turns round to look for the sea, now far away, which once wore and washed them. Gravels occur all along, similar to those ferruginous beds spread about Lynn, and which extend south by Wallington.

Near Peterborough, at Overton Waterville (or, as it is called by the country-people, Cherry Orton), is a pit which, although it has been noticed, and plates of its fossils given, by Dr. Porter in his "Geology of Peterborough," I must here say a few words about.

There is much gravel round Orton; but, as Dr. Porter has remarked, it is only at this pit that shells are found.

In the section, which was some 12 feet deep, there is (1) earthy gravel with the usual pipes, one of which is shaped like a flask. These pipes descend into a gravel (2) with little sand, in which the worn flint and Oolitic fragments rest flat, with vacant interspaces—a feature also noticeable in several neighbouring pits. It also, as do other local gravels, contains numerous dark shining pebbles from the Carstone, but they are less numerous than at Whittlesea. Below this is a shell-gravel (3) half made up of fluviomarine shells, from which my shells were taken. Then comes (4) a brown clay, full of little calcareous concretions, but with few, if any shells, though at its base I found one *Rissoa* and one *Cyclas*; but they may have belonged to the subordinate bed (5), which is a marly slate-coloured clay, mottled with iron, with freshwater shells scattered through it.

The drift-deposits already referred to are to the north of Cambridge. Those now to be noticed are in its more immediate neighbourhood.

East of Cambridge the fine flint-gravel reaches, by Granchester and Comberton, nearly as far as the Boulder-clay of Stow, being here deposited on the Gault.

North of Cambridge it extends in a continuous bed by Barnwell, Chesterton, Histon, Oakington, Long Stanton, Landbeach, Waterbeach, Denny Abbey, and in a less continuous belt nearly all the way to Ely. At Comberton, teeth of the Tichorhine Rhinoceros have been found; but it is only from a few pits that bones can be collected, though at Barnwell and Chesterton they are not rare. I have found shells in the gravel under the Observatory on the St. Neots Road, at Barnwell, Chesterton, and Oakington; but in every case they were land or freshwater forms, though from the gravel of Waterbeach the Woodwardian Museum has a vertebra of a whale, which, from its preservation, was evidently contemporaneous with the formation of the bed. It has lost its epiphyses, and is seemingly worn.

At and beyond Trumpington the gravel is remarkable for the great extent to which its upper 2 or 3 feet are contorted and folded, as though by lateral pressure. Except in some so-called brick-earths near Hadleigh in Suffolk, I never saw more marked instances of the kind on a small scale. But the gravel-flexures may only indicate the site of an ancient forest.

About Cambridge the chief pits are at Barnwell and Chesterton, where the gravel often shows a large amount of false bedding, which varies greatly from year to year.

This gravel consists chiefly of small flint-fragments, generally with sharp angles, often with the angles rubbed off; and rarely specimens may be found which are well rounded. It is no uncommon thing to find a flint well worn on one side, but with the others showing fractured surfaces, which fact clearly indicates that the flint was already a worn and drifted boulder before broken up to form gravel. Phosphatic nodules and shells of the Greensand are not rare; and many of the smaller fossils of the latter bed may be found in the Barnwell gravel in vast numbers. Upper Chalk fossils are common. Lias gryphites, greatly worn, are numerous; and the Oxford-clay gryphites in fragments are not rare. I have found some corals like those of the Coral Rag. The rock-specimens which have come from great distances are rarely large. The largest block which I have seen from Barnwell, measured about a foot and a half in each diameter, and was probably from the Shanklin Sands. Jasper conglomerate is found in angular blocks of a few inches diameter. Granites of various kinds, syenites, and traps of various characters, some of them amygdaloid, are among the common "igneous" rocks, occurring in partly rounded boulders from 3 to about 9 inches in diameter. There are fragments of Oolitic Limestone. But all these are comparatively rare, and might pass unnoticed, but that in sifting the gravel they are necessarily thrown out. At Chesterton they are much more abundant than at Barnwell, though the pits are but a mile apart and the gravel is continuous; but the level is a little lower.

Examined generally, the gravel is formed of layers which extend pretty continuously round the pit. The lowest layer exhibited is quite a coarse bed, with pebbles, mostly rounded. About two feet above this is a bed of yellowish-brown marl, almost clay, irregular in thickness, from a few inches to four feet. At times cuttings display one or two similar but thinner beds in the upper part of the section. The lines of bedding are partly marked by change of material, but for the most part by infiltration of the red oxide of iron.

The most important stratum is the marl-bed, first described by the Rev. P. B. Brodie; for in this are found fragments of plants, seed-vessels of *Chara*, and many shells, some freshwater, others land forms, nearly all now living in Britain, and only a few differing as varieties from the common English species. Here, too, are found the bones of various mammals, probably all, or nearly all, extinct; and in the same bed is evidence of man in his work. The gravel-diggers state that the bones are generally found in the marl-bed. Neither the friable shells, nor the larger bones, seem much, if at all, worn.

It had long been a matter of astonishment that the bed had never given any evidence of a carnivorous animal; but my friend, Mr. Dewick, of St. John's College, first supplied the evidence of their existence by finding a phalange; and Mr. Farren afterwards showed me a well-preserved jaw of the great Cave-tiger from Barnwell.

The bones from Barnwell are:—

*Bos.*—Right os calcis, distal end of left femur, right and left metatarsus, left astragalus, and glenoid end of scapula.

*Equus.*—Distal end of right tibia, hoof, 1st phalange, and 2nd phalange, distal end of left humerus, and teeth.

*Cervus* (*megaceros*, var.).—Distal end of left tibia, distal end of metacarpus, right astragalus, distal end of left humerus, cranium, palate, and left tibia, antler, &c.

*Cervus* (small).—Scapula and left os innominatum.

*Rhinoceros* (*tichorhinus*).—Last premolar right side lower jaw, penultimate molar right side upper and lower jaws, penultimate molar left side upper jaw, and last molar right side upper jaw; right astragalus, 6th and 7th cervical and anterior dorsal vertebræ, right tibia (very young), proximal end of left radius, right condyle of left femur, middle left metatarsal, distal end of left humerus, left tibia, and cranium.

*Elephas primigenius.*—Fourth metatarsal right leg, middle metacarpal right leg, femur, carpal, last true molar right side, set of molars, tusks large and small, and cervical vertebræ.

*Elephas antiquus.*—Molar lower jaw.

*Hippopotamus.*—Right os calcis, left os calcis, and incisor tooth.

The land and freshwater shells of Barnwell are given from a list prepared by Mr. Dewick from the specimens in his own collection, which is the best yet made:—

*List of Land and Freshwater Shells from Barnwell.*

Sphærium corneum, *Lin.*
Pisidium amnicum, *Müll.*
—— fontinale, *Drap.* The typical form occurs together with var. Henslowana.
Unio pictorum, *Lin.*
—— rhomboideus, *Schröt.* Many specimens still retain the ligament. One occurred of almost circular form (L. 1·5 inch; B. 1·9 inch).
Cyrena fluminalis.
Hydrobia marginata, *Mich.*
Bithynia tentaculata, *Lin.*
Valvata piscinalis, *Müll.*
—— cristata, *Müll.*
Planorbis nitidus, *Müll.*
—— glaber, *Jeff.*
—— spirorbis, *Müll.*
—— vortex, *Lin.*
—— complanatus, *Lin.*
—— contortus, *Lin.*
Limnæa peregra, *Müll.*
—— auricularia, *Lin.*
—— palustris, *Müll.*
—— truncatula, *Müll.*
Ancylus fluviatilis, *Müll.*
Succinea putris, *Lin.* Some of the forms approach *S. elegans*, Risso.
Zonites cellarius, *Müll.*
Zonites nitidulus, *Drap.*
—— nitidus, *Müll.*
—— fulvus, *Müll.*
Helix nemoralis, *Lin.*
—— arbustorum, *Lin.* Both the typical form and the var. alpestris, as well as intermediate varieties may be easily found.
—— hispida, *Lin.* Very common. I found one specimen with reversed spire.
—— ericetorum, *Müll.*
—— rotundata, *Müll.*
—— pygmæa, *Drap.* Common. One occurred with reversed spire.
Bulimus montanus, *Drap.*
Pupa marginata, *Drap.*
Vertigo antivertigo, *Drap.*
—— pygmæa, *Drap.*
—— Moulinsiana, *Dupuy.* (Mr. J. G. Jeffreys has kindly verified this determination, and says that it "corresponds in size with continental specimens.")
Clausilia rugosa, *Drap.*
—— biplicata, *Mont.*
Cochlicopa tridens, *Pulteney.*
—— lubrica, *Müll.*
Carychium minimum, *Müll.*

We here find, as in other contemporary deposits, *Cyrena fluminalis*, *Hydrobia marginata*, and *Unio rhomboideus*, which have now become extinct in England. *Vertigo Moulinsiana* has been once met with by Mr. Jeffreys in Ireland, but has not hitherto occurred in England.

The shells are mostly in a very good state of preservation. The Helices retain their bands of colours, and the bivalves are generally found with united valves.

March 15, 1866. Edw. S. Dewick.

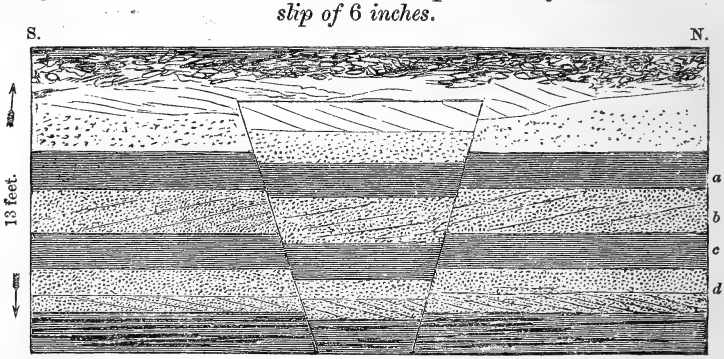
The evidence of the existence of man consists of a cut bone. The specimen is a second rib, like that of an elephant, and was obtained by the Rev. F. J. Blake, M.A., of Caius College, in the spring of 1862. The greater part of the bone is wanting, having been severed at about three inches from the articular end, which part only is preserved. This fossil shows on the severed end numerous cut surfaces, evidently made with some sharp instrument used by a powerful hand. The facets extend all round the end; and it is not impossible that they were made to facilitate the breaking of the bone, much as one would notch a broomstick before putting it across the knee. The specimen is beautifully preserved, and does not show a trace of attrition or gnawing, nor are there on it any other cuts. It is in the usual condition of Barnwell gravel-fossils, of a pale rusty-yellow colour, slightly glossy, and has lost most of its animal matter.

There is no doubt that the whittling is as old as the bone; for, besides the fact of the cut surfaces having the same features as those which are natural, and their very existence being unknown until the fossil came into my hands, there is the satisfactory circumstance of a few of them being covered with a stalagmitic deposit; moreover these facets are slightly concave, as if shrunk from the animal matter having been subsequently removed.

It occurred twelve feet deep, in the freshwater stratum of Barnwell, associated with remains of Elephant, Rhinoceros, and Hippopotamus.

There is another class of facts in connexion with this gravel worth remark; and that is, the "pipes" and what I shall name "walls." The pipes vary much in size and length; the particles of gravel generally dip towards them, though in one instance the edges of these beds on each side were directed *upward*—which I can account for by a gaping of the gravel, and material falling into the hole while it was closing, or by the forcible uprooting of a tree. The *walls* extend from the top to the bottom of the pits; they are more uniform in width than the pipes, and are usually hard, so that when the gravel is dug away they stand out like walls. At Chesterton, one about eight inches thick had the gravel dug away on each side for from twenty to thirty feet. Its sides were hard like mortar. The direction was north and south. One at Barnwell, originally only a foot wide, after a few feet had been cut away terminated in the fault shown in fig. 2.; and when a few feet more were cut down all trace of disturbance was lost.

Fig. 2.—*Section in the Barnwell Gravel-pit, showing a downward slip of* 6 *inches.*




*a.* Marl bed. *b.* Fine gravel. *c.* Marl bed. *d.* Fine gravel.
The width of the faulted piece at the upper marl band is 7 feet.

These seem to me to be the typical facts of the Cambridgeshire gravels; and it is only to be added that Prof. Hailstone and Mr. Warburton, in an early volume of the Geological Society's Transactions, described the coarse gravel capping the Gogmagog and Harston hills. From the Gogs, Prof. Sedgwick and I have collected examples of nearly every rock in the north of England, especially those of the Yorkshire coast (Kelloway rock, the sandstones, limestones, and shales) and the Red Rock of Hunstanton. Though Carboniferous and older Palæozoic rocks and fossils abound, and trap and plutonic rocks are not rare, they are rounded boulders, the flints are often unbroken, and there is a rough stratification. But the most important fact about the deposit is, that descending on the east side towards Fulbourn it becomes Boulder-clay *.

## Part II. Theoretical.

[Abstract.]

In this part of the paper the author endeavours, from internal and other evidence of the deposits, to indicate their origin and their relative age.

1. *Brown- or Boulder-Clay.*—He concludes that, prior to the depression of the country, when the Boulder-clay was formed, the Wash had no existence, and that the Cretaceous barrier between Waynfleet and Hunstanton was not broken through. He inclines to believe that this Boulder-clay was deposited by drifting ice, on the hill-tops &c., much where now found, during a period of change so slow that the fauna was able to migrate and follow it. There is no evidence in the deposit of glacier-action; but it contains rock-specimens such as are now found in Yorkshire strata. It appears to be the oldest drift-deposit of the district; and the author correlates it with the Brown Clay or Till of the Norfolk coast.

2. *Coarse Gravel.*—This is chiefly found capping or bordering the Boulder-clay; and the author infers, from its composition and relations, that it has resulted from the mud having been washed away from the Boulder-clay during the period when the country was rising from the sea. It is chiefly found on hills, and is of the age of the Contorted Drift of the Norfolk coast.

3. *Deposits newer than the Fine Gravel of the Plains.*—These are, first, a Peat, anterior in date to the formation of Whittlesea Meer. Under this is a Marine Clay with remains of Walrus, Seal, &c., *Ostrea, Cardium, Scrobicularia.* It is named by the workmen "buttery clay." Under this is an older Peat containing extinct mammals, such as *Bos frontosus, Bos primigenius, Cervus megaceros.* Among the other species are *Canis lupus, Castor europæus, Sus scrofa, Cervus elaphus, Cervus capreolus, Lutra vulgaris, Ursus arctos,* &c. Among the fossils have been found teeth of Rhinoceros and Hippopotamus, probably derived from the gravel. The fauna of these beds is very similar to that of the newest gravel. They correspond to the peat- and sand-beds which fill the valley of the Mundesley Section.

* In a supplement to a Lecture on the Fens and their Fossils, Professor Sedgwick (in 1862) gave a brief but clear account of these drift-deposits. I have used Professor Sedgwick's names as having the sanction of half a century of teaching, and have freely availed myself of the Professor's experience as given in his Lectures.

4. *Fine Gravels of the Plains.*—The author is of opinion that the physical geography demonstrates these beds to have been of marine origin; and the false bedding is such as estuarine currents would produce. Hence it is inferred that these gravels were formed from denudation of the Upper Chalk and local rocks, and of the coarse gravel and old Boulder-clay. The presence of the marl-bed, composed largely of Cretaceous foraminifera, shows by its fossils that since the period of coarse gravel the country had become capable of supporting many kinds of life. Reconstructed Boulder-clay and gravel must both result from the same cause. The March deposit is regarded as the oldest of the fen gravels, probably formed between the coarse gravel and the marl-bed of the gravel of the plains.

These beds are correlated with the Upper Boulder-clay and coarse gravel of the Norfolk Section.

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## 3. Additional Observations *on the* Geology *of the* Lake-country. By Professor R. Harkness, F.R.S., F.G.S., and Henry Nicholson, Esq. *With a* Note *on two* New Species *of* Trilobites, by J. W. Salter, Esq., F.G.S.

Recent investigations among the Skiddaw slates have made important additions to the fauna of this portion of the Lower Silurian series: the fossils which have been obtained have, for the most part, come from the Coldale valley, from strata which form the lowest rocks of the Lake-country*. There have now to be added to the fossils of this portion of the Skiddaw slates two Trilobites, namely a new form of *Phacops*, found at Whiteside, near Coldale, and *Æglina binodosa*†. To these have to be added perfect tails of *Caryocaris Wrightii*, the portion which had not been discovered when Mr. Salter's figure was published; and these bear out in every respect the restoration of this Crustacean by that palæontologist.

The lower beds of the Skiddaw slates have recently furnished other fossils, among which is a small *Lingula* nearly allied to *L. brevis*, Port., according to Mr. Davidson, and some small oval bodies arranged in a ribbon-shaped form. These latter appear to be ova, and they occur in the greatest quantities where *Caryocaris Wrightii* abounds.

The branching Bryozoon figured in the Memoir referred to in the note has also recently been met with in greater perfection among the "Screes" on the sides of Frozzengill. As figured in Mr. Salter's note, it is represented as small dichotomously branching stems. The portions which have recently been obtained show stronger stems than the original fossils, and these stronger stems have anastomosing thinner portions, giving the fossil an aspect very like the corneous axis of a *Gorgonia*.

* Quart. Journ. Geol. Soc. vol. xix. p. 116.

† The latter, we learn from Mr. J. P. Morris, of Ulverston, was obtained from Outerside, on the south of the Coldale valley, by Mr. Bolton.

The upper portion of the Skiddaw slates, which is more soft and shaly than the middle and lower parts of the group, has also recently furnished fossils which are new to this series in the north of England. The locality yielding these fossils is not in the Lake-country proper, but a spot in the north-east of Westmoreland. The twenty-first volume of the Quarterly Journal of the Geological Society, page 239, contains a section of the Lower Silurian rocks which occur immediately west of the Pennine escarpment, showing the Skiddaw slates rising from beneath the greenstones, porphyries, and ash-beds which form Burney Hill. The Skiddaw slates here form an axis, the north side of which is overlain by the greenstones, porphyries, and ash-beds of Grumpley Hill; and immediately north of the axis, and cutting through the Skiddaw slates, is Crowdundle Beck, into which a small stream flows, which exposes a fine section of their higher beds. The fossils which this section affords are principally Graptolites, among which is *Diplograpsus teretiusculus*, a form not hitherto recognized in the Skiddaw slates; and from this locality there has also been obtained *Agnostus Morei*, Salter.

These additions to the fauna of the Skiddaw slates—a series of deposits which was for a long time regarded as almost unfossiliferous—although not large, are important, as they furnish for the first time evidences of the existence of Trilobites and Brachiopoda in strata which represent the Lower Llandeilo rocks in the north of England.

The thick series of greenstones, porphyries, and ash-beds which in the Lake-country succeeds the Skiddaw slates, has hitherto yielded no fossils, although the slaty ash-beds have been carefully examined for them. These newer rocks are the result of very different conditions from those which gave rise to the Skiddaw slates, the latter being purely sedimentary rocks, while the former were produced, either directly (as in the case of the greenstones and porphyries) or indirectly (in the state of ash-beds), by igneous causes. Notwithstanding the difference in the origin of these two groups of Lower Silurian rocks of the Lake-country, there does not appear to be sufficient evidence to show that any unconformability exists between the Skiddaw slates and the succeeding green rocks.

The band of Lower Silurian rocks which in Cumberland and Westmoreland lies immediately west of the Pennine escarpment contains, among the greenstones, porphyries, and ash-beds, a highly fossiliferous zone, the strata forming which are dark flaggy rocks, reposing on ash-beds which overlie the porphyry of Dufton Pike; and this fossiliferous zone is succeeded by porphyry*. The igneous rocks of this district bear great resemblance to those of the Lake-country; but the fossiliferous zone has a more decidedly sedimentary aspect than any of the ash-beds which are associated with the greenstones and porphyries of the latter area.

Notwithstanding this difference in mineral nature, there is in the Lake-country a zone corresponding with the fossiliferous band of North-east Westmoreland; and it also affords fossils.

The porphyry which, among the Lower Silurian beds on the west

* Quart. Journ. Geol. Soc. vol. xxi. p. 242.

side of the Pennine escarpment, overlies the fossiliferous flaggy strata, is succeeded by a limestone which is the equivalent of the Bala Limestone of Wales, and of the Coniston Limestone of the Lake-country. The Coniston Limestone of the Lake-country is well seen in the valley of Long Sleddale, having been worked on both the east and the west sides of the valley. To the north-west of this limestone, and supporting it, is a porphyry agreeing in all respects with that immediately beneath the Coniston Limestone of Keisley, near Dufton, which separates the limestone from the fossiliferous zone. In Long Sleddale, north-west of this porphyry are ash-beds which have been worked for slates; but the quarries are now abandoned. The old slate-quarry is known as Style End Grassing Quarry, and forms a portion of the southern skirts of Harterfell. Among the débris of the quarry a few fossils may be obtained, which make their appearance in consequence of some of the slaty rocks weathering along the planes of bedding.

At Sunney Brow, a short distance west of Windermere Lake, the same fossiliferous rocks occur, and under nearly the same circumstances as at Style End Grassing. A mass of porphyry here also separates the ash-beds from the Coniston Limestone; and the ash-beds have been worked for slates at Pull Scar, on the side of a hill immediately north-west of Sunney Brow. The fossils are rare in the slaty rocks, but they are by no means uncommon in the green sandstones which interstratify the slaty beds of Pull Scar; and as the coarser rocks have been used for diking, the fossils can be obtained from the walls near the quarry, where they weather out rapidly.

The fossils of Style End Grassing and Pull Scar are nearly identical. They consist of *Stenopora fibrosa, Petraia subduplicata, Orthis vespertilio, O. flabellulum, Strophomena tenuistriata,* and crinoid stems. The fossils of Pull Scar are less distorted by cleavage than those of Style End Grassing, and in both localities the forms are those which are most abundant in the fossiliferous flags of Dufton. The coarser strata of Pull Scar resemble the fossiliferous ash-beds of Snowdon; the finer beds of Style End Grassing are nearly allied to the ash-beds of Grange Hill, which underlie the Bala Limestone of the Chair of Kildare, in both of which deposits fossils similar to those of the ash-beds of the north of England occur.

The fossiliferous flags of Dufton, and the fossiliferous ash-beds of the Lake-country, appertain to the Bala or Caradoc age. There is, in the north of England, beneath these a great thickness of igneous rocks, which separate them from the Skiddaw Slates, and which probably represent the Upper Llandeilo group.

Although the evidence of the occurrence of the Upper Llandeilo in the Lake-country is not satisfactory, the Bala or Caradoc formation is well marked, and is capable of being divided into three distinct groups. The lower is made up of igneous rocks and ash-beds, but has no well-defined base; the middle consists of a mass of highly fossiliferous limestone, with associated black shales, and has been described by Professor Sedgwick under the name of Coniston Limestone; and the upper portion is a series of dark-grey sedimentary rocks, which, as it yields valuable flags, has been designated by Professor Sedgwick the Coniston Flags. The higher portion of this upper series is made up of coarser rocks, termed Coniston Grits by Professor Sedgwick; and these form the top of the Lower Silurian series of the Lake-country.

The fossils of the lower portion of the Bala or Caradoc group have been already mentioned*. Those of the middle part of the series, and also some of those of the upper portion, have been alluded to by Professor Sedgwick†. Of the latter there occurs in an old flag-quarry in Long Sleddale *Graptolites Ludensis*; and in the quarry now wrought at Randy Pike, between Ambleside and Hawkshead, *Phacops obtusicaudatus*, Salter, *Orthoceras filosum*, *O. tenuistriatum*, and *O. subannulatum* are found.

The Coniston Flags, which are extensively worked at Broughton Moor and Kirkby Ireleth Moor, afford additional fossils. These consist of *Diplograpsus pristis* (which occurs in a high state of relief), *Orthis crispa*, and *Cardiola interrupta*.

In the Furness district, to which Broughton Moor and Kirkby Ireleth Moor belong, the three members of the Caradoc formation are well represented, and they are the only Silurian rocks which there occur. Their appearance in this district, to the exclusion of other Silurian rocks, results from two faults, having north-east and south-west directions, with downthrows towards the north-west. These faults were alluded to by Professor Sedgwick at the Aberdeen meeting of the British Association.

One of these faults crosses the country about two miles south of Broughton in Furness, near Rake End, where the coarser beds of the Upper Caradoc, the Coniston Grits, are seen. Immediately south of Rake End is a mossy flat; and to the south of this flat, at Bank End Hill, the Lower Caradoc appears in the form of porphyry. In the mossy interspace the fault occurs. Southward from the porphyry the Coniston Limestone is found, having been worked at Gill End Gill, a short distance south-east of the village of Soutergate; and south-east of the limestone the Coniston Flags again make their appearance. A more southern fault, parallel to the one just alluded to, occurs a little north of Dalton in Furness. This also brings up on its south-east side the Coniston Limestone, which is seen at High Haume.

Such are the two faults and their results; and had they been traced north-eastward, they would have been found to extend beyond the Furness district.

The Coniston Flags at Ross House, near Ulverston, afford *Cardiola interrupta*; and the same rocks a little nearer Ulverston, at Gameswell, yield *Actinocrinus pulcher* greatly distorted by cleavage. The fossils from these localities, and also those from Broughton Moor and Kirkby Ireleth Moor, have been collected by Mr. J. P. Morris, of Ulverston.

At Lowick, west of the Crake, which flows out of Coniston Lake,

* *Loc. cit. suprà*, p. 243.

† British Palæozoic Fossils, p. 356.

Mr. Morris obtained from concretionary-limestone strata *Orthis porcata*, M'Coy (*O. inflata*, Salter), one of the most abundant of the Coniston-Limestone fossils; and to the south of this concretionary limestone the Coniston Flags with *Cardiola interrupta* are again seen. Still further south, "at the south side of Tottlebank Fell, the Ireleth limestone again appears, in the form of calcareous concretions" (Sedgwick, Letters on the Geology of the Lake-district). This Ireleth limestone is the Coniston Limestone, and at Tottlebank Fell it is probably a continuation of the band seen at High Haume.

The repetition of the bands of Coniston Limestone shows that the faults referred to by Professor Sedgwick extend at least as far as the river Crake.

These limestone bands have not yet been detected north-east of this stream; but the mineral character of the rocks which occupy the country east of the Crake shows that they belong to the Coniston Flags and Coniston Grits. The same rocks occupy the country between Ulverston and Newby Bridge; and on the eastern side of Windermere Lake they form the Cartmel Fells. From these circumstances, there is strong reason for inferring that the two faults intersect the older Palæozoic rocks, from their south-west to their north-east boundary.

The rocks occupying nearly the whole of the Lake-country appertain to the Lower Silurian series. There are, however, in the south-east of this area rocks of a newer age, which are well exhibited near Kendal. About three miles north-east of Kendal, near Shaw End, is a quarry in the Upper Caradoc strata called Shepard's Quarry, which affords the same fossil as the rocks at Gameswell, namely *Actinocrinus pulcher*. The strata here dip to the south-east, which is the prevailing inclination of the Silurian strata of the north of England.

To the south of Shepard's Quarry is Benson Knot, the hill which has afforded many Upper Silurian fossils; and to the west of Shepard's Quarry is Potter Fell, where fossils similar to those of Benson Knot occur; and in both these localities the fossils are widely different from those of the Upper Caradoc group.

Two important members of the Silurian series are wanting in the Lake-country, namely the Llandovery rocks and the Wenlock group. In this district we have no smooth *Pentameri*; *Atrypa hemisphærica*, *Encrinurus punctatus*, and other Upper Llandovery fossils are absent; nor do the characteristic fossils of the Wenlock group occur.

In the neighbourhood of Kendal the olive-coloured Ludlow rocks, which abound in fossils, nowhere exhibit the strata on which they repose. These Ludlow rocks seem to be brought abruptly against the Upper Coniston group by faults; and to one of these is referable the close proximity of the Coniston Flags of Shepard's Quarry and the Ludlow rocks of Benson Knot. This fault is probably a continuation of the more southern of the two faults which are so well seen near Ulverston, and which have been traced north-eastward to the Crake. Besides this fault, there is one, which runs west of Shepard's Quarry, and which also places the Ludlow rocks in contact with the Upper Caradoc group; this latter, however, has a different course, and belongs to a different system of faults than those of Furness.

There are in the Lake-country two distinct systems of faults: but they are not confined to it; they occur in the north of England wherever the older Palæozoic rocks present themselves, and they belong to different periods. The system which has a north-east and south-west direction is older than the other; and an instance of the occurrence of this system out of the Lake-country is seen in the section from Melmerby to Roman Fell*. Here the fault brings in contact the Coniston Limestone and the Skiddaw Slates, the downthrow being towards the north-west.

Another and a parallel fault was recognized last summer among these old rocks of the north-east of Westmoreland, to the north-west of that just referred to. It is seen along the course of a stream which flows on the south side of Knock Pike, called Swindale Beck. A short distance east of where this stream crosses the Pennine fault, it flows over grey and purple shales; and among the former are fossils similar to those of the flaggy beds of Dufton, but not in such great abundance. Following the stream upwards, we have on its south-east side Skiddaw slates, characterized by the branching Bryozoon. Here, therefore, within two miles of the fault near Keisley, we have a second downthrow of the rocks to the north-west, which brings into contact the fossiliferous Lower Caradoc beds with the higher portion of the Lower Llandeilo.

These north-east and south-west faults are of an ancient date. They in no way affect the Upper Old Red Sandstone, which in some spots rests unconformably on the older Palæozoic rocks of the north of England; and the elevations and depressions which resulted from the faults were entirely planed away before the period of the deposition of the Old Red Sandstone.

The second system of faults, which has nearly a north and south course, is newer than the Carboniferous age, and was probably produced even after the Permian epoch. One of the faults of this system occurs among the rocks which in Cumberland and Westmoreland lie immediately west of the Pennine escarpment†.

The faults of this system are very abundant in the Lake-country. One of them traverses Windermere Lake and the country north of it; and, passing along the valley in which Thirlmere is situated, it continues onwards by Glenderattera, the valley separating Skiddaw from Saddle-back, to near Overwater, where it brings the green rocks of Binsey Crag, on the east, against the Skiddaw slates, which occupy the comparatively flat country on the west of this hill.

Another of these faults, passing along the valley of the Duddon northwards, intersects the rocks near Buttermere and Crummock-water; and on the west side of the stream connecting these lakes the Skiddaw slates can be seen in contact with the green rocks on this line of fault.

* Quart. Journ. Geol. Soc. vol. xxi. p. 239.
† *Ibid.* p. 246.

Along the lines of these newer faults the most important of the English lakes occur; and they give to the Lake-country its bolder features.

Some lakes, however, such as Hawswater and Wastwater, which have a north-east and south-west course, occupy valleys which appertain to the older system of faults. In the case of Ullswater we have a more complex outline than usually belongs to the lakes of the north of England. The first and lowest reach of the lake has a north-east and south-west direction. At the south-west end of this reach Hallan Crag presents a bold front, which results in part from a fault running north and south, and crossing Ullswater from the valley near Howtown. The middle reach of the lake commences on the west side of the north and south fault; it also has a nearly north-east and south-west direction, and terminates abruptly near the north-western spur of Place Fell: the middle reach seems also to occupy a valley produced by a fault belonging to the older system.

The upper reach runs nearly north and south. It occurs in a valley produced by one of the newer faults, which, crossing Kirkstone Pass, continues southward through Trout Beck; and it is to one or the other of these two systems of faults, or to their combined influence, that the beauty of the Lake-country chiefly owes its origin.

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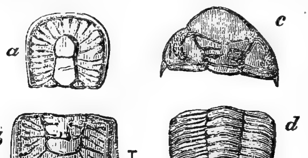
## *Note on Two* new Species *of* Trilobites.
By J. W. Salter, Esq., F.G.S.

1. Phacops Nicholsoni, spec. nov. Figs. *c* & *d*.

There is too little of this species to enable me to give a proper diagnosis. It is evidently a species of the subgenus *Acaste*, and not distantly allied to *P. Brongniartii*, a fossil from the Caradoc or Bala rocks of Tyrone. I have two specimens—one found by Professor Harkness, from which the figure is taken; another, smaller, is in the cabinet of Mr. H. Wyatt Edgell. Each shows something the other does not possess, and I shall describe them together, as the figure is a sketch made up from both specimens.




The whole form is broadly oval, much depressed, about half an inch wide, and about 1 inch long; the head is semicircular, rather pointed in front, three-tenths of an inch long, and more than half an inch wide.

The glabella is trapezoidal, the sides are nearly straight and widely diverging from the base, which is only half as wide as the forehead-lobe. This is transverse, diamond-shaped, bluntly pointed, and angular in front, and divided from the three lateral lobes by a slightly sigmoid furrow, not deep, as in *A. Brongniartii* (the kindred species quoted above), but neatly impressed and nearly reaching to the centre. The upper lateral lobes are triangular, the middle transverse and oval; the basal are linear, transverse, and nodose at the ends. The neck-furrow is strong, and the neck-segment not broader than the basal lobes.

The cheeks (imperfect) appear triangular, and are gently convex for a large space before reaching the very large curved eyes. These have the eye-lobe linear and distinctly marked out; and the lentiferous surface, broad and much arched, reaches from the termination of the upper pair of furrows very nearly to the neck-furrow, which is rather broad and well defined. We do not yet know the free cheeks: they were probably short and mucronate.

The body-segments (seven are preserved in Professor Harkness's specimen) have a rather broad depressed axis, the rays being obscurely nodular at the ends. The axial furrows are slight, and the pleuræ are flat as far as the remote fulcrum, which is placed halfway out. They are deeply, but not widely, grooved to the very end of the obtuse tips.

The pleuræ are bent down from the fulcrum, but not strongly, unless the specimens are both compressed vertically (I think not), and a little recurved.

Tail semicircular, convex only on the lateral lobes, which show five straight long furrows directed a little backward, and as many faint intervening ones. The axis is moderately broad, conical, and rounded at the tip, which reaches nearly to the end of the tail.

*Locality*.—Whiteside, three miles west of Braithwaite, Keswick.

2. Agnostus Morei, Salter. Figs. *a* & *b*.

Ref. Decades Geol. Surv. xi. p. 7. pl. 1. f. 13, 1864.

In the Decade I was only able to give a figure of the head of this most characteristic species, obtained by Mr. Lightbody and myself from the blacklead-bearing shales west of the Stiperstones, Shropshire.

It is an excellent proof that we are right in referring the Skiddaw slates to the verge of these old Shropshire beds; so that the term "Arenig or Skiddaw group" of Sedgwick is no longer a hypothetical association, but indicates a definite horizon.

The head (it is figured at *a* from the Decade just quoted) is subquadrate in outline; and the narrow bilobed and pointed glabella is surrounded by a broad limb, deeply indented by numerous depressed rays, interlined by shorter ones near the margin.

The tail, now figured (*b*), shows exactly the same ornament: numerous (10 or 11) deep long depressions radiating over the limb, not even, but nodose in their character, and interlined by smaller ones toward the margin. The outline is quadrate, the border narrow, except where it is produced into the short spines on the hinder edge; and these occur nearly as far back as the posterior margin. The axis is about half the length of the tail, broad, short, pyramidal above, soon cylindrical, and much flattened, marked across by two pairs of furrows, which do not reach quite across; and there is some indication of an obtuse central tubercle.

*Locality* (of fig. *b*).—Ellergill, near Milburn, Westmoreland. (In the cabinet of Professor Harkness.)

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### 4. *On the* Lower Silurian Rocks *of the* Isle *of* Man. By Professor R. Harkness, F.R.S., F.G.S., and Henry Nicholson, Esq.

The rocks which belong to the lower sedimentary series, and which occupy the largest portion of the surface of the Isle of Man, have been described by Dr. Berger*, and supplemental observations have been made to his memoir by Professor Henslow†.

The Rev. J. G. Cumming has also given a description of the old rocks of the Isle of Man, with especial reference to the Carboniferous Limestone of the island‡.

The older sedimentary rocks of the Isle of Man are also described in Glover's Guide to this island, which gives a condensed statement of the memoirs of Dr. Berger and Professor Henslow§.

The nature and arrangement of the old rocks of the Isle of Man are best seen in the coast-sections, which usually occur in the form of bold cliffs. The interior of the island also affords sections in some of the brook-courses; but the mountains composed of these rocks, which have usually a rounded outline, are covered to a considerable thickness with soil and peat, which hide the rocky masses.

On the south-east side of the island, in the neighbourhood of Douglas, good exposures of rocks are seen. Along the coast from Douglas to about a mile north-east thereof, the strata appear in the form of thin-bedded grey flags, having the mineral characters of the Skiddaw slate, and dipping south-east at an angle of 60°. These thin-bedded strata, on passing downwards, become thicker-bedded. The rocks here are used for building-purposes, and the finer strata, having a distinct cleavage, are to some extent used for slating.

The only trace of organic remains here is *Palæochorda major*, a fossil very abundant in the Skiddaw slates of Cumberland.

A short distance to the north-east, near the village of Onchan, the same thin-bedded Skiddaw slates are seen; but a little to the south-east of this village rocks of another character, consisting of green slates and porphyries, make their appearance. These green rocks form the headland called Bank's Point, and they are well seen at Crowdale on the east side of it. The green rocks and porphyries which occur here are the equivalents of the ash-beds and porphyries which succeed the Skiddaw slates of the Lake-country. They differ, however, somewhat in their mineral nature from the rocks of the latter country in being more quartzose and in having the ashy rocks better bedded. These green rocks of the Isle of Man have the same

* Geol. Trans. vol. ii. p. 29 *et seq.* † Geol. Trans. vol. v. p. 482 *et seq.*

‡ Quart. Journ. Geol. Soc. vol. ii. p. 317 *et seq.*

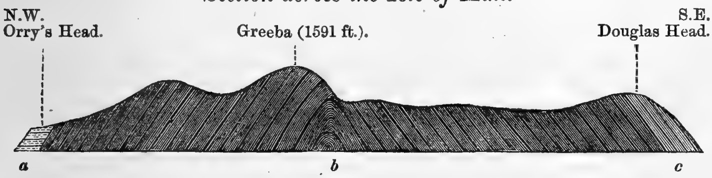
§ The portion on the natural history, including the geology, of the Isle of Man in Glover's Guide was drawn up by the late Edward Forbes.

dip and strike as the underlying Skiddaw slates; and they extend north-eastward to near Clay Head, where the thin-bedded Skiddaw slates again make their appearance.

The Skiddaw slates continue along the coast by Garwick to Laxey. They are much contorted, but have a prevailing south-east dip. North of Laxey, also, Skiddaw slates occur having south-east dips. They are well seen on the high-road to Ramsey, about two miles from Laxey, where a considerable cutting has been made through them; and below this cutting, on the coast, they were formerly worked for slating-purposes.

About half a mile beyond the cutting, and nearer Ramsey, granite is seen on the roadside at a spot called Dhoon; and north of this, about three miles from Laxey, on the road leading to Maughold Head, the Skiddaw slates again appear, also with south-east dips. A little north of this, and on the same road, at Regnabb, a granite similar to that of Dhoon occurs. Further north, at Cornah, a hard light-grey rock with no distinct bedding is seen, and at a short distance to the north-west, at Marebreck, hæmatite has been worked in the Skiddaw slates. About two miles north-east of Marebreck is a bay on the south side of Maughold Head, called Porth Moar; and in the north side of this bay the Skiddaw slates are well seen, dipping north-west at 33°. Here they consist of hard flaggy rocks, grey in colour. On the south side of this small bay the same hard flaggy Skiddaw slates occur with a south-east inclination. An anticlinal axis appears in the Skiddaw slates of Porth Moar; and inland for some distance, either along or near this axis, hæmatite has been wrought.

*Section across the Isle of Man.*




*a.* Old Red Sandstone. *b.* Skiddaw Slate. *c.* Green rocks (Ash-beds).

Maughold Head is composed of Skiddaw slates which dip north-west; and the same rocks and dip prevail along the road from Maughold Head to Ramsey, as far as Ballure.

At Ramsey, and in the country to the north, no rocks are seen, Boulder-clay being the only substance exposed in this flat country; but to the west of Ramsey, as far as Sulby, the mountains, which here rise abruptly from the Boulder-clay plain which forms the northern portion of the island, exhibit exposures of the Skiddaw-slate series.

On the south side of the road leading from Ramsey to Peel, about three miles from Ramsey, is a quarry where road-metal is now worked. The bulk of the rock here is grey hard quartz-rock, with occasional rounded pebbles of quartz imbedded therein. The quartz-rock here has a great affinity to the grey rocks of Cornah, which have no distinct stratification. Here, however, black shales occur in the quartz-rock, which dip at a high angle to the north-west.

The hills immediately south of Sulby, four miles and a half west of Ramsey, have a distinct slaty nature, and the slates have been worked for roofing-purposes. Here also the Skiddaw slates dip towards the north-west. Along Sulby Glen, a narrow valley which leads to the highest land in the island, good exposures of rocks occur; and here, too, the Skiddaw slates dip north-west. Over the col which separates the Sulby River from the river Nib, rocks of the same age occur; and among them the north-west inclinations obtain. These rocks, with the same dip, continue to the river Peel.

From Peel the Skiddaw slates form the coast to Port Erin, and have also north-west inclinations. At Glen May, about four miles south of Peel, these Skiddaw slates have a conglomerate in them; and south of Glen May they abound in quartz veins. At Port Erin the anticlinal axis which was seen as occurring at Porth Moar and extending inland again appears; and on the south-east side of this axis the strata assume the inclination shown among the Skiddaw slates to the south of Porth Moar, namely towards the south-east. The district around Castletown is principally occupied by Carboniferous Limestone, which has been described by the Rev. J. S. Cumming. About two miles east of Castletown, at Lang Ness, the Skiddaw slates are again seen, being overlain on their edge by Old Red Conglomerate. From Lang Ness north-eastward Carboniferous Limestone again occurs, and forms the coast from Derby Haven to a small stream about a mile and a half north-east, called the Santon River. The Skiddaw slates reappear on the east side of this stream, having south-east dips; and with these dips they continue along the coast to Greenwick, where they become coarser in their nature and have a well-developed conglomerate in them like that of Glen May. The Skiddaw slates continue onwards, forming the coast, somewhat contorted but with predominant south-east dips, until Douglas Head is reached. At Douglas Head a change takes place in the rocks, green ash-beds making their appearance and conformably overlying the Skiddaw slates. These ash-beds strike across Douglas Bay, and include within them the Coniston Rocks, upon which the Tower of Refuge is built; and this strike connects the green rocks of Douglas Head with those of Bank How. We consider the Lower Silurian rocks of the Isle of Man to belong to the Skiddaw slates, the lower portion of the green ash-beds and porphyries of the Lake-district and the Lower Silurian rocks of this island being on the exact line of strike of the Skiddaw slates of the Skiddaw country and of their overlying green rocks.

The foregoing section, taken through the centre of the Isle of Man, shows the position of the anticlinal axis which traverses the island in a north-east and south-west direction, as it occurs near the road leading from Douglas to Peel. The more mountainous portion of the island lies on the north-west side of this axis. The section also shows at its south-east end the ash-beds of Douglas

Head; and at its north-west extremity the Old Red Sandstone, in the neighbourhood of Peel, coming against the Skiddaw slates.

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May 23, 1866.

The following communications were read:—

## 1. *Notes on the* Geology *of* Sinai. By the Rev. F. W. Holland, M.A.

[Communicated by Sir R. I. Murchison, Bart., K.C.B., F.G.S.]

(Abstract.)

The peninsula of Sinai may be divided into three geological districts, named from the granitic, limestone, and sandstone rocks of which they are composed.

The whole of the northern portion of the peninsula is occupied by an extensive plateau of limestone, supported on the south by the range of Jebel-et-Tyh, and sloping gradually towards the Mediterranean Sea.

A broad belt of sand, called the Debbet-er-Ramleh, separates this limestone from the southern portion of the peninsula—although small patches of it, apparently underlying the sandstone, are found further south in Wady Badera and Wady Mokatteb, and in the neighbourhood of Jebel Hummam, and also on the north-west of Jebel Serbal, there occur large tracts of a limestone more cretaceous in its character, and abounding with bands of flints. At the latter spot I observed one mountain of Nummulitic limestone; and a limestone of more recent formation, which abounds with fossils, occurs near Tor and Ras Mohammed.

The granitic district forms, as it were, the backbone of the southern portion of the peninsula. Its mountains are frequently seamed from top to bottom with veins of porphyry, greenstone, and basalt, which give them a peculiar striped appearance; this is especially remarkable on the east of Wady Mokatteb, the north-west of Jebel Serbal, and in the wadies between Jebel Musa and Ain Hudera. They are also in some parts capped by a stratum of sandstone of considerable thickness and perfectly horizontal stratification, proving that an enormous denudation has taken place. Both the limestone and sandstone, when found in close proximity to the granitic rocks, exhibit no change in their structure; and thus, as well as by their uniform horizontal stratification, they show that they must have been deposited subsequently to the upheaval of the latter. The only traces of active volcanic agency which are now to be found in the peninsula are the boiling sulphur-springs and hot caves at Jebel Hummam, and the two warm mineral springs near Tor. The mountains of the granitic district appear to be chiefly composed of syenite; but granite, porphyry, gneiss, mica-schist, and quartzose and hornblendic rocks occur in many localities. I did not succeed in finding any traces of metallic ores in this district.

The sandstone formation appears to have formed the great mining-district of the ancient Egyptians in Sinai. The principal places where this formation occurs are Serabit-el-Kadim, Wady Mughâra and the south of Wady Mokatteb, the west of Serbal, and the neighbourhood of Ain Hudera. The sandstone is generally of a reddish ferruginous colour, though its surface is for the most part coated with a dark-brown oxide of iron. The principal Egyptian mines were apparently turquoise-mines, not copper-mines as has been generally supposed. Serabit-el-Kadim and Wady Mughâra were the chief stations. The turquoises appear to be distributed more or less in veins, though their occurrence is very uncertain; and Major Macdonald, who has been working the mines for several years, has often spent weeks with no success, and then suddenly found a large number together.

I do not believe that any traces of copper are to be found either at Wady Mughâra, or Serabit-el-Kadim, excepting at the latter place a thin film of silicate, too small, however, in extent for any practical purpose. The specimens which I have brought from the supposed slag-heaps on either side of the ruined temple on the summit of Serabit-el-Kadim prove most clearly that they are not slag-heaps at all, but merely a natural impure ore of iron and manganese. The siliceous brown iron-ore, however, which abounds near Wady Mokatteb and Wady Mughâra, seems to have been extensively worked both by the Egyptians and also, perhaps, by a less-civilized race after their time; and stone hammers, and flakes of worked flint are frequently found on the mountain-sides.

At a short distance from the mouth of Wady Shellal, on its southern side, Major Macdonald has discovered a large heap of undoubted copper-slag, which still retains a considerable quantity of copper in it. I also obtained a small specimen of a rock containing a very large proportion of carbonate of copper, and some pieces of malachite; but I could not discover the locality whence they had been procured. The sandstone abounds with salt and natron, and the water obtained from it is always more or less brackish. In some of the wadies considerable beds of curiously crystallized salt are found. From the limestone I collected several specimens of fossils, consisting chiefly of Echinodermata and *Exogyræ*; but in the sandstone I found but one organism, a portion of the stem of a fossil plant. A considerable elevation of the western coast of the peninsula has apparently taken place. A few miles to the north of Tor, large quantities of shells in a semifossil state, but similar to the existing species, are found at a height of 20 to 30 feet above the present level of the sea, and large blocks of coral occur at a still higher elevation; considerable raised beaches also occur at Ras Mohammed. Yet I do not suppose that any extensive elevation of the land at the head of the Gulf of Suez has taken place in modern days; nor does it appear from the formation of the ridge of Chalouf-et-Terraba, which separates the Bitter Lakes from the Red Sea, that the two were ever naturally connected, except indeed it were in prehistoric times.

Of the agencies which are still at work in modifying the surface of the country at the present day, frost and rain appear to play the most important part in the higher mountains of the granitic district; but the chemical action of the atmosphere seems to affect to a greater degree the sandstone, by destroying the ferruginous cement which binds together its particles, and thus decomposing it. Yet the changes that are taking place are apparently so gradual and slow, that I feel convinced that the peninsula of Sinai is to this day but little altered in its nature from what it was when the children of Israel wandered in its wilderness more than 3500 years ago.

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## 2. *On the oldest known* British Crab (Palæinachus longipes) *from the* Forest Marble, Malmesbury, Wilts. By Henry Woodward, Esq., F.G.S., F.Z.S. (of the British Museum).

[Plate XXIV. fig. 1.]

I am indebted to my friend Professor Thomas Bell, F.R.S., of the Wakes, Selborne, Hants, for the opportunity of describing this new and beautiful crustacean.

The specimen is from the Forest Marble of Malmesbury, and was discovered several years ago by the well-known collector of Oxford-Clay and Oolitic fossils, Mr. Wm. Buy. It will be seen to have nearly all its limbs *in situ*; and it shows the carapace with four segments of the abdomen united to it, resting upon a slab of Forest Marble covered with the remains of *Pentacrini, Acrosalenia hemicidaroides,* shells of *Avicula, Rhynchonella,* and traces of the drift-wood to which the Oolitic Pentacrinites (like the barnacles of our modern seas) were attached.

The limbs of this crustacean are extremely long and slender; and in this respect, and also in their form and in that of the carapace, with its remarkable prominent tubercles in front, it closely resembles the common "Spider Crabs" (the *Maiadæ* and *Leptopodidæ*) living on our own coasts at the present day, and the Great Japanese Crab, the *Inachus Kœmpferi*, of De Haan. The Upper White Jura of Germany has yielded carapaces of several minute crustacea, which are either Brachyurous or Anomurous; but as no limbs or abdominal segments have been met with, it is more doubtful where to place them in a classification of the fossil forms.

Professor Reuss* and H. von Meyer† have described three genera and twenty-five species of these forms (some of which have been reproduced in Mr. Lowry's 'Chart of Fossil Crustacea'‡); but none of them are comparable with the carapace of *Palæinachus.*

* Sitzungsb. K. Akad. d. Wiss. in Wien, xxxi., 1858.

† Palæontogr. Cassel, 1859–61, Bd. vii. p. 183, t. 23 (Monograph on the *Prosoponidæ*).

‡ *Palæinachus longipes* is there figured with the generic name *Protocarcinus* which had been given to it (in MS.) by Prof. Bell; but it is not adopted here, first, because the fossil has no affinity to *Carcinus*, and secondly, because the prefix "*Proto*" is objectionable in Palæontology.

In the swollen form of the branchial regions, and the well-marked nuchal furrow, it resembles the genus *Inachus*, with which it also agrees in the form and proportion of its limbs; but the bifid and diverging rostral tubercles more nearly agree with the *Maiadæ*, thus offering a connecting link for these divisions of Milne-Edwards's *Triangulares*. The Triangular Crabs are certainly one of the earliest families of Brachyura; and notwithstanding their dull habits, they make up by their exceeding fecundity* for want of strength and cunning, and have thus been enabled to maintain their ground even to the present day.

### Palæinachus longipes, H. W. Pl. XXIV. fig. 1.

Carapace suborbicular, broadest behind; branchial regions large and rounded, their surfaces covered with extremely minute rounded tubercles; the gastric region well defined by a somewhat deep furrow; the frontal and hepatic regions more than half the length of the entire carapace, tumid and ornamented with two subcentral tubercles and a semicircle of five other tubercles; margin irregularly swollen and depressed, and contracting towards the rostrum, which is represented by two prominent widely diverging and rounded horns, at the exterior bases of which, in the recent *Leptopodidæ*, the eyes are placed; these, however, cannot be detected in the fossil.

The abdomen is imperfect, but indicates a female; the lateral margins of the most perfect segment are somewhat angular, deeply grooved across, and also between the central portion and the epimera.

The arm, wrist, and hand have respectively five, three, and two tubercles on their upper angle; the hand is didactyle, and resembles the recent *Stenorhynchus* in form.

The walking legs are of about three times the length of the carapace, very slender, and have a row of minute tubercles upon their upper surface.

Breadth of carapace across the branchial region 8 lines, length from attachment of abdomen to base of rostral spines 9 lines; rostral spines $2\frac{1}{2}$ lines in length; arm about 5 lines; wrist $2\frac{1}{2}$ lines; hand $5\frac{1}{2}$ lines; longest limb 28 lines.

### EXPLANATION OF PLATE XXIV. fig. 1.

Fig. 1. *Palæinachus longipes*, H. Woodw. Forest Marble, Malmesbury, Wilts. Natural size.

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## 3. *Notes on the* Species *of the* Genus Eryon, *Desm., from the* Lias *and* Oolite *of* England *and* Bavaria. By Henry Woodward, Esq., F.G.S., F.Z.S. (of the British Museum).

[Plates XXIV. figs. 2–4, & XXV. figs. 1–3.]

The genus *Eryon* was established by Desmarest (in Brongniart and Desmarest's 'Natural History of Fossil Crustacea:' Paris, 1822)

* The female *Maia squinado* bears at one time upwards of *seventy-six thousand eggs* (Couch).

for certain forms of *Astacidæ*, with extremely broad and flat carapaces, found in the Lithographic stone of Solenhofen, one of the earliest known geological localities on the continent, and perhaps the most prolific in its yield of organic remains.

Only one species was then determined—the *Eryon Cuvieri* of Desmarest (*Macrourites arctiformis* of Schlotheim (1820), *Locusta marina* of Bajer (1757), and first figured by Knorr and Walch in 1755). Since that time Herr Germar, Count Münster, H. von Meyer, Professors M'Coy and Quenstedt have each contributed new species. Lastly, the late Dr. Albert Oppel, of the Royal Bavarian Museum, Munich, a Foreign Correspondent of this Society (whose early death we must all lament*), has collected, revised, and added to our knowledge of this genus, so that in 1862 (the date of his book) the list of recorded species amounted to fourteen†.

Professor M'Coy was the first to record an English species of this genus, the *Eryon Barrovensis*, from the Lias of Barrow-on-Soar, Leicestershire. [See the 'Annals and Magazine of Natural History,' 1849, p. 172.] But as his description varies in some points and is unaccompanied by a figure, I have ventured to delineate it by the help of the fine examples in the cabinet of the Rev. P. B. Brodie, F.G.S., and those in the British Museum. I also subjoin a revised description of it, and notices of other British species of this genus from the Lias and Oolite, collected and lent by Charles Moore, Esq., F.G.S., of Bath, Captain Hussey, of Lyme Regis, and from specimens in the British Museum obtained by E. C. H. Day, Esq., F.G.S., formerly of Charmouth.

### Eryon, Desmar. 1822.

*Coleïa*, Broderip, 1835, Trans. Geol. Soc. 2nd ser. vol. v. t. 12. f. 1 & 2.

1. Eryon antiquus, Brodp., sp.

Although unwilling to abolish a genus named in honour of so great a geologist as the Earl of Enniskillen, I am compelled to endorse the decision of my late friend Dr. Albert Oppel, and make this the first and largest English species of the genus *Eryon* (*Eryon antiquus*, Brodp. sp.)‡.

From the Lias, Lyme Regis.

2. Eryon Barrovensis, M'Coy, 1849. Pl. XXV. fig. 1.

The carapace of this species (like that of its congeners) is extremely flat, about one-eighth broader than long, the posterior margin is truncated, the lateral margins are fringed with minute spines; two indentations intersect the border on either side (the first being somewhat behind, and the second upon the line of the cervical furrow), and enclose between them a short rotundato-quadrate lobe.

* Dr. Oppel died on 22nd December, 1865, at the early age of thirty-four years.

† *Vide* Paläontologische Mittheilungen aus dem Museum des Kön. Bayer. Staates, von Dr. Albert Oppel: Stuttgardt, 1864.

‡ See Oppel's Pal. Mittheil. p. 11.

The sides of the carapace curve rapidly inwards in front, leaving the anterior margin only half the width of the posterior portion.

The carapace is broadly notched in front with two lateral orbital fossæ formed by the lateral angles of the carapace.

A tuberculated ridge passes up the centre of the carapace, from the posterior margin to the cervical furrow, by which it is intersected; it reappears for a short space in front.

Two lateral equidistant tuberculated ridges mark out the branchial regions, and are also continued smoothly upon the frontal portion of the carapace.

Each antenna of the inner pair has two many-jointed setæ, the outer one being slightly the longer. Each of the outer antennæ has a large oval scale attached to its broad basal joint; the setæ are single, and scarcely thicker than those of the inner pair.

The eyes, but rarely preserved, are placed near the base of the scale of the outer antennæ. In a specimen from Lyme Regis (from Mr. Day's collection, and now in the British Museum) the external pair of footjaws (or sixth pair of maxillary appendages), with their broad oblong basal joints and their more slender four-jointed palpi, are well preserved.

The first pair of legs are robust and short, as compared with *Eryon antiquus*, the hand and carpus nearly equalling the length of the middle of the carapace; fingers slender, pointed, of equal length, incurved at the tip, the moveable one most incurved.

The succeeding pairs of feet are much smaller, and are each terminated with pincers, except the fifth pair, which are monodactylous at their extremities. The abdomen is slightly longer than the carapace, and one-third less in width; the first segment is narrow, and has two tubercles on its lateral margins; the second, third, and fourth have each two lateral and a median tubercle; the sixth segment has a median and two lateral ridges; these are continued on the seventh segment or "telson," which is acutely triangular in form; the caudal plates are very broad, and roundly quadrate in form; the outer pair of plates are divided by a curved suture near their extremities as in other *Astacidæ**.

The epimera of the first five segments are rounded; that of the sixth is falcate, and to its lateral and posterior margins the caudal lamellæ are articulated.

*Dimensions* (from a specimen in the British Museum).—Length $4\frac{3}{4}$ inches; extreme breadth of carapace 2 inches 4 lines; length of carapace 2 inches 2 lines; breadth of frontal portion of carapace 1 inch; length of abdomen 2 inches 8 lines, breadth of same $1\frac{1}{2}$ inch; breadth of caudal plates 2 inches 4 lines; extreme length of chelæ 2 inches 10 lines (length of second pair of limbs 2 inches 4 lines, Mr. Brodie's specimen); breadth of first pair of limbs 3 lines, second pair 2 lines.

*Localities.*—Lias, Barrow-on-Soar.

The affinities of this species are more with *Eryon antiquus*, save

* This suture is absent in the outer caudal lamellæ of the Solenhofen species —a most important distinction: they differ widely also in form.

for the extreme length of the forearms of the latter and the more oval form of its carapace.

3. Eryon crassichelis, spec. nov. Pl. XXV. fig. 2.

I have had the opportunity of examining two specimens representing this species,—one a detached and folded carapace, exhibiting the upper surface; the other an almost entire example exhibiting the under surface—a position in which at least nine-tenths of the specimens occur, not only in our own Lias, but in the Lithographic Stone of Solenhofen.

The separate carapace (obtained by Mr. E. C. H. Day, F.G.S., and now in the British Museum) is one-third broader than long, and is altogether more rounded in form than *E. Barrovensis* or *E. antiquus*.

The branchial margin has along its border a row of strong spines, which gradually decrease in size towards the frontal portion of the carapace, where they entirely disappear.

The indentations along the lateral margins of the carapace are less deep, and the lobes formed thereby have not the pointed character seen in *E. Barrovensis* and other species. The orbital fossæ are rounder, and have one spine on their exterior border; the rostral notch is but slightly indented.

Between the orbital fossæ and the nuchal furrow there is seen upon the margin of Mr. Day's specimen a prominent round body, which, from its form, is most probably the eye somewhat displaced; but in *E. arctiformis* they are placed *outside* the outer antennæ.

The surface of the carapace is uniformly and finely punctated, and has the three ridges seen in *Eryon Barrovensis*; but they are *not* tuberculated, save at the posterior margin, where one tubercle is placed at the base of each of the lateral ridges.

A striking distinction marks this species, in the shortness and thickness of the hands (as seen in an almost entire example from the collection of Captain Hussey of Lyme Regis). The fixed and moveable digits are less equal, broader, and more curved than in the other English species.

The four following pairs of limbs are only imperfectly preserved; nor does the underside of the abdomen yield much detail.

The seventh segment (or telson) is perhaps more pointed, and the caudal plates less round, than in *E. Barrovensis*.

The only species with which I am acquainted that is furnished with hands like *E. crassichelis* is the *E. Escheri**, Oppel (also from the Lower Lias); but the specimen is one-half the size and too imperfect for comparison, save in the chelæ. The specimen figured by Oppel is from Mülligen, near Baden.

*Dimensions.*—Carapace (detached): length 2 inches 1 line; breadth 3 inches (measured across the branchial region); breadth of frontal portion of carapace 16 lines.

Nearly entire specimen (Captain Hussey's collection):—Greatest length of animal 3 inches 6 lines; greatest breadth of carapace 1

* See Oppel, *op. cit.* t. 1. fig. 1, p. 10.

inch 10 lines; greatest breadth of abdomen 1 inch 1 line; length of carapace 1 inch 7 lines; length of abdomen 1 inch 10 lines; length of telson 7 lines; length of forearm and hand 15 lines; breadth of hand 4 lines.

4. ERYON WILMCOTENSIS, spec. nov. Pl. XXIV. fig. 3.

A slab from the collection of Charles Moore, Esq., F.G.S., of Bath, contains no fewer than fifteen individuals of a small species* of *Eryon*, which I have been extremely unwilling to treat as distinct from *E. Barrovensis*, on account of the circumstance that the entire group are preserved with their ventral surfaces exposed, and in none can the contour of the carapace be traced.

Among the specimens from the collection of R. F. Tomes, Esq., F.Z.S., is a small carapace without any appendages, which, however, agrees very well in size with the above-mentioned examples, and may, perhaps, be identical with them.

The former is from the railway-cutting at Pyle Hill, near Bristol, from the "insect-bed" or "*Modiola-minima*" bed of the geological surveyors, one of the basement beds of the Lower Lias.

The latter is from Wilmcote, near Stratford-on-Avon, from the "bottom block"-bed of the Lower Lias.

This carapace (see figure) is somewhat shorter and broader in its proportions than *E. Barrovensis* (measuring 14½ lines in breadth, 12 lines in length); the branchial region is more rounded; and the dentations around the margin of the carapace are much wider in proportion to its size; whilst the relative distance across the frontal portion is twice that of *E. Barrovensis*. The surface of the carapace is evenly covered with minute granulations; and there are no large tubercles along the median line, such as occur in the former species.

Whether the Pyle-Hill specimens be identical with the Wilmcote example remains to be proven; in the meantime I have ventured to name the carapace *Wilmcotensis*, as I think it important to draw the attention of Liassic palæontologists to this subject, in the hope that more complete specimens may be sought for.

5. ERYON BRODIEI, spec. nov.† Pl. XXIV. fig. 2.

This unique form is from the Lower Lias rock, Lyme Regis, and is at once distinguishable from the other species of this genus by its more strongly ridged carapace and the straightness of the margin along its branchial regions; the greatest width of the carapace is not in the centre of the branchial portion, but at its extreme front, from which point the breadth decreases to one-third at the posterior margin, which, however, is mutilated. The hepatic region is less dilated laterally, but wider in front than in *E. Barrovensis*; and the orbital fossæ and rostral indentation are less deep. In this specimen one eye is preserved *in situ*. A second furrow (but faintly seen in the centre of other species of *Eryon*) crosses the entire breadth of the

* Measuring 2 inches in their greatest length, and about ¾ inch in width.

† British Museum Collection.

carapace behind the nuchal furrow, entering the margin at the latero-posterior indentation.

A rounded protuberance occupies the centre of the carapace in front of the nuchal furrow, and a small tubercle behind it. There are two lateral furrows upon the branchial region on either side of the mesial ridge. The surface of the carapace is sparingly granulated.

*Dimensions.*— Length of carapace 2 inches (when perfect); greatest breadth 1 inch 10 lines; width in front 11 lines; width at nuchal furrow 1 inch 4 lines.

I have named this example after the president of the Warwickshire Naturalists' Field-club, the Rev. P. B. Brodie, M.A., F.G.S., who has obligingly placed his collection at my service.

6. ERYON MOOREI, spec. nov. Pl. XXV. fig. 3.

Those who have visited the Bath Museum (especially during the British Association Meeting in Bath) will remember the fine suite of fossils from the Upper Lias fish-bed obtained by Mr. Charles Moore, F.G.S., of Bath, who has devoted years of labour to the investigation of this and other Jurassic beds.

Among a number of specimens (including six or seven different species) is the present very perfect little *Eryon*, which I have named after its discoverer.

The original is 14 lines in length, and 6 lines in its greatest width.

The carapace is smooth and nearly oval, but truncated at its extremities, being 4 lines wide at its posterior border, and $2\frac{1}{2}$ lines at its anterior.

A double furrow, uniting in the centre of the carapace, crosses the entire breadth, diverging at the lateral border, and forming, by two slight indentations, a square central lobe on either side, 1 line in breadth.

A small projecting tooth marks the shallow orbital depression on either side, while two prominent rostral spines enclose the antennæ.

The forearm (which is the only limb preserved) is, in its entire length, equal to the length of the carapace, of which the slender didactyle extremities form one fourth part.

The median ridge of the carapace only extends as far as the nuchal furrow.

The frontal central portion is tumid, and is slightly granular anteriorly.

The abdominal segments are 4 lines in width, and are strongly grooved transversely, and have their lateral margins granulated.

The telson is acutely angular; the side lobes are more narrow and pointed than in the other English species, more closely resembling in this respect *E. arctiformis* from Solenhofen.

*Eryon Moorei* is represented in the Solenhofen Stone by *E. Schuberti* of Meyer, from which it differs, however, in the lateral emarginations and transverse furrows on the carapace, *E. Schuberti* being apparently destitute of a nuchal furrow; it differs also in the form of the anterior border of its carapace.

Upper White Lias. Ilminster. Museum of Charles Moore, Esq., F.G.S.

7. Eryon Oppeli, spec. nov. Pl. XXIV. fig. 4.

I beg leave to call attention to a curious specimen of *Eryon* (part of the Häberlein collection, now lodged in the British Museum) from the Lithographic Stone of Solenhofen.

It is preserved upon the plane surface of a slab, and shows the five pairs of limbs, the large and broad maxillipedes with their palpi attached, one of the inner antennæ with its two setæ, and, lastly, the fourth, fifth, sixth, and seventh abdominal segments with their caudal plates attached.

Out of the large number of specimens of *Eryon* which I have been able to examine from Solenhofen, and among the numerous examples figured, I cannot find a single instance in which, as in this individual, the first pair of chelæ are so small as compared with the four succeeding pairs of legs, or in which the caudal plates, including the central plate (the telson) are so remarkably round and broad.

In illustration of the complete manner in which the Solenhofen Crustacea have been treated, I believe this to be the only indeterminable example out of a collection containing upwards of 400 specimens of this class.

I propose to name it *Eryon Oppeli*, after the author of the 'Paläontologischen Mittheilungen,' whose works will long remain his best monument.

Length of forearm 1 inch 4 lines, breadth 2 lines; length of chelæ 2 lines, second pair 18 lines long, breadth $1\frac{1}{2}$ line; length of third pair 14 lines, breadth $1\frac{1}{2}$ line; length of fourth pair 13 lines, breadth $1\frac{1}{2}$ line; all these are chelate, but the fifth pair are monodactylous; length of fifth pair $7\frac{1}{2}$ lines, breadth 1 line.

Maxillæ $5\frac{1}{2}$ lines in length by 3 lines in breadth, semiorbicular in form exteriorly, interior margins straight and finely serrated; palpus 3 lines in length; antennæ $3\frac{1}{2}$ lines in length; abdomen $8\frac{1}{2}$ lines in breadth; telson 7 lines long by $6\frac{1}{2}$ broad—with the overlapping caudal plates, making 11 lines in breadth.

Eryon, sp. ?

I wish to record the fact that Mr. Moore has also obtained from this same Upper Lias rock a fine *Eryon*, which measured at least 6 inches in length, its abdomen 2 inches in breadth, and the carapace probably $2\frac{1}{2}$ inches; much of the latter, however, has been destroyed; and therefore I do not feel warranted in giving it a specific name, as it may perhaps prove to be *Eryon antiquus* when we know more about it.

Eryon, sp ?

Lower Chalk, Steyning. (*Vide* Morris's Catalogue, p. 108.)

This is probably a portion of a *Squilla*, several fragments of which have been found. Two are in the British Museum (from Mrs. Smith's collection), from the hard chalk of Dover; another is in the collection of James Carter, Esq., of Cambridge, and is figured in Mr. Lowry's 'Chart of Fossil Crustacea.' I know of no Cretaceous species of *Eryon*.

| | Lias. | | | Dogger. | | | Malm | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lower. | Middle. | Upper. | Lower. | Middle. | Upper. | Kelloway. | Oxford Clay. | Lithogr. Stone. |
| Eryon, *Desmar.* | | | | | | | | | |
| 1. propinquus, *Schlot.* | .. | .. | .. | .. | .. | .. | .. | .. | * |
| 2. spinimanus, *Germ.* | .. | .. | .. | .. | .. | .. | .. | .. | * |
| 3. orbiculatus, *Münst.* | .. | .. | .. | .. | .. | .. | .. | .. | * |
| 4. elongatus, *Münst.* | .. | .. | .. | .. | .. | .. | .. | .. | * |
| 5. arctiformis, *Schlot.* | .. | .. | .. | .. | .. | .. | .. | .. | * |
| 6. bilobatus, *Münst.* | .. | .. | .. | .. | .. | .. | .. | .. | * |
| 7. longipes, *Fraas* | .. | .. | .. | .. | .. | .. | .. | .. | * |
| 8. Schuberti, *Meijer* | .. | .. | .. | .. | .. | .. | .. | .. | * |
| 9. Redenbacheri, *Münst.* | .. | .. | .. | .. | .. | .. | .. | .. | * |
| 10. Perroni, *Etall.* | .. | .. | .. | .. | .. | .. | .. | * | |
| 11. Hartmanni, *Meyer* | .. | .. | * | | | | | | |
| 12. Edwardsii, *Morière* | .. | .. | * | | | | | | |
| 13. Escheri, *Oppel* | * | | | | | | | | |
| 14. antiquus, *Brod.* | * | | | | | | | | |
| 15. Barrovensis, *M'Coy* | * | | | | | | | | |
| 16. Moorei, *H. Woodw.* | .. | .. | * | | | | | | |
| 17. Wilmcotensis, *H. Woodw.* | * | | | | | | | | |
| 18. Brodiei, *H. Woodw.* | * | | | | | | | | |
| 19. crassichelis, *H. Woodw.* | * | | | | | | | | |
| 20. Oppeli, *H. Woodw.* | .. | .. | .. | .. | .. | .. | .. | .. | * |
| | 6 | .. | 3 | .. | .. | .. | .. | 1 | 10 |

Note.—The species, in the above Table, numbered 1 to 9 are from the Solenhofen Limestone, and described and figured by Dr. Oppel (*op. cit.*), also:—

*E. Escheri* from the Lower Lias, Baden.

*E.* (*Coleia*) *antiquus*, Lower Lias, Lyme: by Mr. Broderip, Trans. Geol. Soc. 2nd series, vol. v. t. 12. f. 1 & 2.

*E. Barrovensis*, Lower Lias, Barrow-on-Soar: by Prof. M'Coy, Ann. Nat. Hist. 1849, p. 172.

*E. Hartmanni*, from the Upper Lias, Würtemberg: by H. von Meyer, Nova Act. Acad. C. xviii. Bd. p. 263.

*E. Perroni*, from the Oxfordian, Calmoutiers, Haute-Saône, France: by M. Etallon, Crust. Foss. de la H.-Saône, Bullet. Soc. Géol. de France, t. xvi. p. 169, tab. 4. f. 1–3.

*E. Edwardsii*, from the Upper Lias, Calvados: by M. Morière, 1864, Bull. de la Soc. Linn. de Normandie, t. viii. p. 89, pl. vi.

For directing my attention to this last species, I am much indebted to Mr. Ralph Tate, F.G.S., the obliging Subcurator of the Geological Society's Museum.

The remaining five species enumerated are figured and described in this paper.

Although the genus *Eryon* occurs fossil at Solenhofen with a *Limulus* so like our own recent species that, I think, no one will doubt their consanguinity, yet the former has died out, and the latter remains to this day.

The *Scyllaridæ*, which take their place at the present day, have only a mimetic resemblance to them, the simulation being assisted in a great degree by the broad scale-like form of the outer pair of antennæ, which are flattened out and lie in a plane with the carapace. They, however, offer some points for comparison, and occur most commonly in the China Seas and on the coast of Japan, associated with recent *Limuli* and forms of *Palinurus*, &c., which are found together in a fossil condition in Bavaria.

Where a series of similar forms occur together, fossil and recent, it is fair to infer a similarity of conditions favourable to such a group.

The wide tracks of fine argillaceous mud which characterize the enormous rivers of China, the coast, and its adjacent islands, agree well with the lithological texture of the Solenhofen beds in which the fossil crustacea lie imbedded; and the terrestrial conditions evidenced by the remains of Sauria, the *Archæopteryx*, and Pterodactyles, with countless *Libellulæ*, spiders, and *Cycadeæ* of large size, point to a continent close at hand, the rivers of which brought down the periodic mud-avalanches which entombed the cuttlefishes and crustacea in such quantities both at Pappenheim and Solenhofen.

By referring to the preceding Table, it will be seen that only three continental species of *Eryon* (*E. Escheri*, *Edwardsi*, and *Hartmanni*) occur in the Lias, the remainder being from the Lithographic Stone (Upper Oolite).

We ought then, I think, either to find many more species in our Oolite, or to regard the lithographic species as the representatives of our Liassic forms in Bavaria.

A comparison of further genera and species from the Lias will show that we have representatives of nearly every form from Solenhofen in our Lias beds.

## EXPLANATION OF THE PLATES

(*Illustrative of the genus* Eryon).

### Plate XXIV. figs. 2–4.

Fig. 2. Carapace of *Eryon Brodiei*, H. Woodw. Lower Lias, Lyme Regis. Two-thirds the natural size. Collection of the British Museum.

3. *Eryon Wilmcotensis*, H. Woodw. Lower Lias, Wilmcote. Natural size. Collection of R. F. Tomes, Esq., F.Z.S.

4. *Eryon Oppeli*, H. Woodw. Lithographic stone, Solenhofen. Natural size; from the original in the British Museum.

### Plate XXV. figs. 1–3.

Fig. 1. *Eryon Barrovensis*, M'Coy. Lower Lias, Barrow on Soar, Leicestershire. One-half the natural size; restored from specimens in the collection of the Rev. P. B. Brodie, M.A., F.G.S., and in the British Museum.

2. *Eryon crassichelis*. H. Woodw. Lower Lias, Lyme Regis. One-third the natural size. Collection of Captain Hussey, Lyme.

3. *Eryon Moorei*, H. Woodw. Upper White Lias, Ilminster. Twice the natural size. Collection of Charles Moore, Esq., F.G.S., Bath.

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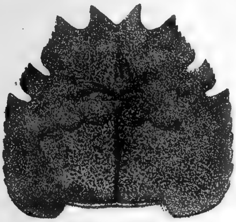

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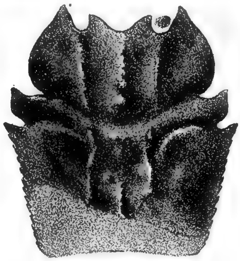

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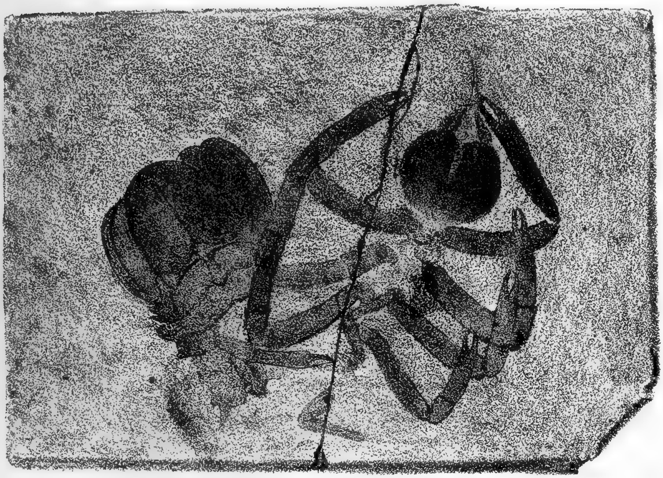
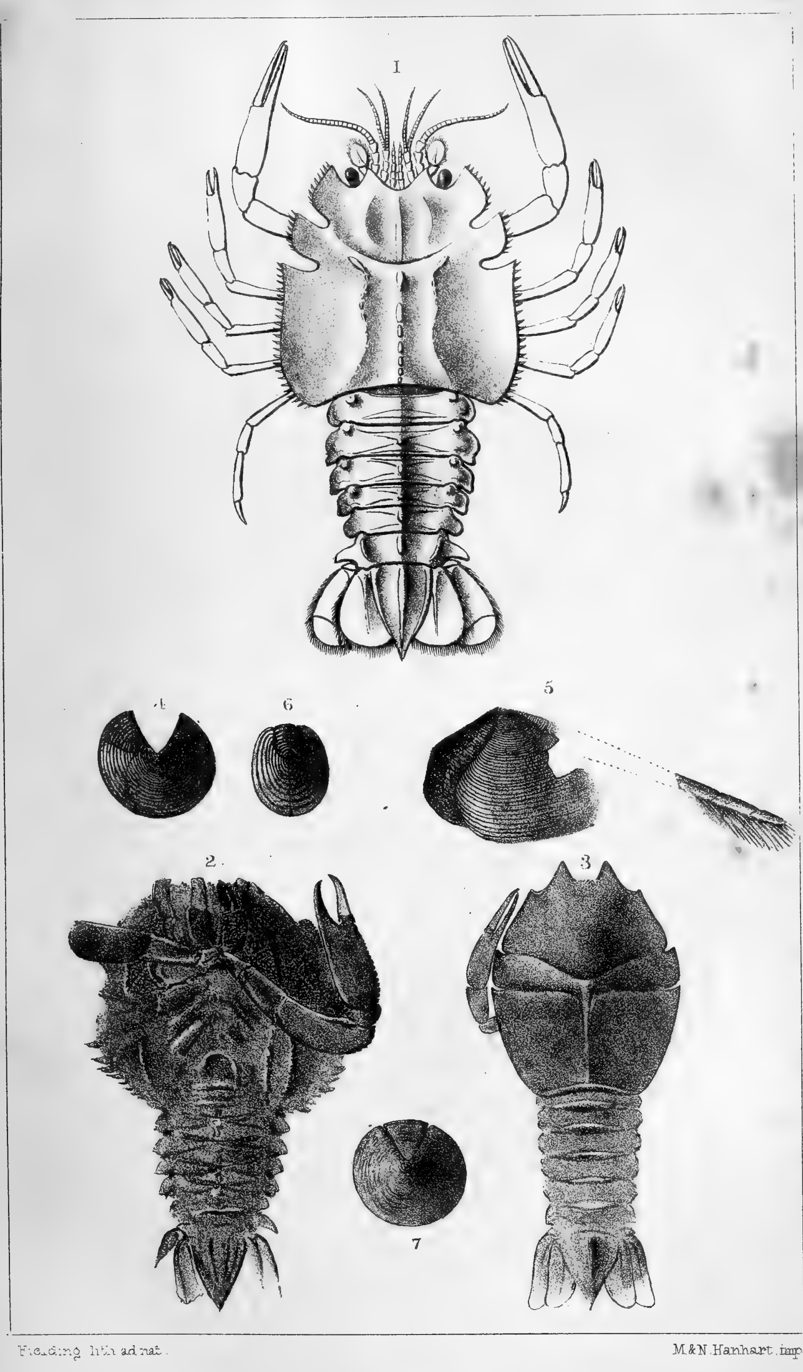


Fielding lith. ad. nat.

M & N Hanhart imp.

JURASSIC CRUSTACEA.




Fielding lith ad nat. M.&N. Hanhart imp.

JURASSIC & SILURIAN CRUSTACEA.

## 4. *On a* New Genus *of* Phyllopodous Crustacea *from the* Moffat Shales (Llandeilo Flags) Dumfriesshire. By Henry Woodward, Esq., F.G.S., F.Z.S.

[Plate XXV. figs. 4–7.]

Having lately received from Mr. D. J. Brown, of Edinburgh, specimens of shells, attributed to *Discina* and *Modiolopsis*, from Garple Burn, near Moffat, I examined them in conjunction with my colleague, Mr. W. Carruthers, F.L.S.; and we were enabled, by the help of these specimens and of others in Mr. Carruthers's own collection, to determine them all to belong to one organism (folded in some instances, and in others spread open), and that not a mollusk, but a crustacean allied to *Apus* &c.

The fossil might readily be mistaken for the upper valve of a *Discina*, having a strong resemblance to *Discina nitida* from the Carboniferous Limestone, and to *Discina lamellosa*, recent, from Peru; but upon a more careful examination nearly every specimen is found to have in the front of the shell a wedge-shaped opening with a well-defined border, which cuts the disk nearly to its centre*.

In a specimen from Mr. Carruthers's collection (Pl. XXV. fig. 7) the wedge-shaped sector which closes this opening remains *in situ*, but the suture can still be detected.

In another specimen, from Mr. Brown's collection (Pl. XXV. fig. 5), remains of the tail-segments are preserved on the same slab with the folded shell.

The carapace, for such it must be considered, is ornamented by concentric lines of growth, which curve slightly inwards upon reaching the margin of the wedge-shaped suture in front. These concentric lines are finer and closer to each other near the apex, and more stronly marked and further apart near its margin. The sector displays similar concentric lines of growth with the rest of the carapace. The form of the shell is slightly conical, as in *Discina*; but many of the specimens, being crushed, do not show the normal form. The apex of the shell is placed immediately behind the wedge-shaped suture before mentioned.

In all the specimens yet seen no dorsal furrow can be detected, the concentric lines passing smoothly in unbroken series around

* Mr. Davidson, to whom Mr. Brown had submitted certain other more minute shell-like impressions from these shales, thus writes concerning them and the fossil at present under consideration:—

"33 Park Crescent, Brighton,
"27th October, 1865.

"My dear Sir,—I send for your inspection the two specimens that were sent to me by Mr. Brown, of Edinburgh, and which were derived from the Dumfriesshire beds. They are certainly obscure fossils; but the specimens you showed me were not Brachiopoda, but, as you said, remains of crustacea.

"Those I send show no indications of the fissure, or notch, and have a much more Brachiopodous look than those in London. One of them somewhat resembles a *Lingula*, the other a *Discina*; but I do not say they are Brachiopoda.

* * * * * * * * * * * *

"I remain, very truly yours,
(Signed) "Thos. Davidson."

"*To H. Woodward, Esq.*"

the posterior surface up to the margins of the suture. The absence of a dorsal furrow at once separates it from *Peltocaris Harknessi* and *P. aptychoides* (Pl. XXV. fig. 6), allied forms of Phyllopodous crustacea found in the same shales.

The wedge-shaped suture, which divides the shield of this crustacean in front, doubtless corresponds with the suture in the shield of *Apus* and the nuchal furrow in the Macrurous Decapods.

A similar line of separation has already been noticed in the shield of *Peltocaris aptychoides*. (See Mr. Salter's paper in the Quart. Journ. Geol. Soc. vol. viii. pl. 21. fig. 10.)

Why, it may be asked, does the shield in this old crustacean, and also in *P. aptychoides*, always separate along this line of suture, and leave the appearance presented in the figure? (Pl. XXV. fig. 4.)

I can best explain this by referring to the recent *Apus*, in which the footjaws, branchiæ, and abdomen appear to be all strongly united to the head, and that to the rostral portion of the carapace; whilst to the far larger posterior surface of the shield the attachment is so slight that specimens always become detached in this manner, and, as in the case of the phragmacone and sheath of the fossil Belemnite, the soft parts of the animal will often be found in one locality and the carapaces *minus* the frontal portion in another.

Such is the case with *Dithyrocaris*, an allied genus, the organs of manducation of which are seldom if ever found with the shields, but in nodules (probably composed of the soft parts of the animal) in a bed by themselves*.

It may be interesting to record that among the specimens from Mr. Carruthers's cabinet is a small example of *Peltocaris aptychoides*, which exhibits the concentric lines of growth as in the *Discina*-like form herein described. (See Plate XXV. fig. 6.)

With the exception of Graptolites, fossils are of rare occurrence in the Moffat shales. Mr. Salter has, as already stated, described† two phyllopodous crustacea, *Peltocaris Harknessi* and *P. aptychoides*. Professor Harkness has found a small Brachiopod (*Siphonotreta micula*, M'Coy), and Mr. J. Stevens, formerly of Moffat, a single specimen of *Tentaculites*.

The addition, therefore, of a new Phyllopod is an interesting discovery. From its resemblance to *Discina*, I have proposed for it the generic name of *Discinocaris*, and the specific appellation of *Browniana* after Mr. D. J. Brown, who first drew my attention to it.

*Dimensions.*—Diameter of disk-shaped carapace 7 lines, sector one-sixth of its arc. A larger specimen folded together probably measured 14 lines in diameter.

## EXPLANATION OF PLATE XXV. figs. 4–7.

(*Illustrative of* Discinocaris Browniana.)

Fig. 4. *Discinocaris Browniana*, H. Woodw. Moffat Shales (Lower Silurian), Dumfriesshire. Natural size. Collection of Mr. D. J. Brown,

* Geol. Mag. vol. ii. 1865, p. 401, pl. 11.
† Quart. Journ. Geol. Soc. vol. xix. p. 87.

Edinburgh. The wedge-shaped rostral portion is absent from this specimen.
5. The same, in which the shield is folded together. Natural size. Collection of Mr. D. J. Brown, Edinburgh.
6. *Peltocaris aptychoides*, Salter. Moffat Shales, Dumfriesshire. Three times the natural size. Collection of W. Carruthers, Esq., F.L.S.
7. *Discinocaris Browniana*, having the wedge-shaped rostral portion *in situ*. Natural size. Collection of W. Carruthers, Esq., F.L.S., of the British Museum.

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## 5. NOTES *relating to the* DISCOVERY *of* PRIMORDIAL FOSSILS *in the* LINGULA-FLAGS *in the* NEIGHBOURHOOD *of* TYDDYNGWLADIS SILVER-LEAD MINE. By JOHN PLANT, Esq., F.G.S.

[Abstract.]

THE author recorded in this paper the discovery, during the autumn of 1865, of fossils at Tyddyngwladis in beds belonging to the Lingula-flags or Primordial zone, and partly referable to species known to occur in other parts of Wales on the same horizon.

A detailed examination of the district, undertaken by the author and Mr. E. Williamson, has enabled them to draw a section extending from the junction of the Lower and Upper Cambrians* at Cefn Deuddwr to the base of Craig-y-Dinas, which was described in detail† by the author.

The following list of the fossils found in the various divisions of the Lingula-beds adopted by the author, and arranged in their order of sequence, commencing with the lowest, have been prepared, after Mr. Salter's examination of the collection.

*Tyddyngwladis Slates (Lower Lingula-beds).*

No. 1. Has not been examined.
No. 2. Anopolenus Henrici, *Salter*.
—— Salteri, *Hicks*.
——, sp.
Paradoxides Hicksii, *Salter*.
Microdiscus punctatus, *Salter*.
Agnostus Davidis, *Salter*.
—— princeps, *Salter*.
——, sp.
Theca, sp.
No. 2. Lingulella unguiculus, *Salter*.
——, sp.
Obolella, sp.
Protospongia fenestrata, *Salter*.
‡Dictyonema Graptolithinum?
No. 3. Agnostus, sp.
Obolella, larger sp.
No. 4. Paradoxides Davidis, *Salter*.
Theca corrugata, *Salter*.

*Cwm Eisen Slates (Lower Lingula-beds).*

No. 5. Olenus cataractes, *Salter*.
——, sp. nov.
Agnostus princeps, *Salter*.
No. 5. Agnostus trisectus, *Salter*.
Track of a Trilobite.
Holocephalina, sp.

*Hafod Owen Sandstones (Middle Lingula-beds).*

No. 6. Olenus, sp. nov.
Conocoryphe, sp. nov.
Lingulella Davisii, *Salter*.
No. 6. Hymenocaris?
Annelid-tracks and borings.
‡Buthotrephis (fucus).

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* The Upper Cambrians of this author comprise the Lingula-flags, or base of the Lower Silurian, of Sir Roderick Murchison and other geologists.

† Published in full in the Transactions of the Manchester Geol. Soc. vol. v. p. 220 *et seq*.

‡ These are not Mr. Salter's naming.

*Rhiwfely Slates (Upper Lingula-beds).*

No. 7. Olenus (Peltura) scarabæoides, *Wahl.*
Olenus spinulosus, *Wahl.*
——, sp. nov., with longer spines.

No. 7. Sphærophthalmus humilis, *Phill.*
Agnostus princeps, *Salter.*
Lingulella lepis, *Salter.*
Orthis lenticularis, *Dalm.*
——, sp. nov.

*Moel Gron Slates (Upper Lingula-beds).*

No. 8. Sphærophthalmus pecten, *Salter.*
—— humilis, *Phill.*
—— bisulcatus, *Phill.*
‡—— alatus, *Bœck.*
Olenus (Peltura) scarabæoides, *Wahl.*
‡Parabolina serrata, *Salter.*

No. 8. Olenus, sp. nov. with long head-spines.
Agnostus princeps, *Salter.*
—— trisectus, *Salter.*
——, sp. nov.
Conocoryphe Plantii, sp. n., *Salter.*
Conocoryphe, sp.

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June 6, 1866.

The following communications were read:—

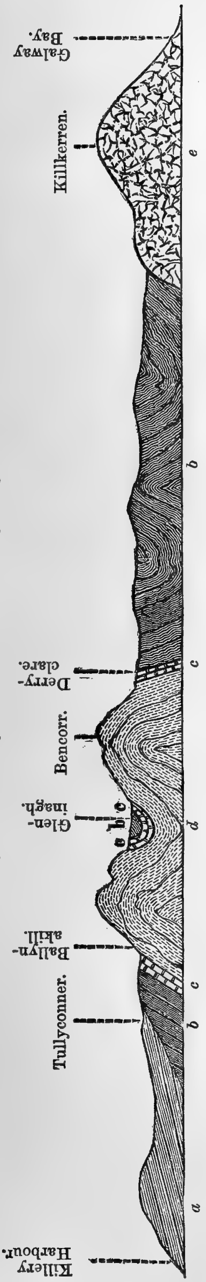
1. *On the* Metamorphic *and* Fossiliferous Rocks *of the* county *of* Galway. By Professor R. Harkness, F.R.S., F.G.S., Queen's College, Cork.

The portion of the county of Galway which lies between Killery Harbour on the north and Galway Bay on the south, includes Connemara and Joyce's country, one of the wildest and most mountainous districts of Ireland.

A section of the geology of this district is given in Sir Richard Griffith's Geological Map of Ireland; and the rocks of the country have been generally alluded to by Sir Roderick I. Murchison in the last edition of 'Siluria.'

The rugged Connemara district is for the most part made up of metamorphic rocks, among which patches of granite occur; and this latter rock is found occupying a considerable area on the south of the metamorphic series, and extending to the northern boundary of Galway Bay. It also constitutes the rocky and moory country known as Moycullen, which lies on the west side of Lough Corrib.

The metamorphic rocks, as they are seen on the northern margin of the granitic area, consist of gneissose strata, which strike east and west, and which, although much contorted, have a prevailing southerly dip, or incline towards the granitic area. On their northern-side rocks occurs a band of limestone, which can be traced westwards from a few miles west of Oughterard, on the shores of Lough Corrib, for a considerable distance, as quarries of it are seen near the road leading from Oughterard to Clifden. One of these appears near where the Maame Road leaves the Clifden Road, at a spot called Butler's Lodge; and here the limestone is light grey in colour and semicrystalline in structure. From Butler's Lodge it passes west-




*Section from Killery Harbour to Galway Bay* (30 miles).

*a.* Fossiliferous Silurians. *b.* Gneissose rocks. *c.* Limestone. *d.* Quartz-rocks. *e.* Granite.

wards through Shindilla Lake, and is again seen on the Clifden Road at the Halfway House, where it has a dip towards the south at 45°. From the Halfway House it is again seen at several spots, where it has been worked, on the south side of Clifden Road to near Recess.

About a mile north of Recess, at the southern base of the hill called Lisoughter, is a small village bearing the name of the hill. Here the limestone again appears, but considerably to the north of its former line of strike. It exhibits at Lisoughter its east and west strike, and passes under gneissose rocks on its south side, but is greatly contorted in its dips. At Lisoughter it abounds in a dark-green variety of serpentine (Loganite), and presents a darker colour than where it occurs as a more easterly band. Besides abounding in serpentine, the limestone at Lisoughter also contains well-developed radiated crystals of tremolite. A short distance west of Lisoughter, at Coulmathan, between Derryclare Lake and Lough Inagh, it is again seen, and here has its usual light-grey colour and its semicrystalline nature. A little to the south-west of Coulmathan, on the margin of a small bay on the eastern side of Derryclare Lake, the limestone also occurs, having serpentine imbedded in it, and exhibiting the aspect which it presents at Lisoughter. From the eastern margin of Derryclare lake it extends westwards on the northern side of the lake, and is again seen on the southern side of Derryclare Mountain. West of this it occurs, in the form of a dark-coloured serpentinous limestone, in the lower course of a stream called the Glencoughan River, which flows from a wild deep gorge between two of the Twelve Bens of Connemara, Bencorr (2336 feet), and Benbreen (2276 feet).

The serpentinous limestone at Glencoughan River dips towards the south and passes under the gneissose rocks. It has on its northern side a mass of quartz-rock, which is seen in the course of the stream a short distance above the limestone, and which dips south, or under the limestone. The latter can be traced, coming up in bosses or covered by a green band of vegetation, from the Glencoughan River, running parallel to, and a short distance from, the Clifden Road, to a house called the Canal Stage, where it crosses from the north to the south side of the road, whence it still strikes westwards and passes beneath the waters of Ballynahinch Lake.

The mass of limestone which lies between the gneissose rocks and the quartz-rocks probably exhibits itself, on the south side of the Connemara Mountains, in more than one band. The limestone and its associated strata have been greatly contorted in this part of the county of Galway, and denudation has also aided in removing the connecting links of the contortions—but not to such an extent as in the country which lies on the north side of it; and by these agencies the strata have been frequently repeated on the surface.

The quartz-rocks which occur on the northern margins of the limestone give rise to the bold mountainous scenery of Connemara. They form the Twelve Bens, and have in many spots a very distinct stratification, and a strike which conforms with that of the limestones. They are, among the Twelve Bens, thrown into great anticlinals and synclinals; and in one of these latter, which forms the east and west valley of the Owenglin River (the stream which flows into the sea at Clifden), serpentinous limestone also occurs. Between the Owenglin valley on the north and the limestone band which passes under Ballynahinch Lake on the south, there is an anticlinal of quartz-rocks. The upper portion of the Owenglin valley is occupied by a district called Barnanoraun; and here the principal quarries of serpentinous limestone occur.

The strike of these limestones here is also east and west; but the dip cannot be made out, as the strata are excessively contorted.

The serpentinous limestones of Barnanoraun thin out towards the east as they approach the quartz-rocks of Benbreen, the mountain at the head of the valley. This thinning out, however, is the result of denudation.

The north as well as the south margin of the valley of the Owenglin is flanked by quartz-rocks; and the contortions which have taken place among the rocks near the centre of the synclinal of the Owenglin valley have so far destroyed the original lamination of the limestone strata as to open out irregular interspaces; and in some cases the original limestone has disappeared, its place being supplied by white carbonate of lime. The serpentinous limestone is here much lighter in colour than that of the more southern band, owing to the serpentine being of a lighter green colour than that which occurs at Lisoughter and its neighbourhood.

With reference to the quartz-rocks of the Connemara district, the arrangement of these and their relations to the limestones and gneissose strata can be well seen in traversing the country which lies between the Twelve Bens of Connemara on the west and the Maame Tork range of mountains on the east. These ranges are separated from each other by a wide valley having a north-west and south-east direction. In this valley is Lough Inagh, the only lake of a considerable size in the Connemara country, which has a north-west and south-east position.

The quartz-rocks are well exposed on the east side of Derryclare Mountain and Bencorr.

They exhibit on this side of the range an anticlinal axis, on the south side of which is the band of limestone before referred to; and on the north side another band of limestone is seen in the valley of Gleninagh. This limestone of Gleninagh also occurs at Feliskin, near the north-east side of Lough Inagh, on the road which is now being made from the Clifden Road northwards to Kylemore. As seen at Feliskin it is of a light-grey colour, and has the subcrystalline nature which the southern band exhibits where it is not charged with serpentine. It dips from the anticlinal which lies to the south of the limestone, and passes conformably under a small area of gneissose rocks which occurs to the north of Feliskin. The rocks, a short distance northwards, soon assume southerly dips, the limestone here occupying a synclinal trough, which, if followed over the mountains westward, would probably be found to connect itself with the synclinal valley of the Owenglin River. Some distance north of Feliskin another anticlinal axis occurs, on the north side of which northern dips again prevail; and above the quartz-rocks limestone again appears, succeeded conformably by gneissose rocks, the latter being in their turn covered *unconformably* by fossiliferous Silurian sandstones, which extend from near Kylemore to the south side of Killery Harbour.

The valley in which Lough Inagh is situated so distinctly separates the Maame Tork range of mountains from that of the Twelve Bens of Connemara, as to justify the inference that it originated in a fault. The Maame Tork range, on the east side of Lough Inagh, presents very bold escarpments towards the south-west; and these escarpments run very regularly north-west and south-east, the direction which the assumed fault takes.

The arrangement of the metamorphic rocks of the west of the county of Galway has an intimate relation to that which occurs among the rocks of the same nature in the county of Donegal*. It also corresponds with that of the Highlands of Scotland, representing the upper quartz-rocks, the upper limestones, and the upper or flaggy gneiss of the latter country, as these have been described by Sir Roderick I. Murchison. With reference to the occurrence of serpentine in connexion with the limestones of the metamorphic series of Connemara, this has of late become a matter of some interest, in consequence of the statement that these deposits afford the *Eozoon Canadense*. The serpentinous limestones of Connemara are of local occurrence; they usually appear in such districts as exhibit the strata highly contorted and broken up.

The lines of lamination in the limestone strata have been opened, and the laminæ have been fractured across, in consequence of the contortions to which the strata have been subjected; and into these openings and fractures the serpentine has been subsequently intro-

* Quart. Journ. Geol. Soc. vol. xvii. p. 268.

duced. Serpentine does not, however, seem to have been the first substance which occupied these cavities. The serpentine, on exposure to atmospheric influence, frequently becomes much weathered, and sometimes entirely disappears, leaving a crystalline skeleton in the form of either tremolite, asbestos, or some other nearly allied mineral. Asbestos is often found lining the sides of the limestone-cavities in decomposed specimens of serpentinous limestones on the east side of Derryclare Lake. This mineral is here so arranged as to present the fine shell-structure alluded to by Dr. Carpenter as forming the proper walls of the chambers of the *Eozoon Canadense,* and which he speaks of as being "made up of a multitude of extremely delicate *aciculi* standing side by side like the fibres of asbestos."

Specimens of the serpentinous limestones from Lisoughter often exhibit in some parts only the tremolitic skeleton, the serpentine proper having disappeared. Specimens also occur in which portions of the serpentine remain intact, while other portions gradually shade off to the condition of tremolite.

The complex nature of serpentine has been frequently alluded to by mineralogists, and also its varying composition. These circumstances result from the variable amount and the variable nature of the skeleton upon which the hydrous silicate of magnesia has been deposited. In the case of the serpentinous limestone of Connemara, there is good reason for inferring that the tremolitic and asbestose skeletons were formed at the period when metamorphic action was changing the purely sedimentary rocks. One of the most abundant minerals produced by this metamorphic action was hornblende, a substance which enters largely into the composition of the gneissose rocks superposed on the limestones; and the tremolitic variety of this mineral appears to have found its way into the cavities of the contorted limestones.

The following is the composition of tremolite from Fahlun:—

| | |
|---|---|
| Silica | 60·10 |
| Magnesia | 24·31 |
| Lime | 12·73 |
| Protoxide of iron variable. | |

tremolite being a silicate of magnesia and lime. The serpentine of Ballynahinch has the following composition:—

| | |
|---|---|
| Silica | 40·12 |
| Magnesia | 40·04 |
| Alumina | 2·00 |
| Protoxide of iron | 3·47 |
| Water | 13.36 |
| | 98·99 |

The occurrence of serpentine in connexion with metamorphic limestones is a common circumstance. It is found in association with the limestones of Glen Tilt; and here, as at Connemara, tremolite is also an accompanying mineral.

The supposed organic portions of the serpentinous limestones of Connemara do not result from animal structure, but purely from mineral association. Had fossils of any kind presented themselves in the limestones of this district, they ought to have occurred in that portion of the limestone which has been least affected by metamorphic action. This is the character of the limestone which occurs in that portion of the calcareous band which lies east of Lisoughter, and which extends to near Oughterard. In this portion of the band the laminæ have not been opened and broken by contortions; and from it the serpentine is absent, and with this absence of serpentine and its associated skeletons of tremolite and asbestos everything like the so-called organic structure disappears.

The fossiliferous Silurian rocks of Connemara and of Joyce's county have been referred to by Mr. J. Kelly in a memoir "On the Greywacké Rocks of Ireland"*. They usually occur on the northern side of the metamorphic range; but there is one locality where this is not the case—namely, on the western shore of Lough Corrib, at a place called Shanballymore, about three miles north of Oughterard. Here, to the north of a small patch of rather fine-grained granite, and to the east of the metamorphic rocks, the fossiliferous Silurian rocks are seen, consisting of a grey flaggy bed associated with thick-bedded strata; but their relations to the rocks which margin them are not seen here, and the fossils are principally procured from the stones in the walls, which have been obtained from the loose fragments scattered about the fields. Another fossiliferous Silurian locality lies at the northern end of Lough Corrib, a short distance west of Cong. At the western extremity of this area the strata come in contact with the metamorphic rocks of Benlevy (1375 feet), and the relations of the fossiliferous beds to the rocks which margin them are well seen. Here, at a short distance to the west of Lough Coolin, which lies under the eastern side of Benlevy, Silurian grits occur nearly horizontal in position, but with a slight inclination toward the N.N.E. Immediately west of these grits is one of the bold escarpments of Benlevy, composed of gneissose rocks, which strike east and west and are vertical in position.

Another locality from which we obtain information concerning the relations of the metamorphic and the unaltered Silurian rocks is in the valley which leads from Maame to Leenane, the latter being on the south shore of Killery Harbour. In this valley there is a stream which flows from the north near Munterown, about three miles S.E. of Leenane. Where the road crosses this stream, at the bridge, a conglomerate in the fossiliferous Silurian strata is seen; it abounds in well-rounded fragments of gneiss and quartz-rocks, which have been derived from the metamorphic series.

On the south side of Killery Harbour, at the head of a valley called Glencraff, which runs from east to west, their relations are also seen. The fossiliferous Silurian rocks form the hills on the north side of the valley; they are well exposed, distinctly bedded, and have an average dip towards the N.W. at 35°. The south side of the valley consists of hills of gneissose rocks, with strata contorted, but having the usual east and west strike.

At Blackwater Bridge, on the road from Leenane to Clifden, and about three miles from the head of Glencraff, Silurian conglomerates are again seen, containing rounded metamorphic rocks; and

* Journ. of the Geol. Soc. of Dublin, vol. viii.

immediately to the south-west of them the metamorphic strata whence these conglomerates have been derived present themselves, with the normal east and west strike.

The fossils which were collected by myself and by Mr. G. H. Kinnahan, of the Irish Geological Survey, who accompanied me during part of the time I spent among the fossiliferous Silurian strata of co. Galway, are the following:—*Favosites Gothlandica, Alveolites Labechii, Halysites catenulatus, Petraia bina, P. ziczac*, M'Coy, *Pleurodictyum problematicum**, *Phacops sublævis*, M'Coy, *Encrinurus punctatus, Fenestella prisca, Ptilodictya lanceolata, Atrypa hemisphærica, Orthis reversa, Pentamerus oblongus, Spirifer plicatellus* var. *radians, Trochus multitorquatus, Holopella obsoleta, Bellerophon.*

The fossiliferous Silurian rocks of Galway, although on the whole dipping from the metamorphic rocks on the north side of which they repose, have many local irregularities. They are succeeded towards the eastern end of Killery Harbour by grey- and purplish-coloured pebbly grits, in which no fossils have yet been found.

These grits are false-bedded; but their strike and dip seem to conform to those of the fossiliferous Silurian beds on which they repose. They appear to form a synclinal trough near the head of Killery Harbour, as on the south side they have a northerly dip, and on the north of this harbour they incline towards the south. These grits form a very bold and rugged mountainous district, in which is Mweelrea (2692 ft.), one of the highest mountains in this portion of Ireland, at the northern entrance into Killery Harbour.

Eastwards from Killery Harbour these rocks appear in the form of rugged precipices, forming the northern side of the mountains which occur on the south side of the Errive River.

The grey and purple grits which overlie the fossiliferous Silurian strata have a great lithological affinity to the so-called Old Red Sandstones which occur to the south of the greenstones and fossiliferous Silurian (Caradoc) deposits of Pomeroy, co. Tyrone.

The fossils of the unaltered rocks of the west of Galway are such as to indicate an horizon more nearly parallel with that of the Upper Llandovery rocks than any other in the Silurian system. Of these fossils, *Atrypa hemisphærica* is by far the most abundant, and is one of the most characteristic of the Upper Llandovery Brachiopods, besides which we have a smooth *Pentamerus*. The Trilobite which occurs most frequently is *Encrinurus punctatus*. With these fossils other Upper Llandovery forms are found; and, although the corals indicate a somewhat higher position among the Silurian rocks, the whole *facies* of organic remains justifies the inference that the fossiliferous Silurian strata of Galway belong to the middle portion of the Silurian system.

* This, I have no doubt, is not strictly a fossil, but the cast of the upper portion of the cup of a tabulate coral. On taking a cast of the *Pleurodictyum* above mentioned, and comparing it with the upper surface of *Favosites Gothlandica*, I could distinguish no difference in form. The tube-like body which so frequently accompanies *Pleurodictyum problematicum* appears to be a cast of the burrow of a parasite like the *Sipunculus heterocyathus*, which bored through corals belonging to the genus *Heterocyathus* (vide Nat. Hist. Review, n. s., vol. ii. p. 80).

The metamorphic rocks upon which these beds repose have already been referred to as the equivalents of the upper quartz-rocks, upper limestones, and upper gneiss of the Highlands of Scotland. As the position of these metamorphic rocks in the sedimentary series is now known in consequence of the fossils which the Lower Limestone at Durness has afforded, and as the position of this limestone is not lower than the Llandeilo flags, we must refer the metamorphic action which has changed the purely sedimentary rocks to an age later than the Lower Silurian period.

Above the representatives of the Llandeilo flags there is, in the Highlands of Scotland, a great thickness of quartz-rocks, limestones, and gneissose strata; and the upper portion of this thick series, in the form of the gneissose strata, very probably represents the Caradoc rocks. If this be the case, it follows that the metamorphic action came into operation towards the close of the Caradoc age. That the metamorphism of the gneissose rocks and their associated strata was complete before the deposition of the Upper Llandovery beds is proved by the occurrence, in the lower portion of the fossiliferous Silurian rocks of Galway, of conglomerates full of metamorphic fragments. All the circumstances which bear evidence as to the period when metamorphism took place among the altered rocks of this part of Ireland place this period in the Lower Llandovery epoch. If this inference be correct, it must be extended beyond the western portion of the county of Galway; for it will embrace not only the whole of the metamorphic rocks of Ireland, but also all those of the Highlands of Scotland, except the Fundamental or Laurentian gneiss.

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## 2. *On the* Metamorphic Lower Silurian Rocks *of* Carrick, Ayrshire. By James Geikie, Esq., of the Geological Survey of Great Britain.

(Communicated by Professor A. C. Ramsay, LL.D., F.R.S., V.P.G.S.)

Contents.



### I. Introduction.

The metamorphic region which forms the subject of this communication was traversed by Sir Roderick Murchison, accompanied by Professor J. Nicol, in 1850; and the former geologist subsequently published the results of that journey, in a memoir upon the geology of the South-western Highlands of Scotland*; but as the end Sir Roderick had in view was mainly to ascertain the structure of the strata and determine their position, his allusions to the metamorphic rocks are necessarily brief. In the spring of 1865 the Geological Survey was extended into the southern regions of Ayrshire, and thus afforded my colleagues (Dr. Young and Mr. A. Geikie) and myself ample facilities for a more minute examination of the beds in question. We recognized the metamorphic character of certain diorites, serpentines, and crystalline felspathic rocks, independently of each other; and in the area that fell to me to survey I was enabled to trace passages between the various altered rocks, which seem to throw light upon the obscure process of metamorphic action. The interest which is attached to the altered strata of this district chiefly consists in the fact that they exhibit certain arrested stages of metamorphic action, so that we can in many instances begin with unaltered beds and trace the gradual changes which they undergo during their passage into crystalline and pseudo-igneous rocks. The large masses of amygdaloid indicated upon the sketch map which accompanies Sir Roderick's memoir, notwithstanding their exceedingly igneous aspect, are nevertheless, as will be shown, not of igneous but of metamorphic origin. Of the same nature are the porphyries, diorites, and serpentines. The resemblance to trap which many of those rocks exhibit is so striking that it will perhaps be difficult to convince a geologist who has not minutely examined the ground for himself of their true character.

With Sir Roderick Murchison's permission, some of the more interesting results obtained during the progress of the Survey are here described.

The metamorphic Lower Silurian rocks surveyed by us may be roughly estimated to cover an area of forty-five square miles or thereabouts. They extend in the direction of the strike (*i. e.* N.E. and S.W.) for ten miles or so, with an average breadth of three miles and a half; but several isolated portions occur beyond the main mass of metamorphic strata. Beginning a little to the south of Girvan, the altered rocks continue, with little interruption, along the coast-line as far as Currarie Port —a distance of about twelve miles. As the coast-line cuts the strata at an acute angle to their strike, nearly all the varieties of metamorphism characteristic of the district are met with in this section. The northern limits of the metamorphic area are exceedingly irregular. The lines traced by us in that direction show altered beds extended among unaltered deposits; and the boundary is still further confused by faultings, and by overlaps of Old Red Sandstone. Towards the south, however, the metamorphic strata are separated from the unaltered greywackés by a long wavy fault which runs inland from the sea-coast at Glendrishaig, and, keeping to the

* Quart. Journ. Geol. Soc., vol. vii. p. 137 *bis*.

line of strike (S.W. to N.E.), terminates at Pinmore Bridge on the river Stinchar, where it is cut off by another fault coming from the west.

The metamorphic rocks usually dip at a high angle, while the strike corresponds in a remarkable degree with that of the unaltered strata of the surrounding country. On the Survey-maps we have distinguished three great groups of rocks, viz. *Felstones, Diorites, Serpentines.*

Felspathic rocks are by far the most abundant, and are very varied in structure and aspect. The diorites and serpentines, on the other hand, have a more definite character, and are usually interbedded or very closely associated. It is worth noting, that, if we traverse the strata from south to north, we shall find that interbedded diorites and serpentines alternate with great belts of felspathic rock. Thus, starting from the fault which forms the southern boundary of the metamorphic rocks, we first cross amygdaloidal, finely crystalline, and brecciiform felspathic rocks. Thereafter, as at Balhamie Hill, we come upon serpentine with associated diorites. Leaving Balhamie Hill, we again pass over a belt of felspathic rocks, until, at Carleton Hill and Lendalfoot, we find ourselves once more among diorites and serpentines, and so on with the beds to the north.

The bounding fault on the south unfortunately throws some doubt on the relation which the metamorphic rocks bear to the unaltered strata. But, notwithstanding the south-east dip of the latter, the downthrow is to the north; and therefore the metamorphic strata must occupy a somewhat higher horizon than the unaltered wackés against which they abut. Little isolated portions of metamorphosed rock are met with here and there among the unaltered greywackés alluded to, often far removed from the chief area of metamorphic strata; but an account of their probable origin and connexion with strata denuded away is reserved for a forthcoming memoir of the Geological Survey. Several areas of unaltered strata, enclosed and surrounded on all sides by metamorphic rocks, will be described below as representing the nature of the beds which have become metamorphosed. The unaltered strata of this region exhibit the usual character of the Lower Silurian greywackés and shales of the southern uplands of Scotland. They are all strongly felspathic, but are usually more highly impregnated with alkaline matter than the Silurian rocks of Berwickshire, Peeblesshire, Selkirkshire, and other districts which have been examined by the Survey. Many of the beds effervesce freely with acids, showing the presence of lime, while the abundance of magnesian matter has often tinged the rocks with green. Immediately south of the metamorphic region, the unaltered Silurian strata are not markedly magnesian, but they still contain in places a not inconsiderable admixture of calcareous matter.

At present attention is directed to a generalized description of the metamorphic strata, for the purpose of tracing the various stages in the process of alteration, and of thereby attaining to some knowledge of the causes which have induced metamorphism.

The strata to be described consist of felspathic rocks, diorites, serpentines, and altered limestone and calcareous greywacké.

## II. Felspathic Rocks.

The felspathic rocks cover a large area in the metamorphic region under review. They are exceedingly well exposed along the sea-coast, where they rise into rugged broken cliffs, fissured with numberless inlets and retiring coves. Very good sections are also obtained in the streams that drain into the Stinchar, while the hill-sides themselves are roughened with fine exposures of the same rocks. These felspathic masses consist chiefly of four varieties—amygdaloid, felspar-porphyry, brecciiform rocks, and finely crystalline and compact felstone,—all of which are closely related, both as regards the manner of their occurrence and the mode of their formation.

### A. *Amygdaloid.*

The felspathic amygdaloids are largely developed throughout the district, but may be best studied along shore, between Knockgowan Hill and the mouth of the river Stinchar, and at many points on the coast-line north of Bennane Head. They are also very well seen at numerous places along the line of fault that separates the metamorphic rocks on the north from the unaltered greywackés to the south. They have, in general, an exceedingly igneous aspect, especially on the coast, where they form rugged stacks, and weather into rough lumpy-shaped masses on the cliffs. Seen from above, the igneous character of these rocks could scarcely be doubted. Where they are most typically developed, they often look as if made up of large bombs—an appearance which not infrequently gives place to a columnar structure. A closer inspection shows us their abundant amygdaloidal cavities; and these, taken in connexion with the roughened and sometimes almost trachytic surface of the stone, seem at first sight to indicate a former state of igneous fusion.

*Colour, Composition, Texture, Fracture.*—The prevailing colour of the amygdaloids south of the Stinchar is a pale greyish blue, passing into dark green and grey; north of Bennane Head they generally assume a light purplish brown, with occasional areas of greyish blue. The matrix consists of a paste of felspathic matter, with here and there a variable admixture of magnesia and lime. In texture these amygdaloids sometimes resemble the felspathic traps of the Ochils, the Pentlands, and other Old Red regions. This, especially, is the case with those light-purplish-brown varieties which lie exposed along the shore to the north of Bennane Head. The harder portions of the rock show a very finely crystalline texture; but in the more alkaline and earthy areas crystals can seldom be detected, the matrix appearing like a fine felspathic mud, shot here and there with a few minute points of felspar. In the district south of the Stinchar, the felspathic amygdaloids seldom exhibit this earthy texture; on the contrary, the matrix is harder, less alkaline, and more generally crystalline, but always very finely so. The *fracture* varies, of course, with the texture of the rock; it is usually rough and irregular, like that of many traps, but sometimes conchoidal.

*Amygdaloidal Cavities.* — The amygdaloidal cavities are very abundant, but are often partially aggregated in areas, leaving the surrounding portions of the matrix less profusely pitted. They invariably assume a globular shape, except where two or more have become confluent, when the cavity resulting from their union is usually of irregular form. They are of all sizes, from mere points up to globules as large as a sweet pea; but larger cavities are not uncommon. Perhaps the most abundant sizes are those which may be compared to turnip and mustard seeds. Carbonate of lime is the mineral most usually met with in these cavities; but zeolites and decomposing magnesian minerals are abundant in places; hard white felspar is also occasionally met with.

The most continuous exposure of the rocks in question occurs along the coast, between Knockgowan Hill and the river Stinchar. Throughout this section the bedding is often very distinct, the strike corresponding with that of the unaltered greywackés of the adjoining districts, viz. N.E. and S.W. But frequently all trace of bedding is lost, even when the rock-masses are viewed from a little distance. Here and there occur bands of a hard and highly altered red greywacké mudstone passing into Lydian stone; and occasionally we come upon portions of fine pebbly and brecciated greywacké, resembling at a first glance the comminuted paste of a volcanic ash. Courses of greywacké, distinctly granular, alternating with thinner bands and shales, also make their appearance in some parts of the section. All these regularly bedded and undoubtedly aqueous rocks are interstratified with, and, when their strike is prolonged, seem to pass into, felspathic amygdaloid and finely crystalline felstone.

It has been stated that a first view of the amygdaloid would lead one to infer an igneous origin for that rock; to one, however, who had previously explored the greywackés of the surrounding country, and familiarized himself with their texture and mode of weathering, this apparently igneous aspect is not always so striking. In many places the greywackés of the non-metamorphic regions are exceedingly hard, and sometimes approach to crystalline in texture. Moreover the weathered crust of the amygdaloid, like that of the greywackés, is seldom more than a line or so in thickness; and the rock when broken shows a very general absence of that dull earthy texture which among Scottish traps usually attends an amygdaloidal structure.

From the distinctly bedded nature of the amygdaloids, and their alternation with other rocks to be described in the sequel, these masses, if of igneous origin, are manifestly *not intrusive*. On the other hand, if we believe them to have been poured out at the earth's surface, we shall look in vain for those flattened amygdaloidal or vesicular cavities so characteristic of true amygdaloidal trap. The shape of the vesicles, as already mentioned, is invariably spherical. If this appearance were confined to certain limited areas, or only showed itself irregularly here and there, we could not consider it anomalous; but when we meet with the same spherical cavities throughout the entire mass of the amygdaloidal beds over an area many square miles in extent, it seems difficult to believe that the beds in question could ever have been in motion like any ordinary streams of molten rock. These and other considerations threw doubt upon the apparently igneous character of the rocks under review; and a careful examination of the district north of the village of Ballantrae eventually revealed their truly metamorphic origin. The coast-section north of Bennane Head first yielded what are considered to be the proofs of this metamorphic action. The same appearances frequently recurred in other places; but a condensed description of the part of the coast-section alluded to will perhaps suffice for the present.

Between Balcreuchan Port and Port Vad a most interesting series of rocks is laid bare. Distinctly bedded greywackés and shales occur sporadically, but are quickly surrounded on all sides by confused felspathic masses, for many of which we should require special names. Felspar-porphyries, felstones, amygdaloids, a remarkable green rock stuck full of stones, and brecciiform masses which look as if they had been violently pounded up in place are some of the varieties we meet with.

*Succession of Changes*:—1 a. *Unaltered Strata.*—The most unaltered beds hereabouts are red, brown, and greyish sandy greywackés. In places they are particoloured, showing yellow and green blotches, owing to the decomposition of alkaline matter, with which all the beds appear to be more or less charged.

1 b. *Slightly altered Strata.*—The next beds to be noted are more hardened, and often have a baked appearance; they also consist of greywackés—green, brown, red, and purplish blue. The dirty-green beds are always highly magnesian and calcareous; the grey and brown beds less so; the red beds still less so, often apparently with no recognizable amount of alkaline matter. The same may be said generally of the purplish-blue varieties, which, however, are not of common occurrence along this part of the coast. All these beds are much jointed, often to such an extent that they crumble down into little angular fragments. This is markedly the case with the compact red shales. The stratification is frequently contorted and crumpled.

2. *Granular Strata with Vesicular Areas.*—A little south of Balcreuchan Burn the greywackés upon the shore exhibit some very remarkable appearances. These beds, although altered to some extent, still show well-marked bedding, and are in places quite granular. Little specks of a reddish-brown shale, similar to the small hardened clay-galls in the greywackés of Peeblesshire, were occasionally detected. The beds are felspathic, and have a greenish tinge from the abundance of magnesian matter which they contain. Carbonate of lime also enters somewhat largely into their composition. Completely isolated and surrounded on all sides by this comparatively unaltered greywacké occur several vesicular areas. The matrix of these areas has the same general character as the rest of the beds, differing in

this only, that it never is pebbly or granular. They vary in diameter from a few inches to a foot and upwards across. In the smaller areas the form assumed is irregular; but as they increase in size they become bomb-shaped or rudely spherical. The amygdaloidal vesicles are always round, save where two or more have coalesced to form a confluent ragged cavity. They vary in size from that of the finest seed up to vesicles with kernels like small sweet peas. Larger cavities than this are rare. The "sweet-pea" cavities are for the most part aggregated towards the centre of a vesicular area, the vesicles decreasing in size as they approach its circumference. In this way each little amygdaloidal area shades off imperceptibly into the unaltered greywacké in which it appears to be imbedded. Outside of such an area the greywacké has usually a pasty aspect, not unlike the dull matrix of some highly basic trap, but not infrequently a granular texture; and even small specks of dark shale may be obtained only a few inches from the amygdaloidal portions of the rock. The vesicular areas most commonly occur not far from each other, but often they lie widely apart. We may obtain them in contact, or from an inch to several yards asunder, the intervening parts of the bed being always destitute of amygdaloidal structure, and frequently showing a granular and sometimes even pebbly texture.

The rocks which have just been described exhibit well-marked bedding, and alternate in places with coarse shales. The softer beds weather away, leaving the harder bands isolated; the joints are like those of typical greywacké, square, sharp, and well defined. In short, the general appearance of the beds is quite that of the Lower Silurian rocks in the unaltered regions of the surrounding country.

3. *Amorphous Green Paste-rock.*—In the peculiar masses that have next to be considered all trace of bedding has disappeared; the jointing is obscure and ramifying, and the general aspect of the rocks as unlike any regularly stratified deposit as it could well be. The masses referred to consist of a greenish pasty matrix, thickly set with felspathic bombs. At first sight the rock closely resembles a volcanic ash, and, as seen from the cliffs above, one would scarcely hesitate to call it so. The tough felspathic matrix weathers away with a rough, almost trachytic surface, leaving the bomb-like stones standing out in relief. It most usually assumes a dirty greenish hue, sometimes a dark brown. The texture is dull, like that of those portions of greywacké already described as encircling a vesicular area. We may define the matrix shortly as a greenish alkaline felspathic paste in which no distinct crystals are apparent. The pseudo-bombs are of all sizes, from fragments only an inch or two across to blocks several feet in diameter. When broken, their weathered crust is found to be only a line or so in thickness. They consist of purplish-blue and brownish-red felstone, fine-grained, and look as if they might all have been derived from one bed of felstone. The usual globular amygdaloidal cavities are also characteristic of nearly all the pseudo-bombs. These pseudo-bombs are therefore considered

to be identical in origin with the vesicular areas of the less altered greywacké beds. They occur in greater abundance than these last, thus evincing a more advanced stage of metamorphism—an inference which is further strengthened by the pasty aspect of the green felspathic matrix. The larger pseudo-bombs generally approach to a rounded form, and increase in numbers until they often impinge, and by their union form spheroidal masses of felspathic amygdaloid. When the pseudo-bombs press closely, the structure of the rock becomes columnar. The passage into felspathic amygdaloid can thus be distinctly traced.

4. *Felspathic Amygdaloid.*—A general description of the amygdaloid has been given above; but a few additional notes may be added here. It shows most usually a spheroidal structure; when it becomes columnar, the columns are found to obey no order in the mode of their occurrence. They seldom continue long in one direction, but occur at all angles to any given plane. Between this rock and the green paste-rock (or nascent amygdaloid) there is, as just pointed out, a close relationship. We therefore find the two rocks intermingled and blended in a very confused manner. Taking a general view of this part of the coast, however, there appears to be a rude alternation of pseudo-ashy beds with felspathic amygdaloid. Examined in detail, no such arrangement is visible. Here may be seen an irregular area of pseudo-bombs projecting from their green paste, surrounded on all sides by felspathic amygdaloid; there, again, may appear amorphous masses of amygdaloid completely enclosed in "green paste-rock." The amygdaloid becomes in places porphyritic with felspar, and passes into felspar-porphyry. During this passage the matrix gradually loses its basic appearance, and the amygdaloidal cavities decrease both in numbers and size. The rock thus insensibly shades into felspar-porphyry.

### B. *Felspar-porphyry.*

This is an intensely igneous-like rock. The felspathic matrix, which is sometimes sparingly magnesian, is of chocolate-brown and red colour, with a dull hard compact texture. It is profusely porphyritic, with tabular crystals of greyish felspar. Sometimes little spherical cavities may be detected in the body of the rock; but this is rare. At its junction with comparatively unaltered greywacké, however, the felstone is in some places punctured with numerous vesicles, which vary in size from mere pin-points up to the usual small "sweet-pea" cavities. In its central portions the rock is amorphous, but at its junction with greywacké it sometimes shows a spheroidal structure. The phenomena exhibited both by the felspar-porphyry and the greywacké on these occasions deserve attention. At the foot of Balcreuchan Burn we come upon an area of well-bedded greywackés, completely surrounded on all sides by crystalline rocks. The greywackés are often much crumpled and infinitely jointed, and some portions have undergone a peculiar brecciating process which will be described in the sequel. On their upturned ends rests an irregular cap of felspar-porphyry, which here assumes the character of an overlying trap, with a most uneven bottom. At its southern boundary it presents some remarkable appearances, losing its usual amorphous nature and becoming largely spheroidal. The spheroids have a reddish hard-glazed exterior, and show innumerable spherical cavities like mere pin-punctures, but occasionally larger. The spheroidal masses measure from two or three to five or six feet in diameter. At their junction with the greywacké, the portions visible are encased in shells about half an inch in thickness of hard fine-grained reddish greywacké, much jointed, and sometimes crystalline like felstone. To what extent the porphyry spheroids are enclosed in these peculiar greywacké shells or cases was not ascertained. When two spheroids impinge, the "case" in which each is enveloped appears as if it had been sucked in between the rounded masses of felspar-porphyry. The shells may be separated from the rock; and their inner surfaces are then found to be coated with porphyritic felspar crystals; but these crystals nowhere penetrate beyond the surface, to which they appear to be merely adherent.

In other places, where enveloping shells or cases are wanting, a distinct passage can be traced from the porphyry into the greywacké. The porphyritic crystals become gradually smaller, until at last they disappear, and thus leave a red compact or finely crystalline felstone. This rock, again, shades off into hard reddish greywacké.

The passage from amygdaloid into felspar-porphyry has been given above; the latter, indeed, is most commonly associated with the former.

*Recapitulation.*—Before attempting to describe the other forms of metamorphism displayed in this district, I may recapitulate some of the facts advanced, and state the inferences which seem to be fairly deducible from them.

An examination of the less altered rocks of the metamorphic region will show that the strata are of variable composition, some portions being more highly alkaline than others. The large amount of calcareous, and especially of magnesian matter is indeed very striking. This alkaline character of the strata may be considered one of the causes of that intense metamorphism to which many of the beds have been subjected; for those which contain the largest admixture of alkaline matter appear to have been peculiarly susceptible of change. The green magnesian and calcareous greywackés are often studded with vesicular and amygdaloidal areas; on the other hand the less alkaline deposits are frequently merely hardened, without assuming any pseudo-igneous structure. A broad general view of the whole series of strata thus gives alternating masses of more or less distinctly crystalline and altered rocks; but when viewed in detail the various metamorphic rocks are generally found to be confusedly mingled together, interlacing and blending in the most irregular manner.

The little patches of unaltered greywacké which occur here and there in midst of metamorphic strata are interesting, as they seem to throw some light upon the process by which the felstones, amygdaloids, and porphyries have been produced. Regarding the origin of the isolated amygdaloidal areas two opinions may be held. We may suppose the cavities to have been formed by gases during a pasty condition of the rocks, and the amygdaloidal minerals to have been subsequently introduced. In this case the origin of the vesicles would be entirely analogous to that of the cavities in lava. But evidence is not wanting which seems to lead to the inference that the vesicular nature of the altered wackés may be due to segregation, the excess of alkaline matter having separated from the felspathic matrix to store itself up in little globules. [The same kind of phenomena may be seen in many trap-rocks. Globules of quartz, which are clearly not due to infiltration, abound in some felstones, and they have also been detected in other igneous rocks.] Towards the centre of an amygdaloidal area the vesicles are largest, and from the centre outwards they gradually decrease in size, until they become so small as to require a lens to distinguish them. In this manner amygdaloidal areas shade off into the unaltered granular portions of a wacké. It would seem, therefore, that, as long as the metamorphic action proceeded, the vesicles increased in size until they had reached their maximum*. Towards the circumference of an area, as the action extended, the vesicles, it may be supposed, continued to expand by receiving fresh supplies of gaseous matter. The metamorphism, however, having suddenly ceased, left its work incomplete; and thus we find the smallest cavities at the edge, and the larger ones in the centre, of an amygdaloidal area. That vesicles, however, may have been formed by the segregation of amygdaloidal minerals † is rendered probable by the fact that the matrix in which they occur is commonly harder and more compact (in other words *less alkaline*) and of a darker colour than the surrounding wacké. It has also been pointed out that the hard non-alkaline beds with which the softer magnesio-calcareous wackés are interstratified have remained comparatively unaltered. So far as was seen they are never amygdaloidal. The number of globular cavities is always greatest where the rock undergoing alteration is most highly alkaline. Of course, it must be admitted that these appearances are also explicable on the assumption of the gaseous formation of the cavities; for the same action which could only impart a crystalline or semicrystalline texture to less basic strata might reduce highly alkaline wackés to a pasty condition in which gas-cavities would readily form. But, although the cellular character of these metamorphic rocks is doubtless mainly due to the expansive power of imprisoned gas, yet the occasional origin of the cavities by segregation must not be overlooked. Future chemical analyses will enable us to clear up this point.

* When the cavities are very closely aggregated, they are usually smaller than when they occur in less numbers.

† I refer here to cavities of magnesian and calcareous matter; it has been already stated that, associated with these minerals, zeolites and hard white felspar also occur in some places. Whether (on the supposition that the cellular nature of the rock is due to segregation) the zeolites and felspar are contemporaneous with or have supplanted the alkaline minerals can only be conjectured.

The amorphous green paste-rock with its pseudo-bombs, it was said, is only a more altered greywacké, the pseudo-bombs corresponding to the amygdaloidal areas of the distinctly bedded and less altered wackés. The whole appearance of this peculiar rock betokens a greater degree of metamorphism. The bedding has gone; the amygdaloidal areas or pseudo-bombs are in greater abundance; and their matrix is harder, and sometimes even semicrystalline. The manner in which these pseudo-bombs become aggregated, so as to form by their union masses of felspathic amygdaloid, has been described above.

It may be objected to this that the green paste-rock, instead of exhibiting an arrested stage of metamorphism, may be merely the decomposing wacké of an igneous rock. But the pseudo-bombs do not exfoliate like the spheroidal portions of a decomposing trap; their weathered crust (seldom thicker than a penny) is itself quite hard. The composition of the green paste differs considerably from that of the pseudo-bombs: the latter show apparently no alkaline matter, save in their amygdaloidal cavities; while the former is abundantly charged with it, and in its unweathered portions it has the same composition. It is difficult to believe that a rock so constituted could have resulted from the decomposition of a felspathic trap. If the pseudo-bombs were the only solid parts remaining of such a decomposed and weathered trap, we should expect to find them shading off into the surrounding decayed portions of the bed. But nothing of this is apparent. Their junction with the green paste is so sharply defined, that no one who sees that rock can for a moment suppose it to have resulted from the decomposition of a felspathic amygdaloid having the same mineralogical character as the pseudo-bombs. Bearing in mind the occurrence of distinct amygdaloidal areas in well-bedded and granular greywacké, I am convinced that in the green paste-rock we have just the same phenomena, but in a higher state of development.

The felspar-porphyry must be regarded as the maximum stage of metamorphism exhibited by the felspathic rocks of the district. The passage from granular sedimentary beds into this very igneous-like rock can be so well traced as to leave no doubt of its metamorphic origin; while the peculiar junction of its spheroidal portions with comparatively unaltered greywacké is quite unlike any junction of igneous and aqueous rocks. The manner in which the shells or cases are moulded round the spheroids of porphyry appears to indicate that they were once in a sufficiently pasty condition to allow of their being pressed outwards by the increasing spheroids of felstone. But it would almost seem as if their want of alkaline matter, by rendering them less easily assailable, had stopped the further progress of the metamorphic action in their direction. It is certainly very remarkable that, although we find the felspar crystals of the porphyry well developed on the surfaces of the spheroids, and even coating the concave side of the shell-cases, we yet cannot detect here a passage from the one rock into the other. Upon the whole, it is perhaps preferable to regard the cases of hard reddish rock as merely a stage in the metamorphism. We may suppose the porphyry spheroids, during the period of their outgrowth, to have been constantly surrounded with a paste of felspathic matter, in which the felspar crystals were generated. Thus, as the metamorphism proceeded, case after case would become obliterated and absorbed into the body of the rock, while, at the same time, new cases of felspathic stuff would continue to form on the fresh surface of each outgrowing spheroid.

The felspar-porphyry is only very sparingly amygdaloidal. The surface of the spheroidal portions is, indeed, often abundantly pitted; but the body of the rock rarely if ever shows any amygdaloidal cavities; nevertheless a passage from amygdaloid into felspar-porphyry may occasionally be traced. Some greywackés must therefore have passed through the stages of "green paste-rock" and amygdaloid before they at last became metamorphosed into felspar-porphyry. But the gradation to be observed from granular greywacké into finely crystalline felstone, and from that into porphyritic felstone, shows us that porphyry may sometimes be produced directly from aqueous rocks without an intermediate vesicular stage. All will depend upon the composition of the rocks undergoing alteration. If they are highly basic, a vesicular condition will probably precede the production of porphyry; if, on the other hand, the beds are less basic, a previous vesicular stage does not seem necessary to the formation of porphyritic felstone.

### C. *Brecciiform Rocks.*

The anomalous brecciiform beds which are now to be described are of sporadic occurrence. Followed along the general strike of the strata they quickly die out, even when they have attained a considerable thickness. They are typically developed on the coast near Bennane Head, and the beautiful hill of Knockdolian is made up of them. No description can convey an adequate notion of their character. Knockdolian Hill consists of a mass of brecciiform rock, entirely amorphous and unstratified, except in one or two places, where, however, the appearance of bedding may be due to jointing. The brecciiform fragments are of all sizes, from mere dust up to stones twice the size of a walnut; but much larger fragments are common enough: while most are of angular shapes, many have a somewhat rounded and subangular aspect, often bearing a striking resemblance to the small lapilli of a volcanic ash. They consist of fine-grained and compact felspathic rocks. Matrix is usually wanting, but is sometimes present in meagre quantity: when it occurs abundantly, the rock has all the appearance of a scoriaceous ash; and on such occasions it sometimes becomes difficult to distinguish it from the green paste-rock. The composition of the matrix is chiefly felspathic, with an admixture of crystalline carbonate of lime in some places. But, as just remarked, matrix is for the most part wanting, and the stones are huddled together in the direst confusion. In the rock of Knockdolian Hill one or two rounded stones were obtained, whose smoothed surfaces told their story of former attrition by water. But how they had come to be imbedded in the angular breccia, and what the origin of that breccia could be, there was no evidence in the hill to show. An examination of the coast-section, however, was more successful. Near Bennane Head the high road skirting the sea overlooks a large mass of Knockdolian rock. The shape of the stones hereabouts generally approaches to roundness, but they are often of very irregular form. Water-worn stones, some of them six inches across, are here not uncommonly intermingled with the angular and subangular fragments of which the great bulk of the rock consists. Some of these rounded stones show only a partially water-worn surface, the other portions being roughened and subangular. Such water-worn stones increase in number until we find them, in one place, forming a rude band, the direction of which corresponds with the strike of a little area of unaltered stratified wacké, which is here completely surrounded by amorphous Knockdolian-rock. It is noteworthy that the smoothest and more perfectly rounded stones are those composed of the hardest and most compact rock; while those which have lost their smoothed surfaces consist of less hard and compact rock and are very generally amygdaloidal, the vesicles being of the usual spherical shape. We are therefore justified in concluding that the brecciiform rocks under review have resulted from the alteration of beds of conglomerate. The stones often look as if they had been squeezed while in a softened condition. I have picked out two water-worn stones, which appeared to have been flattened against each other; and sometimes a somewhat rounded amygdaloidal stone would be found with with a harder pebble partially squeezed into it, and strongly adhering. A few stones, all much of a size, seemed as if they had been pressed together while in a softened state, and had thus assumed regular hexagonal forms.

There are several other points of interest in connexion with these brecciiform masses, especially as regards their relations to the green paste-rock; but their consideration at present would involve too much detail. In places where the original condition of the beds has been closer-grained or finely comminuted, we may have areas somewhat analogous to the pseudo-bombs of nascent amygdaloid: these, by their union, go to form a compact felstone.

The coarser parts of Knockdolian rock also shade off into a similar hard compact shattered felstone—a result brought about by the welding or soldering together of the angular brecciiform fragments*.

### D. *Finely Crystalline Felstones.*

A large proportion of the felspathic metamorphic rocks consists of finely crystalline and compact felstone. These rocks are well exposed at various points along the coast to the north of Bennane Head, but they are better seen upon the whole in the interior of the country, along hill-sides and in stream-sections. They seldom show

* Conglomerates in various stages of alteration have been examined in other localities of the district, and will be described in the Memoir of the Geological Survey to accompany the Map, sheet 7.

well-marked bedding; but occasional dips may be observed. Their general character is that of a shattered, close-grained, finely crystalline, sometimes compact rock, becoming coarsely crystalline and even porphyritic in places. Passages from hardened granular greywacké into semicrystalline rock, and from that into the close-grained felstone, are of common occurrence. Not infrequently areas of granular wacké may be obtained completely encircled by felstone, both being evidently parts of the same bed; and, on the other hand, portions of finely crystalline felstone make their appearance in the midst of comparatively unaltered wackés. These are certainly not dykes, nor intrusive masses, but are merely metamorphosed parts of the beds among which they occur; for they distinctly shade off into the semicrystalline and granular matter which encloses them. They seem in this way to be analogous to those vesicular areas so characteristic of some basic greywackés. The greywacké beds which have been partially converted into compact felstones are most usually fine-grained rocks with little or no calcareous or magnesian matter; and this insufficient supply of alkaline matter probably accounts for the absence of amygdaloidal cavities. Whenever the strata begin to get alkaline, the altered crystalline areas become amygdaloidal.

When the strata have originally consisted of alternations of very highly basic with less alkaline beds, the resulting metamorphic masses exhibit a great variety of rocks. Thus on the shore at Lendalfoot the sea-stacks and skerries show confused alternations of felstone, felspar-porphyry, hardened granular greywacké, altered limestone, hyperite, diorite, diallage-rock, serpentine, and occasional brecciiform beds; but although there is much confusion in detail, still, when viewed on the large scale, the direction of the masses agrees with the strike of the rocks of the district. The fine-grained felstones hereabouts are remarkable chiefly as showing how felspathic rocks may in places become diorites. In this metamorphic district no rigid line can be drawn between the two, either by mineralogist or geologist. Near Lendalfoot the felstones are often thickly studded with blotchy crystals of white felspar, which, being much harder than the matrix, stand out in relief on weathered surfaces. These crystals are aggregated in a very irregular manner. They are of small size where they are most abundant; but in the more sparsely porphyritic areas of the felstone they are usually larger, being sometimes an inch in length. Occasionally the beds show more or less distinct crystals of hornblende, which increase in number until, by their abundance, they impart a dark hue to the rock. This, then, we should call *diorite*. But for fuller details I must again refer to a forthcoming memoir of the Geological Survey.

### III. Dioritic Rocks.

The dioritic strata do not occupy so large an area as the felspathic rocks; they are also of more interrupted occurrence, frequently appearing as small lenticular layers interstratified with serpentines, but very rarely with felstones. The more extensive rock-masses present very much the same contour as the metamorphic felspathic strata, forming rounded hills and knolls with a somewhat lumpy outline.

Under the term *dioritic* are included all those rocks which consist essentially of silicates of lime and magnesia set in a felspathic base or matrix; but a description of the many phases presented by the class of rocks referred to is beyond the scope of this communication. They show every gradation of texture, from a rock nearly compact to dioritic masses in which the crystals often exceed an inch in length.

The principal varieties are diorite and hypersthenite, both of which are occasionally foliated. The felspar usually associated with hornblende and hypersthene in these rocks is a hard white variety. Diallage-rock occurs sparingly in one or two localities; sometimes a well-marked diorite exhibits crystals of white and clear quartz, and thus becomes a syenite.

Where the dioritic rocks are typically developed they are invariably associated with serpentine. With this rock they exhibit interesting junctions, to which reference will presently be made.

## IV. Serpentine.

Serpentine rock abounds throughout the district; it consists of two principal varieties—*foliated* or *schistose*, and *compact*.

1. *Schistose Serpentine.*—This is very plainly a bedded rock, and is generally interstratified with diorites. It varies in colour from reddish-brown to green. The folia correspond with planes of bedding; but in some places the foliation is rude and irregular, and, in the absence of well-marked dips in adjoining crystalline and gritty beds, cannot always be asserted to coincide with original lamination. Vein-like ramifications of diallage-rock, consisting of masses of diallage-crystals, sometimes intersect the schistose varieties of serpentine. The joints are often abundantly coated with soapstone, chloritic matter, and other silicates of magnesia and alumina.

2. *Compact Serpentine.*—This occurs in much larger masses. Dark and pale green are its usual colours, but areas of red and beautifully mottled green and red varieties are not uncommon. Sometimes it is poryhyritic with diallage, and very frequently with bronzite. Traces of bedding have seldom been observed in these rocks themselves; but the trend of the masses agrees with the strike of the rocks of the district, and interstratified lenticular beds of diorite are of common occurrence, thus showing that the compact serpentines, like the altered strata with which they are associated, are truly bedded rocks. The association of serpentine with limestone will be adverted to presently.

A few notes upon the coast-section between Pinbain and Lendalfoot may serve to throw some light upon the probable origin of the serpentines of this neighbourhood. On the shore near Pinbain occur some vertical beds of dark shales closely associated with a spheroidal brecciiform rock similar to some of those described above. These shales are often much twisted and broken, and are interstratified here and there with interrupted bands of altered wacké, which are also brecciated. There are many points of interest connected with the brecciiform stones at this place; but these cannot be considered here. The most notable feature about the beds is the occurrence of limestone in the shales. Among much disturbed and brecciiform beds may be seen a large block of limestone, four feet across. It looks as if it had been forcibly pushed into its present position; for the shales are all puckered and squeezed about it. Many smaller calcareous fragments occur in its vicinity. In their neighbourhood the beds are abundantly veined with carbonate of lime; but these veins are chiefly confined to an irregular band or area along the direction of the strike. There can be no doubt that the veins have resulted from the dissipating, *in situ*, of a limestone, they and the honeycombed and amorphous-shaped blocks being all that now remain of that bed. A yard or two from this point may be seen irregular nodular calcareous bands in dark greenish shales, which are here much less disturbed. The confusion observable in the former case must therefore in great measure be due to the withdrawal of the limestone. Leaving these shales and continuing the section southward we come at once upon highly metamorphic strata, consisting chiefly of serpentine with interbedded dioritic masses and occasional areas of felspar-porphyry. The bed immediately associated with the dark greenish shale is a serpentine; but the junction, unfortunately, is not well seen. There can be no doubt, however, that the schistose serpentine is merely a metamorphosed shale. All serpentine-rock contains less or more alumina, and many of the ophiolites of this neighbourhood are in this way very impure; indeed it is often impossible to distinguish between highly magnesian shale and impure schistose serpentine. Geologically, the latter is only an altered condition of the former. The veins of diallage which are sometimes found in these shaly and schistose varieties may not improbably represent calcareous veins similar to those that traverse the dark shales alluded to above, subsequent metamorphic action having converted them into diallage. The silica and magnesia necessary to this change would, of course, be derived from the impure magnesian rocks through which the veins ramify, and which at the time the veins were forming were assuming their present ophiolitic character. In like manner, the bronzite, especially in the more compact serpentines, may partially represent the carbonate of lime that was diffused through the rock before alteration began. Crystals of bronzite and diallage are so abundant throughout large areas of serpentine as frequently to form a *fifth*, and sometimes even a *third*, of the bulk of that rock. The condition of the beds before metamorphism ensued may therefore have been that of impure or muddy dolomitic or magnesian limestones. In support of this view it may be mentioned that, in less altered areas of the district, limestone has been met with which was sometimes magnesian.

Of course it may be said that this magnesian character has been superinduced by metamorphic action. Perhaps it has; and if the process of alteration had been continued, we might have had serpentine in place of an impure magnesian limestone. We must suppose that metamorphism is a gradual operation, and that the rocks acted upon assume various characters as the action proceeds. Serpentine is evidently an advanced stage in the process.

3. *Association of Diorite and Serpentine.*—The junction between serpentine and diorite is often very distinct; but in other places where the latter is fine-grained and highly magnesian, it passes so insensibly into the former that we are frequently at a loss to tell at what point we must cease to call the rock a *diorite*, and when we ought to begin to describe it as *serpentine**. In cases of this kind we may reasonably infer that the original composition of the beds which has given rise to the diorites shaded gradually into that of those more highly magnesian beds whose metamorphism has resulted in serpentine. On the other hand, when the junction between that rock and diorite is well marked, it appears probable that the composition of the various strata before metamorphic action began was also well marked, one bed not shading off into another as in the previous case.

A few notes on the better-marked junctions of serpentine with diorite may be interesting. As it approaches diorite, serpentine frequently becomes rudely schistose and sometimes quartzose—so much so that it might occasionally be described as a highly silicated felspathic schist, tinged green with magnesian matter. Here, also, it sometimes shows irregular interrupted bands of yellow, green, and brown Lydian-stones. The junction with the diorite is very irregular, the serpentine appearing as if it had been caught up every here and there, while occasionally long branching fingers of magnesian matter are protruded into the diorite. Small veins of diorite, also, in some cases pass into the serpentine. It is, no doubt, appearances of this kind which in some cases have led geologists to consider serpentine as of igneous origin. On the sea-shore at Lendalfoot many excellent junctions of the nature alluded to may be studied. The strata at this place are very much confused; nevertheless alternations of serpentine with diorites and felstones succeed each other in such a way as to indicate that we have here the original bedding.

## V. Limestone.

It now only remains to add a few words about the limestones †

* On the hills a little to the north-east of the village of Colmonell (river Stinchar) a very peculiar serpentine occurs. Interspersed throughout a base of dark-green serpentine (which in places is porphyritic with bronzite) abundant granules and interrupted nodular threads of white felspar make their appearance. The matrix in which this felspar occurs is *harder* than the other portions of the rock, where the serpentine presents its normal character. As this peculiar rock certainly passes into diorite (hornblende and felspar) there can be no doubt that the hardening of the green serpentinous matrix is due to the presence of lime in chemical union with the silicate of magnesia.

† These limestones have yielded fossils of Lower Silurian age, a list of which

and calcareous wackés. These, as we should expect, are of very limited extent. They never continue any distance, but speedily give way in all directions to metamorphic rocks. The limestone of Craigneil is a remarkable example. The hard and tough nature of this rock has enabled it to withstand denudation better than the more easily wasted conglomerates and altered wackés by which it is surrounded. It rises into a conical hill, the form of which is evidently due to glacial action. Although this bed is of considerable thickness, it yet dies out very suddenly along the strike; and the same appears to be the case with the limestone at Bougang. Of the Craigneil limestone itself not much need be said here, further than that it is a very impure rock, and ought in places to be termed merely calcareous greywacké. It is associated on the south side with schistose serpentine and conglomerate. To the west and east it is replaced by altered, crystalline and amygdaloidal greywackés.

*Association of Serpentine with Calcareous Strata.*—At Laffincleary, serpentine is curiously associated with a highly calcareous wacké and impure limestone. The serpentine occurs as veins and amorphous areas, and is itself veined with carbonate of lime. The calcareous beds have in places assumed the brecciiform structure of Knockdolian rock. On the old raised beach at Whilk, at Bennane Head, at Leffin Knowes, on the farm of Balnowlart, on Knockdolian Hill, in an old quarry at Bougang, at Knockdhu Bridge, and many other places, limestone or calcareous wacké is found abundantly intermingled with magnesian matter, and occasionally passing into serpentine. The rock is generally much confused and broken, the joints being coated with such silicates as steatite, chlorite, &c.

These calcareous areas are, as remarked, always of small extent, and occur quite sporadically, often with no apparent relation to each other. But occasionally they seem to follow a certain line corresponding to the direction of the strike. Little patches of serpentine, in the same manner, often make their appearance at intervals on a given horizon. Whether these last indicate the former existence of impure magnesian and calcareous wackés or limestones, like the sporadic beds just referred to, can only be conjectured.

With regard to the former extent of such limestones as those at Craigneil and Bougang not much can be said. Metamorphic action has in all probability considerably reduced their bulk; but there are good grounds for believing that they never covered any large continuous area, but, on the contrary, were from the first of partial and irregular occurrence.

## VI. Conclusion.

In the foregoing general sketch of the phenomena of this interesting region, speculations on the probable nature of the agent or agents by whose means the alterations were effected have been purposely omitted. It is usually much easier to say what has not caused such changes than to state what has; but in the present

will be found in Sir Roderick Murchison's memoir already referred to. *Vide* Quart. Journ. Geol. Soc. vol. vii. p. 154.

instance, at least, there can be little doubt that the metamorphism ought to be assigned to hydrothermal action. The very partial manner in which the strata have been affected—the frequent occurrence of unaltered areas among crystalline rocks and *vice versâ*—the various degrees of intensity which characterize the metamorphism, even when the beds undergoing change have much the same composition—all seem to point to the partial distribution of moisture or water in the strata at the time metamorphic action ensued, so that when heat began to attack the beds, its influence was aided in a greater or less degree by the amount of water present in the rocks. The probable source of this water will be considered presently.

Many portions of the strata have merely undergone a process of hardening, which has sometimes given to the beds a semicrystalline texture—a change which might be brought about without fusion or softening. But the appearances presented in some places require us to infer a former pasty or almost semifluid condition. It is unnecessary to recapitulate the evidence on this head; but reference may be made to a few of the facts already adduced.

The phenomena connected with isolated amygdaloidal areas are especially worthy of study. The little cells have attained their spherical shape at a time when the matrix had a certain plasticity. If this plasticity had been caused by dry heat, it is difficult to understand how the granular portions of the same beds should have escaped change, especially as their composition does not differ from that of the amygdaloidal areas. The whole series of phenomena associated with the gradual increase of separate amygdaloidal areas, and the progressive formation in this way of spheroidal and columnar amygdaloid, appear explicable only on the assumption of hydrothermal action.

The appearances presented by felspar-porphyry seem to bear out the same view. Nothing is more striking than the often close association of highly metamorphic with comparatively unaltered areas. Greenish granular wacké has been observed so close to felspar-porphyry that only a thin irregular ribbon of rudely schistose serpentinous matter kept the two rocks from touching. It was in this wacké that isolated vesicular areas were first detected; so that, although the beds retain in great measure their granular structure, yet they cannot be said to be quite unaltered. But that they should have experienced so little change in the immediate vicinity of a rock the nature of which evinces great intensity of metamorphic action is not a little surprising. It is not improbable, however, that the felspar-porphyry, having been reduced to a soft or viscous state, has been partially forced out of its position by the weight of superincumbent strata pressing upon it, and in this way intruded among other rocks which had not undergone the same degree of change. Of the truly metamorphic origin of the felspar-porphyry there can be no doubt. Its behaviour at other points has been referred to above.

Of the stones of the brecciiform rocks or altered conglomerates, it was remarked that they are for the most part of angular and subangular shapes, but often with a general approach to roundness, especially when imbedded in a matrix. The whole aspect of these stones forcibly suggests hydrothermal action. In many places the pebbles have been mutually squeezed, so as to become distorted, and sometimes to assume hexagonal forms, thus implying a somewhat softened condition*.

Without going into more detail, allusion may be made to an interesting point in connexion with certain metamorphic rocks of Lower Old Red age, belonging to another district of Ayrshire, situated some miles to the north-east of Girvan, on which the Survey was engaged during the past year. The rocks of this district are chiefly felspathic varieties, and present very much the same phenomena as has been shown to characterize the altered felspathic wackés of the Silurian strata. Near the farm of Knockdon, on the Water of Girvan, occur conglomerates and felspathic sandstones which have been converted in places into dark and light pink felstones. Many portions of these felstones were found to be porphyritic, often abundantly so, with fan-like radiating fibrous crystals of a dark greenish zeolite. Sometimes the same mineral occurred in amorphous blotches. These zeolites did not fill up amygdaloidal cavities, but were in every way analogous to the porphyritic crystals of a felspar-porphyry. We must therefore admit that, in some way or other, water has had to do with the production of these metamorphic felstones.

The nature and origin of the veins which traverse the metamorphic Silurian rocks of Carrick afford very strong support to this conclusion. I cannot enter here into the evidence which goes to prove that the thick ramifying veins of carbonate of lime, diallage, felspar, zeolite, &c., are all of the same age as the metamorphism, and are not due to subsequent infiltration. Veins of carbonate of lime have been described as proceeding from imbedded blocks of limestone; knotted strings of diallage crystals have been pointed out as forming part of the bed in which they occur; veins of felspar are associated with exceedingly coarse diorite in such a way as to show that their origin must be contemporaneous with that of the diorite; while abundant veins of a beautiful white fibrous zeolite, that traverse the strata in many places, are also to be assigned to the date of the general metamorphism. Mr. Richard Smith, of the Geological Museum, Jermyn Street, kindly undertook the analysis of this zeolite, the composition of which he ascertained to correspond with that of pectolite†.

* But such distorted stones must be carefully distinguished from the appearance presented by a fine-grained semicrystalline felspathic rock which seems to be entirely made up of little rounded pellets like pebbles. This, however, is a superinduced structure. The pellets vary from the size of peas to that of hazelnuts. When they press closely, they frequently become five- or six-sided. It is difficult to account for this peculiar structure; but that it has been induced by hydrothermal action, and not by dry heat, is borne out by the testimony of the surrounding metamorphic phenomena.

† Since Mr. Smith's analysis was made, I find that pectolite had been obtained by Prof. James Nicol from the same neighbourhood.

Assuming that the metamorphism of these strata has been mainly effected by hydrothermal action, a word or two may be added regarding the probable source from which the water has been derived. All rocks are found to contain a variable amount of water; but the strata nearest the surface of the earth are, for the most part, better saturated with moisture than the beds at lower depths. The supply, when derived from rains and the water of springs, rivers, and lakes, must from various causes be very partially distributed. If, therefore, the intensity of metamorphic change be influenced by the amount of water present in the rocks, we should expect to find the strata often showing sporadic areas of alterations. Nor need we be surprised when metamorphic beds occur superimposed upon less metamorphosed and unaltered rocks. With regard to wide regional metamorphism, like that of Canada, the Scottish Highlands, and Norway, it is probable that the strata acquired their metamorphic character while they lay underneath the bottom of the sea. During such a period or periods of submergence, water could not fail to find its way into the subjacent rocks, down through which it would continue to percolate until it reached a point where the conditions of heat might enable it to attack the strata and gradually effect their metamorphism. The action of the heated water would doubtless be often aided by the chemical reagents it held in solution, and the ultimate character of a metamorphic rock might not infrequently depend upon the nature of such acid and saline solutions. But the present aspect of the Carrick metamorphic rocks, at all events, is certainly not due to this cause alone, but chiefly to the original composition of the unaltered strata. The elements necessary to the formation of diorites and felstones were not introduced by water during the process of alteration, but already existed in the beds before metamorphic action began.

On the hypothesis that the water necessary to hydrothermal action has been supplied in the manner indicated, we can understand how the lower beds of the Silurians of Carrick have escaped alteration; for either the water percolating downwards never penetrated so far, or else was present in too small quantity to induce a wide-spread change. It is quite consistent with the views supported above, to suppose that during its downward passage the water may have been deprived of certain chemical reagents before it reached great depths, so as in some measure to have become weakened, and thus less capable of affecting the condition of the strata. When its passage, however, was aided by jointing and fractures, it might occasionally sink to great depths, and there give rise to metamorphic action. In this manner, we may account for those isolated areas of crystalline rock that occur among the unaltered strata, on a lower horizon than the chief metamorphic masses.

The only igneous rocks of the district are a few dykes of felstone and greenstone, which are evidently of much later date than the metamorphism. The granular wackés through which they pass usually remain quite unaltered, even at their immediate junction with the trap. Nor is there the slightest evidence of the existence of any underlying mass of igneous rock, the heat of which might be supposed by some to have caused the alteration of the strata. In the second metamorphic area to which I have had occasion to refer, igneous rocks are largely developed; but, curiously enough, the most highly altered strata occur at a distance from the intrusive traps. The rocks immediately surrounding one large mass of felstone, about a mile and a half in circumference, were for the most part quite unaltered. They consist of conglomerates and chocolate-coloured sandstones and grits. But outside of this unaltered area, felspathic grits and sandstones have become felstones, and conglomerates have been in places changed into bright-pink and fawn-coloured porphyry. We cannot, therefore, consider intrusive trap to have been the source of heat in the metamorphic areas referred to, and must thus accept the theory, so ably supported by many geologists, that the temperature necessary to metamorphic action has been derived from the central heat of the earth.

The facts advanced in the foregoing communication seem to prove:—

1st. That the strata owe their metamorphism to hydrothermal action.

2nd. That the varying mineralogical character of the rocks is due principally to original differences of chemical composition, and not to infiltration of foreign matter at the time of metamorphism.

3rd. That the highly alkaline portions of the strata have been most susceptible of change.

4th. That in beds having the same composition, but exhibiting various degrees of alteration, the intensity of the metamorphism has been in direct proportion to the amount of water passing through the strata.

5th. That in some places the rocks have been reduced to a softened or pasty condition.

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3. *On a* Cheirotherian Footprint *from the* Base *of the* Keuper Sandstone *of* Daresbury, Cheshire. By W. C. Williamson, Esq., F.R.S., Professor of Natural History, Anatomy, and Physiology in Owen's College, Manchester.

[Communicated by the Assistant-Secretary.]

(The publication of this paper is unavoidably deferred.]

[Abstract.]

The specimen in question was discovered by Mr. J. W. Kirkham, in the Lower Keuper Sandstone at Daresbury Quarry. It differs from all footprints hitherto obtained from this district, in being more quadrate, and distinctly that of a scaly animal; the separated toe is also less recurved, and approaches nearer to the other toes. The

arrangement of the scales corresponds very closely with that seen in the foot of the living Alligator; many of them run across the foot in oblique lines, as is common amongst living Crocodilians, leaving no room to doubt that they represent true scales, and not irregular tubercles, such as are seen on the skin of some Batrachians. Traces of other impressions of feet occur on the slab, particularly an imperfect one with much larger and more oblong scales, especially under the heel; and this difference is so very similar to what is seen in the fore and hind feet of many Saurians, that Prof. Williamson believed that they did not belong to a Batrachian animal at all, but that they were Saurian, if not Crocodilian, in every feature.

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## 4. A Description *of some remarkable* "Heaves" *or* Throws *in* Penhalls Mine. By J. W. Pike, Esq.

(Communicated by C. Le Neve Foster, D.Sc., B.A., F.G.S.)

This mine is situated in the parish of St. Agnes, in the county of Cornwall, and stands on the sea-coast, three or four hundred yards from the edge of a bold precipitous cliff rising to a height of 300 feet above the sea-level.

Pryce, in his valuable old book 'Mineralogia Cornubiensis,' and Carne and Hawkins in papers read some forty years ago before the Royal Cornwall Geological Society, together with many other writers, refer to the heaves of the celebrated Pink lode, which is now a part of Penhalls Mine.

A paper was also read in 1815 before this Society, by Mr. John Williams, entitled "Account of some Remarkable Disturbances in the Veins of the Mine called Huel Peever," the appearance of the lodes in which mine present the nearest approach to the dislocations in the Penhalls district.

The nature of the ground or "country" is a light-grey, distinctly stratified "killas" (the clay-slate of many geological writers, though not a cleaved rock) with a pretty regular dip towards the north of from 20° to 25°.

In the immediate neighbourhood of the workings the ground is traversed by:—

1. Four or five tin-lodes, varying from 4 feet to a few inches in width, dipping north at about the same angle as the killas, and composed of the oxide of tin, with a little iron and copper pyrites in the middle,—the walls or outsides, locally called capel, being a hard grey killas with quartz and schorl. The only distinction between the different lodes is in the appearance of the tin-stone, which varies in the size of the grain and in colour.

2. Three or four "downright" lodes averaging a foot in width and running east and west. Their composition is something between the tin-lodes and the "gossans;" indeed in depth they generally decrease in size and pass into gossans.

3. Numerous "gossans"* (lodes or veins), varying from a few

* A gossan in most parts of Cornwall consists very largely of an ochreous

inches to 3 feet in width, running somewhat about east and west, dipping, although mostly south, at various angles, and composed of a "voughy" or cavernous quartz, with crystals often coated with brown iron-ore, and copper and iron-pyrites. They often present a very irregular appearance, being split up in small branches.

4. A great number of "slides" or faults, of from 3 inches to a foot in width, dipping at various angles, and mostly with an east and west bearing. There are some, however, called "caunting" slides, running north-east and south-west. They are formed, no doubt, by the dislocations of the adjacent "country," consisting as they do of decomposed killas, as if the rock had been ground together and then acted on by water.

Lastly. Four cross courses (north and south veins), one only of which is of any consequence. It averages $3\frac{1}{2}$ feet in width, is nearly perpendicular, and is filled in with decomposed killas and masses of quartz.

The influence which these lodes and veins exert on each other will be seen in the transverse sections (figs. 1 & 2),—the tin-lodes (that is, Cowling's) and the Flat lode being thrown by the "downrights," gossans, and slides, the "downrights" by the gossans and slides, and the gossans by the slides, although there does not happen to be an example in the section of the latter case. A southern dip in the traversing vein throws the lode traversed up in going from S. to N., and a perpendicular or northern dip depressing it; in other words, the "hanging wall" of the traversing vein seems to have moved down, or the "footwall" to have moved up—the wider the traverse the further the heave. The cross course masters all the east and west veins, throwing them to the right hand a distance of from 20 to 30 fathoms, the tin-lodes being thrown further than those of more recent formation. The cross courses, however, have to yield to the "caunting" slides, as seen in an adjoining mine, which throw them a little on the side of the acute angle. The mineral productiveness of the tin-lodes is increased by the proximity of the gossans, but not by that of the slides.

As before stated, the dip of the "country" is generally pretty regular; yet still very marked evidence of disturbance can easily be perceived in some places, the line of stratification presenting a very wavy form. This is especially seen sometimes near the gossans and slides, where, at the immediate point of junction, the beds of killas are found to bend up on one side and down on the other, affording additional proof of the direction of the heave. The relative ages of all these veins may be at once determined from the above facts. Taking the well-known law, that a lode or vein traversed is older than the one traversing it, as a guide, we shall have:—

| | |
|---|---|
| 1. Tin-lodes. | 4. East and west slides. |
| 2. "Downrights." | 5. Cross courses. |
| 3. Gossans. | 6. "Caunting" slides. |

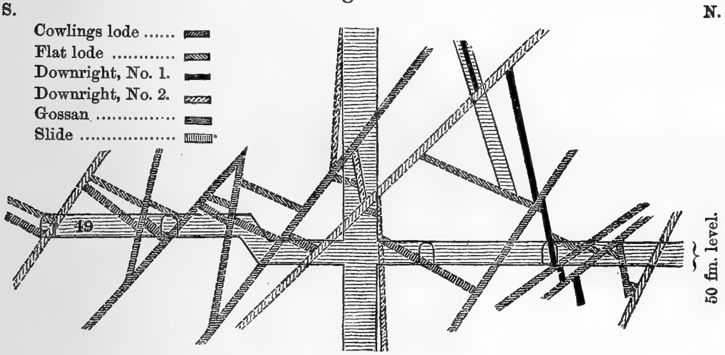
Slides, according to Carne, are generally considered to be of more

brown iron-ore. At St. Agnes the meaning attached to the term is somewhat different.

recent formation than cross courses; but in this district the contrary seems to be the case in those of an east and west bearing. It is needless to state how perplexing these "Will o' the Wisp" kind of lodes are to the miner, no sooner being found than lost; and although he may generally be able to tell which way to turn to regain them, yet still they have often been acted on by so many conflicting influences that he is sometimes at a loss how to proceed.

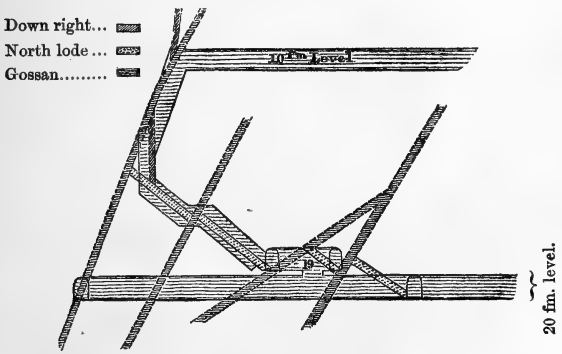
An instance of this complication can be seen in the section (fig. 1) in the engine-shaft, a little above the 50-fathoms level, where a downright, No. 2, acts on Cowling's lode, throwing it down, but just misses the flat lode, which is caught by the slide and thrown up.

Fig. 1.




Engine shaft.

Fig. 2.




The district has nevertheless yielded great riches, and has been worked from time immemorial.

## June 20, 1866.

The following communications were read:—

### 1. *On the* Structure *of the* Red Crag. By S. V. Wood, F.G.S.

Mr. Prestwich has, I believe, for several years inclined to the opinion that the Red and Fluviomarine Crags are coeval; but, so far as I am aware, he has not expressed that opinion in print. In 1863 my son had arrived at a similar conclusion; and in a paper by him, published in the 'Ann. & Mag. Nat. Hist.' for March 1864, he showed that the Chillesford beds overlie alike both the Red and Fluviomarine Crags, and that the Red Crag itself was not all of one age, but divisible into distinct portions, the uppermost of which he regarded as newer than the Fluviomarine, and intermediate in age between it and the Chillesford beds.

In December 1864 another paper by my son was read before this Society (but was afterwards withdrawn, and an epitome of it, together with a map of the Upper Tertiaries of the East of England, printed for private circulation), wherein he contended that the so-called Weybourne Crag, the Cromer Boulder Till, and the Contorted Drift formed a separate series, to which he assigned the term "Lower Drift," and that this in common with the Red and Fluviomarine Crags was overlain by the great body of sands which intervene between the Crag and the Boulder-clay, and to which he applied the term "Middle Drift," distinguishing the Boulder-Clay as the "Upper Drift."

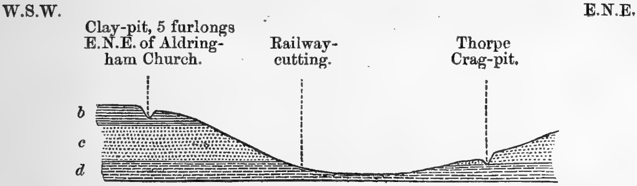
In November 1865 a paper, by the Rev. O. Fisher, was read before this Society (and published in their 'Quarterly Journal,' Feb. 1866), wherein he impugns the position of superiority which had been given to the Chillesford beds, and assigns their position in the following descending order:—1st, Fluviomarine (Norwich) Crag; 2nd, Chillesford Clay; 3rd, Mya-bed beneath the Clay; 4th, Red Crag.

In this state of things I determined with my son to reexamine the whole country between Woodbridge and Easton Bavent Cliff; and the result of that examination appeared to show the undoubted superiority of the Chillesford beds to the Fluviomarine Crag in the case of the pit at Thorpe, near Aldborough, as also in the pits at Bulchamp and Wangford.

In the first place I examined and collected from the shell-bed at the foot of Easton Cliff, and also in the pit found by Mr. Fisher at Yarn Hill. I quite agree with that gentleman that it is exactly the same bed as that in the micaceous sands discovered at Chillesford by Mr. Prestwich and others in 1849, and which Mr. Fisher designates as the Mya-bed,—the only difference being that the Easton and Yarn Hill development of it points to a somewhat estuarine character, by the absence of *Mya truncata*, so common in it near Chillesford, and by the substitution for that shell of *Mya arenaria*—a feature which the Yarn-Hill and Easton bed shares with what (as my son informs me) is identically the same bed, recently discovered by Mr. Rose at Toft Monks, on the Waveney, opposite Beccles. The shells which Mr. Rose has collected from this place (of which he has kindly sent me a list), with those collected by myself and Mr. Fisher at Chillesford and at Easton and Yarn Hill, now furnish a tolerably complete fauna of this formation.

The only pits of the true Fluviomarine or Norwich Crag (so far as my knowledge goes) that exist in Suffolk are three—one at Thorpe, near Aldborough, another at Wangford, and the third at Bulchamp. In the case of the first, although there is no evidence of oblique bedding, the bed dips at an angle of 7° or 8°, and I have no doubt that a slight fault or upheaval has taken place, bringing the Crag to the surface at this one point only, which is at some height above the base of the contiguous cliff at Thorpe. On the opposite side of the railway, however, and upon the top of the hill, occurs a pit of the Chillesford Clay. The bed is unmistakeable; and, as one stands at the edge of the Clay-pit, the Crag is visible, in the hollow below, at a distance of about a quarter of a mile, so that one may look down from the top of the Chillesford Clay, some 20 or 25 feet, on to the Crag exposed in the other pit (see fig. 1).

Fig. 1.—*Section showing the position of the Thorpe Crag-pit relatively to the Chillesford Clay* (3 furlongs).



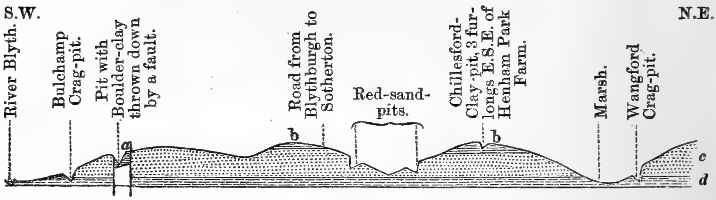

*b*. Chillesford Clay.
*c*. Red sands between Fluviomarine Crag and Chillesford Clay (*d* 3′ & 4′ of Diagram).
*d*. Fluviomarine Crag.

A little south of the line joining the two occurs a pit of red sand, belonging, as I consider, to the sands intervening between the Norwich Crag and the Chillesford Clay; the railway-cutting, a furlong still further south, is in the same sands. This is the pit in which Mr. Fisher says *Mytili* occurred, and which he regards as immediately underlying the Boulder-clay; the sands, however, I consider to be those intervening between the Thorpe Crag and the Chillesford Clay.

The Crag in the pit at Bulchamp, which is a few feet above the marshes of the Blyth, has, like the Thorpe pit, been subject to some disturbance, bringing it to the surface at this place only; for in none of the pits in the red sand around at the same level does the Crag appear; but in a pit about 2 furlongs to the north the Boulder-clay has been let down beside the red sand by a vertical throw, which, calculated from the place of the Boulder-clay on the neighbouring hills, cannot be less than 40 or 50 feet. No pit of Chillesford Clay now remains open near enough to this to show a satisfactory section.

At Wangford the Crag is at the surface continuously for about a furlong, at the bottom of a hill, and comes out with the red sands over it immediately above some marsh-ground. On the opposite side of the valley, divided from the Crag by this marsh, a Chillesford-Clay-pit occurs, on the top of the hill, distant about half a mile, occupying precisely the same position relatively to the Crag-pit as does the Chillesford-Clay-pit at Thorpe to the Crag-pit there (see fig. 2). Were it not for the interception of the view by a row of high trees, a

Fig. 2.—*Section showing the position of the Bulchamp and Wangford Crag-pits relatively to the Chillesford Clay* (2 miles).




*a.* Boulder-clay.
*b.* Chillesford Clay.
*c.* Red sands between Fluviomarine Crag and the Chillesford Clay (*d* 3′ and 4′ of Diagram).
*d.* Fluviomarine Crag.

spectator standing on the edge of the Clay-pit here would look down into the Crag-pit some 20 to 25 feet below him, in the same manner as is the case at Thorpe. Nothing but an actual vertical section (which would require to be 30 feet at least in height) could, I think, show more clearly the superiority, in these places, of the Chillesford Clay to the Fluviomarine Crag than do these two sections. With respect to the passage upwards of both the Fluviomarine and Red Crags into the Chillesford beds, it is only necessary to observe that there is nothing to indicate any break either physically or palæontologically. In the case of the Fluviomarine Crag the interval is represented by a mass of red sand, of which abundant sections occur around Wangford and Bulchamp, and which, as I have said, is in section at the Mytilus-pit of Mr. Fisher at Thorpe, and in the adjacent railway-cutting. The sand containing the shell-bed, which passes evenly into the Chillesford Clay, and shells of which occur in the base of the clay itself in the Cliff at Easton, is, I have no doubt, only the upper portion of these sands; but no sufficient section seems to exist to show the passage. In the case of the Red Crag this interval of sand is, as my son pointed out to me, occupied by the upper or horizontal portion of the Red Crag, exposed in the pit below the church at Chillesford—that to which I have further on to refer as the Scrobicularia-crag; but neither of us could form a positive opinion whether or not this Crag had been laid dry in the interval between its deposit and the overspread of the sand containing the Chillesford shell-bed (Mya-bed of Fisher). Pot-holes descend into it, but it is not altogether clear whether these are of the age of the sand, or of post-glacial origin; the even bedding of the sand over them seems, however, to point to the former. Be this as it may, I do not regard the break, if break there be, as anything more than the laying dry for a short period of the shoal-deposit of the Scrobicularia-crag prior to the overspread of the sand, and I now adopt the view expressed by my son that the horizontal Crag which rests on the oblique at Chillesford, and underlies the Chillesford beds, and which has always, and I think rightly, been regarded as part (although it be the uppermost part) of the Red Crag, is newer than the true Norwich or Fluviomarine Crag of Thorpe and Wangford.

The palæontological aspects presented by the Red Crag, however, are the principal objects to which I desire to call attention, as affording evidence of one of the most rapid changes in a fauna, when measured by the vertical thickness of the beds furnishing it, that geology affords; and as the most convenient and concise way of representing the beds between the base of the Crag and the Boulder-clay, to the lower portion of which my observations refer, my son has prepared the annexed diagram, with a list of the various sections from which it results, embodying the succession and relationof these various beds according to his latest researches (see pp. 548, 549).

In the case of the Coralline Crag, we have evidence that it contains the exuviæ of animals the most removed from our own marine fauna, in the fact that in it are the remains of 27 genera that are extinct in the British seas:—

| | | |
|---|---|---|
| *Cultellus. | Nucinella. | *Pleurotoma. |
| *Panopæa. | Hinnites. | Cassidaria. |
| Pholadomya. | Lingula. | Terebra. |
| Coralliophaga. | Orbicula. | *Columbella. |
| Chama. | Sigaretus. | Triton. |
| *Cardita. | *Pyramidella. | Pyrula. |
| Verticordia. | Fossarus. | *Voluta. |
| Erycinella. | *Cancellaria. | Ditrupa. |
| *Scintilla. | *Ringicula. | Cleodora. |

The genera marked with an asterisk are represented at Walton-on-the-Naze.

From this it is fair to infer that this Crag belonged to a period long antecedent to the deposition of the Red. Indeed so far as the word "Crag" indicates any material affinity between the two formations it misleads, since, remote as it is, and severed from the present time by a considerable sequence of deposits and events, the oldest part of the Red Crag is less removed, palæontologically, from the present time (and far less so from the Chillesford beds) than it is from the Coralline Crag thus associated with it in name, but dissociated from it in fact. The Red Crag, on the other hand, contains within itself the evidence of a transition by stages, from the oldest, where its affinities were to some extent with the coralline, and in a greater extent with the existing Mediterranean, to its newer stages, in which the shells are very few and confined to types peculiarly northern. Of these stages the oldest and best-marked is that of Walton-on-the-Naze: this Crag contains a fauna presenting a facies strongly indicative of an origin or connexion with more temperate seas; and although there is an absence from this bed of not less than 17 of those 27 genera before mentioned as belonging to the Coralline Crag (a few of which may perhaps be due to difference in depth of deposition), still the presence of such species as *Ovula spelta, Natica millepunctata, Tapes texturatus*, and *Cardita corbis*, now found only in the Mediterranean, gives a presumption that the seas which deposited these fossils were older than any other parts of the Red Crag. But the aspect of this portion of the Crag is not more marked by the presence of such forms as these, than it is by the entire absence from it of those species whose connexion is now with the colder regions of the north, such as *Panopœa Norvegica, Tritonium antiquum* (dextral var.), *Leda lanceolata*, and others; and it may be more especially remarked that in the Walton Crag there has not been obtained a single *unequivocal* specimen* of any species of the genus *Tellina*, while the shells in the upper beds of the Red Crag are composed mainly of individuals of one or other of the species of that genus.

*List of Species of Mollusca from the Crag at Walton-on-the-Naze.*

(*a* denotes abundance.)

UNIVALVES.

Ovula spelta, *Linn.*
Cypræa avellana, *J. Sow.*
—— Europæa, *Mont.*
—— retusa } *J. Sow.*, var.?
—— Angliæ }
Voluta Lamberti, *J. Sow.*
Columbella sulcata, *J. Sow.*
Nassa conglobata, *Broc.*
—— elegans, *Leathes.*
—— granulata, *J. Sow.*
—— propinqua, *J. Sow.*
*a.* —— reticosa, *J. Sow.*
Buccinum undatum, var. striatum.
*a.* Buccinopsis Dalei, *J. Sow.*
*a.* Purpura tetragona, *J. Sow.*
—— lapillus, *Linn.*
Murex tortuosus, *J. Sow.*
*a.* Tritonium antiquum, var. contrarium.
—— buccinatum?
—— costiferum, *S. Wood.*
Trophon muricatum, *Mont.*
Mangelia Boothii, *Smith.*
—— cancellata, *J. Sow.*
—— lævigata, *Phil.*
—— mitrula, *J. Sow.*
—— turricula, *Mont.*
Cancellaria coronata, *Scacchi.*
Cerithium variculosum (lima?).
—— granosum, *S. Wood.*
Cerithium tricinctum, *Brocchi.*
Turritella incrassata, *J. Sow.*
Aporrhais pes-pelicani, *Linn.*
Odostomia unidentata, *Mont.*
Pyramidella læviuscula, *S. Wood.*
Eulima polita, *Linn.*
Leptoxis? terebellata, *Nyst.*
——? pendula, *S. Wood.*
——? suboperta, *J. Sow.*
Trochus cinerarius, *Linn.*
—— cineroides, *S. Wood.*
—— ziziphinus, *Linn.*
—— papillosus?, *Dacosta.*
—— subexcavatus, *S. Wood.*
—— Adamsoni, *Payr.*
*a.* Natica catenoides, *S. Wood.*
*a.* —— hemiclausa, *J. Sow.*
—— helicina, *Broc.*
*a.* —— multipunctata, var. }
—— millepunctata }
Capulus Ungaricus, *Linn.*
—— obliquus (Piliscus?).
—— militaris, *Mont.*
Calyptræa chinensis, *Linn.*
Tectura virginea, *Müll.*
Emarginula fissura, *Linn.*
Fissurella Græca, *Linn.*
Actæon Noæ, *J. Sow.*
Conovulus pyramidalis, *J. Sow.*

BIVALVES.

Anomia, sp.
Ostrea edulis, *Linn.*
Pecten opercularis, *Linn.*
—— pusio, *Pennant.*
—— tigrinus, *Müll.*
Lima exilis, *S. Wood.*
—— Loscombii, *J. B. Sow.*
Mytilus edulis, *Linn.*
Modiola barbata, *Linn.*
—— costulata, *Risso.*

* There is one specimen of *T. prætenuis* in my cabinet with the locality of Walton attached, but it is of so old a date that I have now no recollection of it.

Bivalves (*continued*).

Modiola marmorata, *Forbes*.
a. Pectunculus glycimeris, var. subobliquus.
Arca lactea, *Linn.*
Nucula lævigata, *J. Sow.*
Kellia suborbicularis, *Mont.*
Scintilla ambigua, *Nyst.*
Montacuta bidentata, *Mont.*
Lucina borealis, *Linn.*
Cardium edule, *Linn.*
a. —— Parkinsoni, *J. Sow.*
—— venustum, *S. Wood.*
Cardita (senilis) sulcata?
—— scalaris, *Leathes.*
—— corbis, *Philippi.*
Astarte Basterotii?, *Lajonk.*
—— incrassata, *Broc.*
—— crebrilirata, *S. Wood.*
—— gracilis?, *Münst.*, var.
a. —— obliquata, *J. Sow.*
—— triangularis, *Mont.*
Astarte digitaria, *Linn.*
Cyprina Islandica?, fragment.
—— rustica, *J. Sow.*
Tapes virgineus, *Linn.*
—— texturatus, *Lam.*
Venerupis Irus, *Linn.*
Cytherea rudis, *Poli.*
Venus fasciata, *Dacosta.*
—— imbricata, *J. Sow.*
a. Artemis lentiformis, *J. Sow.*
—— lincta, *Pulteney.*
Gastrana laminosa, *J. Sow.*
Tellina crassa, *Penn.*
Abra alba, *W. Wood.*
—— fabalis, ? *S. Wood*, var.
Mactra arcuata, *J. Sow.*
—— truncata, ? ovalis.
—— deaurata, *Turt.* (fide *J. Brown*).
Solen gladiolus, *Gray.*
—— ensis, *Linn.*
Cultellus tenuis, *Phil.*
Cochlodesma complanatum, *S. Wood.*
Pandora pinna, *Mont.*
Corbula gibba, *Olivi.*
Corbulomya complanata, *J. Sow.*
Panopæa Faujasii?, *Mén. de la Groy.*
Saxicava rugosa, *Linn.*
a. Pholas cylindrica, *J. Sow.*
—— crispata, *Linn.*
Terebratula grandis, *Blumen.*

The next well-marked division of the Red Crag is that from which I obtained the principal part of the fauna described in the 'Monograph of the Crag Mollusca.' It occupies the country lying between the Stour and Deben, as well as the left bank of the estuary of the Deben; and its richest development in the yield of mollusca is on either side of that estuary. In physical structure it is unlike that of Walton (which is principally stratified horizontally, and due to subaqueous deposit), and possesses for the most part that highly oblique bedding which I now believe can have originated only in beach-action. In this crag we have the intermingling of the greater proportion of the Walton fauna with that northern fauna which forms the preponderating or characteristic feature of the succeeding horizons, to which I have hereafter to refer.

In the Sutton Crag the following species, common or not unfrequent at Walton, have never been found by me except under the suspected character of derivatives from the Coralline Crag—*Ovula spelta, Columbella sulcata, Nassa elegans, Natica catenoides, N. multipunctata, Nucula lævigata, Cardium Parkinsoni*, and others; while on the other hand the following species, foreign to the Walton deposit, occur, viz. *Tritonium antiquum* (dextral var.), *Cardium Grœnlandicum, Leda lanceolata, L. limatula, Cardium angustatum, Tellina lata, T. obliqua, T. prætenuis, Mactra ovalis, Mya arenaria, M. truncata*, and others. The peculiarly northern forms, however, so characteristic of the higher horizons, are comparatively rare, and the whole facies of the fauna presents the appearance of that transitional state which is intermediate between the more southern or Mediterranean fauna of Walton and the more peculiarly British and northern aspect afforded by the Crag of Butley, which I have now to mention. It will be convenient for reference if I designate this as the Sutton Crag.

The district intervening between the banks of the Deben and the exposure of the Red Crag around Butley is occupied by high heath-land formed of the sands interposed between the Crag and Boulder-clay; and, the coast-line corresponding to it being low, we have no recurrence of the Red Crag until we come upon that exposed by the denudation of the Alde valley around Butley, Chillesford, and Sudbourn. The Crag there, although in physical structure entirely resembling that between the Deben and the Stour, possesses a dissimilar fauna. In it there are, however, many of the forms which characterize the Sutton Crag; yet they are subordinate to those of northern aspect, which begin here to preponderate. For instance, although *Pectunculus glycimeris*, which is so abundant in both the Walton and Sutton horizons, is present, and in the lower part of the Butley Crag not uncommon, yet it becomes subordinate to such forms as *Tellina obliqua*, *T. prætenuis*, and *Cyprina Islandica*, which here begin greatly to prevail. In the upper portions of this Crag, namely that upon which at Chillesford and Tunstall Heath the Scrobicularia-crag rests, this feature is yet more marked, and the *Pectunculus* becomes a rare shell, while *Mya truncata*, *Tellina obliqua*, *T. prætenuis*, *T. lata*, *Cyprina Islandica*, and *Mactra ovalis*, which form an enormously preponderating proportion of the Chillesford bed (*e* of diagram), become especially abundant. This is the Crag which is found at the base of the pit below Chillesford church, in several of the pits in Butley parish, and in that one pit near Sudbourn church in which the Red Crag is seen resting on the Coralline. It also occurs in a run-down pit upon Tunstall Heath.

Resting upon this Crag, in the pit under Chillesford church, occurs the uppermost portion of the Red Crag. It is slightly oblique at the base, but becomes horizontal in its upper beds, gradually losing that red colour to which the Red Crag owes its name. The actual horizon at which this Crag sets in is marked in a distinct manner by the incoming of a shell not yet found in the lower horizon, namely *Scrobicularia piperata*. This shell, although thus abruptly appearing, occurs in profusion, and in association almost exclusively with those forms which greatly preponderate in the Chillesford beds, namely *Cyprina Islandica*, *Mactra ovalis*, *Tellina obliqua*, *T. lata*, *T. prætenuis*, and *Mya truncata*. These shells form almost the entire fauna of the uppermost portion of the Red Crag, showing a great contrast to the richer fauna of the older horizons. The *Scrobicularia* again becomes extremely rare in the Chillesford beds. Only one other pit is known to me in which this Crag occurs: it is on Tunstall Heath, distant 6 furlongs N.E. by E. from Chillesford church, marked on the Ordnance Map "Sandpit." Divided from this Crag by only about 4 or 5 feet of brown sand, occurs the true Chillesford bed described by Mr. Prestwich in 1849, and industriously searched by me afterwards. The fauna derived from this bed (*e* of diagram) and from the other exposures of the same formation in northern Suffolk is contained in the subjoined list:—

*List of Shells from the Chillesford Beds.*

| | Chillesford. | Easton Bavent. | Toft Monks, Upper bed. | Yarn Hill. | |
|---|---|---|---|---|---|
| Buccinum undatum, *Linn.* | * | ...... | ...... | * | Rare. |
| Tritonium antiquum, *Linn.* | * | * | * | ...... | Rare. |
| Purpura lapillus, *Linn.* | ...... | * | * | | |
| Cerithium tricinctum ?, *Brocchi* | ...... | ...... | ...... | * | |
| Turritella communis, *Risso* | * | | | | |
| Litorina litorea, *Linn.* | * | * | * | * | |
| Natica catena ?, *Da Costa* | * | * | ...... | * | |
| —— Guillemini | ...... | ...... | ...... | * | N. Alderi? (*Fisher.*) |
| —— clausa, *Brod. & Sow.* | ...... | ...... | * | | |
| —— helicoides, *Johnston* | ...... | * | | | |
| Actæon tornatilis, *Linn.* | ...... | * | | | |
| Ringicula buccinea | ...... | ...... | ...... | * | (*Fisher.*) |
| Paludina lenta | ...... | ...... | ...... | * | (*Fisher.*) |
| Succinea oblonga | ...... | ...... | ...... | * | (*Fisher.*) |
| Mytilus edulis, *Linn.* | * | * | * | * | |
| Pecten opercularis, *Linn.* | * | * | | | |
| —— tigrinus, *Müller* | ...... | ...... | * | | |
| Modiola discrepans ?, *Mont.* | * | | | | |
| Nucula Cobboldiæ, *J. Sow.* | * | * | * | | |
| —— tenuis, *Mont.* | * | | | | |
| Leda lanceolata, *J. Sow.* | * | ...... | ...... | ...... | Not uncommon. |
| —— limatula (myalis) | * | * | * | * | *Id.* |
| —— semistriata, *S. Wood* | ...... | ...... | * | ...... | Fragments. |
| Cardium edule, *Linn.* | * | * | ...... | * | |
| —— fasciatum, *Mont.* | ...... | ...... | * | | |
| —— Grœnlandicum, *Chemn.* | * | * ? | | | |
| Cardita senilis, *J. Sow.* | ...... | ...... | * | | |
| —— scalaris | * | ...... | ...... | ...... | (*S. P. Woodward.*) |
| Scintilla ambigua, *Nyst* | * | | | | |
| Lucina borealis, *Linn.* | * | ...... | * | | |
| Cyprina Islandica, *Linn.* | * | * | * | * | Fragments. |
| Astarte sulcata, *Da Costa* | ...... | ...... | * | | |
| —— compressa, *Mont.* | ...... | * | | | |
| Tellina crassa, *Pennant* | * | | | | |
| —— lata, *Gmel.* | * | * | * | * | Abundant. |
| —— obliqua, *J. Sow.* | * | * | * | * | *Id.* |
| —— prætenuis, *Leathes* | * | * | * | * | *Id.* |
| Mactra ovalis, *J. Sow.* | * | * | * | * | *Id.* |
| —— subtruncata | ...... | ...... | ...... | * | (*Fisher.*) |
| Scrobicularia piperata, *Gmel.* | * | ...... | ...... | ...... | One specimen. |
| Abra alba, *W. Wood* | * | ...... | * | | |
| Panopæa Norvegica, *Speng.* | * | | | | |
| Corbula gibba, *Oliv.* | ...... | * | * | | |
| Mya arenaria, *Linn.* | ...... | * | * | | |
| —— truncata, *Linn.* | * | ...... | ...... | ...... | Abundant. |

Besides the above, Mr. John Taylor, of Norwich, has given, from what he terms the Upper Crag at Bramerton, Postwick, and Thorpe (which my son regards as the Chillesford bed), *Astarte borealis*, *Lucina divaricata*, *Scalaria Grœnlandica*, and *Calyptræa sinensis*.

In addition to this, Mr. Rose has sent me the names of the following species from Toft Monks, from the "Lower bed;" but as this may not improbably belong to the horizon of the Fluvio-marine Crag itself, or at least of the sand intervening between that Crag and the Chillesford beds, I append them separately, viz.:—

| | |
|---|---|
| Pecten opercularis. | Circe minima. |
| Pinna. | Donax trunculus. |
| Nucula nucleus. | Saxicava rugosa. |
| Leda myalis. | Clavatula turricula. |
| Diplodonta rotundata. | Cancellaria costellifera. |
| Venus ovata. | Scalaria Grœnlandica. |
| Tapes perovalis (?). | Ringicula buccinea. |

The foregoing list from Toft Monks is entirely on the authority of Mr. Rose; the others are upon my own, unless where otherwise expressed.

With respect to the false-bedded and horizontal or water-deposited Crag, which seems to occur in channels cut through the oblique or Beach Crag of Sutton, and at the base of which only the Coprolite-beds occur, it is difficult to bring it into a satisfactory correlation with any of the other horizons to which I have alluded. The bed is composed of such degraded materials, being in the upper part almost entirely comminuted, that one cannot resist the inference that it has been derived, in great measure, from the destruction and redeposit of the material of the oblique Crag which surrounds it. From this circumstance, its fauna cannot be satisfactorily arrived at, as the greater portion may be, and probably is, derivative; added to which, the existence of the phosphatic nodule-band, with its miscellaneous assemblage of fossils of various ages, marks it as something altogether distinct from the beds of the Red Crag in contact with it. I have myself verified the fact which has been pointed out, that angular and apparently ice-borne chalk-flints occur in it; and this circumstance would certainly seem to point to its age being rather that of those upper horizons which I have described, in which the northern forms prevail, and where ice-transport came into action, than that of the surrounding oblique-bedded Crag of Sutton, in which so large a proportion of the more southern types that are peculiarly the characteristic of the Walton Crag are intermingled: and it may be, as my son supposes, that the lower part of this Crag is the water-deposited equivalent of the highly-beached and oblique Crag of Butley and Chillesford, and the upper that of the Scrobicularia-Crag. Certain it is that, unlike the oblique Crag, which everywhere presents a rugged surface to the red sands which overlie it, this phosphatic nodule-crag passes up into those sands by interbedding.

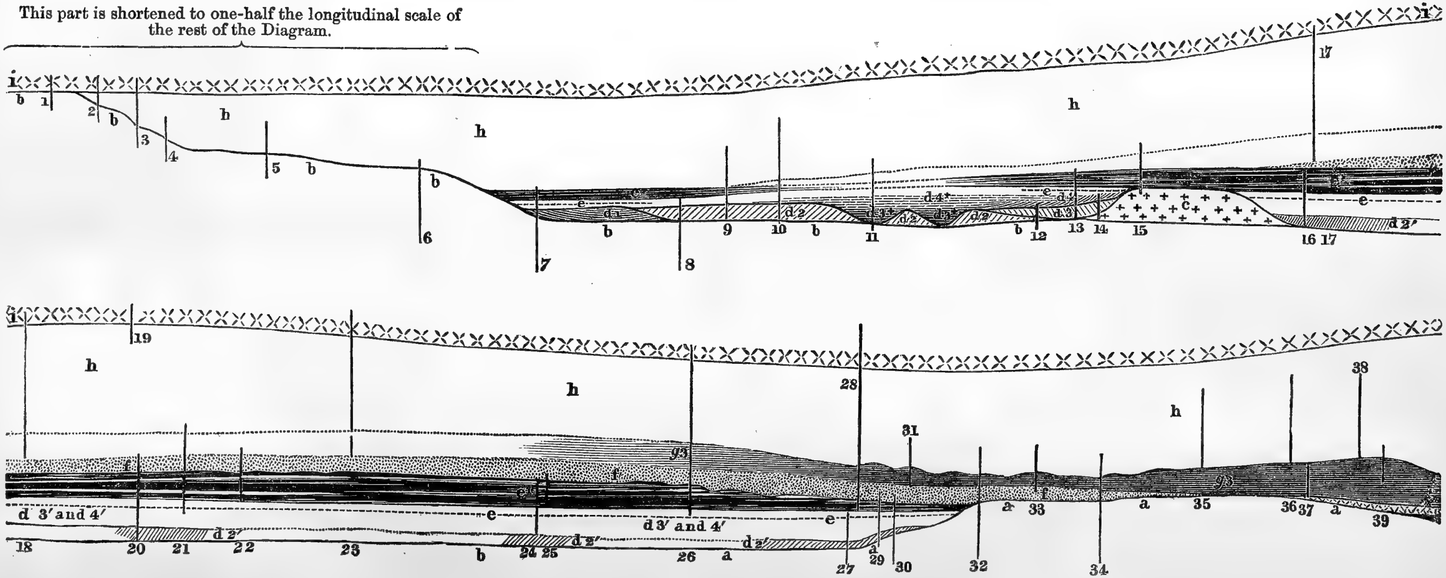
## EXPLANATION OF THE DIAGRAM SECTION.

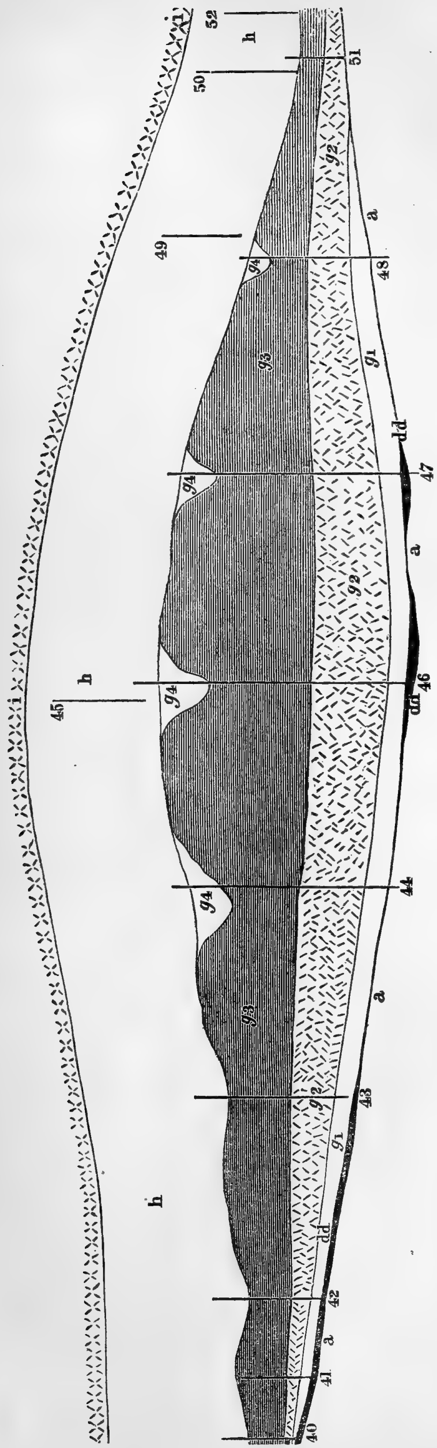
By S. V. Wood, Jun., Esq., F.G.S.

The line of section starts north from a point about 6 miles south-west of Chelmsford, and proceeds through Chelmsford and Witham to Colchester; then turning east, reaches the sea near Walton Naze. It proceeds thence to near Woodbridge, whence it turns north-east, and reaches the coast again at Aldborough, which it follows as far as Pakefield, whence, turning north-west, it is carried through Beccles, Rockland, Bramerton, Brundall, and Thorpe, to Norwich. Proceeding thence in a northerly direction through Wroxham, Coltishall, and North Walsham, it reaches the coast again at Hasborough, and follows the coast to Weybourne, and, running thence parallel to the coast, terminates near Wells.

*a*, Chalk. *b*, London Clay. *c*, Coralline Crag. *d*, Red and Fluviomarine Crag, divided as follows:—$d^1$, Walton Crag; $d^2$, Sutton oblique or Beach Crag; $d^3$, Butley oblique or Beach Crag; $d^3+$, Horizontal Crag, with phosphatic nodule-band at the base; $d^4$, Scrobicularia-crag, slightly oblique at the base, but horizontal in the upper part; $d^4+$, Alternations of sand and comminuted shell overlying phosphatic nodule-Crag (equivalent of $d^4$); $d^{2\prime}$, Fluviomarine Crag; $d^{3\prime}$ and $d^{4\prime}$, Unfossiliferous sand (equivalents of $d^3$ and $d^4$); these sands are 20 feet and more in thickness around Southwold and Aldborough, but attenuate near the edge of the Crag in Norfolk, thinning there from 11 to 4 feet in different sections. *e*, Chillesford shell-bed (*Mya*-bed of Fisher; and at Bramerton, Postwick, and Thorpe near Norwich, this is the Upper Crag of J. Taylor); this bed is not constant, although the sand containing it is so: the prevalent shells of this bed are *Tellina obliqua*, *T. prætenuis*, *T. lata*, *Cardium edule*, *Purpura crispata*, *Litorina litorea*, *Cyprina Islandica*, *Mactra ovalis*, and, at Chillesford, *Mya truncata*: the *Tellinæ* prevail over all others; mammalian remains occur in it at Chillesford, Easton Cliff, and Saxlingham; *e′*, The Chillesford Clay; laminated clay interbedded with sands at the top; the base of this clay contains in places the shells of *e*. *f*, The Bure-valley beds: these are fossiliferous only in places, and only where they rest on the chalk, the shells occurring in small patches; they consist of sands with shingle-beds: the prevalent shells are *Tellina obliqua* (very common), *Cyprina Islandica*, and *Cardium edule* (*T. prætenuis* and *T. lata* cease to prevail): these beds are often considerably indented into *e′*. *g*, The Lower Drift, or Lower Glacial, divided as follows:—$g^1$, The Weybourne sand; this thins out between Mundesley and Bacton. East of Cromer it is generally stained with the débris of beds *dd*, and becomes in places, particularly towards Mundesley, laminated with clay bands, in which condition it forms the laminated beds of the Rev. J. Gunn. Between Cromer and Weybourne it (or at least the base of it) forms the Norwich Crag of Samuel Woodward, of Sir Charles Lyell, and of the Rev. J. Gunn. The prevalent shells are *Tellina obliqua*, *Cyprina Islandica*, *Purpura crispata*, *Cardium edule*, and *Tellina Balthica* (*solidula*), which latter shell here makes its appearance in profusion. The occurrence of this shell at any lower horizon is doubtful; and *if* it does occur, it must be excessively rare. It is given by S. P. Woodward from Postwick "top bed;" and a specimen is in the Norwich Museum, marked from Coltishall; but these are doubtful localities. *Tellina lata* and *T. prætenuis* have either disappeared at the horizon of $g^1$, or become too rare to be readily detected. It also yields mammalian remains. $g^2$, The Cromer Boulder-Till (Boulder-clay of Sir Charles Lyell and Lower Boulder-clay of the Rev. J. Gunn). This at one extremity passes into a white marl, formed of redeposited chalk finely ground up. $g^3$, The Contorted Drift. This bed ceases to be contorted east of Mundesley, and becomes regularly and closely stratified. Between the termination of the coast-section (at Hasborough) and North Walsham, it passes into a tenacious green Brick-clay; approaching the coast, near Yarmouth, it changes to a reddish sandy brick-earth, and further south into red sand. West of Weybourne it changes into chalky loam and sand with chalk-grains. $g^4$, Intermediate beds of gravel occupying deeply-cut troughs through $g^3$ and $g^2$ and underlying *h*. *h*, Middle Drift or Middle Glacial: sand and gravel. This bed is chiefly fine, light, yellow, siliceous sand; but towards London, and where present in the more central counties, is extensively interbedded with gravels, and sometimes with thin beds of sandy brick-earth. *i*, The Upper Drift or Upper Glacial, being the widespread true Boulder-clay, of great thickness before denudation. *dd*, The Forest-bed and gravel, containing fluviatile shells and mammalian remains, being probably the land equivalent of the beds from $d^1$ to *f*. This has been destroyed in part by the waters of $g^1$. N.B. The so-called Forest-bed at Easton Bavent is a post-glacial and very recent peat, occupying the valley-bottoms and occurring on the beach only in the places where the valleys open to the sea. The dotted lines show the continuation of deposits, where their distinctive characters are obscure, or where they are represented only by an undistinguishable mass of sand, except in the case of the Fluviomarine Crag ($d^{2\prime}$), which may not be continuous, but possibly the deposit of more than one estuary.

Fig. 3.—*Diagram representing the structure of the beds between the base of the Red Crag and the base of the Upper Drift (Boulder-clay).* By S. V. Wood, Junr., F.G.S. (200 miles).





40
41
42
43
44
45
46
47
48
49
50
51
52
a
dd
g1
g2
g3
g4
h
i

The perpendicular lines in the diagram indicate the sections afforded at the following places:—

1. That by numerous pits south-west of Margaretting, in Essex.
2. That by Margaretting railway-cutting and by pits in the Chelmer valley above Chelmsford.
3. That by the railway-cuttings and by pits between Chelmsford and Marks Tey. N.B. h *is unavoidably represented too thin in the above localities.*
4. That by the cuttings near Colchester.
5. That by the cuttings of the Tendring Hundred Railway, between Colchester and Thorington.
6. That by Frinton Cliff, near Walton-on-the-Naze; *h* remains here in patches of only a few feet in thickness, capped by a warp containing fragments of *i*.
7. That by Walton-on-the-Naze Cliff. The beds $e'$ here overlap the Crag and rest on the London Clay to the south, but not at the north end of the cliff; *e* occurs in a few faint patches only, and the shells are too decayed for extraction.
8. That by Bawdsey Cliff.
9. That by a pit immediately on the Sutton side of the Woodbridge ferry, and by a pit a furlong south of Ferry farmhouse, Sutton. In the former pit the beds $e'$ are slipped from their place, and are marked by a clump of trees growing on them, but in the latter are *in situ*.
10. That by the pit at Wilford Bridge over the Deben, and by numerous pits in Ufford adjoining. The Crag is found by digging in the Wilford-Bridge pit. (The vertical line 10 should have been drawn only into the upper part of $d^2$.)
11. That by the Coprolite workings of Sutton, Shottisham, Foxall, Newbourn, and Brightwell.
12. That by the pits at Butley, near the Abbey, and near the Oyster Inn.
13. That by the pit behind, and by that below Chillesford church. N.B. The Boulder-clay (*i*) has, by a down-throw, been slid obliquely on to $e'$ in the former pit; but *i* and *h* may be seen in their true relation in a pit distant one furlong N.N.W. *i* may also be seen faulted down beside $d^{3\prime}$ and $d^{1\prime}$ in a pit (marked "*Sand pit*" in the Ordnance map) by the river, 9 furlongs E.S.E. of Chillesford church.
14. That by a pit 7 furlongs N.E. by N. of Sudbourn church.
15. That by several pits in Iken and in parts of Sudbourn from 2 to 3 miles N. and N.E. of Sudbourn church. N.B. By reason of the tortuous boundary afforded by the ridge of Coralline Crag rock to the bay in which the Red Crag was accumulated, the Red Crag reenters the district, as a spit, near Section 14, and does so again in small dimensions at Aldborough. This is not shown in the diagram.
16. That by the clay-pit 5 furlongs, and by the (Thorpe) crag-pit one mile E.N.E. of Aldringham church, and by the sand-pits and railway-cutting south of the crag-pit.
17. That by the country between the clay-pit and the west side of Aldringham Green.
18. That by Dunwich Cliffs. N.B. $g^3$ is represented in these cliffs by a dark-orange sand which comes up in the southern part of the cliff-section; *h* is very thick here (about 50 feet). *i* occurs for a few yards only, and immediately north of the ruins. There is also a deep bed of post-glacial gravel under the ruins, and a later post-glacial yellow loam, as well as a black warp over all.
19. That by Southwold Cliff. The cliff is too obscure to show whether the sand forming much of it is *h*, or is post-glacial; but at the north end (at the kiln) *i*, together with thick post-glacial beds capping it, and containing freshwater shells, has been thrown nearly into the vertical.
20. That by the clay-pit 2 furlongs east, and the crag-pit 4 furlongs north-east, of Henham-Park farm; and by various sand-pits along the Blyth valley. N.B. *i* may be seen faulted down beside $d^{3\prime}$ and $d^{1\prime}$ in a pit by the farm-house 3 furlongs E.S.E. of Bulchamp Workhouse, and the same distance N.N.E. of the Bulchamp crag-pit. A pit of oblique-bedded rounded pebbles occurs close to the 101 milestone, E. of Henham Hall, and another

6 furlongs N.N.W. of it, which are worthy of special visit; the latter shows continuous oblique bedding in a vertical section of 25 feet. They seem to be beaches of the age of *f*, but may be of that of $d^2$. In the clay-pit a piece of the upper bed of $e'$ has been transported, dropped again, and interbedded with *f*.

21. That by Easton Bavent Cliffs.
22. That by Covehithe Cliff. N.B. There is a bed of loam, sometimes contorted, resting on a denuded surface of $e'$ at the north end of Easton and south end of Covehithe Cliff; but it seems to be post-glacial and to have no connexion with $g^3$. There is also a post-glacial gravel-capping to the cliff, and a more recent sand in the valley-depression. Similar sections to 21 and 22 occur in several brick-fields between Wangford and Frostenden.
23. That by Pakefield Cliff. $g^3$ comes up at the base of the cliff, but is better exposed at Corton Cliff, 6 miles further north (and out of the line of section), where it is at one part contorted, with gravels in the contortions; *h* is here thinner, varying from 25 to 35 feet.
24. That by the Brick-field at Toft Monks, near Beccles, 5 furlongs N.N.W. of the 110th railway mile-post. N.B. The gravels capping *e* in the section are *not* the bed *f*, but post-glacial. Post-glacial gravels also occur in a pit immediately north of the kiln, sharply faulted down beside *h*. By ascending from the Brick-field for a furlong, the beds up to and including *i* are passed over.
25. That by the Brick-field at Ingate, Beccles.
26. That by numerous pits near Rockland Staith, and in Surlingham (6 miles east of Norwich). In one pit at Rockland Staith, $g^3$ is faulted down beside *f*. In a pit at Surlingham Wood the upper beds of $e'$ are laterally squeezed up, the lower remaining horizontal. The upper beds of $e'$ are also much eroded by the shingle-beds of *f*. The sections in *h* and *i* are on the top of the hill.
27. That by the Bramerton Crag-pit.
28. That by the hill descending to the Crag-pit.
29. That by the pits behind Brundall Station, and beside the railway 4 furlongs west of that Station.
30. That by the Crag-pit at Thorpe, near Norwich. N.B. The Postwick-Grove Crag-pit adjoining includes from $d^{2'}$ to *e* only. In the section in the pit east of Postwick Church $d^{2'}$, $d^{3'}$, and $d^{4'}$ seem absent, and *e* to rest on the chalk, showing the rapid approach of the edge of the deposit. The same is the case at Saxlingham, which is out of the line of section. At the pits on Smockmill Common, Saxlingham, the shells are in a friable condition, and *e* is sand; but at the pits 3 furlongs W.N.W. and 5 furlongs S.W. by W. respectively from the Baptist Meeting-house, Saxlingham, *e* is in the condition of gravel with mammalian remains, *e* at these places resting on the Chalk. $e'$ caps *e* in all the pits at Saxlingham, although its development is feeble.
31. That by the Brick-earth-pit, 2 furlongs N.N.W. of the Thorpe Crag-pit, and the Brick-field one furlong further N.N.W.
32. That by numerous chalk-quarries and brick-pits near Bishop's Bridge, Norwich, and on the Catton side of Mousehold Heath. N.B. The Heath itself is capped by a very deep bed of post-glacial gravel.
33. That by the Brick-fields at Plumstead Street, 6 miles north-east of Norwich.
34. That by the Brick-pits ½ mile north of Wroxham Bridge, by Horstead Marl-staith, and by the Lime- and Brick-kiln immediately north of Coltishall village. N.B. It is only in this neighbourhood that the bed *f* has yielded fossils.
35. That by the heath-country between Westwick and North Walsham.
36. That by two deep pits 6 furlongs south-east of North Walsham.
37. That by the Brick-pits and Marl-pits in the valley of North Walsham. $g^2$ occurs here in the form of very chalky marl coming out in the bottom of the valley.
38. That by Edingthorpe Heath.

39. That by the Brick-pit on Edingthorpe Heath, 6 furlongs E. by N. of Austin Bridge; a sharp anticlinal a few yards wide brings $g^3$ to the surface here.
40. That by Hasborough Cliff. The upper part of $g^3$ here consists of finely stratified silt, which in places is deeply denuded, the base of *h* occupying the denuded depressions, in some of which partial bands of brick-earth occur, which form, I believe, the Upper Boulder-clay of Mr. Gunn at this place.
41. That by the Cliff north-west of Bacton, east of Field Barn.
42. That by the Cliffs further west, and N.N.E. of Field Barn.
43. That by the Cliff near Mundesley. $g^3$, which has hitherto been regularly stratified, begins to become contorted. N.B. There is a post-glacial bed in the valley at Mundesley.
44. That by the Cliff near Beacon Hill, Trimmingham. $g^4$ here cuts in places through $g^3$ into $g^2$; the dimensions of the diagram do not permit of this being represented. N.B. $g'$, which has hitherto been black with the débris of *dd*, becomes yellow sand and ceases to be laminated.
45. That by Felbrigg Heath.
46. That by the Cliff near Cromer. $g^1$ is here and in Nos. 47 and 48 divided from *h* by an indurated gravel-pan. N.B. Between 44 and 46, $g'$ again becomes stained with the débris of *dd* and partially laminated.
47. That by the Cliff near Sherringham.
48. That by the Cliff near Weybourne. N.B. Midway between 47 and 48, $g^3$ begins to lose its contortions, and to become stratified again; $g^2$ and $g^3$ also become difficult of distinction, and together to assume the condition of chalky loam.
49. That by Weybourne and Kelling Heaths.
50. That by Salthouse Heath.
51. That by various pits in the valley of the Glaven. $g^2$ and $g^3$ are here represented only by chalky loam, or marl, with occasional beds of chalky sand.
52. That by Saxlingham Heath (6 miles from Weybourne).

The section as it stands in No. 52 is continued west to Wells, except that *h* is almost wholly denuded, $g^2$ and $g^3$ occupying the surface of the country through Field Dalling, Binham Abbey, and Wigton. In a pit 4 furlongs east of Copy's Green, Wigton, a sand comes up beneath $g^2$ and $g^3$ (which are represented by a sandy chalky loam). This may be the recurrence of $g^1$ at this part.

By the Railway-cutting east of Wells Town a very fine section is afforded of $g^2$ and $g^3$, in the form of a chalky loam resting on the chalk and partially underlain by boulder-gravel. South and south-west of Wells, *h* comes on again in thickness at Holkham Triumphal Arch and near Fakenham.

By the term "post-glacial" is meant beds that have been deposited subsequently to the great denudation which ensued upon the close of the formation of *i*. None of these appear in the Diagram, which represents the state of things at the commencement of the formation of *i*.

It will be seen by the above that the Chillesford beds, *e* and *e'*, and the sand- and pebble-beds, *f*, which, by reason of their strict conformability to the base of *h* over the crag area, were treated in the "*Remarks in explanation of the Map of the Upper Tertiaries of the Counties of Norfolk, Suffolk, Essex, Middlesex, Hertford, Cambridge, Huntingdon, and Bedford, with parts of those of Buckingham and Lincoln, and accompanying sections,*" as belonging to the lower part of *h*, are no longer so regarded. Their true position in the sequence of deposits has been arrived at by tracing the thick Contorted Drift of the coast, through a series of unequivocal sections, into the comparatively thin bed of brick-earth which overlies the sand and pebble-beds, *f*, near Norwich.

This modifies the interpretation put in the "Remarks" upon Nos. 9, 10, 14, 24, and 25 of the sections accompanying them,—*k* in that part of section 9, which is near Norwich, comprising the beds *e*, *e'*, *f*, and $g^3$ of the above Diagram; and in the western part of section 10 the beds *f* and $g^3$, in addition to the Middle Drift *h*; while in section 14 it includes at Sudbourn, Aldborough, Thorpe, Easton, and Covehithe the beds *e*, *e'*, and *f*; and at Kessingland and Corton the beds $g^3$ and *h*. In section 24, *k* represents $d^{3'}$ $d^{4'}$, *e*, and part of *e'*, and in section 25 the beds from the base of *f* to the middle of *h*.

## 2. *Note on* Supposed Remains *of the* Crag *on the* North Downs *near* Folkestone. By H. W. Bristow, Esq., F.R.S., F.G.S.

On my return to London, after an excursion made in May 1857, in company with Sir Charles Lyell, Professor Ramsay, and Messrs. Prestwich and Godwin-Austen, to the district of Kent, from which fossils had been got which were thought to be of the age of the Crag, I made a memorandum on the subject, of which the following is a copy:—

"With regard to the sands, &c., seen at Paddlesworth and elsewhere, accompanied by thin bands of iron-grit, I have seen nothing from which it would be at all reasonable to infer that the beds in question were any other than those of the Lower Tertiary (that is, of the Woolwich and Reading series), occurring in their proper position on the denuded surface of the Chalk.

"Beds like the Paddlesworth ferruginous sands occur in the Hampshire Basin, where a part of the Woolwich and Reading series is represented by ferruginous clayey sands, with masses of ferruginous grit, &c*. Another strong resemblance is also borne by these last beds to those of Paddlesworth in the red colour of the sands, as may be observed more particularly at Whiteparish, in Wiltshire, where it would seem that when the mottled clays are replaced by sands the colouring matter is often persistent although the mineral character of the rock varies. With regard to the greater development of ferruginous grit at Paddlesworth, that alone is not enough to afford reliable evidence one way or the other, and in either case it might be a mere local condition over the particular area in question, iron being more or less diffused throughout the lower London Tertiary beds—in some cases (as in that of the basement bed of the London Clay over a small area in Dorsetshire) to the extent of furnishing a very rich bed of iron-ore, which, under favourable circumstances, would prove highly valuable for smelting-purposes.

"If these Kentish beds can be proved to belong to any other member of the Tertiary series, it is only to be done by a careful examination of the evidence given by the fossils. There ought to be little difficulty in this, from the very great interval between the two sets of strata, and from the fact that about 50 per cent. of recent forms ought to be found in beds of the age of the Lower Crag."

P.S.—From an examination of the fossils shown to him at that time, Mr. W. H. Baily believed them to be of London-Clay age.

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## 3. *On the* Warp (*of* Mr. Trimmer)—*its* Age *and probable* Connexion *with the* Last Geological Events. By the Rev. O. Fisher, M.A., F.G.S.

[Abridged.]

I am not aware that any geologist since the late Mr. Trimmer has

* The ferruginous bands at Paddlesworth are not seen to be fossiliferous; and the fossiliferous ironstone from the pot-holes at Lenham is not seen *in place*, and may therefore belong to any period.

devoted a paper to the elucidation of the subject of what he has called the "warp" or the "warp of the drift"*. In his paper "On the Soils of Kent" he lamented the slight attention that had up to that time been paid to "the period which intervened between the desiccation of the bed of the glacial sea and the commencement of the historic era of geology." Had Mr. Trimmer lived until the present day, he would have seen the earlier part of that period receive at least its due share of attention. The closing portion of it, which saw the formation of that warp or subsoil on which the fertility of our fields chiefly depends, has not, so far as I know, received any particular attention since Mr. Trimmer's valuable labours were prematurely terminated.

My attention has for some time past been attracted to this subject, and in my paper on the Brick-pit at Lexden† I hinted at its importance as containing records of the latest geological changes.

Mr. Trimmer appears not to have arrived at any satisfactory conclusion as to the causes which have produced the warp. He says, "The majority of soils and subsoils in the British Isles are composed only in part of the débris of the rocks on which they rest, and in part of materials transported from various distances by forces of considerable intensity, differing from ordinary atmospheric action, which were in operation at the close of the glacial period. I have called these results the warp of the drift or the erratic warp"‡. But he leaves us in ignorance as to the nature of these forces, further than that, in his "Geology of Norfolk" (Journ. Agric. Soc. vol. vii. p. 465), he says that "it appears to have been a deposit from turbid waters returning to a state of tranquillity." Nevertheless, in his paper "On the Soils of Kent," first referred to, he speaks of the great variability of soil within a few acres. This is a well known fact, and appears incompatible with the explanation of the warp being thrown down from a flood of turbid water, which must have produced very equable soils over moderate areas.

In stating that the warp differs more or less from the subsoil on which it rests, Mr. Trimmer adds that "on sands it contains a greater mixture of argillaceous matter, producing a sandy loam of different degrees of adhesiveness; on clay it contains an admixture of sand, producing a clay loam, or, at any rate, clays less adhesive than than those of the subsoils."

These remarks are undoubtedly just. The warp is influenced in its character by the stratum on which it rests, but at the same time often contains ingredients which cannot have been derived from it.

Whence, then, have these ingredients come?

It is well known that the surface of the subjacent stratum, wherever it is of a soft nature, such as clay, sand, gravel, or chalk, is worn into furrows and hollows, sometimes into pits and pipes. The sections I have chiefly had an opportunity of studying for the purpose of this paper have been in clay, sand, and gravel, which have,

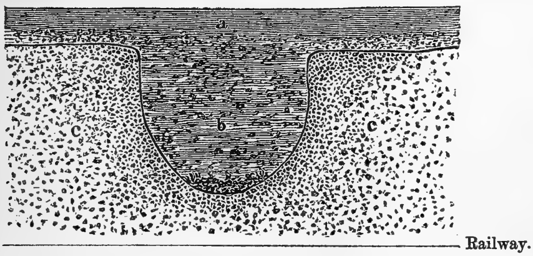
* Quart. Journ. Geol. Soc. vol. vii. p. 31.
† *Ibid.* vol. xix. p. 396.
‡ *Loc. cit.* p. 32.

for my present purpose, an advantage over calcareous strata, in that they are not soluble by water, and the phenomena therefore are less complicated. As far as my observations extend, I have found that cylindrical pits and pipes are generally confined to soluble beds, and that the normal form of the cavities in clays, sands, and gravels is that of troughs or furrows*. They are usually filled with materials derived from some neighbouring higher ground, and consequently generally differing from the subjacent stratum at that spot; and it is by the admixture of the contents of the furrows with the material of the subjacent stratum that the warp, which is derived from the two conjointly, comes to contain materials mixed in a different proportion from that in the subjacent bed.

These furrows must be important indications of the mode of denudation of those surfaces where they occur; nevertheless, being simply the tool-mark of the *last* agent which has moulded the surface, if we could determine from them what that was, we need not exclude other and different ones which may have preceded it.

For the sake of a name I shall call the materials which fill these furrows the "trail." And I will now give a few examples of them in diagram.

Fig. 1.—*Section of a furrow which crosses the Tendring Hundred Railway, near Great Bentley Church, Essex.*




It is 7 feet deep, full of grey sandy and gravelly clay (*b*), eroded in brown sands (*c*). The warp (*a*) covers it. There is a layer of pebbles at the bottom of the furrow, and roots have penetrated throughout it. The gravel is more angular than that of the glacial drift from which it has been derived, many of the rounded pebbles having been broken up into angular fragments.

At the gravel-pit, Ballast Quay Farm, near Wivenhoe, Essex, two masses of trail have been left, being too clayey for use. They are parallel to each other; one of them is fifty yards long, the other not much less. Erosion has gone on beneath them, which is shown by the pebbles of the warp, and also of the trail, lying in festoons. They are inclined at a small angle to the surface-drainage. They occur in sandy glacial gravel.

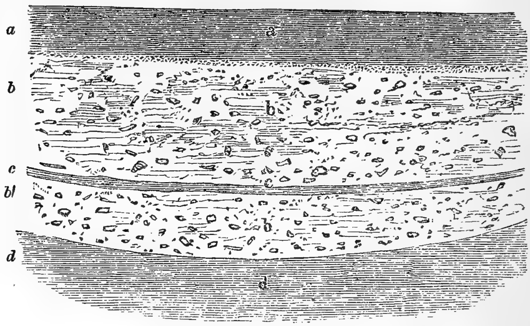
* For examples of these troughs, see figs. 1 and 5. London clay dug for ballast at Bentley Tey, near Great Bentley, to the depth of 5 feet, exposed a section of a furrow ten yards long and a yard wide, running in the direction of the drainage of the surface.

And first, as I have already observed, the trail is derived from some not very distant point of higher ground.

Secondly, where the trail contains pebbles it will be noticed that their axes, more frequently than not, deviate from the horizontal position.

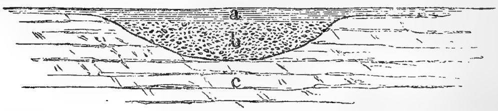
Thirdly, the trail sometimes contains portions of incoherent beds, which nevertheless are not scattered and disseminated as would be

Fig. 2.—*Section of Trail in a Pit east of Chillesford Church, Suffolk.*



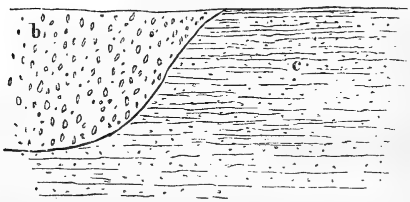

*a.* Warp defined by an intermittent layer of pebbles of chalk and small flints.
*b.* Trail from Boulder-clay with chalk and oolitic pebbles and fossils.
*c.* A layer of drift from the Chillesford Clay.
*b'.* Drift from the Boulder-clay, a repetition of *b*.
*d.* Chillesford Clay.

Fig. 3.—*Section of Trail at Calne Railway-station, Wilts.*




*a.* Warp. *b.* Trail of red sandy gravel. *c.* Coral rag.

Fig. 4.—*Section of Trail at Woking, Surrey.*

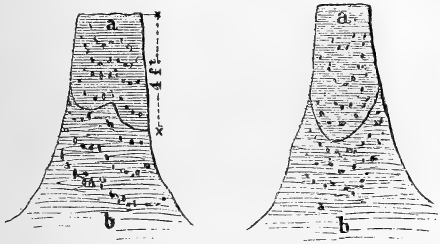



*b.* Trail, with axes of pebbles mostly vertical.
*c.* Sandy clay horizontally stratified. The locality is nearly level.

the case if they had been water-drifted. I have noticed this fact, especially, in some Crag-pits in Suffolk. For instance, in the large Coralline Crag-pit near Aldborough, Mr. S. V. Wood, jun., has mentioned patches of what he supposes to be Red Crag, and also phosphatic nodules, overlying the Coralline. Both of these occur in the trail. The so-called Red Crag probably consists of a portion of the *Mya-truncata* bed, which would occur in ordinary sequence a furlong or so up the hill. The drifted fragment is much distorted, but nevertheless not scattered. There are similar patches of this bed in the trail in an old Crag-pit on the Saxmundham road, about a mile and a half from Aldborough.

A similar case was seen by Mr. Boyd Dawkins and myself at Walton-on-the-Naze, where an angular lump of London Clay, about eighteen inches in diameter, was entirely enveloped in a mass of gravelly trail.

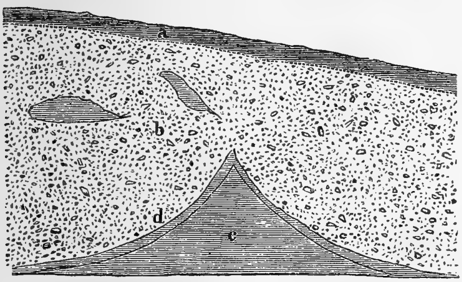
Fig. 5.—*Section across a furrow of Trail covered by Warp, left standing after the removal of the surrounding gravel for ballast, Wivenhoe, Essex.*




*a.* Warp.
*b.* Trail.

The position of the pebbles in the trail, and still more so the contorted but unscattered condition of incoherent material, show that the trail has been transported in a plastic state (as mud) moving by its own gravity, or else pressed onwards by some other agent.

Fig. 6.—*Section of Trail near Villa Farm, Tendring Hundred Railway.*




*a.* Warp.
*b.* Trail of sandy gravel.
*c.* London clay.
*d.* Weathered surface of London clay, full of Slickensides.

I can cite instances which prove that considerable force has been involved in this process. In a railway-cutting near Wivenhoe, in Essex, I found at the side of a valley one of these furrows in London clay, about 13 feet deep, filled with such sand and gravel as caps the tableland around. The clay, for the thickness of 4 or 5 inches, was kneaded into a plastic state, laminated, and full throughout of polished surfaces of slickensides, showing that the trail which filled the furrow had been pushed forwards under great pressure, and had carried forward with it the surface on which it rested. A few pebbles, which had become engaged in the clay, had received a considerable amount of polish. The weathering extended about as far as the clay had been moved. A specimen of this clay is deposited in the Society's Museum. Similar instances were seen by Mr. Boyd Dawkins and myself at Walton-on-the-Naze, and by Professor Liveing and myself at Aldborough.

It is very desirable that the trail should diligently be searched for organic remains. As yet I have never seen any vestiges of such, either animal or vegetable, within it. It will constantly be found filled with roots; but that is owing to its inviting their presence by the subterranean drainage caused by the usual clayey lining of the bottom of the furrows.

As far as I have had opportunities of examining the furrows, I have noticed that they are largest and most numerous in the neighbourhood of valleys, and are either parallel or inclined at a small angle to them. If, as I believe, they are connected with the phenomena of denudation, this is what we should expect.

If there ever was formerly a universal spread of trail over the general surface of the land, it has now disappeared, and the only remains of it are to be found in the furrows, which lie deeper than the latest general denudation has extended.

There can be no doubt that these furrows, with the trail which they contain, are older than the warp, and that their contents have contributed to form the warp or general subsoil; and thus we see the reason why the surface-soil sometimes varies so remarkably over limited areas; for these patches of trail are not universal, and where they occur they influence the composition of the soil to considerable but not to great distances.

There can, I think, be not much doubt that there was a time when our country was comparatively, if not entirely, bare of the present covering of vegetation; for the denudation which formed these furrows can hardly be supposed consistent with a clothing of turf or forest. When the more severe climatal conditions, whatever those may have been, which conduced to the denudation had passed away, the country would become gradually covered with vegetation, and the work of rain and rivers and frost, under their more ordinary conditions, would commence to modify the form and state of the surface.

Let us now consider the final preparation of the warp. Conceive the face of the country, as the denuding forces left it, consisting of the bare rock, thinly covered in places by the trail of material left behind by that agency, and in places occupied by furrows, or shallow hollows, filled with similar stuff. This is the foreign material to be incorporated with the subjacent rock to form the warp.

Atmospheric causes have operated from that distant day to the present in bringing about the result. Rain and, during drought, winds have tended to spread the finer materials of the surface. Frost has affected the envelope as far as it could penetrate, mixing the natural rock with the adventitious matters. After vegetation had commenced, roots have played an important part in the work, and the earthworm, as Darwin first pointed out *, has contributed a by no means inconsiderable share to the general result.

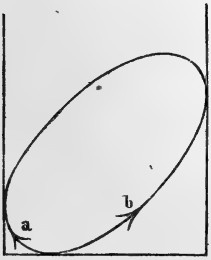
Of these agents I will touch only upon the work of frost and rain.

And first of frost. Suppose a mass of loam containing a pebble to be frozen, what takes place? The loam, by virtue of the water which it contains, expands, and this expansion necessarily takes place entirely upwards. The pebble does not expand. The consequence must be that some of the loam, which surrounded the pebble laterally, will be pressed over its upper surface. When the thaw occurs the soil sinks again, and, there being now more material above the pebble than before, it is forced to imbed itself at a lower level. There is another action which conduces to the same result. The frost enlarges in every direction the hole in which the pebble lies. As soon as the ice melts, the pebble sinks to the bottom of the hole, by this means gaining a depression equal to the thickness of the coating of ice which surrounded it. The subsequent rain and the subsidence of the soil fill up the vacuity.

It is evident that from this cause the larger stones will descend faster, because their relative displacement in the general loam will be in proportion to their linear dimensions; and the materials of the warp will be arranged vertically according to the relative magnitude of the constituents, to whatever depth the frost may penetrate: and we may expect to find a layer of stones in its lower part, as in fact we do.

This action will, however, be modified by the effects of rain. For that, on the other hand, carries down the finer particles of the soil through the interstices among the coarser materials, and fills the spaces which the frost opens; and the examination of the warp beneath a lens reveals this arrangement of the finest clay enveloping the sandy particles. Pebbles taken out of the warp are also covered with a fine polished coating of clay. Hence any layer of clay, however thin, originally on the surface will be distributed equably throughout the whole depth of the warp.

Fig. 7.—*Diagram illustrating the motion of a pebble in a plastic medium.*




The erect position, already noticed, of the included pebbles, is in many cases common to the warp as well as to the trail. This effect is probably not always produced in the same way. The following appear to be some of the possible causes of the phenomenon.

It is well known that a plate, or other heavy lamina, will sink through water with its plane horizontal. In the same manner a pebble of an elongated elliptical form would sink through *water* with its axis horizontal. But if it sank through mud the *friction* would play a more important part than the *resistance*,

* Transactions Geol. Soc. 2nd ser. vol. v. p. 505.

especially if its motion were slow; and the effect of friction would be to place the pebble on end. It will be easily seen in the figure that the friction throughout the portion *a* will tend to place the axis horizontal, while that throughout *b* will tend to place it vertical. It is evident that the latter will preponderate.

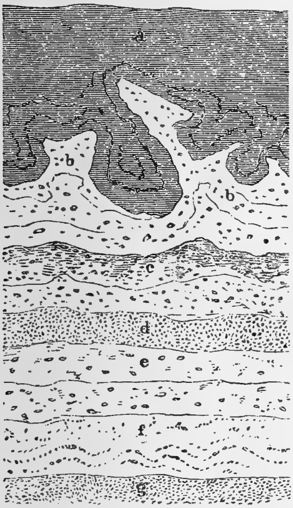
I doubt, however, whether in nature we have cases of pebbles which have been arrested while descending by their own gravity. The action of frost, as indicated already, seems to be a more probable cause of their descent; and their verticality may be thus accounted for. The upward motion of the matrix, while expanding under the influence of frost, will be, relatively to the pebble, gradually increasing from its lowest point upwards. The friction will therefore be greater towards the upper end of the pebble, and the effect will be similar to that just described, but more considerable.

It will be observed that the pebbles near the sides of a furrow of trail are more generally vertical than those in its more central parts. This has arisen from the dragging of the materials from above downwards against the wall of the cavity, while it was being widened and deepened. If a line be drawn through the centre of the pebble parallel to the section of the side of the cavity, the motion of the particles of the matrix between this line and the wall will, from the retarding effect of friction against the wall, be less than on the further side. Now, since the pebble tends to partake in the motion of the enveloping matrix, it is clear that the effect produced will be a tendency to roll it over, in the same direction that a pebble would roll down the wall of the furrow. This tendency to roll, however, will be resisted by the imperfect mobility of the particles of the matrix *inter se*; and the resistance will be the greater the more the figure of the pebble deviates from sphericity. It seems, then, that when the pebble has assumed a position in which the moment of the rolling force is so far reduced by its position as to be counterbalanced by this resistance, it will remain permanently so, and move forward without further rolling. The position in question will be one in which the longer axis is approximately parallel to the wall of the cavity. And hence the pebbles at the sides will be more or less nearly vertical.

Though I cannot give any measurements, I may observe that the effects of frost seem to have extended at the time the warp was formed much deeper than they do at present.

Mr. Trimmer has noticed, in his paper "On the Soils of Norfolk" (Journ. Royal Agricultural Society, vol. vii. pt. 2), that, as a rule, the warp is thicker upon the tablelands, thinner on the flanks of hills, and, again, thicker in the bottoms of valleys. In short, there has been a slow drifting action from the higher to the lower grounds; and it will accordingly be observed that the warp on the sides of hills and at their feet tallies less with the fundamental rock, but consists chiefly of the materials brought from the higher grounds. How, then, does this drifting take place? Unless I am mistaken, it is partly subterranean. Every one must have noticed the singularly eroded line of junction often existing between the warp and the subsoil. This I believe to be the sections of channels of drainage, and that the drainage carries forward some material with it. Some such action as this may account for the flat-topped elevations, like the tenons in the framework of a dissected puzzle, which often occur in or near the line of junction of the warp with the subsoil, especially (if I mistake not) where the latter contains calcareous matter and has suffered partial solution. The erosion at the bottom of two contiguous subterranean channels would leave an elevated ridge between them, and the superincumbent soil sinking in a general mass would then flatten the crest of the ridge. By a continuance of such a process, with slightly shifting directions in the drainage, those complicated foldings would be formed the cause of which, at first sight, seems so incomprehensible.

Fig. 8.—*Section of a Pit in Victoria Road, Cambridge.*




*a.* Warp.
*b.* White sandy brick-earth.
*c.* Yellowish sandy earth.
*d.* Fine sandy gravel.
*e.* Yellowish brick-earth.
*f.* Fine gravel, more contorted than the layers above and below.
*g.* Sand.
The sands contain *Bythinia*, &c.

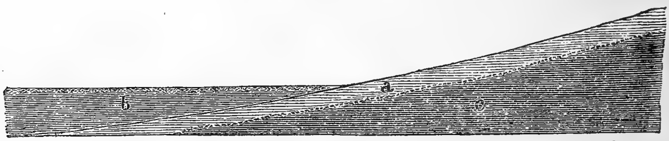
Contortions of the kind alluded to, when occurring in gravel-beds, are sometimes explained by the action of floating ice; but that cause can only have operated under water. These contortions have in some way or another resulted from subaërial causes; and though I see difficulties, I think this explanation may be the right one.

In the instances from the Cambridge gravel-pits the percolation and consequent erosion seem to have taken place in the layer beneath the ductile clay, which is folded into such remarkable forms. Had it been on its upper surface, the layer must have been cut through. It must be recollected that slight inequalities slowly formed in the surface of the ground by such subsidences would be continually levelled by the action of rain, herbage, and worms.

The next question which I propose to enter upon relates to the age of the warp. The causes to which I have attributed its formation—frost and rain, wind, earthworms, and the growth of herbage—are causes in operation at the present day; and therefore it might be expected that the warp is the latest geological formation. Yet I believe that conclusion would be incorrect.

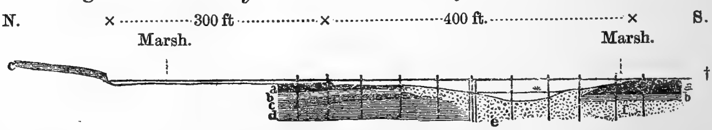
It is evident that it has been formed for a long period, because the layer of pebbles usually seen at its base will be frequently found to have descended to the depth of a foot or more over the mouth of any subjacent pipe which may happen to have been formed in a calcareous rock. In a similar manner channels of slight subterranean drainage will be found to deflect the layer. These effects must have taken some time. But a more definite measure of its age was first noticed by Mr. Trimmer in his paper "On the Soils of Kent"*. He there states that he had found "in the neighbourhood of Faversham, *below the level of high-water mark,* lacustrine and fluviatile deposits covered by non-fossiliferous deposits analogous to that of the erratic warp of Norfolk." I have noticed myself the passage of the warp below the level of high-water mark in the estuary of the Colne. About two miles below Colchester the outline of the rising ground, marked by the unbroken continuation of the warp, passes beneath the silt of the estuary. The surface of the silt, now reclaimed for

Fig. 9.—*Section in a ditch on Tendring Hundred Railway, near Colchester.*




*a.* Warp passing beneath (*b*) Silt of the estuary. *c.* London clay.

Fig. 10.—*Railway Viaduct over Alresford Creek, Essex.*




* Low-water mark. † High-water mark.

*a.* Estuarine mud of the present marsh. *d.* Probably London Clay.
*b.* "*Scrobicularia*"-clay. *e.* Gravel.
*c.* Warp. *f.* Sandy gravel.

† The line of section on the south side does not meet the upland again, but after crossing some marshy ground, runs into the estuary of the Colne.

Specimens from this section are deposited in the Society's Museum.

meadowland, must be about 6 feet below high-water mark. The section was seen in a ditch by the side of the Tendring Hundred Railway.

Another instance of the same kind in the same neighbourhood was disclosed in the sinking of the cylinders on which the rails are

* Quart. Journ. Geol. Soc. vol. vii. p. 36.

carried across Alresford Creek. The first cylinder was sunk in the marsh, the second at the edge of the tideway. The sections given to me were :—

*First Cylinder.*

| | ft. | in. |
|---|---|---|
| Estuarine mud ........................ | 8 | 0 |
| Black gravelly mud with shells............ | 0 | 6 |
| "Yellow virgin soil," *i. e.* "warp" ........ | 3 | 0 |

*Second Cylinder.*

| | ft. | in. |
|---|---|---|
| Estuarine mud ........................ | 8 | 0 |
| Black gravelly mud with shells............ | 0 | 6 |
| "Yellow virgin soil," *i. e.* "warp" ........ | 3 | 0 |
| "Bluish-yellow clay," probably weathered London Clay .................... | 6 | 0 |

I examined the materials thrown out of these cylinders, and they agreed perfectly with the descriptions given to me by the foreman of the works. The warp was met with as far as the fourth cylinder—that is, about 200 yards from the edge of the marsh. These facts prove that the warp was formed before the last depression of the land; for the tide rises 10 or 11 feet above its surface. It may have extended to a greater depth below high water than this; for it is quite possible that the reason of its not occurring in the middle of the tideway may be, that it has been denuded.

I met with another proof of the antiquity of the warp, of a different kind, but of a similar significance, on the same line of railway.

Fig. 11.—*Section showing Warp cut off by erosion of a stream.*


*a.* Warp. *b.* Recent silt.

Just west of Great Bentley, where on the map stands the letter "s" in the word "millions," the railway crosses a valley. The small stream which it contains has deepened the original valley by about 12 feet, leaving a bank on the western side. A section of this bank was visible in a freshly cut ditch on the north side of the railway; and it was noticeable that the warp was cut off at that point. The soil of the recent flat bottom was a silt without any true warp upon it.

I believe it will turn out that the true warp, with its line of pebbles at its base, does not extend over alluvial flats*, but (unless it happens to have been denuded) passes beneath the recent deposits. In short, it accompanies the original surfaces of denudation.

* No true warp was seen where the culvert was put in between Alresford and Frating.

The surface of the high-level gravels, and of the brick-earth which often covers them, appears to have been affected by the same furrowing action which has operated upon the surfaces of older beds. They are also enveloped by the true warp, which seems to have been formed chiefly by severe winter frosts, and by other subaërial causes, before the last depression of the land; for, as I have shown, the warp is covered by the alluvial deposits. In the valley of the Stour, about Sudbury, in Suffolk, the valley-gravels are to be seen furrowed by trail from the higher grounds. The flints from the Boulder-clay in the trail are there coarser than those in the gravel which contains the furrows. An excellent section of the trail is also to be seen in the Ilford Brick-pits.

We have, then, data for fixing the period of the formation of the warp over the surface left, in all probability, in a bare condition by a preceding general denudation. It was subsequent to the period when the *Elephas primigenius* lived in company with *E. antiquus*, and when chipped implements were used; for the gravels which contain those associated relics have been affected by the denudation which preceded the formation of the warp. But it was previous to the growth of the newest submarine forests, which occupied the surface before the last depression of the land. It appears to have been the period which, before the glaciers of Scotland finally disappeared, left the moraines described by Mr. Jamieson as having been formed anteriorly to the deposition of the Carse clay*; for there seems little doubt that that clay is the equivalent of the marine silt with *Scrobiculariæ* which covers our English submarine forests, and that the elevation which Mr. Jamieson tells us must have been so general over a large part of the western seabord of Europe† was followed by a depression, if not quite so general, at least very extensive.

Upon reviewing the changes which have been indicated by the phenomena discussed in the present paper, we have disclosed, in the first instance, a condition of the surface when the general features of the landscape were the same as at present, during which the great mammalian fauna flourished contemporaneously with the fabricators of the chipped flints.

We have, subsequently, though perhaps not in immediate sequence, a period of extensive denudation, indicated by the furrows filled with materials from the higher grounds, which have travelled in a plastic state, and which I have called "trail." This denudation brought the surface almost exactly to its present form. The period of the formation of the warp succeeded, in which the winter frosts seem to have been more severe than at the present time.

It was either during this period, or shortly afterwards, that the submarine forests flourished. A submergence of moderate amount, measured by a few tens of feet, next followed, and the Scrobicularia-mud was deposited over the lowest forest-grounds. The sea was then depressed again, and the recent period commenced.

The changes of form in the present surface which have taken place since that time may, I believe, be easily recognized, since they

* Quart. Journ. Geol. Soc. vol. xxi. p. 173. † *Ibid.* p. 180.

usually interrupt the more general contour of the surface. One of these has been noticed, in the case where the warp has been cut off by a stream.

When this paper was read before the Society, certain speculations were entered into, in which it was attempted to correlate the above sequence of events with those indicated by Mr. Croll as flowing from his theory of climatal changes. It has been thought, however, that these questions had better be reserved for future discussion, and that the paper should appear in the present abbreviated form.

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### 4. *On* Faults *in the* Drift-gravel *at* Hitchin, Herts. By J. W. Salter, Esq., F.G.S., A.L.S.

At Hitchin there is an admirable section laid open by the deep cliff-cutting of the Great Northern Railway, which exhibits faults affecting both chalk and an old gravel which, thanks to the investigations of Mr. Seeley (in Cambridgeshire) and the independent research of Mr. Thomas McKenny Hughes (nearer Hertford), I am enabled to refer to the Boulder-clay period.

There is no ambiguity in this section. The chalk rises from the railway-level in bold cliffs, 60 or 70 feet high, capped here by chalk-drift, and there by fine, yellowish, stratified gravel—the latter in certain spots, *e. g.* the lime-kilns, coming down almost to the level of the road, and again rising up to near the top of the cliff. The beds of chalk undulate a good deal; and the older gravel follows its curves into curious depressed spaces, both north and south of the station. These depressions are, as the section will show, due not to erosion, but to faults*.

The upper gravel, which fills pipes in the chalk, and everywhere caps both chalk and drift, is much more varied in its composition than the lower and older gravel; often it is a chalk-rubble, especially along the higher ground, but interstratified with gravelly loam, full of broken and worn chalk-flint. More commonly it is a darker-coloured, yellow, gravelly clay or loam; and in this latter condition it may be seen in the large deserted gravel-pit just south of the bridge for the high road from Hitchin, south of the station. Close to this bridge is a conspicuous fault in the chalk, which runs across the railway, but is most easily seen on the east side. It runs 30° E. of N.

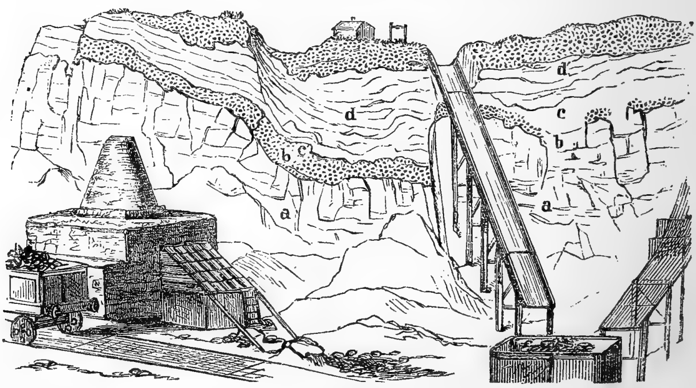
Following this southwards, past the opening of the gravel-pit, we again find the chalk in a low cliff-cutting, with numerous vertical fissures, and capped by a conglomerate of rounded flint-pebbles, chalk-

* The faults in Boulder-clay, seen in the Ely section, and described by Mr. Harry Seeley (Geol. Mag. vol. ii. No. 18), must not be forgotton, nor his remark as to this faulting having taken place previously to the present modification of the country's surface. The downthrow is described as at least 40 feet, and perhaps more. The faults in the Hitchin section have been recognized by Mr. S. V. Wood, jun., who has drawn them in section No. 6, illustrating his memoir entitled "Remarks in explanation of the Map of the Upper Tertiaries of the counties of Norfolk, Suffolk, Essex, Middlesex, Hertford, Cambridge, Huntingdon, and Bedford, with parts of those of Buckingham and Lincoln, and accompanying sections. 1865."

pebbles, and ironstone-nodules cemented pretty firmly together, and passing up into fine yellow sand, laminated and well bedded, and this again covered by the gravelly loam which lies indifferently upon chalk or sand. The chalk is fissured, rises in little craggy prominences into the drift (*b*), or shows steep short escarpments against which the chalk-rubble has accumulated. I saw it in this form at Hertingfordbury a few weeks back.

However, we have only to return to the station, and enter the bay in the cliff where the lime-kilns are at work, to see the accompanying section. South of the gravel-shoot, the chalk descends rapidly, dipping N. or N.W. to within 10 feet of the road-level, and is much shattered in the hollow. The fine gravelly sand, underlain by 2 or 3 feet of conglomerate, follows it; and then, just under the shoot (which seems put there to protect the section), it is suddenly faulted to the extent of at least 7 feet, and probably more, showing the clean face of a fault which has cut through chalk, chalk- and flint-pebbles, and gravelly drift, the faces of the faults, three or four in number, and parallel to each other, being as clearly defined in the hard drift and conglomerate bed (the pebbles of which are often fractured across) as in the chalk itself. The loam and chalk-rubble mixed descend irregularly into the hollow, and leave generally but a foot or two of undenuded gravel-drift above the conglomerate.

*Section of Chalk, Drift, and Upper Gravels at Hitchin Station.*




*a*. Chalk. *b*. Drift. *c*. Pebble-bed. *d*. Fine gravelly sand.

The section here is so very clear as to admit of no doubt; and I leave the matter for the consideration of those who are apt to forget that faults in the drift imply a very recent modification of the surface by movements similar in kind, if in less degree, to those which produced our mountain-ranges.

## 5. *On some* Flint Implements *lately found in the* Valley *of the* Little Ouse River, *near* Thetford. By J. W. Flower, Esq., F.G.S.

(The publication of this paper is unavoidably deferred.)

[Abstract.]

The sands and flint-gravel on the right bank of the river Ouse at Thetford form a terrace 8 to 10 yards above the river, and about 40 yards distant from it. At a spot called Red Hill a large number of flint implements have lately been obtained from this gravel, at from 12 to 15 feet below the surface, and within a foot or less of the chalk on which the gravel rests; and some were found in the same gravel filling pot-holes in the chalk.

The author pointed out the exact correspondence, as regards geological position and relations, between the Thetford gravels and the flint-implement-bearing beds of Amiens, Abbeville, Fisherton, Icklingham, Hoxne, &c. He further noticed the close resemblance which these implements and some others discovered in England bear to those of the valley of the Somme; and concluded by expressing his dissent from Mr. Prestwich's conclusions, and stating his own views on their mode of accumulation, remarking that, in his opinion, these implements were manufactured prior to the severance of this island from the continent.

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## 6. Geological Notes *of the* Pacific Coast *of* Ecuador, *and on some* Evidences *of the* Antiquity *of* Man *in that* Region. By J. S. Wilson, Esq.

(Communicated by Sir R. I. Murchison, Bart., K.C.B., F.R.S., F.G.S.)

[Abstract.]

The western slope of the Cordilleras is occupied with projected volcanic matter, presenting an irregular aggregation of boulders, gravel, sand, fine earthy matter, or ashes, and pumice. The boulders are of various sizes, and consist principally of the more ancient and the hardest plutonic rocks. Small angular fragments of granite are occasionally met with many miles from where that rock is found at the surface, and where there exists no evidence of their having been transported by water.

In some of the older strata of this volcanic rock, extending along the coast and some distance inland, occur cavities, that have been once occupied by the roots of trees, in their original place alongside prostrate stems, which indicate that there were periods of repose of the volcanic agencies by which the materials constituting this rock were distributed. Traces of forest-vegetation in the volcanic material were found on the coast and in some of the older beds of that deposit, commonly below high-water mark, and also at various points up the river Esmeraldas, and at all altitudes up to the foot

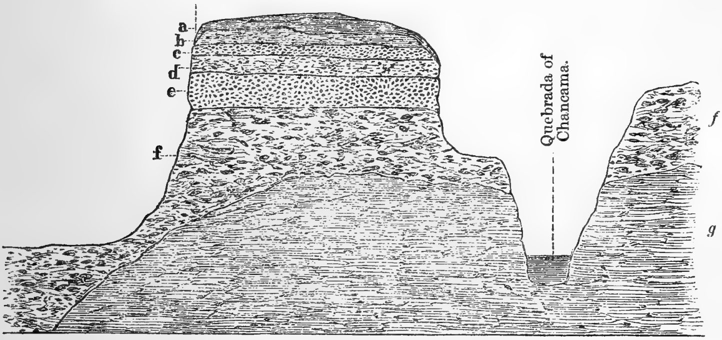
of Pichincha. In this latter locality, and in beds of more recent date than those which extend to the coast, roots and stems of small trees, completely carbonized, have been found, some descending to the depth of 100 feet below the surface. Whilst the trees in this latter locality, though of more recent production, are converted into perfect charcoal, those of the older volcanic deposits are not at all carbonized. And, again, the wood of the buried forest at the mouth of the Esmeraldas, lying only 12 to 15 feet under beds of an estuarine clay, and much more recent than either of the above, is partially carbonized, and resembles lignite. It is the author's opinion, in regard to the charred wood in the vicinity of Pichincha, that, as the ashes and dust thrown out by that volcano fell in dense showers over the surrounding country, the heat still retained by this matter carbonized the trees which it enveloped and buried.

It is beneath this volcanic deposit, or in some of its lowest beds, that the gold-drifts are found, as at Playa de Oro, Cachibi, at Barbacous, New Granada, &c. And it is only when this deposit has been removed, or where ancient river-courses have been again penetrated by waters of more recent times, that gold is found in this part of Ecuador and the adjoining part of New Granada.

The projected volcanic matter is distributed in terraces, the most recent of which extends along the shores of the Esmeraldas, and is but slightly above high-water mark. The second rises in some places 10 feet above the former, and is extensive at the lower part of the Esmeraldas and up the valleys of its lower tributaries. A third, presenting a distinct margin, rises about 8 feet higher; and above this rise three other terraces, respectively, in their orders of ascent, 15, 12, and 6 feet. This is the arrangement which (with the exception of the lowest and therefore the most recent terrace) is clearly defined in ascending the north side of the river Esmeraldas from opposite the river Viche to the Quebrada of Chancama (see section). At the former place the terraces recede from the river to an undetermined distance, but which is evidently extensive, and are said to reach to the Rio Verde, which receives a portion of the drainage from them: this seems the more probable, as but an inconsiderable amount of the water falls into the Esmeraldas. The series of terraces is again met with in the road above the mouth of the river Sadi, their continuation being partially broken by the projection of a range of hills. It is observable in this locality that the river has cut its way deep across the terraces, and in many places completely through the volcanic matter, and regained its more ancient bed on the Carboniferous rocks.

Rocks of Tertiary age are represented in the limestone cliffs, resting on shale, north of the Rio Verde, and at the side of the river Esmeraldas, just above the old town of that name, where the limestone is overlain with the volcanic deposits. Again, the Tertiary limestone was found much further up, where the river passes through a range of hills in the vicinity of the river Caninde; here it appears by the river-side in enormous white angular blocks, which had evidently fallen from the side of the precipitous hill behind: the limestone appeared to rest on the volcanic deposits, and it was the washing away of this latter from underneath that caused the harder limestone to break off in those enormous blocks. So far as the author's observations yet extend, the earlier beds of the volcanic material are at least contemporaneous with the Tertiary limestone; and the accumulation of these volcanic outcastings continued until long after the close of the Tertiary period, but became gradually more circumscribed.

*Section of Point at Chancama.*




*a.* Vegetable mould.
*b.* Clay and sand with pottery.
*c.* Water-worn gravel and clay with pottery.
*d.* Gravel and clay with pottery.
*e.* Sand and gravel.
*f.* Trash-rock.
*g.* Blue slaty rock with fragments of shells.

The second of the terraces described contains, in many places, remains of articles of human art (broken pottery, earthen figures, and fragments of gold ornaments) at various depths below the surface, but in all cases below high-tide mark, from which fact it is apparent that this region, during its occupation by man, stood higher above the sea than it does now. But the sea gradually encroached on the land, till it attained a height of about fifteen feet above its former level. That the duration of time occupied by this advance and retreat of the sea must have been very great is apparent when we consider that the stratified earth of the plain is simply the sediment brought down by the rivers and deposited beneath the margins of the sea, in some places to the depth of ten feet above the surface on which the ancient cities stood. Again the land sank and deposited those low flats and islands found at different places along the sea-margins. The land is again gradually sinking.

The pottery-stratum is traceable along a line of 80 miles of coast, and, by partial observations, is determined to occur under corresponding conditions for a distance of 200 miles more.

The discovery of pottery in a formation considered by the author immensely older than the clay-beds of the coast, in the uppermost, excepting one, of the terraces described, was made at Chancama, situated 24 miles from the coast, 180 feet above the sea, and 50 feet above the Esmeraldas river. The section (see fig.) exhibits undisturbed sea-distributed gravel and sands, 6 feet 6 inches in thickness, the lower part of which contains fragments of pottery.

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## 7. *On the* Relations *of the* Tertiary Formations *of the* West Indies. By R. J. Lechmere Guppy, Esq., F.G.S. *With a Note on a* New Species *of* Ranina, by Henry Woodward, Esq., F.G.S.; *and on the* Orbitoides *and* Nummulinæ, by Prof. T. Rupert Jones, F.G.S.

(Abridged.)

[Plate XXVI.]

Contents.



### I. The Palæontology of the Caribean Area.

#### § 1. Introduction.

It may be that some apology is needed for again bringing before the Geological Society the subject of West-Indian Geology. I should not, indeed, have ventured to do so, but for the circumstance that the considerations involved do not alone concern the geology of the West Indies, but have an important bearing on several questions connected with the distribution of organic beings in Europe and Asia, and on the correlation of deposits in those countries. These questions have much interest for geologists; and I believe that the facts and arguments presented in this communication are such that my labour in bringing them together will not be lost, even if the hypothetical views I have built upon them should prove to be untenable. Moreover the present communication forms a necessary sequel to those I have already had the honour of laying before the Society.

My object now is to present some general remarks on the results obtained by recent investigations into the geology and palæontology of the West-Indian islands. But before going into these, it may be as well that I should review our knowledge of the deposits, beginning with the oldest Tertiary formations.

#### § 2. Eocene Formations.

The existence of Eocene strata in Jamaica has been demonstrated by Mr. Barrett* and by Dr. Duncan and Mr. Wall†. Determinable

* Quart Journ. Geol. Soc. vol. xvi. p. 324. † *Ibid.* vol. xxi. p. 1.

fossils are rare; but three species of corals have been enumerated by Dr. Duncan, none of which are new.

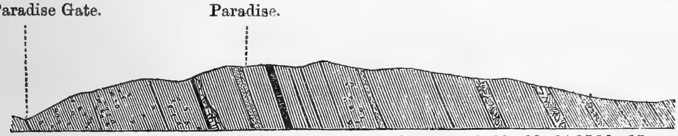
No strata of ascertained Eocene date have been shown to exist elsewhere in the Caribean area; but it is probable that some of the deposits attributed to the Miocene period in Trinidad pass down into it, as will be mentioned in the next section.

## § 3. Lower Miocene Formations.

I shall use the terms Lower and Upper Miocene, upon this as upon former occasions, not as implying equivalency to the Upper and Lower Miocene of Europe, but merely as marking what seems to me, at present, the relative age of the formations under consideration.

a. *Trinidad.*—In this island there is a very extensive development of Tertiary formations; and it is exceedingly difficult to refer all the beds to their proper places in the series, owing to the want of sections showing their relative position. The Geological Survey of the West Indies divided them into five groups*. Of these, the strata exposed at San Fernando, which were probably included in the "Naparina Marls," and those classified as the "Tamana Series," seem to me to be the oldest. The beds at San Fernando consist of gypseous marls, with shales and irregular limestones, all inclined at a very high angle. In the annexed section (fig. 1) I have endeavoured to give an idea of the stratigraphy of the beds, which is very obscure, owing to the face of the cliff being in great part hidden by slips from the top.

Fig. 1.—*Section at San Fernando* ($\frac{3}{4}$ mile).

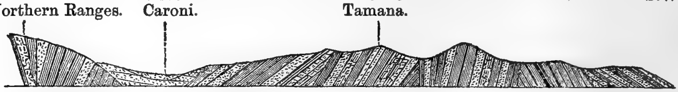



1. Brown clays and marls, sometimes indurated.
2, 3. Gypseous marls, with indurated layers and beds strongly impregnated with asphalt. Concretions containing fossils converted into selenite.
4. Indurated asphaltic marl.
5. Irregular dark-blue limestone, containing numerous fossils generally converted into calcspar, or replaced by semiliquid asphalt (*Ranina* and fish-teeth).
6. Asphaltic marls, more or less indurated, with occasional fossils (*Orbitoides*, &c.).
7. Sandstone (*Turritella, Cardium, Nummulina*).
8. Dark indurated marls and shales containing much asphalt.
9. Orbitoides-bed. Black asphaltic bed consisting chiefly of the shells of *Orbitoides* and *Nummulina*.
10. Asphaltic and gypseous clays, shales, and marls (*Terebratula, Echinolampas, Trochus, Cardita, Orbitoides*, &c., chiefly found in indurated gypseous layers or nodular concretions).
11. Indurated marls containing much asphalt. Fossils very rare.
12, 14, 16. Blue clays, unfossiliferous.
13, 15, 17. Gypseous marls. Fossils rare and usually imperfect.

* Report on the Geology of Trinidad, p. 35.

Fig. 2 is a diagram to show the general relations of the above and other deposits in Trinidad alluded to in this paper.

Fig. 2.—*Diagram Section to show the general Relations of the Formations in Trinidad.*




1. "Caribean Group."
2. Neocomian.
3. San Fernando Beds. } Lower Miocene.
4. "Tamana Series." }
5. "Caroni Series." } Upper Miocene.
6. "Moruga Series." }
7. "Detrital Series."

The following is a list of the fossils which have been determined from the San Fernando beds:—

Natica phasianelloides, *D'Orb.*
Terebratula Trinitatensis, *Guppy.*
—— cameoides, *Guppy.*
—— lecta, *Guppy.*
Gryphæa athyroides, spec. nov.
Echinolampas ovum-serpentis, *Guppy.*
Spirorbis clymenioides, spec. nov.
Ranina porifera, *H. Woodw.*, spec. nov.
Orbitoides Mantelli, *Morton.*
Cisseis asterisca, spec. nov.

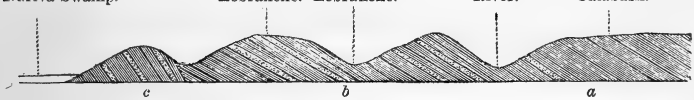
Besides these fossils there occur species of *Pinna, Arca, Trochus, Cardita, Lucina, Nummulina, Heterostegina,* &c.* Only one of the Mollusca has been identified with a Miocene species, none with recent species; and the general affinities of the fossils appear to be Nummulitic. I have for the present retained these beds in the Miocene, because they had been so classified by the Geological Survey. Mr. Woodward has been kind enough to determine for me the *Ranina,* and his note describing the species is appended. It will be seen that the evidence furnished by the Crustacean is in favour of the view I have taken of the age of the San Fernando beds.

The beds exposed at Manzanilla Point, on the east coast of Trinidad, consist of a succession of sands, calcareous sandstones, and dark shales. Their stratigraphical relations to the San Fernando beds cannot be ascertained, as they are deposited on the opposite side of the ridge of Neocomian strata. The diagram (fig. 2), in which they are included in the Tamana series, shows their general position; and I have added a section (fig. 3) to make their stratigraphy more clear. The beds which are seen on the coast at Manzanilla seem to pass on the north under strata assigned by the Geological Survey to the Caroni (Upper Miocene) series; but it is not quite clear whether the passage is conformable or not, owing to the swamps which occur near the junction in the coast section. To the south the extension of the series is hidden by the detrital (post-tertiary) deposits and by the Nariva swamp. The beds may be traced inland for a distance of four miles, when they end abruptly and unconformably on the Neocomian rocks. As the organic remains collected by the Survey have not been described, I cannot affirm that the deposits classified by

* Geologist, vol. vii. (1864) p. 160; and Quart. Journ. Geol. Soc. vol. xxii. p. 295.

them in the Tamana series all belong to the same horizon as the Manzanilla beds. There does not, however, appear to be any reason on stratigraphical grounds why these latter, with the San Fernando beds, should not be older than the other Tertiaries of Trinidad.

Fig. 3.—*Section from Nariva Swamp to Mount Calabash, 3½ miles from the coast* (6 miles).




*a.* Clays and shales (Caroni series).
*b.* Clays, calcareous sandstones, &c. (Manzanilla beds).
*c.* Sandstone and indurated clays (Neocomian).

Their organic contents seem to consist of a different assemblage of species to that found in the other Miocene deposits, containing at the most, out of more than thirty species of Mollusca collected by me, but four found elsewhere. Consequently I place these formations, provisionally only, in the Lower Miocene until further evidence may be forthcoming as to their true age.

The fossils from the Manzanilla beds which are now described, consist of the following species:—

| | |
|---|---|
| Ancillaria lamellata, spec. nov. | Cercomya ledæformis, spec. nov. |
| Venus Walli, spec. nov. | Erycina tensa, spec. nov. |
| Dosinia cyclica, spec. nov. | Arca Trinitaria, spec. nov. |
| Mactrinula macescens, spec. nov. | —— filicata, spec. nov. |
| Corbula vieta, spec. nov. | Cardium castum, spec. nov. |

Of the above, the *Ancillaria* somewhat resembles *A. glandina* of the Paris and London basins. *Dosinia cyclica* is a remarkable form, connecting the genera *Dosinia* and *Cyclina*. *Mactrinula macescens* is distantly related to *M. prætenuis* (Conrad) of the American Eocene, and more closely to *M. plicataria*, a living species of the Indian seas. *Corbula vieta* occurs in the Miocene of Jamaica and the Pliocene of Trinidad. It is allied to *C. gibba* and *C. pisum* of the Hampshire, Isle of Wight, and Belgian Tertiaries. *Erycina tensa* strongly resembles a Paris-basin species. With regard to *Cercomya ledæformis*, if I have rightly determined the generic relations of that shell, it will be the first recorded appearance of the genus in beds of so late a date. Among the undetermined shells are a *Strombus* and a *Pleurotoma*, which are possibly identical with species from San Domingo and Jamaica; but as the specimens are imperfect I do not venture to name them.

b. *Anguilla*.—The Miocene strata in this island consist of a white marly limestone containing a large number of Mollusca and Echinodermata, the former mostly in the state of casts and specifically indeterminable. The Echinodermata are better-preserved. I have no data as to the position of the beds; but it is worthy of remark, in respect to the influence of the conditions of mineralization upon the remains preserved in the rocks, that in Anguilla, where the deposits seem to resemble in composition those of Malta, we have an analogous fauna in a very similar state of preservation. In both cases the Echinoderms are numerous, large, and well-preserved, and they are accompanied by the teeth of Pycnodont fishes. The Mollusca, on the other hand, occur chiefly as casts. Could we find well-preserved examples of the shells occurring at Malta and Anguilla, they might present us with a closer resemblance between the faunas of these localities than has as yet been established for any of the groups of Mollusca found fossil in the West Indies and in Europe.

The remains determined from the Anguilla beds belong to the following species*:—

Natica phasianelloides, *d'Orb.*
Solarium quadriseriatum, *Sow.*
Ficula carbasea, spec. nov.
Pecten Mortoni, *Ravenel.*
Orbitolites complanatus, *Lam.*
Cidaris Melitensis, *Wright.*
Echinometra acufera, *Blainv.*
Clypeaster ellipticus, *Mich.*
Echinolampas semiorbis, *Guppy.*
—— lycopersicus, *Guppy.*
Echinoneus cyclostomus, *Leske.*
Schizaster Scillæ, *Desmoulins.*
Brissus dimidiatus, *Agass.*

c. *Antigua.*—Details of the strata in Antigua have been furnished by Nugent† and Dr. Duncan‡. The latter has described several corals, besides giving a summary of the geological features of the Miocene formation in the island.

## § 4. Upper Miocene Formations.

a. *San Domingo.*—In the northern part of San Domingo there is an extensive development of Miocene formations, consisting chiefly of greenish or bluish sandy shales overlain by beds of shingle and limestone. None of these beds seem to have suffered the great disturbances which have affected the formations in Jamaica and Trinidad, and the usual dip is only 6° or 7°§. A large number of Mollusca and Zoophytes have been obtained from the blue shales, most of which have been described, the Mollusca by Messrs. Carrick Moore and Sowerby ||, and the Corals by Dr. Duncan ¶. The entire thickness of the series as given by Colonel Heneken does not seem to exceed 600 or 700 feet. The following are the Mollusca:—

Cassidaria lævigata, *Sow.*
Cassis sulcifera, *Sow.*
Oniscia Domingensis, *Sow.*
Strombus pugilis, *Linn.*
—— ambiguus, *Sow.*
—— Haitensis, *Sow.*
—— proximus, *Sow.*
—— bifrons, *Sow.*
Conus Haitensis, *Sow.*
Conus symmetricus, *Sow.*
—— stenostoma, *Sow.*
—— planiliratus, *Sow.*
—— marginatus, *Sow.*
—— Domingensis, *Sow.*
—— solidus, *Sow.*
—— catenatus, *Sow.*
—— interstinctus, *Guppy.*
—— consobrinus, *Sow.*

* Quart. Journ. Geol. Soc. vol. xxii. p. 298.
† Geol. Trans. 1st ser. vol. v. p. 459.
‡ Quart. Journ. Geol. Soc. vol. xix. p. 408, and vol. xx. p. 20.
§ Heneken, Quart. Journ. Geol. Soc. vol. ix. p. 115.
|| Quart. Journ. Geol. Soc. vol. vi. p. 39, and vol. ix. p. 129.
¶ *Ibid.* vol. xix. p. 406, and vol. xx. p. 20.

Conus gracilissimus, *Guppy*.
Murex Domingensis, *Sow*.
Typhis alatus, *Sow*.
Persona similima, *Sow*.
Triton variegatus, *Lam*.
—— femoralis, *Linn*.
—— gemmatus, *Reeve*.
Oliva cylindrica, *Sow*.
—— hispidula, *Lam*.
Mitra Henekeni, *Sow*.
—— varicosa, *Sow*.
Fasciolaria semistriata, *Sow*.
—— intermedia, *Sow*.
Turbinellus ovoideus, *Kien*.
—— validus, *Sow*.
—— Haitensis, *Sow*.
Latirus infundibulum, *Gmel*.
Fusus Henekeni, *Sow*.
—— Haitensis, *Sow*.
Pyrula melongena, *Linn*.
Marginella coniformis, *Sow*.
Cypræa Henekeni, *Sow*.
—— pustulata, *Lam*.
Voluta pulchella, *Sow*.
—— soror, *Sow*.
Columbella Haitensis, *Sow*.
—— venusta, *Sow*.
Cancellaria lævescens, *Guppy*.
—— Barretti, *Guppy*.
—— Moorei, *Guppy*.
Pleurotoma Henekeni, *Sow*.
—— venustum, *Sow*.
—— consors, *Sow*.
—— Haitense, *Sow*.
—— Jaquense, *Sow*.
Terebra flammea, *Lam*.
—— sulcifera, *Sow*.
Terebra inæqualis, *Sow*.
—— bipartita, *Sow*.
Phos Moorei, *Guppy*.
—— elegans, *Guppy*.
Nassa incrassata, *Müll*.
Cerithium plebeium, *Sow*.
—— uniseriale, *Sow*.
Natica subclausa, *Sow*.
—— sulcata, *Born*.
—— phasianelloides, *D'Orb*.
Solarium quadriseriatum, *Sow*.
Dentalium Mississipense, *Conr*.
Petaloconchus sculpturatus, *Lea*
Vermetus papulosus, *Guppy*.
Bulla striata, *Brug*.
—— paupercula, *Sow*.
—— granosa, *Sow*.
Corbula viminea, *Guppy*.
Venus Paphia, *Linn*.
—— puerpera, *Linn*.
Lucina Pennsylvanica, *Linn*.
—— tigrina, *Linn*.
Tellina biplicata, *Conr*.
Cardita scabricostata, *Guppy*.
Cardium Haitense, *Sow*.
Pectunculus acuticostatus, *Sow*
Arca patricia, *Sow*.
—— Noæ, *Linn*.
—— consobrina, *Sow*.
—— pexata, *Say*.
Pecten Thetidis, *Sow*.
—— inæqualis, *Sow*.
—— oxygonus, *Sow*.
Spondylus bifrons, *Sow*.
Chama arcinella, *Lam*.
Ostrea virginica, *Gmel*.
Teredo fistula, *Lea*.

There are several undescribed species in the Geological Society's collection.

b. *Jamaica*.—As I have so recently given an account of the Miocene Mollusca of Jamaica*, I need do no more than give the names of some additional species. These are:—

Turritella tornata, spec. nov.
Corbula vieta, spec. nov.
Neæra costellata, *Desh*.†

The Corals of the Miocene deposits of Jamaica have been described by Dr. Duncan‡. Three species of Echinoderms are known from the Tertiaries of Jamaica: they have been named by Michelin; but one only (*Clypeaster ellipticus*) has been described or figured.

c. *Trinidad*.—I have alluded to the Caroni series in my paper on the Jamaican fossils. Its relation to the other Tertiaries is shown by the diagram (fig. 2). Further particulars will be found in the 'Geological Report on Trinidad' §; and it is only necessary now to

* Quart. Journ. Geol. Soc. vol. xxii. p. 281.
† I learnt the occurrence of this shell in Jamaica from Mr. J. Gwyn Jeffreys.
‡ Quart. Journ. Geol. Soc. vol. xxi. p. 1.
§ Wall and Sawkins, Geological Report on Trinidad, p. 41.

give a list of the fossils determined by me. The Moruga series is classified with the Caroni series by the Geological Survey of the West Indies; but I have no information as to its fossil contents, beyond the list of genera given in the Report. The following species are from the Caroni series at Savanetta on the Parian side of the island:—

| | |
|---|---|
| Turbinellus ovoideus, *Kien.* | Pecten oxygonus, *Sow.* |
| Solarium quadriseriatum, *Sow.* | —— comparilis, *Tuomey & Holmes.* |
| Petaloconchus sculpturatus, *Lea.* | Ostrea virginica, *Gmel.* |
| Dosinia acetabulum, *Conrad.* | Ficula carbasea, spec. nov. |
| Tellina biplicata, *Conrad.* | Teredo fistula, *Lea.* |

The Mollusca occur generally of large size. Several of the undetermined species resemble shells from San Domingo; but their condition is such as to render it unsafe to give the names.

Numerous seams of coal occur in the series, some of which, being of workable thickness (3 to 4 feet), may eventually prove of use. There are at present no facilities for getting at the coal, owing to the want of roads and paucity of inhabitants in that part of the country where the beds are exposed.

d. *Cumana.*—I have already alluded to the nature of the beds containing Miocene fossils at Cumana on the north coast of Venezuela*. Further particulars will be found in Mr. Wall's communication "On Venezuela and Trinidad." † The fossils have not hitherto been determined; but a list of the genera will be found in the Appendix to the Geological Report on Trinidad ‡. The following is a list of the species which I have been able to determine:—

| | |
|---|---|
| Pyrula melongena, *Linn.* | Melanopsis cepula, spec. nov. |
| Murex Domingensis, *Sow.* | Turritella tornata, spec. nov. |
| Persona simillima, *Sow.* | Turbo castaneus, *Gmel.* |
| Fasciolaria Tarbelliana, *Grat.* | Natica sulcata, *Born.* |
| Columbella venusta, *Sow.* | Bulla striata, *Brug.* |
| Conus gracilissimus, *Guppy.* | Venus Paphia, *Linn.* |
| —— symmetricus, *Sow.* | —— Woodwardi, *Guppy.* |
| Oliva hispidula, *Lam.* | —— cancellata, *Linn.* |
| —— cylindrica, *Sow.* | Cytherea juncea, spec. nov. |
| Marginella coniformis, *Sow.* | —— convexa, *Say.* |
| —— interrupta, *Lam.* | Lucina Pennsylvanica, *Linn.* |
| Cancellaria Moorei, *Guppy.* | —— tigrina, *Linn.* |
| Terebra inæqualis, *Sow.* | Cardium Haitense, *Sow.* |
| Pleurotoma Haitense, *Sow.* | Pectunculus pennaceus, *Lam.* |
| —— Barretti, *Guppy.* | —— acuticostatus, *Sow.* |
| Phos elegans, *Guppy.* | Arca consobrina, *Sow.* |
| Nassa solidula, spec. nov. | —— pexata, *Say.* |
| Cerithium plebeium, *Sow.* | —— incongrua, *Say.* |
| —— uniseriale, *Sow.* | |

From this list, which must be regarded as a provisional one, it will be seen that the proportion of recent species (39 per cent.) is greater than has been determined for any of the other Caribean Miocene deposits. This may be partly due here, as elsewhere, to the facility with which I have been able to identify recent species. Of the fourteen recent species, only three have not been recorded from other West-Indian Miocene beds. Of the total of thirty-seven spe-

* Quart Journ. Geol. Soc. vol. xxii. p. 282.
† *Ibid.* vol. xvi. p. 460.
‡ Report, &c. p. 163.

cies, nineteen have been found in Jamaica, and twenty-five in San Domingo, leaving but seven now enumerated for the first time from the Caribean Miocene. From this analysis it will be seen that it would be difficult to separate the Cumana beds from the Caribean Miocene, and at the same time that it is probable they represent one of the highest stages of that formation.

## § 5. The Age of the Caribean Miocene.

The affinities of the organic remains of the Caribean Miocene are stronger with foreign species, both Midtertiary and Recent, than with the existing fauna of the West Indies, indicating an antiquity somewhat greater than would be adduced for them from the proportion of extinct species, which I cannot consider greater for those deposits I have classed as Upper Miocene than 80 per cent. In my paper on the Jamaican fossils I showed that the proportion of recent species was 20 per cent.; and by comparing the list I have given of the San Domingan Mollusca, it will be seen that a similar proportion obtains for them. In explanation of the discrepancies between my list and previous estimates, I may remark that I cannot consider the *Pyrula consors* of Sowerby to be distinct from the *P. melongena* of Linné, nor the *Ostrea Haitensis* of Sowerby to be specifically distinguishable from the *O. virginica* of Gmelin. Mr. Carrick Moore, in the latter of his papers on the San Domingan fossils, reduced the proportion of living species to 8 or 9 per cent.; but this was done by assigning certain of them to deposits of a later period. However, as those species have been found in Jamaica and elsewhere associated with the characteristic fossils of the Caribean Miocene, I have not felt myself justified in excluding them from the Haitian list.

## § 6. Other Tertiary Formations in the West Indies.

There exists in several of the West-Indian islands undoubted later Tertiaries containing a very large proportion of recent species. This seems to have been partly the cause of the confusion as to the age of some of the fossils. Our knowledge of the geology of these islands being so limited, some authors have inferred that all the fossils were derived from the same formation. It is often difficult to distinguish between the rocks composing the newer and older formations, both being sometimes white calcareous deposits, and the newer frequently being the hardest.

The Tertiary formations of Guadeloupe have been studied by Duchassaing, who divides them into Newer and Older Pliocene and Miocene*. To the first of these are assigned, amongst other deposits, those containing human remains. From the Older Pliocene Duchassaing obtained twenty-six species of Mollusca, many of which he identified with recent species†. He records from the same beds thirteen Echinoderms, of which seven are extinct. It would seem that these results are somewhat discordant; and when we consider

* Bull. Soc. Géol. de France, sér. 2. vol. iv. (1847) p. 1093.
† *Ibid.* sér. 2. vol. xii. p. 753.

that some of the Mollusca are identified with European Eocene species, it is obvious that we cannot consider our knowledge of the Tertiaries of Guadeloupe at all exact. In Duchassaing's list eight corals are mentioned. Dr. Duncan has also treated of the fossil corals of Guadeloupe*.

Duchassaing refers centain deposits to the Miocene. From the lower volcanic sands, which he includes in this formation, he only gives us the names of two Mollusca, one of which he considers to be identical with a Paris-basin species, and the other occurs in his Older Pliocene. According to Moreau de Jonnés†, the Miocene formation includes *Terebratulæ* like those of more ancient strata. If this is the case, it may be the equivalent of the San Fernando beds in Trinidad.

M. Payen found fossils in Guadeloupe referable to *Cypræa*, *Terebratula*, *Spatangus*, and *Echinus*. Deshayes considered these to be Quaternary, and the *Terebratula* to belong to a new species‡.

In Trinidad, beneath a large unfossiliferous detrital series, there exists a Pliocene formation, exposed at Matura on the east coast, from which I have already published a list of species§. Many of my determinations were doubtless erroneous; but to provide for mistakes of this kind I affixed marks to such of the species as I had compared and found identical with recent forms. I see no ground for changing my opinion as to the relative age of these beds, although it is probable that the percentage of extinct species is somewhat greater than stated.

The greater part of the island of Barbados appears to consist of Tertiary rocks which have been divided into two main divisions. The newest of these, the coral-limestone, contains a large number of recent species. No extinct species of Mollusca are recorded from it. The Scotland formation is considered to be older, and the following shells have been described from it‖:—

Scalaria Ehrenbergi, *Forbes*.
Nucula Packeri, *Forbes*.
Nucula Schomburgki, *Forbes*.

This formation was considered to be Miocene by Professor Forbes; and it seems to include the deposits containing siliceous organisms¶. Dr. Duncan has described, in his paper before cited, three species of corals from Barbados.

Barbuda contains a formation resembling the coral-limestone of Barbados. It consists of a white calcareous deposit full of shells, all of which are, as far as I have examined, of existing species. The existence of a Miocene formation in that island seems, nevertheless, to be indicated by the corals described by Dr. Duncan. That palæontologist has also described corals from Montserrat &c.

* Quart. Journ. Geol. Soc. vol. xix. pp. 412, 452.
† Cited by Duchassaing, Bull. Soc. Géol. France, sér. 2. vol. iv. p. 1093.
‡ Bull. Soc. Géol. de France, sér. 2. vol. xx. (1863) p. 475.
§ Geological Magazine, vol. ii. (1865) p. 256.
‖ Schomburgk, History of Barbados, p. 565.
¶ Ehrenberg's account of these fossils was partly translated in Ann. Nat. Hist. vol. xx. p. 115.

D'Orbigny has published figures of a number of fossils from Cuba, which he identifies, for the most part, with recent species* ; but as they are all casts, it is difficult to place reliance on the determinations. Two of his species I have recognized in the Miocene beds of Jamaica, San Domingo, and Trinidad. One of these is the *Natica phasianelloides*, and the other is *Tellina Sagræ*, which seems to me identical with *T. biplicata* of Conrad.

Beyond some general notices scattered through various works, I believe but little more is known of the geology and palæontology of the West Indies than I have indicated. The present summary, though not, perhaps, of much interest as far as it relates to the later Tertiaries, will be of service to future investigators of West-Indian geology†.

## II. Descriptions of the New Species.

1. Nassa solidula, spec. nov.

Shell turreted, thick, costated by stout distant rounded ribs, which are almost developed into tubercles on the angle of the whorls, and are cancellated by numerous fine and close spiral costellæ, of which there are usually two finer in the interval between two larger ones; spire conical, sharp; whorls 8, somewhat angulate above, the last much larger, forming two-thirds of the length of the shell; outer lip dentate, thickened externally, forming a varix; columellar margin with a narrow callus; columella strongly twisted; canal short, abruptly reflected.

This form is related to *N. prismatica*, Brocchi; but there are considerable differences, among which are the relative narrowness of the present shell and its sharper spire.

*Locality.*—Cumana, Upper Miocene.

2. Ancillaria lamellata, spec. nov.

Shell ovate-conic; spire elevated, acuminate, spirally striated; last whorl rather ventricose, spirally striate above; aperture suboval, elongate; columellar margin rather strongly folded and bearing a lamellar parietal tooth or plait, which extends into the interior, obstructing the posterior part of the aperture.

* Paléontologie de Cuba.

† Besides the various memoirs already cited, the following will be found in the publications of the Geological Society:—

Bahamas.—Nelson, Quart. Journ. vol. ix. p. 200.

Barbados.—Skey, Geol. Trans. 1st ser. vol. iii. p. 238; Ehrenberg, Quart. Journ. vol. iv. pt. 2. p. 19.

Bermuda.—Vetch, Geol. Trans. 2nd ser. vol. i. p. 172; Nelson, Geol. Trans. 2nd ser. vol. v. p. 103.

Jamaica.—De la Beche, Geol. Trans. 2nd ser. vol. ii. p. 143; Owen (On a Fossil Mammal), Quart. Journ. vol. ii. p. 541.

Montserrat.—Nugent, Geol. Trans. 1st ser. vol. i. p. 185.

Trinidad.—Nugent, Geol. Trans. 1st ser. vol. i. p. 63.

Jamaica.—Sawkins, Quart. Journ. vol. xix. p. 35.

With the exception of those by Owen and Ehrenberg, the above papers relate chiefly to the physical and mineralogical structure of the islands.

This shell, near in general shape to *A. glandina*, is distinguished by the enamel which is spread over the spire being regularly and distinctly spirally striated or grooved, and by the strong parietal plait. In some examples the spiral grooving covers the whole of the whorls; but in others the greater part of the last whorl is smooth. The columella is grooved in a similar manner.

Lower Miocene, Manzanilla, Trinidad.

3. Ficula carbasea, spec. nov.

Shell pyriform, somewhat ventricose; spire short, scarcely elevated; whorls 5, ornamented with equidistant raised spiral lines, of which there are three finer between every two of the larger lines, their interstices being cancellated by numerous fine subequal raised lines, which scarcely rise upon the spiral ones; suture sunk; aperture ovate, wide, nearly as long as the shell.

This species closely resembles *F. clathrata*, Lam., from which it is distinguishable by the ornamentation.

Trinidad (Caroni Series); Anguilla.

4. Melanopsis capula, spec. nov.

Shell ovate-turreted; spire conical, sharp; whorls about 7, regularly increasing, ornamented superiorly with fine costæ, becoming obsolete on the last whorl, which forms more than half the length of the shell; suture linear, impressed; aperture ovate; outer lip simple, prominent; collumella twisted; canal short and broad.

I do not know of any form resembling this species, which was probably not a freshwater shell. It may possibly have been an estuarine form. It reminds one of a shortened and widened *Eulima*, or even a *Stylifer*.

Upper Miocene, Cumana.

5. Turritella tornata, spec. nov.

Shell turreted, elongate; whorls numerous, increasing very gradually, ornamented with two spiral keels, each bearing a moniliform row of granules; the upper keel accompanied by a granular line halfway between it and the linear suture; the rounded concavity between the keels having also two fine linear spiral rows of moniliform granules; aperture subquadrate.

Upper Miocene, Cumana; Jamaica; San Domingo.

6. Corbula vieta, spec. nov.

Shell subtrigonal, nearly equilateral, rounded at both extremities, scarcely truncate posteriorly; right valve turgid, ornamented with numerous stout, rounded, concentric costæ; umbones prominent.

This shell is variable as to height, small examples approaching in form to *C. elevata*, Conr. It appears to be most closely allied to *C. gibba* and *C. pisum*, from which it is distinguished by its greater size and stouter concentric ribs, of which there are between thirty and forty on the large valve of well-grown examples of *C. vieta*. It is also less truncate posteriorly than the species mentioned.

Lower Miocene, Manzanilla, Trinidad; Upper Miocene, Jamaica. It also occurs in the Pliocene of Trinidad.

7. Cercomya ledæformis, spec. nov.

Shell transverse, elongate, inequilateral, thin, closely covered with numerous fine and regular longitudinal or concentric ridges; anteriorly rounded; posteriorly produced into a pointed rostrum, of which the upper margin is concave; posterior cardinal area strongly impressed.

In addition to the strong ridge defining the cardinal area a second ridge runs from the umbo to the end of the rostrum, upon which, in some examples, the concentric ridges rise into small points.

I have not been able to observe the details of the hinge of this shell. The right valve alone has occurred to me in a moderately perfect state; but fortunately I have discovered some shattered left valves, which prove that this shell is not a *Pandora* with a flat left valve, which I at first imagined it might be. I have therefore considered it to belong to the genus *Cercomya*, which has not hitherto been recorded from Tertiary rocks.

Lower Miocene, Manzanilla, Trinidad.

8. Mactrinula macescens, spec. nov.

Shell oblong-subtrigonal, thin, compressed, nearly equilateral, with broad transverse sulcations, which begin at the keel-like ridge on the posterior margin, and are continued to the rounded and somewhat produced anterior margin; umbones small, depressed; posterior marginal area separated by an acute keel, extending from the umbo to the angle of the inferior margin; hinge with a double cartilage-pit and a Λ-shaped cardinal tooth in the left valve; laterals in the same valve lamellar, forming a deep groove for the ligament; laterals in the right valve lamellar, doubled; cardinal tooth obsolete.

The nearest recent ally of this shell is *M. plicataria*, Linn., which is an inhabitant of the Indian Ocean. It is more distantly related to *M. prætenuis*, Conrad, of the Eocene deposits of North America.

Lower Miocene, Manzanilla, Trinidad.

9. Venus Walli, spec. nov.

Shell subtrigonal, somewhat inequilateral, anteriorly rounded, posteriorly somewhat angular, ornamented with numerous small and fine close radiating costellæ, interrupted by high concentric crenulate ridges, which are higher and closer towards the ventral margin; umbones small, prominent; lunule impressed, sinuately striated, circumscribed by a sharp groove; posterior cardinal area distinct, striate.

On the disk the costellæ are distinctly paired, with a smaller intermediate costella between each pair; but near the keel which runs from the umbo to the posterior angle, separating the striate posterior margin, the costellæ are larger and single, and the concentric ridges die away into the striations.

This species is related to the recent *V. cancellata*.

Lower Miocene, Manzanilla, Trinidad.

10. CYTHEREA JUNCEA, spec. nov.

Shell subtrigonal, rounded anteriorly, and somewhat angular and truncate behind, ornamented with numerous thin concentric lamellæ, alternately rather higher; posterior cardinal area slightly folded, rather indistinct; lunule impressed, striated; umbo small, incurved; hinge-teeth strong, the hinder (of the right valve) bifid, the two anterior ones compressed, close together, and having before them a deep oblong pit for the reception of the tooth of the opposite valve. Hinge-area with a long groove extending from the termination of the ligament nearly to the posterior angle.

Upper Miocene, Cumana.

11. DOSINIA CYCLICA, spec. nov.

Shell nearly orbicular, thick, subinequilateral, scarcely swollen, finely and regularly concentrically striated, with occasional deeper subrugose lines of growth towards the ventral margin; umbones small, compressed, and closely approximate; lunule entirely wanting; margins plain. Hinge consisting of a broad flat plate circumscribed by the raised dorsal margin; teeth three, large; the central and largest one placed immediately under the umbo; the other two lamellar and divergent, the posterior one largest.

This shell has the general shape of *Dosinia discus*. It is also allied to *D. orbicularis* of the Bordeaux deposits. It wants the lunule and the small anterior tooth ascribed to the genus *Dosinia*, and I thought at first of referring it to *Cyclina*. The general character of the hinge, as well as of the exterior, however, resembles that of *D. orbicularis* so closely that I have decided to place it under the same generic name as that species. It is evidently intermediate in some respects to the two genera mentioned. It is readily distinguished from *D. acetabulum*, another species to which it bears some resemblance, by the very different arrangement of the hinge-teeth, by the total absence of a lunule, and by the umbo being less incurved.

Lower Miocene, Manzanilla, Trinidad.

12. CARDIUM CASTUM, spec. nov.

Shell subovate, somewhat oblique, ventricose, ornamented with about twenty-two stout, rounded, radiating ribs, imbricated by numerous transverse striæ, which are continuous across the interstices; umbones small, prominent; posterior margin divided from the disk by a rounded carination; margins pectinate.

Allied to the recent *C. obovale*, Sow. In young examples the difference in size of the ribs on the disk and those on the posterior margin is more marked, and gives a strongly carinate appearance to the shell, which is scarcely so conspicuous in larger specimens.

Lower Miocene, Manzanilla, Trinidad.

13. ERYCINA TENSA, spec. nov.

Shell ovate, subequilateral, minutely striated concentrically with about fourteen low and somewhat distant radiating ribs; anteriorly rounded, posteriorly truncate; umbones not prominent.

I do not know of any recent or fossil West-Indian species at all resembling this shell, which seems to be related to *E. obliqua*, Caillat (*E. nitidula*, Desh.), of the Paris basin.

Lower Miocene, Manzanilla, Trinidad.

14. ARCA TRINITARIA, spec. nov.

Shell solid, subtriangular, oblique, rather inequilateral, with about forty unarmed ribs, which occasionally become imbricated towards the ventral margin; umbones prominent, curved, separated by a ligamental area with grooves corresponding to the anterior hinge-teeth; posterior margin nearly flat, cordate, divided from the disk by an abrupt angular carination; anterior edge short, rounded; ventral edge nearly straight; inner margin strongly dentate. Hinge-teeth numerous, lamellar, the lateral ones bent into an angle.

Allied to *A. ponderosa*, Say. It may easily be distinguished by the number of ribs and by other characters. It may possibly have been confounded with *A. incongrua* by the Geological Survey; but it is very distinct from that species. *A. Trinitaria* may be distinguished from all other Arks with which I am acquainted by the strong angular posterior ridge and flat posterior margin, which give so peculiar an appearance to the shell. The lateral hinge-teeth, which are bent into the form of an L, also afford a good character for the distinction of this species.

Lower Miocene, Manzanilla, Trinidad.

15. ARCA FILICATA, spec. nov.

Shell subquadrate, oblique, somewhat inequilateral, rather inequivalve, with about thirty ribs, broader than their interstices, and nodosely crenate, becoming nearly smooth on the disk of the right valve; beaks prominent, oblique, their apices rather remotely separated by a broad and well-developed lanceolate ligamental area; margins strongly dentate, rounded, forming angles anteriorly and posteriorly with the hinge-line, which is straight, and furnished with a regular series of small parallel teeth.

A species allied to *A. pexata*, but having the umbones separated by a well-developed ligamental area, which is nearly wanting in that shell.

Lower Miocene, Manzanilla, Trinidad.

16. GRYPHÆA ATHYROIDES, spec. nov.

Shell oval, gibbous, slightly irregular; upper valve convex, marked by deep and wide sulci of growth; lower valve broadly carinate along its mesial portion from the umbo to the front margin, plicated by several obsolete radiating folds; lines of growth strongly marked, undulated; umbo small, produced, and abruptly truncate.

This oyster resembles an irregular Brachiopod; and the umbo of the lower valve is produced and truncated by a circular concavity resembling a foramen, but which does not extend into the interior. The microscopic structure also excludes it from the class Brachiopoda.

San Fernando beds, Trinidad.

17. SPIRORBIS CLYMENIOIDES, spec. nov.

Tube coiled, discoidal, compressed; whorls usually three to four, flattened or even fused together, with sinuo-radiate lines of growth; periphery carinate; aperture constricted, circular; nucleus with an obsolete aperture nearly as large as the terminal one.

The nearest species to this is *S. spirulæa*, Lam. (*Spirulæa nummularis*, Schlot.), from which the present species may be distinguished in never having the last whorl produced or separated.

San Fernando beds, Trinidad. Specimens frequently occur in the cherty nodules, containing immense numbers of *Orbitoides Mantelli*, *Nummulina*, *Cardita*, and the curious fossil next to be described.

CISSEIS, nov. gen.

Body small, depressed, unattached, divided into rays; oscula few, large, generally disposed along the summits of the rays, and surrounded by more numerous pores, which are developed on both surfaces.

18. CISSEIS ASTERISCUS, spec. nov.

Body divided into obtuse, somewhat carinate rays, generally four, but occasionally more; oscula disposed along the summits of the rays, and particularly on the subconical apex; pores numerous.

The oscula, or larger apertures, are disposed in a group of seven or eight upon the apex, from which a row is continued along the summit of each ray. The general form of the body is that of a small *Palmipes*. Between the rays and towards the margins the pores become smaller and less distinct.

The nature of this body is so problematical that my object in describing it is rather to make known its existence, and possibly to obtain some hint as to its true nature, than to draw any inference from its occurrence. It is found in considerable numbers among the *Orbitoides* and *Nummulinæ* at San Fernando, in Trinidad. As it appears by its structure to be more akin to the fossil sponges than to any other organisms, I have described it as such, at the same time giving it a generic name which does not involve any view as to its true affinities. It may possibly be a Foraminifer; but the nature of the pores and the want of division seem to be against that view, and the same characters appear to preclude our placing it with the Echinodermata. In all the specimens I have examined the pores are filled with a mineral infiltration, in a similar manner to those of the *Orbitoides*. The structure is perhaps as near to that of *Sparsispongia* as to that of any other organism.

## III. OBSERVATIONS ON THE RELATIONS OF THE CARIBEAN MIOCENE FAUNA.

From the researches which have been made into West-Indian Palæontology it appears that the fauna of the Miocene period in these islands presents some marked distinctions from that of the United States, and had a stronger resemblance in several of its leading characters to that of Europe,—not that there were no species common to the Miocene of the West Indies and that of North America, but that those types which give a distinctive character to the fauna of the Caribean Miocene, and which assimilate it to that of Europe, were absent from the North American province. When to this is added the likeness of the Miocene faunas of the West Indies and of Europe to that now existing in the east, it becomes a matter of high interest to explain the causes of that similarity, especially as it has been urged of late that a similarity of organic contents implies a want of contemporaneity in the containing deposits when separated by a considerable interval in space. Such explanation may possibly be found in the former distribution of land and water allowing or preventing the free migration of organic beings.

Respecting the Atlantis hypothesis, it is unnecessary to suppose that the Atlantis existed as a continent up to the close of the Miocene period. It appears just as easy to account for the facts by supposing the existence of such a connexion antecedently to the Miocene period*; for, as far as regards the Swiss flora, Heer does not consider any of the species to be identical with living or fossil American forms. If they are merely closely allied species, they may have been derived from common ancestors in the Eocene period, or, at any rate, in the beginning of the Miocene. Our views on this point must partly depend on the longevity of vegetable species as compared with those of Mollusca; but, as bearing on the subject, we have the testimony of Lesquereux and Newberry that the Eocene plants of America are closely related to those of the Miocene of Europe, as well as to the recent flora of the former country†; and American geologists seem to entertain no doubt as to the Eocene age of these remains, the deposits in which they are imbedded having been proved to pass under the Claiborne (Eocene) beds.

I see, then, some ground for adhering to the views entertained by Forbes and Godwin-Austen, concurred in by Darwin, and supported by Dr. Duncan's investigations, that Europe was probably during the Miocene period much in the condition of the present Pacific Ocean, and that, as observed by the latter palæontologist, it is reasonable to infer the prolongation of the maze of islands across the Atlantic. The Mollusca of the Caribean Miocene generally betoken a clear sea, and probably lived on the slopes of coral-banks. As confirmatory of this view, I may cite the absence of littoral shells from the Caribean Miocene fauna.

When the climate of Europe became inimical to the existence of those species which were adapted only to a high temperature, they would migrate or become extinct; and supposing that the Atlantis had in the meantime become broken up and submerged, their migration would take place towards the east, presuming that there was a sea-passage in that direction, which seems to be generally considered

* *Vide* Intellectual Observer, No. lvi. pp. 88–97. Mr. Jenkins informs me that his paper was written in ignorance of the coincidence in the views we entertain on this subject, and without a knowledge of the contents of this paper.

† Dana, 'Manual of Geology,' p. 513.

extremely probable. It would also render the palæontological facts more easy of explanation if it could be shown that the breaking-up and submergence of the Atlantic land began in the west and proceeded towards the east. From such a succession of circumstances it would result that, while the European Miocene fauna would be related to the Eastern recent fauna, the relations of the Caribean Miocene fauna would be towards the European Miocene and the Eastern recent faunas, which seems to be in conformity with the facts already set forth, as I shall further endeavour to show in this paper. The affinities with the Eastern fauna are, as might be expected, somewhat less close than with the European Miocene.

The inferences arrived at from a study of the Asiatic recent and Tertiary faunas gives support to the view that the migration of organized beings was towards the east, and not from the east. Mr. Jenkins, in his paper on Javan fossils, has ably summed up the arguments on this head*; and it is obvious that if Miocene forms migrated from Europe to the East Indies, where they are in part still living, they could hardly get across the Isthmus of Panama in time to be imbedded in Miocene deposits, unless the latter could be shown to be equivalent in time to the later Tertiaries of Europe (Pliocene), which, considering the great change in the fauna since the deposition of the Caribean Miocene, a change indicated by the extinction of 80 per. cent. of the Mollusca, can hardly be assumed on such grounds.

I shall now consider more particularly the tendency of the testimony furnished by the fossils. And, taking first *Cytherea planivieta*, of the Miocene of Jamaica, it is to be observed that this fossil has no near recent ally in the West Indies, but it is closely related to *C. erycinoides* of the Miocene of Europe. Now both *C. erycinoides* and *C. planivieta* are closely related to *C. erycina* of Ceylon. As it is a physical impossibility that a migration should take place from the existing to a fossil fauna†, it follows that the Miocene form must have migrated to the east. But as the West-Indian shell is allied to the Bordeaux species, it may have been that its route lay through southern Europe, which it possibly reached through northern Africa. Its West-Indian Miocene form was thus *C. planivieta*, its European Miocene form *C. erycinoides*, and its Eastern form *C. erycina*. Lest it should be supposed, however, that I rest my case on a single species, I will mention some other examples. Taking the Echinoderms first, we find that three species of *Echinolampas* occur in the Caribean Miocene, their nearest allies being found in the Maltese beds. That genus is quite extinct in the West Indies, its place being filled by *Echinometra*, which is as abundant now amongst the Antilles as the extinct Echinolampades were formerly. The only recent species of *Echinolampas*, three in number, inhabit Senegal, the Red Sea, and the Pacific. *Cidaris Melitensis*, of Anguilla, is to me undistinguishable from the Maltese urchin. Of the genus *Cidaris* the living species are chiefly found in Eastern seas.

* Quart. Journ. Geol. Soc. vol. xx. (1864) p. 62.

† Hamilton, Address to the Geol. Soc., Quart. Journ. Geol. Soc. vol. xxi. p xciv.

*Schizaster Scillæ* is another species common to the Miocene of Anguilla and the Maltese beds. No recent species are known of *Schizaster* in the West Indies, the only species so described (*Periaster Cubensis*) being really a fossil from Cuba and Guadeloupe. The present distribution of the six recent species, including two Periasters, is North Europe, Mediterranean, Red Sea, and Australia. These three genera are plentifully represented in the European Miocene. A mollusk of strongly marked type, which has analogous relations, is *Tellina biplicata*, found fossil in North America, in San Domingo, and Cuba, and in the Caroni series of Trinidad. It is closely allied to *T. Sobralensis* of the Portuguese Tertiaries, and to *T. ephippium* of the Indian seas. Among the extinct forms we find many relationships of this sort; but in all the cases here cited the affinity is most decided; and I have confined myself to those where the indicated alliances of the fossils are much more close than to any existing West-Indian forms, and I have avoided genera such as *Natica*, *Turritella*, *Pecten*, *Murex*, &c., where the affinities of different species are so various and complex as to render comparisons somewhat doubtful. But I will now consider the bearing, which is scarcely less remarkable, of some of those still-existing species of Mollusca which have been found in the Caribean Miocene. The most noticeable of these are *Bulla striata*, *Lucina Pennsylvanica*, and *L. tigrina*. The two former, which occur in the European Miocene, have not, I believe, been found in the Eastern seas, nor do they exist on the west coast of America. Had they not been discovered in the Caribean Miocene, their existence in the West-Indian seas might have been cited to show that species from the European Mid-tertiary fauna had migrated to the West Indies, whereas now that they are found to occur in the Miocene of the West Indies such an inference becomes more doubtful. *Lucina tigrina* is so well-known and so well-marked a species that its distribution is of some interest here. We find that this species, fossil in the Miocene of San Domingo and of Europe, is now found living in the West Indies, at Senegal, in the Red Sea, the Mozambique Channel, and the Indian seas, and it also occurs fossil in Egypt*. It does not occur on the west coast of America. But in order to avoid the inevitable length to which this paper would run were I to attempt to enumerate all the cases of this kind, I have appended a table in which a few of the most striking of these affinities are displayed. I will therefore conclude this part of the subject by mentioning two more instances—that of the genus *Cassidaria*, which is represented by two species in the Caribean Miocene, but confined in the living state to the Mediterranean, and that of the genus *Malea*, which, like *Cassidaria*, has species in the Miocene of Europe, but its living species occur in the Eastern seas, none being known from the West Indies.

* Deshayes, Conchyliologie, vol. i. pt. 2. p. 795.

IV. Table showing the Affinities, of some of the Fossils of the Caribean Miocene.

a. *Species still living.*

| | European Miocene. | Living in |
|---|---|---|
| Nassa incrassata ......... | N. incrassata. | Mediterranean. |
| Triton gemmatus ......... | ..................... | Philippines, &c. |
| Pyrula melongena ...... | P. melongena. | West Indies. |
| Bulla striata .............. | B. striata. | West Indies. |
| Venus Paphia ........... | V. Paphia | West Indies. |
| —— puerpera ........... | ..................... | Indian Ocean. |
| Lucina Pennsylvanica ... | L. Pennsylvanica. | West Indies. |
| —— tigrina ............... | L. tigrina. | West Indies, Red Sea, Senegal, Mozambique, Indian Seas. |
| Ostrea Virginica ......... | O. Virginica. | North America. |

b. *Extinct Species.*

| | European Miocene analogue. | Living analogue. |
|---|---|---|
| Cassis monilifera ......... | C. diadema. | |
| Cassidaria sublævigata... | ............................... | C. striata. Mediterranean. |
| Oniscia Domingensis ... | O. cithara. | O. cancellata. Madagascar &c. |
| Persona simillima ....... | ............................... | P. clathrata. Madagascar &c. |
| Typhis alatus ............ | T. affinis, *Eichw.* | T. pinnatus. Eastern Seas. |
| Mitra Henekeni ........ | M. scrobiculata, *Brocchi.* | M. filosa. Eastern Seas. |
| Ficula carbasea........... | F. clathrata, *Lam.* | F. reticulata. Eastern Seas. |
| Columbella gradata ...... | C. curta, *Bell.* | |
| Cytherea planivieta ...... | C. erycinoides. | C. erycina. Ceylon. |
| Tellina biplicata ......... | T. Sobralensis, *Sharpe.* | T. ephippium. Indian Ocean. |
| Pecten Mortoni ......... | ............................... | P. Japonicus. Japan. |
| Cidaris Melitensis......... | C. Melitensis. | |
| Clypeaster ellipticus...... | ............................... | C. Australasia. Eastern Seas. |
| Echinolampas semiorbis | E. hemisphæricus. | Living species in Eastern Seas. |
| —— lycopersicus......... | E. scutiformis. | |
| Schizaster Scillæ ......... | S. Scillæ. | |
| Fasciolaria Tarbelliana | F. Tarbelliana, *Grat.* | F. filamentosa. Ceylon &c. |
| Cancellaria Moorei ...... | C. ampullacea, *Brocchi.* | |

The tendency of all these facts can hardly be mistaken, and I think I have said enough to show that my conclusions are based on no mere superficial analogy. I have endeavoured to suggest what seems the most probable explanation; and I may add that, as it has been shown that it is highly probable that a great part of North Africa was submerged within the Tertiary period*, it may be that a part of the West-Indian Miocene fauna migrated to south Europe and the East by that route. As I have already mentioned, *Lucina tigrina* occurs fossil in Egypt. It will be unnecessary for me to say more on this point, because it is easier to explain the migration of species on this side of the Atlantic than to account for the mode in which they crossed that ocean. It is not, however, without some

* See Martins, Rev. des deux Mondes, July 1864, cited in the President's Address, Quart. Journ. Geol. Soc. vol. xxi. p. lxxxiii.

significance for this view that the corals of the Miocene beds of Madeira are analogous to those existing in the Red Sea*.

The arguments which have induced me to favour the view that there was some former connexion between the shores of the Atlantic, do not entirely forbid the supposition that there may have been, during some part of the Tertiary period, a connexion, by the way of Panama, between the Atlantic and the Pacific. Mr. G. H. Saunders discovered fossils of the Caribean Miocene on the isthmus in a cutting of the Panama Railway†. Mr. Carrick Moore has given us a list of West-Indian Miocene species related to Pacific forms‡, all of which, however, do not occur on the coast of America. There is also a certain relationship between the recent faunas of the two sides of the isthmus, as indicated by the following list of species either identical or so nearly related as in some cases to present difficulty in their separation:—

| | | | | |
|---|---|---|---|---|
| Cytherea Dione, | West Indies and Mazatlan. | | | |
| Purpura patula, | West Indies and Panama. | | | |
| Modiola Braziliensis, | ,, | ,, | | |
| Mactra similis, | ,, | ,, | | |
| Purpura undata, | West Indies | | = P. biserialis, | Panama. |
| —— sp., | ,, | ,, | = P. nodosa, | ,, |
| Arca illota, | ,, | ,, | = A. Tayboyensis, | ,, |
| —— Adamsi, | ,, | ,, | = A. solida, | ,, |

This is not intended as an exhaustive list; but it is obvious that there is nothing in it that would lead us to assume anything more than a very partial migration. We do not find here that strong chain of affinities which leads us from the Caribean through the European Miocene to the shores of Madagascar and Ceylon. We find, indeed, that those typical forms which are common to the Caribean Miocene and the Indian seas do not occur on the west coast of America.

The general conclusions at which I have arrived may be shortly stated as follows:—

1. That the distribution of fossil and recent species shows it to be highly improbable that the West-Indian Miocene forms reached the localities where they occur as fossils by way of the Isthmus of Panama, or by an easterly route from Europe or from the Indian seas.

2. That it is probable that there was during the early and middle Tertiaries such a connexion between the shores of the Atlantic as admitted of the migration of organized beings from one side to the other, although the continents may not have been absolutely joined.

In regard to the latter of these conclusions, it seems that the evidence before us can scarcely yet justify any positive assumption as to the particular direction in which the migration of species took place, or whether the origin of the typical forms of the Miocene was on the western or the eastern side of the Atlantic, or in the intermediate region. Another view is that there might have been an interchange of species; but this would require a closer and more perma-

* Lyell, 'Elements of Geology,' 6th ed. p. 668.

† Quart. Journ. Geol. Soc. vol. ix. p. 132.

‡ *Ibid.* vol. ix. p. 131.

nent connexion of the two sides of the Atlantic. On the whole, the balance of evidence appears to be in favour of the view that there was migration from the western to the eastern side of the Atlantic.

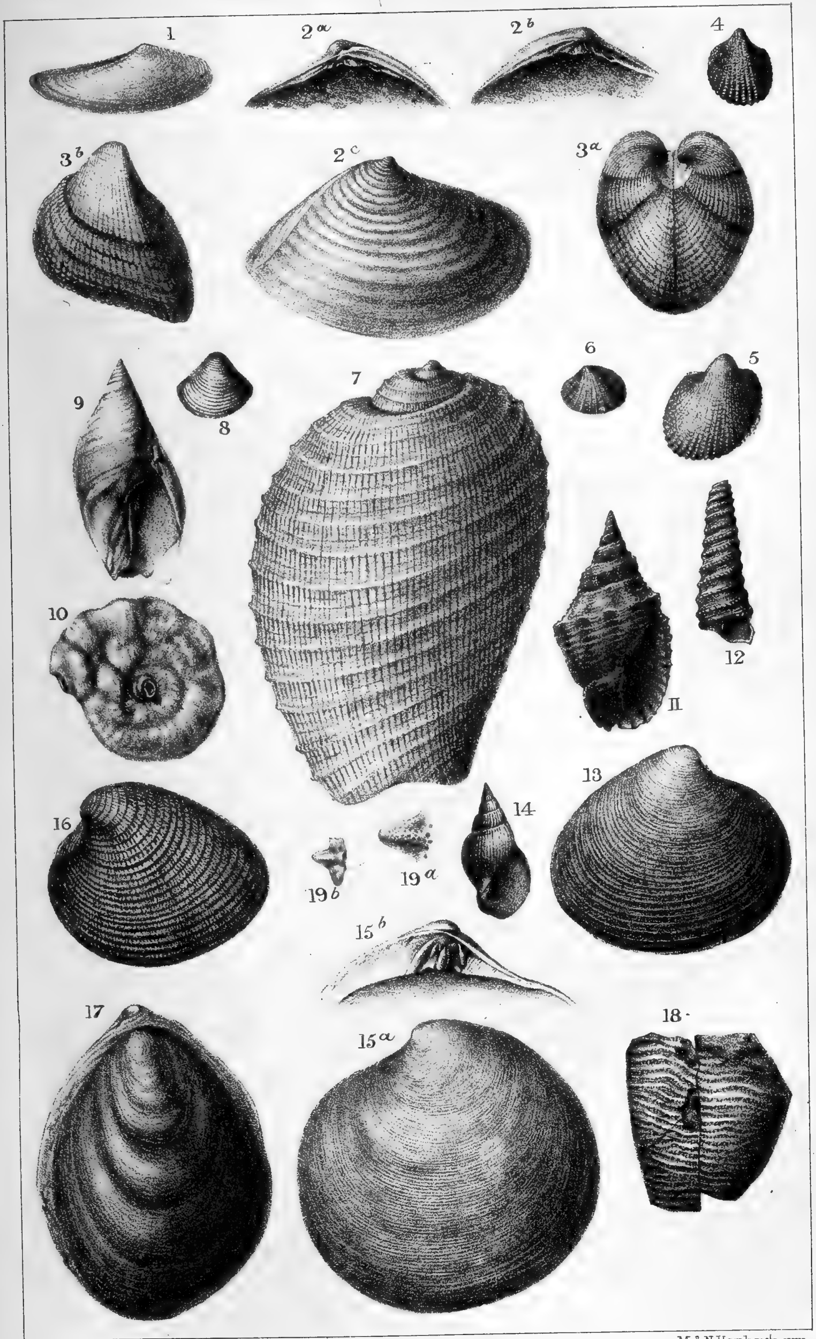
In conclusion, I may observe that I have been unavoidably led to support a modification of the Atlantis hypothesis provisionally, and until it can be clearly shown what theory can best reconcile the facts. It is to be hoped that our information relating to the Tertiary formations will be increased by all who have it in their power to do so; for principles may thus be made manifest which may hereafter be applied to the study of the older formations. I readily admit that I have by no means exhausted the analogies of the fossils treated of in this paper. I fully believe that more relations will be established between the fossil faunas of San Domingo and Jamaica and Europe and the living fauna of the Indian seas than I have been able to determine satisfactorily. I am aware of the shortcomings of my papers in this and other respects; but I trust that others may be induced to carry out still further the comparisons I have attempted, and to show their real import. It may be that I have fallen into some errors; but I hope that the true inferences may be drawn from the facts. I believe that one of those inferences will be, that the Miocene of the West Indies must be included in the same great period of time as that of Europe, and may therefore be considered, in a geological sense, synchronous—though even in this instance the doctrine of homotaxis may be so far true that neither the commencement nor the termination of the Miocene period, as indicated by organic types and limited by physical changes, may have been simultaneous in the European and Caribean areas.

## EXPLANATION OF PLATE XXVI.

(*Illustrative of West-Indian Tertiary Fossils.*)

[The figures are all of the natural size, with the exception of fig. 19 *a*.]

Fig. 1. *Cercomya ledæformis*. Manzanilla, Trinidad.
2. *Mactrinula macescens*: 2 *a*, hinge of left valve; 2 *b*, hinge of right valve; 2 *c*, exterior of left valve. Manzanilla, Trinidad.
3. *Arca Trinitaria*: 3 *a*, posterior view of the shell with the valves united; 3 *b*, exterior of left valve. Manzanilla, Trinidad.
4. *Cardium castum*. Manzanilla, Trinidad.
5. *Arca filicata*. Manzanilla, Trinidad.
6. *Erycina tensa*. Manzanilla, Trinidad.
7. *Ficula carbasea*. Savanetta, Trinidad.
8. *Corbula vieta*. Manzanilla, Trinidad.
9. *Ancillaria lamellata*. Manzanilla, Trinidad.
10. *Spirorbis clymenioides*. San Fernando, Trinidad.
11. *Nassa solidula*. Cumana.
12. *Turritella tornata*. Cumana.
13. *Cytherea juncea*. Cumana.
14. *Melanopsis cepula*. Cumana.
15. *Dosinia cyclica*: 15 *a*, exterior of right valve; 15 *b*, hinge of right valve. Manzanilla, Trinidad.
16. *Venus Walli*. Manzanilla, Trinidad.
17. *Gryphæa athyroides*. San Fernando, Trinidad.
18. *Ranina porifera*. San Fernando, Trinidad.
19. *Cisseis asteriscus*: 19 *a*, portion magnified; 19 *b*, the whole of the fossil, natural size. San Fernando, Trinidad.




E. M. Williams, F.L.S. F.Z.S. del. & lith.

M & N Hanhart imp

WEST INDIAN TERTIARY FOSSILS

## NOTE *on a* NEW SPECIES *of* RANINA (R. porifera) *from the* TERTIARY STRATA *of* TRINIDAD. By HENRY WOODWARD, F.G.S., F.Z.S.

A SPECIMEN of a Crustacean placed in my hands for examination by my friend Mr. R. Lechmere Guppy, from the Tertiary formation of Trinidad, proves to be a portion of the dorsal surface of the carapace of a Brachyurous Decapod—nearly approaching the *Anomura*—belonging to the subsection *Notopoda* and the genus *Ranina*.

The species of this genus (which was established by Lamarck in 1801) are not only most singular in form, but they are of special interest to the palæontologist as occurring in the Nummulitic Limestone of Bavaria, Austria and Italy, Asia Minor, Scinde, and the West Indies (Trinidad), and also in the Oligocene of Germany and the Miocene of Turin. Nor has the genus now disappeared; for at the present day it is represented by the *Ranina dentata* of Latreille, which is found living in the Sandwich Islands, the Moluccas, the Mauritius, and Japan (De Haan, Siebold's 'Fauna Japonica,' 1833, p. 139, t. 34 & 35), whilst a nearly allied genus, the *Raninoides*, Edw., is found living in the Philippine Islands and Trinidad, having been collected in this latter locality by Mr. Guppy.

The following is the list of all the species known to the author:—

RANINA

1. *Aldrovandi*, Ranz (Mem. di Storia nat. Dec. 1, 1820, p. 73, t. 5).
   Lower Eocene Nummulitic formation. Kressenberg, Valdenega, and Madugi d'Auzago.
2. *Tchihatcheffi*, d'Arch. (Progr. de la Géol. iii. p. 303).
   Nummulitic formation. Asia Minor.
3. *Marestiana*, König (p. 20, taf. 5. fig. 1, 2).
   Nummulitic formation. Kressenberg and environs of Verona.
4. *Haszlinskyi*, Reuss (Foss. Krabben, p. 22, t. 4. f. 4, 5).
   Upper Eocene? Eperies, Hungary.
5. *speciosa*, Münster, sp. (Münst. Beit. zur Petrefact. iii. p. 24, t. 2. f. 1–3).
   Oligocene. Bünde.
6. *oblonga*, Münster, sp. (*l. c.* p. 24, t. 2. f. 4).
   Oligocene. Ebenda.
7. *palmea*, Sismonda (Acad. Leop. Crost. Foss. Piemonte, t. 3. f. 1).
   Miocene. Colle di Torino.
8. sp. (Reuss, Foss. Krabben, p. 21, t. 5. f. 3, 4).
   Nummulitic. Environs of Vicenza.
9. sp. Nummulitic formation. Kurachee, Scinde. Collected by Major W. E. Baker. (In British Museum.)
10. *porifera*, H. W. Tertiary. Trinidad. R. L. Guppy, Esq.
11. *dentata*, Latr. (De Haan, 'Fauna Japonica,' 1833, p. 139, t. 34 & 35).
    Living. Japan, &c.

The *Raninæ* are all burrowing forms of Crustacea, living for the most part in deep water, buried in sand or mud, for digging in which their limbs are most admirably adapted.

Unfortunately none of the appendages are preserved in the specimen under consideration; but all the species of this genus are curiously sculptured upon the dorsal surface of their carapaces, and this ornamentation is extremely characteristic of the group. It consists of irregular transverse pectinated ridges, sometimes interspersed with small punctations, the ridges being more or less curved and intercalating with one another.

In Prof. Reuss's work (Foss. Krabben der k.-k. Akad. der Wissenschaften, Wien) these peculiarities are very well shown; but neither in these nor in the various specimens which I have been able to examine can I detect the same ornamentation as that observable in the *Ranina* from Trinidad.

Each minute point forming the pectinated border to the several ridges has a small indented pit near its extremity, which has suggested the specific name *porifera* (see Plate XXVI. fig. 18). It is to be hoped, however, that more perfect specimens will reward the zealous labours of Mr. Guppy, as the determination of species upon the evidence of a single fragment, offering such meagre characters as the one now noticed, is by no means safe, except in very peculiar and well-marked forms, such as the species of the genus *Ranina*.

With regard to the species nos. 8 and 9 in my list, I am inclined to consider that figured by Prof. Reuss from the Nummulitic formation of Vicenza and the specimens brought over by Major Baker from Scinde (and now preserved in the British Museum) to be identical.

The pectination is coarser and stronger than in *Ranina porifera*, and there are no indented pits at the extremities of the teeth forming the transverse serrations on the surface of the carapace.

I beg, therefore, to propose for these specimens the specific name of *Ranina Reussii*, in honour of the distinguished Austrian palæontologist who has figured it in his work.

## NOTE *on the* ORBITOIDES *and* NUMMULINÆ *of the* TERTIARY ASPHALTIC BED, TRINIDAD. By Professor T. RUPERT JONES, F.G.S.

THE asphaltic rock yielding *Orbitoides* and *Nummulinæ* in abundance is described in the 'Report on the Geology of Trinidad' (1860, p. 37), by Messrs. Wall and Sawkins, as a highly inclined bed of bituminous shelly marl, protruding on the coast at San Fernando, on the west side of the island, and forming part of the "Naripima Marl," in the "Newer Parian Group," regarded as being probably Miocene, whilst the "Older Parian," on which it rests, is Neocomian in age.

In 1863 Mr. R. L. Guppy read a paper descriptive of this peculiar stratum before the "Scientific Association" in Trinidad, pointing out that its shelly contents are Orbitoides and Nummulites, the former predominating; and he suggested that in all probability they would be found to be of the same species as those referred to in my "Note on the Nummulinæ and Orbitoides of Jamaica" (Quart. Journ. Geol. Soc. vol. xix. p. 514). This opinion is confirmed by a careful examination of specimens of the asphaltic stratum, with which Mr. Guppy has favoured me.

Boiled several times in turpentine, this rock loses its bitumen, and resolves itself into loose *Orbitoides* and *Nummulinæ*, with a few other Foraminifera, and (when cleaned by acid) a small proportion of green-black sand and very few rounded grains of quartz. On the weathered surfaces of the rock, and in pieces carefully burnt, many perfect *Orbitoides* may be recognized; and probably throughout the mass the specimens are mostly well preserved; but it is difficult to get them out whole and clean, except by long steeping in hot turpentine, changed from time to time. The *Nummulinæ* keep rather more perfect in the process of cleaning. The many aspects, however, of the broken specimens enable us to determine their relationships without the trouble of grinding and polishing. When the asphalt is driven off by heat, the Nummulites often fall into two pieces by splitting along their median line of chambers; but this horizontal section is not generally so useful in determining species as the exposure of the successive surface-layers.

The majority of the *Orbitoides*, mainly constituting this rock, are small and biconvex, with somewhat expanded edges, about $\frac{1}{8}$ inch broad and $\frac{1}{16}$ inch thick at the centre. There are also occasional evidences of broader, thin *Orbitoides*. The *Nummulinæ*, not nearly so numerous, are smaller still; biconvex, with a sharpish edge, and measuring about $\frac{1}{12}$ by $\frac{1}{30}$ inch. A fragment of a small *Nodosaria raphanus* and a *Discorbina* also occurred to me, together with a piece of a little Echinoderm-spine*.

The *Orbitoides* is exactly the same as the variety from the Tertiary sand of Orakei Bay, New Zealand, described and figured by Karrer, in the 'Novara Expedition' (Geol. Theil, I. Band, 2. Abtheil. Palæont. p. 86, pl. 16. fig. 21), as *O. Orakeiensis*, Karrer, which, there is reason to believe, is a variety of *O. Mantelli*, Morton, a species found in America, the West Indies, and Sinde (see Geol. Mag. vol. i. p. 75, and p. 103). The Nummulite is one of the small "sinuo-radiate" varieties (sometimes simply "radiate"), such as are referred to by me in the note on the Jamaican *Nummulinæ*, and in the 'Geol. Mag.' *loc. cit.*, as present in the West Indies, Sinde, and Europe (Vienna) in rocks probably of Middle Tertiary age. It may be catalogued as *N. Ramondi*, Defr. (=*N. radiata*, D'Orb.), which is found associated with *Orbitoides* in Jamaica, Antigua, and Sinde.

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8. *On the* Discovery *of new* Gold-deposits *in the* District *of* Esmeraldas, Ecuador. By Lieut.-Col. Edward St. John Neale, H.M. Chargé d'Affaires in Ecuador. Communicated by the Secretary of State for Foreign Affairs.

Within the last few weeks† unworked and hitherto unknown gold-deposits have been discovered in the district of Esmeraldas; and I am informed by the President, who has received specimens of the gold of a very pure quality, that it is the intention of the Government to send a scientific Commission, at the head of which will be Dr. Jameson, a British subject who has been many years in Quito, to report upon the probable yield of the gold-district.

* Mr. Guppy believes he saw Polyzoan remains in this band; but possibly detached pieces of the cellular superficial layers of the *Orbitoides*, much resembling *Cellepora* &c., may be the forms alluded to.

† This communication was dated April 18th, 1866.

Should this survey prove satisfactory, as anticipated, I am informed that the Government of this Republic will be prepared to enter into engagements with foreign speculators and capitalists.

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9. *On* Bones *of* Fossil Chelonians *from the* Ossiferous Caves *and* Fissures *of* Malta. By A. Leith Adams, M.B., F.G.S., Surgeon, H.M. 22nd Regiment.

Remains of more than one species of River-tortoises have turned up occasionally in the Maltese caves and fissures of the downcast and denuded districts, in localities situated from three to six miles and a half apart, and always associated with remains of the fossil Elephant, *Hippopotamus Pentlandi*, *Myoxus Melitensis*, and Birds—the last, chiefly aquatic, including the *Cygnus Falconeri* of Parker, besides a *Lacerta*, of about the dimensions of the common Chameleon, and one or more Frogs. The nature and arrangement of the deposits and conditions of this fossil fauna clearly show that all the remains had for the most part been conveyed into the above situations by the agency of large bodies of water which at one time overflowed the greater portion of the eastern half of Malta. None of the Chelonian bones examined by me give indications of the presence of either land or marine species, but agree in their characters with the Elodians and Potamians. The largest comprise part of the right and left femurs of perhaps the same individual, a detached lower extremity of a humerus, several tibiæ, and one cervical vertebra from Mnaidra Gap, besides a large caudal vertebra from Benghisa Gap, which is six miles distant from the former, and situated at the extreme south-east point of the island. Among organic remains from the Zebbug Cave, in the middle of the island, I also observed fragments of bones of individuals equal to, if not somewhat larger than, any here described; also a portion of a humerus of a species of very much smaller size. A glance at the femurs above mentioned shows, by their oblong heads and the trochanters being separated by a deep and arched depression, that they belonged to either a Marsh- or River-tortoise. Their dimensions are as follows:—

| | |
|---|---|
| Transverse measurement from head to trochanters... | 3·5 inches. |
| Antero-posterior length of tuberosities.................. | 2·6 „ |
| Length of head .............................................. | 2·5 „ |
| Breadth of head ............................................ | 1·9 „ |
| Girth of head ................................................ | 6·5 „ |
| Girth of neck................................................. | 6·0 „ |
| Depth of intertrochanter notch ........................ | 3 lines. |
| Girth of shaft, three inches below the trochanters...... | 4·5 inches. |

thus representing an individual nearly four times as large as the *Chelys matamata*, and about two feet in height. A tibia entire, but belonging to a smaller individual than the last, is 3·6 inches in length, with a girth of 2 inches in the middle; whilst that of its proximal end is 4·5 inches, and the distal 3·5 inches. Another tibia, which has lost its lower extremity and part of the shaft, retains 4·5 inches of the upper portion; the circumference of the head is 5·3 inches, and of the middle of the shaft 2·5 inches. The lower extremity of a humerus is 2·3 inches across the articulation; the furrow on the external border is faint, which, again, distinguishes the bones in question from those of marine turtles.

A cervical vertebra, possibly the 5th or 6th, has lost its anterior half; but the convex end and vertebral foramen, together with the articulating processes, are entire. The breadth of the convex articulating surface of the body is 1·4 inch, by 1 inch in thickness; entire height of the vertebra 2·2 inches. The caudal vertebra from Benghisa Gap has also lost its posterior portion; and transverse processes of the body, with the concave articulation, canal, and anterior superior articulating facets, are preserved. The concave articulation is 0·9 inch broad by 0·7 in the antero-posterior direction; the height of the vertebra 1·7 inch, and diameter of the canal 0·3 inch.

A humerus of a very small species of Tortoise from the débris of Zebbug Cave shows only the head and a portion of the shaft, the curved condition of the latter clearly distinguishing it from the Marine, whilst the greater comparative width between the tuberosities separates it from the Land, and assimilates it to either the Marsh or River families. The fragment measures from the head to the tuberosities 5·5 lines; distance from one tuberosity to the other 5 lines. The head is 3·5 lines vertically, and 3 lines broad; girth of shaft 3 lines.

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## 10. *On the* Discovery *of* Remains *of* Halitherium *in the* Miocene Deposits *of* Malta. By A. Leith Adams, M.B., F.G.S., Surgeon, H.M. 22nd Regiment.

Various forms of Cetacea have been met with in the four upper beds of the Miocene strata of the Maltese group. The discovery there of teeth of *Zeuglodon* by Scilla, and the abundant remains of one or more species of Dugong allied to recent forms and *Balænæ*, show the prevalence of these mammals in the seas of the period. They are met with in the greatest numbers in the sand-bed and nodule-bands of the Calcareous Sandstone. In the latter situation I lately discovered a tooth which appeared to me to belong to the *Halitherium*, and in the sand-bed an ear-bone and caudal vertebræ of possibly the same genus. The tooth and ear-bone I have shown to Professor Owen, who has confirmed their identity with the above-named genus.

Tooth of *Halitherium*.

The molar, possibly a penultimate, has lost one of its fangs. The crown is encased in thick shining enamel, and is 9 lines in length by 8 lines in breadth; the height of the crown is 2·6 lines. The fangs are two in number; the anterior small, the posterior large and diverging. The length of the latter is 7·5 lines.

The accompanying sketch represents the crown (nat. size), which probably shows a more advanced state of wear than any figured by Cuvier*.

The ear-bone is entire, and measures 1·4 inch in breadth, by 9 lines in vertical diameter.

The specimens referred to in this note are in the Museum of the Geological Society.

## 11. *On the* Affinities *of* Chondrosteus, *Ag.* By John Young, M.D., F.G.S.

(This paper was withdrawn by permission of the Council.)

[Abstract.]

The object of this communication was to show, from the characters of the skeleton, that *Chondrosteus* belongs not to the Chondrostean division of the ganoids as stated by Agassiz, but to the Holostean division, since it possesses a well-ossified basioccipital; and the lateral walls of the cranium are composed of bones answering to the cartilage bones of ordinary Teleosteans.

## 12. *Notice of* New Genera *of* Carboniferous Glyptodipterines. By John Young, M.D., F.G.S.

Since the publication, in 1861, of Professor Huxley's memoir on the classification of Devonian Fishes, several new genera have been established, and the intervals between some of the families (tabulated at p. 24, Mem. Geol. Surv., Decade x.) thereby diminished.

Rhizodopsis, Huxley. Fig. 8.

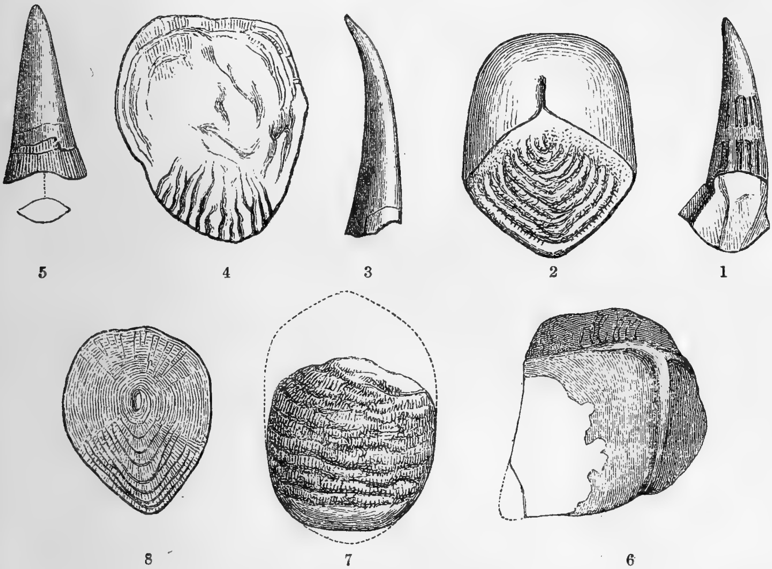
The specimens to which this generic name has been given are those whose scales Prof. Williamson described and figured in the Phil. Trans. 1849, under the name of *Holoptychius sauroides*, a term which has also been applied to a tooth which it will appear is generically distinct from *Holoptychius*.

The body of this fish tapers to a point posteriorly; its greatest depth is at the pectoral arch. Head depressed; orbits forward; gape wide, extending behind them. Maxilla in a single piece, furnished with fine, equal, conical teeth; premaxilla not preserved. Mandible straight, deepest posteriorly, expanded at the symphysis; contains teeth of two sizes; the larger, three or four in number, plicate at the base, strong, conical, slightly incurved; the smaller, one-fourth of the size of the preceding, like them strong, conical: the surface of all the teeth above the plicate base is smooth. Jugular plates in two pairs, principal and posterior. No trace of median or lateral plates. The occipital region is closed in by three bones, in front of which are the parietals in close approximation. The facial bones are not determinable. Operculars large, subquadrate; suboperculars a half smaller, rounded anteriorly. The parietals, operculars, and jugulars are ornamented with fine, parallel or bifurcating ridges. The facial bones and jaws have their surfaces reticu-

* Ossemen Fossiles, pl. xxxviii. figs. 9, 10, & 11.

lated by similar anastomosing ridges. The pectoral arch is well developed, and supports a subacutely lobate fin with rounded margin. The two dorsals, the ventrals, and anal are of nearly equal size, and opposite each other respectively. The tail is heterocercal and rhomboidal.

Figs. 1–8.—*Illustrating the teeth and scales of some new genera of Carboniferous Fishes.*




| | |
|---|---|
| Fig. 1. Rhomboptychius, tooth. | Fig. 5. Rhizodus, tooth. |
| 2. Rhomboptychius, scale. | 6. Megalichthys, scale. |
| 3. Strepsodus, tooth. | 7. Dendroptychius, scale. |
| 4. Rhizodus, scale. | 8. Rhizodopsis, scale. |

The scales vary somewhat in size and shape on different parts of the body; they are arranged in very oblique series, and range from nearly orbicular to elongate cordate. The upper surface is ornamented with concentric and radiating striæ; the latter are most strongly marked over two triangular areas whose bases correspond to the centre of the anterior and posterior margins respectively; the former occupy the lateral surfaces between those areas. The under surface is marked by more or less numerous growth-lines, presents a subcentral raised boss, and is usually pitted over a small area immediately behind the centre; no corresponding tubercles are visible on the upper surface, whose free area averages two-thirds of the whole surface. The lateral line is well marked and nearly straight.

The notochord is persistent; the osseous rings surrounding it are short and narrow. The upper arches are distinct and well ossified.

These characters are in the main those of the family to the cycloidal section of which *Holoptychius* belongs. But from that genus *Rhi-*

*zodopsis* is separated by the presence of teeth of two sizes, by the thinner scales, and by the regularity of the striate ornament over their whole surface, contrasting with the coarse tuberculation of the posterior and smoothness of the anterior area of the scales in the Old Red Sandstone genus. From *Rhizodus* the absence of trenchant teeth is a broad distinction; the character of the scale-ornament of the former, as described below, is equally diagnostic.

The specimens which have been selected as typical of the genus average 5 inches in length. For them the specific name *R. sauroides* has been used, as in Prof. Williamson's paper, which contains the only published description in England of the scales. Other specimens, whose length is estimated at 12 or 15 inches, are imperfectly preserved; it remains to be seen whether they are specifically distinct, or whether the greater thickness of their bony scales is merely a concomitant of the greater size of the fish. The same doubt exists in the case of the small flexible scales, whose possessors probably did not exceed 2 inches in length.

In a paper "Ueber das Vorkommen von *Rhizodus Hibberti*, Owen, *Megalichthys Hibberti*, Agassiz and Hibbert, in den Schieferthonen des Steinkohlengebirges von Volpersdorf in der Grafschaft Glatz" (Zeitschr. deutsch. geol. Gesellsch. p. 272, 1865), Roemer figures at least one scale presenting distinctly the characters of *Rhizodopsis*. The concentric and radial sculpturing is described nearly as above, with the minor difference that the concentric seem of equal prominence with the radial ridges. But there is some confusion in the author's mind—there is at least in his remarks—about the identity of his specimens with the Scottish genera. For in speaking of the teeth of *Rhizodus* he omits notice of their distinctive feature, the double trenchant edges and the elliptical form of the transverse section of the tooth; both are figured (taf. vi. f. 5), but only the plicate base is described. Again, it is said that the thick Scottish scales (which are not horny, as Roemer says, but osseous) show, when carefully split off in layers, the same ornament as those which he has figured as *Rhizodus*. Admitting the hazard of criticism without sight of the specimens, I cannot help suspecting that Roemer has fallen into the not uncommon error of mistaking internal structure for superficial ornament. The suspicion is further strengthened by his statement of the occasional occurrence of a *prominent boss on the outer surface* of his *Rhizodus*-scales. That such a boss is invariably present on the under surface is well known; but I have never seen a scale in this or any other ganoid on which the ornamentation has such a structure for its centre. Abrasion of the under surfaces of thick scales in which the boss remains intact while the deeper structure of the scale is exposed, would give somewhat of the appearance described, and is of not unfrequent occurrence. But while the presence of *Rhizodus*, Owen, in the German coal-strata must be held as unproved, the interesting fact still remains that the genus *Rhizodopsis* is unquestionably common to the English and German coal-fields: on the identity of the species it is impossible to form an opinion.

RHIZODUS, Owen (=*Apepodus*, Leidy)*. Figs. 4 & 5.

The teeth of two sizes and trenchant on both edges, on which this genus is founded, and its distinctness from *Holoptychius* and *Megalichthys* established, are accompanied by scales which are distinguished from those of the latter genus by the fact that their anterior area is cycloidal and concentrically striated, not smooth and rhombic. The free area, on the other hand, is covered with coarse tubercles, and has a general resemblance to that of *Holoptychius*.

No fragments have yet been found from which the shape of the body or the structure of the head can be determined. One or two varieties of the teeth occur; thus one edge only may be trenchant, the posterior (?) being evenly rounded. Of such teeth some are angulated more or less sharply, their section passing from triangular with rounded angles to polygonal. None of the varieties have been named, as it is possible that they may be individual differences; further, the determination of several teeth hitherto isolated has proceeded so rapidly that it is better to wait for more materials.

Leidy (Journ. Acad. Nat. Sc. Philadelphia, iii. 1855–58) described and figured a tooth of a Carboniferous genus *Apepodus*, between which and *Rhizodus*, as known to British palæontologists, no substantial difference can be detected. The same beds, said to be of Carboniferous age, yielded scales which Leidy figures as *Holoptychius Americanus*; their characters are very similar to those of *H. giganteus*, Agassiz (Poiss. Vieux Grès Rouge, pl. 24. f. 3–10). Whether these beds be of Carboniferous age, as affirmed by Leidy, or Upper Old Red, the association of the two genera in the same deposit is an interesting fact not yet paralleled in this country.

The scale figured is taken from a large block of limestone from the Gilmerton quarries near Edinburgh. A similar block is so placed in the rooms of the Royal Society there as to render its examination a task of difficulty. The scales are associated, on it, with typical teeth of *Rhizodus*, and with fragments of pectoral arches and other portions of the skeleton.

The scales are rotundo-quadrate, the anterior margin flattened, the posterior slightly produced. They are thick, bony; their under surface is marked by concentric growth-lines, and bears a large or small, but constant, subcentral boss. The overlapped, anterior area of the upper surface is never less than a moiety of the whole; it is covered with fine concentric and a few radial striæ. The free surface is thrown into broad undulations, which are approximately parallel

* It is commonly stated that *Megalichthys Hibberti* is the synonym of *Rhizodus Hibberti*. Dr. Hibbert's paper, which is as remarkable for its rare generosity as for the extent of the research it sums up, contains a passage which shows that Agassiz had not wholly overlooked the different forms of the teeth, though he afterwards underrated their importance. Agassiz, it is said, proposed the name *M. falcatus* for a form of tooth to be distinguished from that of Burdiehouse by being very sharp on the edges. *Rhizodus* is abundant in the Burdiehouse beds. The assertion, therefore, of a difference as well in locality as form can only be explained by the rapidity with which the great naturalist passed from place to place, and thus, while he increased the materials for his scheme of classification, slipped into minor errors of detail.

to the margins of the scale, and about their own breadth apart. The frequent interruptions of the concentric ridges gives the appearance of coarse tuberculation, which is increased by the roughened condition of the summits of the isolated portions. The intervening interspaces frequently show fine radial striæ, which may, however, be those of the deeper, exposed by erosion of the upper layers*.

To the definition of the genus which Owen gave from the form of the teeth only, M'Coy, in 1848 (Ann. Nat. Hist.), added the characters of the scales, which he described as "thin, rotundo-quadrate, with smooth under surface, and subcentral boss." If by "thin," in another place "rather thin," any marked difference is implied between *Holoptychius* and *Rhizodus*, the examples of the latter on which the present article is founded do not confirm the implication. Thin scales there are of the form stated by M'Coy; but they never attain the dimensions of the larger number of *Rhizodus*-scales. They are those of *Rhizodopsis*, whose superficial ornament is, further, very different. Portions of scales, one or more laminæ of scales, are of not uncommon occurrence; and these, perhaps, have suggested the above generic character. But the probability that M'Coy has mixed up two genera, not then recognized as distinct, is increased by the ornament ascribed to *R. Hibberti* (Pal. Fossil. p. 612), viz. "close vermicular" ridges. Assuming that these ridges are in reality superficial, and not portions of the deeper structure, there are only two Carboniferous genera (to be described hereafter) whose scales are of equal size, and present an approach to this kind of sculpture. They are *Dendroptychius* and *Rhomboptychius*. But in the former the close-set ridges are subordinate to more distant larger ones, in the latter they traverse conspicuous concentric grooves. The specimens of *Rhizodus* which have occurred to me show as great a variety in point of thickness as those of *Holoptychius*, e. g. *H. Andersoni* and *H. giganteus*. This difference of size may be specific; but species can scarcely be founded on isolated scales showing only their under surface. The examples which revealed their upper aspect were as thick as those of *H. giganteus*, and, besides the undulating (not tuberculo-linear) sculpture, had the anterior area also striated (not smooth), differences which seem to be generic as between the Carboniferous and Old Red fishes.

The surface of the pectoral arch and dentary bones is covered with fine tubercles, close-set in small (apparently young) specimens; but in the large the tubercles are confluent by their bases, so as to cover the whole surface with irregular pits or grooves bounded by ridges of unequal height. A very fine pectoral arch (belonging to the Natural History Museum, Edinburgh), referred to this genus on account of the presence of a doubly trenchant tooth, has around it numerous fragments of fin-rays—long slender tubular rods of very dense texture, similar to those observed in *Dendroptychius*.

* The descriptions of Hibbert (Trans. Edin. Roy. Soc. xiii. 24) are unfortunately very meagre; but there is, I think, reason for believing that the ornament of *Rhizodus*, as above described, is intended in the figures of the scales, pl. 10. figs. 1–3, the specimens figured come from the same beds as those to which I have referred.

No other portion of the skeleton has as yet been recognized.

Comparison of Williamson's sections of the scales of a Carboniferous *Holoptychius* (*loc. cit.* fig. 24) with those in the Poiss. Foss. du Vieux Grès Rouge, further confirms, by the difference of minute structure, the generic distinctness of the fishes from the two series of rocks. Further discussion of these microscopic characters is reserved for another occasion; but the vertical section just mentioned, in Williamson's paper, is interesting in this, that while the description corresponds with that of the under surface of *Rhizodus*-scales, the form and structure of the upper surface would agree well with that of a tuberculated scale on which little or no ganoin was developed, such a scale in fact as I believe that of *Rhizodus* to have been. But the point requires further investigation.

HOLOPTYCHIUS, Agassiz (excl. *Rhizodus*)*.

The characters of this genus are summed up in the memoir already mentioned (p. 5), thus:—

"Head depressed; caudal extremity conically tapering, orbits far forward; gape extends far back. Frontals distinct from one another and from the parietals, which are large and coadapted, though quite distinct. The occiput is covered by three bones, a median and two lateral. There are two principal and a number of lateral jugular plates, and there is no rhomboidal median plate between the two principal jugulars. Some of the teeth are larger than the others, and longitudinally striate at their bases. The paired fins are very acutely lobate, and there are two dorsal fins in the posterior half of the body. The ventrals are situated under the first dorsal, and are succeeded by a single anal. Tail little more than semirhomboidal, the upper half being much less developed than the lower."

The diagnosis of this genus from *Rhizodus* by dentitional characters and the difference in sculpture of the scales has already been spoken of.

DENDROPTYCHIUS, Huxley. Fig. 7.

The bony scales to which this name was given are characterized by the division and subdivision of the grooves which traverse their exposed surface. They are nearly equilateral, with rounded angles. They vary in size on the same individual; the largest measure about $\frac{12}{10}$ths in length by 1 inch in breadth; but the average is $\frac{7}{10}$ths by $\frac{6}{10}$ths. The overlapped area is covered with fine striations, concentric and radial, the latter being most marked over a triangular area whose base is the centre of the anterior margin. The exposed surface, slightly smaller than that of the preceding, is sharply bounded by an arcuate line whose convexity looks forward. From this line the sinuous branching grooves run, those from the centre radially, those from the lateral parts more directly backwards; they are larger and fewer in number on the larger scales; their interspaces are marked with fine anastomosing grooves. The under surface is smooth,

* The scales described under this name by Williamson belong, as has been already mentioned, to a wholly different genus, *Rhizodopsis*.

and marked with concentric growth-lines; a subcentral boss projects from a shallow depression. The structure of these scales closely resembles that of *Holoptychius*.

No teeth are found with them, but many ossified vertebræ with neural and hæmal spines, and the ventral fin-bones and rays.

The best-preserved vertebræ are those along with which the pelvic bones occur. They are longer than broad, slightly constricted in the middle; their shallow terminal concavities occupy the whole articular surface, and are perforated by a small notochordal foramen, whose area is one-seventh of the whole surface. They decrease in size from before backwards; the anterior having the following ratio to the posterior. $\frac{\text{Length}}{\text{Breadth}}, \frac{7}{11} : \frac{5}{9}$ (in tenths).

The neural spines, about $2\frac{1}{2}$ inches in length, are mostly seen in profile; their section is pentagonal, much compressed laterally. At a short distance from the base, a slight constriction marks off the articular end, whose convex surface slopes upwards and backwards, so as to form an angle with the axis of the shaft. The arch included between the two laminæ is low and wide.

The hæmal spines, of nearly equal length with the neural, consist of a slender tapering shaft, sigmoidally curved, and terminated at the proximal end by two thin plates triangular in profile and enclosing between them an arch whose height equals one-fourth of that of the whole process.

Neither hæmal nor neural spines are found in actual contact with the vertebræ, whose outer surface is removed, so that the nature of the connexion is not seen. But from being constantly found near the vertebræ, and from the analogy of other allied genera, it may be inferred that they were simply articulated with the vertebræ.

The pelvic arch consists, on either side, of a bone $3\frac{1}{5}$ inches long, of two triangles united at their apices; the superior, 2 inches long, is $\frac{1}{4}$ inch broad at its upper end; the inferior, $1\frac{1}{5}$ inch long, measures $1\frac{3}{5}$ inch along its free or lower margin, to which was articulated a row of (probably five) tarsal bones, three of which remain in position. They decrease in size towards one side, the longest of the three being $1\frac{1}{5}$ inch, the shortest $\frac{4}{5}$ of an inch in length; they are compressed at both ends, constricted and cylindrical in the middle. To the distal smaller ends of these were articulated other similar metatarsal bones, whose number cannot be guessed at; the only two members of this row seen in place measure $\frac{4}{5}$ of an inch in length. To these were attached the fin-rays, long cylindrical rods of a compact dark enamelloid substance, like that which invested the vertebræ and pelvic bones, and traversed by a narrow canal. Their proximal ends are compressed; distally they taper; but no transverse divisions are present in any of them.

Locality: Palace, Craig. Airdrie.

Strepsodus, Huxley. Fig. 3.

The tooth so named has already been figured in the Journal of the

Tyneside Naturalists' Club as *Holoptychius sauroides*, a species founded by Agassiz, but not described by him. Its reference to *Megalichthys* is equally inaccurate. The discovery of the vertebræ and scales belonging to the tooth confirms the propriety of its erection as a separate genus.

The teeth vary in size, the exserted portion being $\frac{1}{10}$ to $\frac{15}{10}$ inch in height; but the smallest exhibit the characteristic form. The ovoid laterally compressed base gradually contracts into a circular shaft very slightly recurved, and near the apex twice bent almost at right angles, so as to have a bayonet form; the tip is sharply conical. The convexity of the shaft and the posterior half of the lateral surfaces are longitudinally striate; the anterior half of the circumference is smooth. Hence it follows that the most anterior striæ are the shortest, those nearest the posterior mesial line the longest. A narrow smooth band, equal in breadth to the interval of any two striæ, runs up the concavity; and from this the striæ depart on either side at a very small angle, tending upwards and forwards towards the anterior surface. Their number is increased by bifurcation, or by the intercalation of new striæ; none pass on to the first knee-bend of the tooth. The lateral compression may be simple or proceed to form a shallow depression which does not occupy more of the lateral surface than one-half in breadth or height, and near the base gives the transverse section a dumb-bell shape. The basal plications are rather rounded undulations than the sharp folds of other Rhizodonts; they do not interfere with the striations.

No skull has been found; but a fragment of a mandible is preserved, whose vertical measurement, if complete, is small in proportion to the height of the tooth. Close to the alveolar margin a patch of the outer surface remains, and shows smooth tubercles connected by low ridges in a reticulated pattern, like that of the jaw of *Rhizodus*. The mode of arrangement of the teeth is very uncertain. There can be no doubt, however, that different sizes occurred in the same jaw, the larger projecting at intervals above the smaller, as in *Rhizodus*.

A slab from the Fifeshire coal-field, lent me by Mr. John Young of Glasgow, exhibits these teeth along with scales which are thinner than, but essentially similar to, those of *Dendroptychius*. They are cycloidal, the anterior margin is flattened, and the posterior somewhat pointed. The exposed area is relatively smaller than in *Dendroptychius*, less even than in *Holoptychius*. The radiating grooves are narrower, straighter, and fewer in number than in the last-described genus, and very rarely, if ever, bifurcate. The concentric striæ of the overlapped area are faintly and equally radiated at all points. The growth-lines are indistinct on the smooth under surface; a longitudinally oval flattened boss projects from the centre; and from it a line frequently runs to the middle of the anterior margin, against which the concentric lines on either side appear as if faulted. The scales, in consequence of their delicacy, are not well preserved: this description may afterwards, therefore, require correction; but the main features are unmistakeable in their similarity to those of *Dendroptychius*.

The vertebral characters are well marked. The vertebræ are thin osseous rings slightly constricted in the middle; the concavity of both surfaces is shallow, and involves nearly the whole breadth. The diameters are unequal, their difference ranging from one-fifth to one-eighth of the longest measurement.

The notochordal foramen is also not a complete circle; its longest and shortest diameters coincide with those of the vertebræ, of whose area it occupies from one-fourth to a half.

The extreme examples measured in tenths of an inch are as follows:—

| | | | |
|---|---|---|---|
| Breadth of ring | 9<br>7 | Breadth of foramen | 3<br>2·5 |
| | 25<br>21 | | 7<br>6 |

In the majority the length (or antero-posterior measurement) is between two-tenths and three-tenths at all points; but the deeper examples show an inequality in this respect—the length at opposite points of the ring varying considerably, as 2·5 to 2·25 in one case, as 4·75 to 3 inches in another.

Straight bones, similar to the neural spines of *Dendroptychius*, occur in the same slab; they measure $2\frac{1}{10}$ inches in length. Associated with scales showing the above-mentioned characters, there is in the Andersonian Museum, Glasgow, a pectoral arch with which are connected several bones giving attachment to long undivided fin-rays.

Locality: English and Scottish fields, from the Coal-measures to the Lower Limestones.

RHOMBOPTYCHIUS, Huxley. Figs. 1, 2.

These scales vary from cordate-ovate to rhombic: the length in the former case exceeds the breadth; in the latter the reverse holds. In general symmetrical, the elongated scales sometimes show undue prominence of one anterior angle. The free and overlapped surfaces are nearly equal in the rhombic scales; but in the cycloidal the former is much the smaller. In both forms the punctate free surface is ornamented with coarse straight ridges which follow the outline of the sides, meeting at an angle posteriorly, and thus giving a rhombic aspect to the scale. The intervals of these ridges are crossed, chiefly near the margin, by finer radial ones. The pattern may lose its regularity—only two or three marginal ridges being complete, and the remaining surface set with irregular tubercles. This occurs in those scales which most nearly resemble the rhombic scales of *Megalichthys*; but the resemblance stops here; for though in some specimens of *Megalichthys* the bony surface exposed by the absence or non-development of the enamel shows irregular tuberculation, or even a faintly rhombic pattern like that just described, the scales presenting these characters have their anterior area bounded by straight lines, and do not show the cycloid outline of those of *Rhomboptychius*, those straight lines, however, which bound anteriorly the free area being common to both. The under surface is smooth;

growth lines are confined to the margin; the oval boss is subcentral. The outer surface of these scales is finely punctate, dense, and semilustrous.

The Andersonian Museum of Glasgow contains a large slab on which are displayed the vertebral column and upper surface of the cranium of this genus. About fifty vertebræ are seen, of which the anterior are the shortest and broadest, the caudal being longer and narrower. The cranium is flattened superiorly; its surface is tuberculated and traversed by mucous grooves, and lines which seem to be the sutures of the coalesced bones.

The cranial and facial portions occur as separate masses, the components of each being intimately united. The facial portion, consisting of the bones anterior to the frontals (those, namely, which compose the muzzle), very closely resembles that of *Megalichthys* and *Diplopterus*. Its crescentic anterior, or intermaxillary and vomerine, portion bears within and close to either outer extremity a large tooth; and on either side of the middle line is a similarly socketted tooth. The small marginal teeth are continuous with two curved rows of equally small teeth which pass in front of the outer pair of tusks, and curving to their inner side meet in the middle line at the anterior part of the basilar bar, whose surface is closely set with fine denticles.

The cranial shield is solid; its elements, intimately united by suture, correspond in number with those found in the cranial roof of *Megalichthys* (Poiss. Foss. pl. 63). But the well-ossified basilar region includes a massive basioccipital which projects behind the vertical posterior wall of the cranium, and sometimes has its length increased by the coalescence with it of at least the first vertebral ring, whose neural processes remained distinct. The anterior part of the cranial is sometimes deficient, the sphenoidal (and prootic?) portion becoming detached. In a lateral view, the ascending alisphenoidal (?) plates and an incomplete interorbital osseous septum are well seen.

The lower boundary of the elongated orbital space is nowhere preserved, the only surviving parts of the lateral surface of the head being the large opercular plates and the maxillæ.

The maxilla is slender in front, and sends off near its truncated extremity a strong process directed inwards and forwards, for articulation, probably, with the prefrontal or ethmoidal region. It gradually expands posteriorly, and bears on the greater part of its inferior margin, which is rounded and slightly deflected at the lower posterior angle, a row of strong, sharp, abruptly conical teeth of uniform size; their bases are strongly plicate, their upper portion usually finely reticulated. Between the maxillæ and the basilar bar the roof of the mouth seems to have been closed in by a pair of plates like those of *Megalichthys*, whose surface is set with fine rasp-like teeth, bounded by a row of small, stout, conical teeth. The connexions of these parts are nowhere seen.

The mandible is a strong bone, deep in front, tapering posteriorly on both margins; the transversely elongated, saddleshaped articular surface looks obliquely upwards and backwards, giving, when the great length of the bone is considered (for it reaches to nearly opposite the hinder cranial margin), an enormous gape. The symphysial extremity is imperfect; but the arrangement of the teeth is probably similar to that in the other genera of the *Crossopterygidæ*; that is to say, a row of small conical teeth borders the outer dentary margin. About the middle of the bone several large distant teeth occur, having their sockets internal to the marginal row. These teeth are strong straight cones, plicate at the base, surrounded at or above the middle by one or more rings of short longitudinal furrows or pits. The inner or splenial margin bears numerous rasp-like teeth. The splenial and dentary margins are thus separated by an interval, considerable in front (where the large teeth are socketed), but narrowing behind, and ceasing a little in front of the articular end of the mandible. The outer surface of the bone is covered with fine tubercles and less prominent connecting ridges. The aspect is thus rather granular than reticulate.

The vertebræ of *Rhomboptychius* are osseous rings, two of which measured respectively $\frac{17}{10}$ and $\frac{13}{10}$ of an inch in diameter, $\frac{7}{10}$ and $\frac{4}{10}$ in length. The area of the notochordal foramen is three-fourths of the whole surface, greater, therefore, than in *Strepsodus*, but less than in the typical annular vertebræ of *Megalichthys* and *Rhizodopsis*. The spines associated with them on specimens in the British Museum consist of a cylindrical recurved shaft, an articular head with convex inferior margin, and a compressed distal extremity*.

Portions of jaws are found in the same beds with the remains just described, whose outer surface is similarly ornamented, and whose teeth are disposed in the same way. But these teeth are remarkable for the great breadth of their bases as compared with the rapidity with which they taper to a fine point, often incurved.

MEGALICHTHYS, Agassiz.

For the cranial and vertebral characters of this genus, and the advance which the latter show upon the Saurodipterines with which it is associated, I would refer to p. 12 of Prof. Huxley's Essay, already quoted.

The resemblance between *Megalichthys* and *Rhomboptychius* is very close, both in cranial structure and in the arrangement of the dentigerous bones. Mention has been made above of palatal tooth-bearing plates. These are two in number, triangular, with rounded anterior apex; their posterior extremity is not seen, two inches being the greatest length to which they are exposed. Each plate bears

* In this and other genera it must be remembered that only those vertebræ are spoken of which occur in actual association with characteristic portions of the fishes to which they are ascribed. This caution is necessary, and, at the same time, perhaps not always protective against error. For, on the one hand, there are good grounds for suspecting in some genera a difference in dimensions and even proportions of the vertebræ in the same column, and, on the other, the presence of vertebræ belonging to more than one individual is possible on the same block. The number of vertebræ still unaccounted for is large; but it would be both premature and out of place to enter on their description here.

a marginal row of short, very stout conical teeth with fluted bases; the rest of their surface is set with similar but smaller teeth, which are more distant over the anterior portion, but posteriorly pass into a dense rasp of minute denticles. The connexions of these plates are not seen; but they probably fitted into the angles formed on either side by the maxilla and sphenoid. Since 1861, specimens illustrating the form of the fins have been acquired by the Museum; but the description and illustration of these parts are reserved, the purpose of this paper being merely to give the diagnostic characters furnished by the scales and teeth.

The teeth are conical, more or less incurved, and of very elegant proportions. Both jaws, the premaxillary region above, and the anterior part of the mandible, contain teeth larger than the numerous small ones which occupy the edge of the bones, and, as in *Rhomboptychius,* form an angulated row across the roof of the mouth. The surface of the majority is smooth; many, however, are covered with very fine ridges, which involve merely the outer portion of the enamel, and, as Mr. Davis has pointed out to me, disappear by attrition. These lines are either parallel or anastomose to form a fine reticulation; but nothing approaching the pattern of *Strepsodus,* either in position or symmetry, is found. In a note read before the Society in February, I proposed the abolition of *Centrodus,* M'Coy, on the ground that that tooth is avowedly a fragment, that it is unaccompanied by either bone or scale, and that it is identical in character with teeth unmistakeably associated with Megalichthyic remains. I have since had the satisfaction of finding that Mr. Davis had arrived at the same opinion, a tablet of teeth from Carluke bearing, as synonyms, *Megalichthys* and *Centrodus.*

The scales and head-bones of *Megalichthys* are covered by a layer of smooth, porous ganoin. When this is detached by accident, the subjacent surface of bone is also smooth, but perforated by the larger and smaller tubes passing up from the interspaces in the osseous substance of the scale. Such is the typical appearance; but in a large number of examples (fig. 6) the ganoin both of scales and bones is patchy and incomplete, covering nearly the whole of the surface, and only interrupted by circular spaces, which are distinguished by their concentrically sloping margins from the mucus-pores, which are surrounded by a thin raised ring; or the ganoin only occurs as scattered points. A carefully prepared section of a scale through such an isolated patch shows that, beneath the ganoin, the structure is the same as in the typical *Megalichthys*-scale, of which Williamson has given an excellent description. The ganoin ceases on either side with an abruptly rounded margin, which dips down to and stops at the average surface of the scale; for it coats a low eminence made up of the kosmin or non-corpusculated bone, the tufts, capillary tubes, and the upper series of Haversian canals. Adjoining the patch the surface of the scale is smooth, and has, as in *Rhomboptychius,* a close and semilustrous aspect. Under the microscope it is seen that a thin layer of kosmin coats this part of the scale, whose irregularities are formed of the upturned laminæ of bone.

The Haversian system is in direct communication with the surface, giving rise to the wide pores. Sections of *Rhomboptychius* show the same structure, as do those of *Rhizodopsis* (*H. sauroides*) in Williamson's memoir. The absence of ganoin is therefore not the result of accident, but is due to the same cause in *Megalichthys* as in the other two genera named—non-development.

Though the main facts regarding these genera are sufficiently well ascertained, much still remains to be done in the working out of their details. The statements I have made will, in all probability, require modification and correction as better-preserved specimens turn up.

From comparison of a large suite of specimens it appears that, while the typical scales of *Megalichthys* and *Rhomboptychius* are sufficiently distinct, the examples are very many which may, in the absence of other proof, be referred to either genus. Great differences of the scales of the same individual might account for the apparent confusion; but no specimens have been found sufficiently complete to make this certain.

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## 13. *Note on* SUPPOSED BURROWS *of* WORMS *in the* LAURENTIAN ROCKS *of* CANADA. By J. W. DAWSON, LL.D., F.R.S., F.G.S., Principal of M'Gill University, Montreal.

AMONG other indications of fossils in the Laurentian rocks, mentioned in my paper on the structure of *Eozoon**, are certain perforations resembling burrows of worms, found in a calcareous quartzite or impure limestone from Madoc, in Upper Canada. They occur in specimens in the Museum of the Geological Survey, and also in specimens subsequently collected by myself at the same place.

The beds at Madoc, containing these impressions, underlie, unconformably, the Lower Silurian limestones, and are regarded by Sir W. E. Logan as belonging to a somewhat higher horizon in the Laurentian than the Eozoon Serpentines of Grenville. They are also less highly metamorphosed than the Laurentian rocks generally. They are described in Sir W. E. Logan's Report on the Geology of Canada, 1863, at p. 32.

The impressions referred to consist of perforations approaching to a cylindrical form, and filled with rounded siliceous sand, more or less stained with carbonaceous and ferruginous matter, more especially near the circumference of the cylinders. These superficial portions being harder than the containing rock, and of darker colour, and also harder than the interior of the cylinders, project as black rings from the weathered surfaces; but in their continuation into the interior of the mass, they appear only as spots or lines of a slightly darker colour, or stained with iron-rust.

When sliced transversely and examined under the microscope, they appear as round, oval, or semicircular holes drilled through the

* Quart. Journ. Geol. Soc. Feb. 1866.

rock, and lined around their circumference with dense and dark-coloured siliceous matter, while the axis, which is often of a bilobate form, is comparatively transparent and of softer texture. The perforations are often at right angles to the bedding, but in some cases nearly parallel with it.

In regard to the origin of these perforations, I suppose that they may have been either (1) burrows of worms filled with sand subsequently hardened and stained at the surface, or (2) tubes composed of sand, like those of *Sabella*, or (3) cavities left by the decay of Algæ, and filled with sand. The first I think the most probable view.

Figs. 1–5.—*Illustrating supposed Annelid-tubes from the Laurentian Rocks of Canada.*

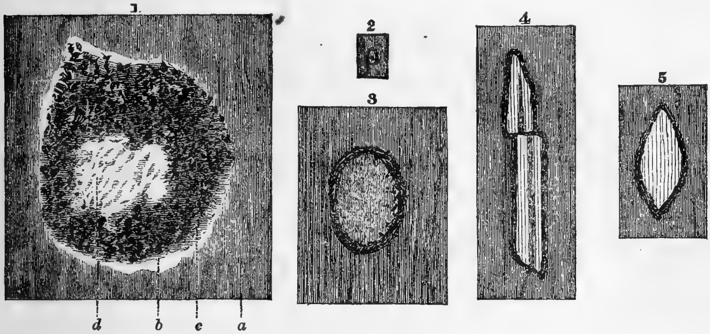


Fig. 1. Transverse section of Worm-burrow. Magnified, as a transparent object.
*a.* Calcareo-siliceous rock.
*b.* Space filled with calcareous spar.
*c.* Sand agglutinated and stained black.
*d.* Sand less agglutinated and uncoloured.

Fig. 2. Transverse section of Worm-burrow on weathered surface. Natural size.
3. The same, magnified.
4. Spicule, magnified.
5. Lenticular body, magnified.

I may add that the beds at Madoc containing these supposed fossils, hold also on their weathered surfaces impressions with rude casts of concentric laminæ, like those of *Stromatopora* or *Eozoon*, but too obscure for determination. The limestones interstratified with these beds also contain fragments of *Eozoon*, not fossilized by serpentine, but simply by carbonate of lime, carbonaceous fibres, spicules like those of sponges, and lenticular bodies of unknown nature.

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*Winkler, T. C.* Musée Teyler. Catalogue systématique de la collection paléontologique. Part 4. 1865.

*Zittel, K. A.* Die Bivalven der Gosaugebilde in den nordöstlichen Alpen. 1866.

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PART II. MISCELLANEOUS.

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# CONTENTS OF PART II.

*Alphabetically arranged—the Names of the Authors in capital letters.*

# TRANSLATIONS AND NOTICES

OF

# GEOLOGICAL MEMOIRS.

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## Defence *of the* "Colonies."—Part III. By M. J. Barrande.

[Défense des Colonies.—III. Étude générale sur nos étages G–H, avec application spéciale aux environs de Hlubocep, près Prague. Par J. Barrande 1865.]

This last contribution from the pen of M. Barrande treats specially of the two highest members of his "third fauna," which are well developed in the typical district of Hlubocep, and are subdivided by the author as follows :—

| | | | metres. |
|---|---|---|---|
| H | *h* 3. | Soft grey and greenish shales | 20–40 |
| | *h* 2. | Shales alternating with thin bands of impure sandstone | 150–200 |
| | *h* 1. | Variously coloured highly fossiliferous shales, with a few calcareous bands at the base | 20–60 |
| G | *g* 3. | Compacted nodular limestone | 50–100 |
| | *g* 2. | Shales containing thin layers of calcareous nodules | 20–150 |
| | *g* 1. | Beds of nodular limestone | 150–200 |

The lowest division of *g* rests conformably on F, the passage from the one member to the other being gradual. Between *g* 1 and *g* 2 there nowhere exists any strongly marked line of separation; on the contrary, the transition takes place by repeated alternations of thin bands of limestone and beds of shale, the former diminishing in thickness as we ascend to higher levels, while the intervening beds of shale become progressively thicker. Towards the central portion of *g* 2 the nodular limestone bands are reduced to a few subregular layers, or are altogether absent. The passage into the overlying *g* 3 is equally gradual. Thin bands of yellow and red nodular limestone separate the shales towards the highest part of this division, and becoming more and more numerous as we ascend, finally become predominant, and are succeeded by the compacted nodular limestone beds *g* 3. This latter resembles precisely the lower bed *g* 1, but differs widely in the species and relative number of its organic remains. In the vicinity of Chotecz and Hinter Kopanina *g* 2 contains beds of trap-rock interstratified with the shales.

Between *g* 3 and *h* 1 the transition is more marked, although at Hortin and near Holin there is an apparent alternation of the higher beds of the one with the lower beds of the other. In some localities, however, as in the valley of Srbsko, the shales of *h* 1 abut against the higher limestone of G. Nevertheless M. Barrande is unwilling to admit that there exists a real unconformability between the two members, and endeavours to explain away the discordance by the supposed effects of denudation and subsequent change of position (p. 19). The two higher members of H rest conformably on the lower one. They are entirely unfossiliferous, with the exception of a few fucoidal impressions on the surfaces of the sandstones which characterize the middle division.

Of the rich fauna contained in these two zones in Bohemia, amounting altogether to 254 species, a very small number only are known to Britain. The fish-remains referred to the genera *Coccosteus, Asterolepis, Gompholepis,* and *Ctenacanthus,* which occur in *g* 1, are all absent from British Silurian strata. *Coccosteus* first appears in zone F, but the species does not pass up. Hence vertebrate genera which characterize our Old Red Sandstone series, in Bohemia occur many hundred feet lower down in the geological scale.

As regards the Invertebrata the general results are given in the following Table:—

*General Table of the Vertical Distribution of the Fossils in the Stages G and H.*

| Genera and species. | E. | F. | G. | | | H. | | | Species common to | | | | Total number of recurrent species from |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $g^1$. | $g^2$ | $g^3$ | $h^1$ | $h^2$ | $h^3$ | $g^1$ & $g^2$. | $g^2$ & $g^3$. | $g^1$ & $g^3$. | G & H. | G–H. |
| Fishes | ... | ... | 4 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Crustacea | 3 | 18 | 49 | 5 | 2 | 2 | ... | ... | 3 | 1 | 2 | 2 | 7 |
| Cephalopoda | 15 | 7 | 39 | 8 | 62 | 5 | ... | ... | 5 | 2 | 4 | 4 | 13 |
| Pteropoda | 1 | 3 | 10 | 3 | 2 | 2 | ... | ... | 2 | 2 | 2 | 2 | 6 |
| Gasteropoda | 2 | 5 | 16 | 3 | 2 | ... | ... | ... | 1 | 1 | 0 | 0 | 2 |
| Brachiopoda | 8 | 20 | 29 | 8 | 5 | 2 | ... | ... | 7 | 3 | 2 | 2 | 12 |
| Acephala | 1 | 3 | 17 | 8 | 5 | 4 | ... | ... | 1 | 0 | 4 | 1 | 6 |
| Radiata | ... | ... | 6 | 4 | 1 | ... | ... | ... | 2 | 0 | 1 | 0 | 3 |
| | 30 | 56 | 170 | 39 | 79 | 15 | | | 21 | 9 | 15 | 11 | 49 |
| | | | 303 | | | | | | | | | | |

The total number of species in the two stages G and H is therefore 303, which, deducting 49 for recurrent species, leaves 254 for the entire fauna. Of the 15 species which occur in H, there are only 4, namely, *Orthoceras equisetum,* Barr., *Avicula consanguis,* Barr., *A. rarissima,* Barr., and *Cardiola retrostriata,* V. Buch, which are not contained in G. The latter, however, occurs in E.

56 species pass up from stage F, and 30 from stage E. Of these 86 species, 12 are common to both these stages, leaving 74 species, or one-third nearly, as common to the two upper and two lower zones of the third fauna.

*g* 1 and *g* 3 are undistinguishable lithologically, but are easily recognized by the difference in their palæontological contents, all the classes, except the Cephalopods, being largely represented in *g* 1, while the Cephalopods are more numerous in *g* 3, in the proportion of 3 to 2 (p. 54).

*g* 2 and *h* 1 may be similarly distinguished. The two beds together contain 54 species. Of these, about 16 species occur in the lower beds which do not occur in the higher, while the higher contain two species only which are not found in the lower. The two highest members of H are unfossiliferous and are not therefore liable to be confounded with the shale below.

Comparing the Silurian system of Bohemia with that of England, M. Barrande finds that while a complete correspondence exists between the grand divisions, it does not extend to the minor ones. Thus the fossils which characterize the Upper Silurian system of England and the "third fauna" of Bohemia, considered as a whole, constitute one and the same general fauna, which, at its commencement, presented very close relationship, but which, from local or other causes, underwent in each country a different evolution, and hence that the different zones in the two countries as distinguished by their fossils are merely local subdivisions which have no correspondence, although comprised in the same period of time during which the Silurian system was being deposited. Thus we find that of the 2000 species which characterize the third fauna of Bohemia and the 500 in England there are only 57 species in common, 32 of which had existed previously in British Lower Silurian rocks, although some of them do not appear in the second fauna in Bohemia. Of these 57 species, 50 occur in the Wenlock, and 27 in the Ludlow rocks, and one passes up into the passage-beds. In Bohemia 51 of these 57 species are found in stage E, 12 in stage F (7 being recurrent species), 5 in stage G (4 being recurrent species), and 1 in stage H (*Lingula cornea*) (pp. 175 & 176).

It appears, therefore, that, abstracting the passage-beds, the Upper Silurian fauna of England is sufficiently (manière satisfaisante) represented in the stage E of Bohemia, and that stages F, G, and H of the Prague Basin, and especially the two last, are not certainly present in England (p. 177).

To render this more clear it may be well to state that the chief palæontological characters of G are (1) the predominance of Trilobites, and especially of *Dalmanites* and *Bronteus*, and the presence of *Calymene* in the horizon of *g* 1; (2) the reappearance of Cephalopods of the genera *Phragmoceras* and *Gomphoceras* in *g* 3, which had disappeared at the close of stage E; (3) the appearance of *Gonatites*, relatively considerable, analogous to those of the Devonian system which had already been ushered in by some rare forms in stage F; (4) the sporadic appearance of *Coccosteus* and *Asterolepis**, hitherto generally considered as exclusively proper to the Devonian period. These elements are entirely wanting in England, not only in the Wenlock and Ludlow rocks, but even in the passage-beds. If, therefore, we give to palæontological evidence the value we have hitherto attributed to it in the classification of deposits, and above all in the comparison

* Carboniferous?

of basins geographically separated, it is evident that in England there is no distinct subdivision which can be considered as especially the stage G of Bohemia; and the same remark is applicable to stage H, of which the fauna is but a feeble continuation of that of G.

In Russia and the Baltic provinces the progress of discovery has confirmed the equivalence, already laid down in 1845 by Sir R. Murchison, between the Silurian rocks of the Isle of Oesel and those of England; but Dr. Schmidt remarks that the subdivisions of the Ludlow rocks cannot be recognized in the upper zones of the Island of Oesel, and it is important to observe that of the 43 species of fish belonging to this zone, 12 of them, among which *Pterichthys* [*Asterolepis*] occurs at Ohhesaare-Pank associated with *Phacops Downingiæ*, *Calymene Blumenbachi*, *Orthoceras bullatum*, *O. trocheale*, *Cardiola interrupta*, *Pterinea retroflexa*, *Retzia Salteri*, *Strophomena filosa*, *Chonetes lata*, and other Wenlock and Ludlow fossils, showing as remarked by M. Barrande, that the presence of fish-remains by no means vitiates the Silurian character of the last phases of the third fauna. From a comparison of the list of fossils supplied by Dr. Schmidt with those of Bohemia, it appears that 21 species are common to both localities, of which 20 belong to stage E, and that, notwithstanding the number of fish-remains, the highest zone of the Isle of Oesel is anterior in age to stage G of Bohemia, but that fish of many types appeared there at an earlier period than than they did in the Silurian basin of Prague.

In Sweden and Gothland stage E is represented by 22 and stage F by 10 species common to those countries and Bohemia, thus confirming the views of Sir R. Murchison and Dr. Schmidt of the existence of the Wenlock and Ludlow rocks, the higher zones G and H being entirely absent. In Norway, as in Sweden and Gothland, nine-tenths of the species common to that locality and Bohemia belong to stage E, stage F being but feebly represented; beds referred to the middle part of the Ludlow period being surmounted conformably by unfossiliferous sandstones and marls 1000 feet in thickness, which are considered by Prof. Roemer to be of Devonian age, In Thuringia, Saxony, and Franconia, beds corresponding with the first phase of Barrande's third fauna, namely, zone E, are succeeded by deposits placed more or less high in the Devonian series. The Silurian rocks of the Harz have been referred by Prof. Giebel to the horizon of the Wenlock in England and zones E and F in Bohemia, and the presence of *Monoprion Sagittarius* removes all doubt as to their Silurian age; but the mixture of Lower Devonian forms with those of the third fauna, together with several types of fishes, and especially *Ctenacanthus*, recall the upper calcareous zones F and G of Bohemia; but the large number of species of *Capulus* which coexist with these fish-remains in the Harz contrasts with the nearly total absence of that type in zone G, whilst analogous forms are sufficiently common in zone F and again in zone E; and although some Brachiopods, like *Rhynchonella cuneata*, are referable to the former, the greater number appertain rather to the latter. At present, therefore, the data are too fragmentary and incomplete for the position of these beds to be determined with certainty (p. 211); but it is possible that further research in the Harz may sooner or later confirm the facts observed in Bohemia, of the sporadic appearance of fishes towards the close of the Silurian period, along with *Dalmanites, Bronteus, Acidaspis,* and other types characteristic of zone G (p. 212). Moreover, it is possible that the deposits of the Harz form part of the great Palæozoic zone of the north like those of the environs of Hof, and were separated from the Bohemian basin by an ancient barrier of gneiss and other crystalline rocks. In Spain, Sardinia, and France no beds higher than zone E have been observed, unless it is in the department of the Lower Loire, where M. Cailliaud has observed the coexistence of several species characteristic of stage F, with others considered as Devonian.

Crossing the Atlantic, M. Barrande considers the North American representatives of his third division of the Silurian system, and arrives at somewhat different conclusions from those drawn by MM. de Verneuil, D. Sharpe, and Hall. Excluding the Clinton and Medina groups as passage-beds between the two great divisions of the system, he includes the Niagara group and the whole of the Lower Helderberg series as representing his zone E. Zone F is represented by the Oriskany Sandstone, the remaining members of the upper Helderberg series being regarded as representing generally zones G and H; and he considers that, by means of certain Devonian forms in the Upper Helderberg series, these beds are more intimately connected with the Devonian system of Europe than are those of Bohemia, which contain a smaller number of Devonian types.

Recapitulating his facts, M. Barrande observes that the countries in the neighbourhood of Bohemia, namely, Saxony, Thuringia, and Franconia, do not present a single trace of the last phase of the third fauna, but that the first phase of this fauna is distinctly recognized. The Silurian rocks of these countries appear to belong to the great northern Palæozoic zone, like England, Russia, and the Harz, the faunas of which present us with more marked connexions with the phase of life appertaining to zones G and H.

Norway and Sweden, which belong to the same northern zone, and are intimately related to England by the character of the earlier portions of its Upper Silurian fauna, present none of the phases of the latter part of that period. France, Spain, and Sardinia on the contrary, although forming, like Bohemia, part of the great central Palæozoic zone, and presenting the earlier phase of the third fauna, are equally devoid of the latter portion; but there are beds, considered in France as representing the Lower Devonian system, which contain fossils similar to forms disseminated through zones E, F, and G.

In England, the Isle of Oesel, and the Harz, zones G and H appear to be partially represented. In the Upper Ludlow and passage-beds of England we find six genera of fishes associated with fossils of Silurian types; but the Trilobites *Dalmanites* and *Bronteus,* and the Cephalopods with a contracted orifice, characteristic of the higher beds of Bohemia, are absent, as also are the *Goniatites* and *Cardiola retrostriata.* In the Isle of Oesel, where the number of fishes amounts to 43 species, among which are *Coccosteus* and *Asterolepis,* there are associated with them numerous fossils characteristic of the earlier period of the third fauna, whilst the Crustaceans and Cephalopods appertaining to the latter part of that fauna are entirely wanting. In the Harz, however, the presence of *Ctenacanthus* among fishes and of *Dalmanites* and *Bronteus* among Trilobites, associated with forms of Devonian type, renders it probable that the limestones of Mägdesprung represent an epoch near those represented by stages G and H (p. 266).

In the United States of America the closest analogy to the fauna of G and H is found in the Upper Helderberg group (especially in the State of New York), which, by its Gasteropods, Acephala, and Brachiopods, presents clearer connexions with the Devonian fauna of Europe than do the similar zones of Bohemia.

With respect to the connexions between these two higher zones and the Devonian system, after passing in review all the evidence to be derived from organic remains, the author arrives at the conclusion that generally they are not more directly united to the Devonian fauna than are the higher zones of any of the other Silurian countries where the third fauna has a less vertical development, and is even reduced to its first phase; for if in Bohemia they contain the genus *Goniatites*, which is not met with elsewhere, in the former they contain several genera of fishes, and of other types, as *Calceola*, *Grammysia*, *Pleurodictyum*, &c., which occupy a distinguished rank among Devonian fossils, and which are completely wanting in the Bohemian Silurian rocks. And, with reference to specific connexion, the two upper stages in Bohemia contain fewer species identical with Devonian forms, and fewer representative forms, than do the inferior stages E and F. In fact his researches lead him to the apparently paradoxical conclusion that the two highest members of his third fauna present less strong connexions with the Devonian system than do those which immediately precede them.

Taken, therefore, from a palæontological point of view stages G and H preserve completely a Silurian character, and are not united to the Devonian system except by those usual links which announce the approach of a succeeding period. [H. B. H.]

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ELEMENTS *of* CHEMICAL *and* PHYSICAL GEOLOGY. By Dr. GUSTAV BISCHOF, For. Mem. G.S., &c. Vol. II. Second Edition*.

[Lehrbuch der chemischen und physicalischen Geologie. Von Dr. Gustav Bischof, For. Mem. G.S. Zweite gänzlich umgearbeitete Auflage, Band II. Bonn, 1864.]

IN this volume of the new edition of Dr. Bischof's well-known 'Elements of Chemical and Physical Geology,' the whole of the material of the former edition has been re-arranged, more especially with a view to condensation, but, as a large amount of additional matter has been incorporated, the dimensions of the work are still very great, the

* Volume i. of this edition was noticed in Quart. Journ. Geol. Soc. vol. xx. Part II. Miscel. p. 13.

volume in question extending to not less than 952 pages of large octavo size; the bulk would have been still further increased if all the analyses contained in the first edition had been given in full, instead of being merely referred to in foot-notes, as is done in several instances. While in the first volume the general chemical principles involved in the changes of the earth's crust are set forth, the second treats of the salts occurring in the mineral kingdom, taking the widest sense of the term and according to the ordinary chemical classification. The volume is divisible into three parts, the first comprising the Haloid salts, the second the oxy-salts of acids which are easily soluble or miscible in all proportions with water, and the third those of the nearly insoluble silicic acid, or silicates. A fourth division treats of the most important of the minerals which, in the author's opinion, have been produced from the decomposition of silicates. The volume may in fact be regarded as a purely chemical mineralogy, in which, without referring to their external characteristics, the composition, formation, metamorphism, replacement, and decomposition of the non-metallic minerals is considered, the metallic minerals being reserved for a third volume.

The division into chapters is continued from the first volume, commencing with chapter xvii. and ending with chapter xlii. The first chapter (xvii.) contains general remarks on the alkaline and earthy chlorides, bromides, iodides, and fluorides, and on their presence in crystalline rocks and lavas. Chapter xviii. is devoted to chloride of sodium, under the headings of rock-salt and salt-lakes; the former is shown to be deposited from sea-water by slow evaporation, on account of its great purity, rock-salt being perhaps the nearest approach to a pure chemical compound occurring in nature, some varieties yielding by analysis 100 per cent. of chloride of sodium. The salt from brine-springs, on the other hand, being produced by rapid concentration of the solution, decrepitates when heated, portions of the mother-liquor containing uncrystallizable chlorides being entangled among the crystals. The great difference in the relative proportion of gypsum and common salt existing in sea-water and in saliferous rocks is explained by showing that, although sea-water contains 16·4 times more salt than gypsum, the smaller absolute amount of the latter salt represents 63 per cent. of the total necessary for saturation, while the chloride of sodium only amounts to 7 per cent. It is evident therefore that the solution will be sufficiently concentrated to allow of the deposit of gypsum when 37 per cent. of water has been evaporated, whereas it will be necessary to remove not less than 93 per cent. before any salt can be separated. In this way the great masses of gypsum and anhydrite accompanying the salt-masses of the Alps may be supposed to have been formed, by partial concentration of sea-water which was removed before the salt had time to be deposited. The notices of salt-lakes contain numerous interesting particulars of the composition of the water of the Elton Lake in the Crimea, which is remarkable for the large amount of chloride of magnesium, and the variable amount of common salt, that it contains at different seasons of the year.

Chapter xix. treats of fluorides, the author noticing the combinations of fluorine with other elements; fluor spar, its production, association, and pseudomorphic forms, and the more complex minerals cryolite, topaz, and pycnite. It is suggested that the latter may be formed from cryolite, a double fluoride of sodium and aluminium, when the fluoride of sodium is replaced by a silicate of alumina, topaz being produced when the same replacement affects a portion of the fluoride of aluminium.

In chapter xx. the alkaline and earthy carbonates are treated at considerable length, commencing with the degree of solubility of artificial and natural carbonates of lime; then follow the methods by which calcareous pseudomorphs are formed. The carbonates of magnesia, baryta, strontia, iron, and manganese are treated in a similar manner, but the interesting subject of the formation of dolomite is reserved for the next volume. The subject of the composition of the natural carbonates of iron, sparry iron ore, clay-ironstone, black band, &c., is most elaborately treated, no less than fifty-seven analyses of these minerals being given.

Chapter xxi. treats of the different earthy sulphates, gypsum, Epsomite, heavy spar, and celestine, their various methods of occurrence, transformations, &c. The difficulty of finding an origin for the great masses of sulphate of baryta common in the newer mineral deposits, no baryta-salt being recognizable in the composition of crystalline rocks, is adverted to, as are also the recent researches of Max Mitscherlich*, who announces the presenceof baryta, varying in quantity from 0·45 to 2·33 per cent., in felspars from the Eifel and S. Gothard. The production of sulphate of baryta by the double decomposition of solutions containing witherite and gypsum is described at length, with numerical illustrations.

Chapter xxii. on phosphates, commences with a notice of the various minerals containing phosphoric acid other than the ores of the heavy metals; the author then treats of Fownes's investigations on the presence of phosphates in crystalline rocks and lavas, and proceeds to consider the solubility of the different substances containing phosphate of lime in water saturated with carbonic acid. This varies very greatly, apatite requiring 393,000 parts of water for complete solution, while the scrapings of the bones of a freshly killed ox dissolve in 4000 parts, and precipitated neutral phosphate of lime requires only 1500 parts. Phosphate of lime is formed when alkaline phosphates are heated with silicate of lime. When phosphate of lime dissolved in carbonated water is brought into contact with alkaline fluorides, fluoride of calcium is deposited and phosphate of soda remains in solution. This reaction is suggested as a probable cause of the increase of fluorine in fossil bones. Phosphate of iron (Vivianite) is noticed at some length, and a description is given of its occurrence in the bones forming the skeleton of a drowned miner, which was found in the Scharley zinc-mine in Silesia, upon reopening the workings after they had been closed for three centuries. Vivianite may be produced by double decomposition from apatite and sulphate or carbonate of iron. Notices of the best known occurrences of phosphates

* Pogg. Ann. vol. cxi. p. 351.

n vegetable and animal structures, as well as in sedimentary rocks, with remarks on the continued circulation of phosphoric acid from the minerals, through plants to animals, and its return through the decomposition of organic remains to the mineral state, close the chapter.

Boracic acid and borates form the subject of chapter xxiii.; the occurrence of boracic acid in the Suffioni of Tuscany associated with sulphate of ammonia and chloride of ammonium is described; and the decomposition of boracite in the limestone from which the hot springs rise is suggested as a means of origin. The formation of tourmaline, &c., is reserved for the chapter on the origin of granite.

The third and most important part of the work, comprising chapters xxiv. to xli., extending to nearly 600 pages, treats of the various silicates found in nature, and the general remarks at the commencement treat of their probable composition and origin. Of the former subject it is remarked that the formulæ in use for the more complex silicates are of little other value than that of expressing the individual views of the chemists by whom they are propounded. Throughout this portion of the work the composition of the minerals is expressed chiefly by their oxygen quotients, that is the fractions obtained by dividing the amount of oxygen in the protoxide and sesquioxide bases taken together by that of the silica. With regard to the origin of crystalline silicates, the author is disposed to consider them as essentially formed by the action of water from amorphous masses; thus he remarks that, as a rule, lavas, especially those of newer date, are not crystalline, although when sufficiently thick they may take years in cooling: this view is especially brought out in the consideration of the origin of leucite, a mineral which occurs most abundantly and in the largest crystals in Vesuvian lavas of pre-historic origin. Even at ordinary temperatures glass becomes crystalline when exposed to atmospheric changes for a long period, as has been shown by Brewster and Zirkel in mediæval glass taken from the windows of Saint Andrew's and Cologne Cathedrals.

The system of arrangement of the descriptive notices of the silicates is based upon the relations of their pseudomorphs to each other, the series being commenced with the zeolites, which never appear except in their own proper forms; felspar is made to take the second place, from the fact that orthoclase has been found in the forms of laumonite and analcime, and therefore may under certain circumstances be derivable from zeolites. The last members of the series are the difficultly decomposable substances: mica, chlorite, steatite, serpentine, &c., which are found as pseudomorphs of almost all the harder silicates. Especial reference is made to the remarkable contrast between the extreme divisibility of mica due to physical structure and its almost absolute stability against chemical changes from the action of the air. This property is assumed to be due to peculiar isomeric conditions of the component silicates. As might be supposed in a substance forming the ultimate product of alteration of a great number of different minerals, micas vary very much in composition, the maxima and minima of the chief components are given as follows:—

| | | | | | | |
|---|---|---|---|---|---|---|
| Silica...... ........... | 36 per cent. min. | | | 71 per cent. max. | | |
| Alumina............... | 6 | ,, | ,, | 38 | ,, | ,, |
| Iron oxides........... | 0 | ,, | ,, | 36 | ,, | ,, |
| Magnesia ........... | 0 | ,, | ,, | 29 | ,, | ,, |
| Potash .............. | 2 | ,, | ,, | 14 | ,, | ,, |
| Lithia ................. | 0 | ,, | ,, | 5·7 | ,, | ,, |
| Fluor ................. | 0 | ,, | ,, | 10·4 | ,, | ,, |

Water is present up to about 4 per cent., and organic matter is occasionally found in considerable quantity, as for instance in the lithia-mica of Altenberg, which is treated in quantities of 16 cwts. at a time for the production of lithia.

Serpentine forms the subject of chapter xxxix.; it is considered throughout as a product of alteration, the view of its igneous origin being distinctly repudiated. In like manner in the chapter on quartz and other forms of silica the views of the so-called "Plutonists" are combated to the uttermost. The volume is closed by two chapters on magnetic and titanic iron-ores considered as products of the alteration of silicates, a view which is not generally held in countries where those minerals are most abundant, as in Scandinavia and North America. [H. B.]

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*On the* BRACHIOPODS *and other* BIVALVES *of the* ST. CASSIAN BEDS. By Dr. LAUBE.

[Proceed. Imp. Acad. Sciences, Vienna, March 23, 1865.]

THE Brachiopods of St. Cassian offer a greater analogy in their general facies with those of the Palæozoic period than those of the Mesozoic deposits, as Prof. Suess has already observed with respect to the Brachiopod-fauna of the Hallstatt strata. At all events, the St. Cassian strata represent an important period in the development of this class, three Palæozoic genera, *Cyrtina*, Dav., *Spirigera*, D'Orb., and *Retzia*, King, finding in them their last representatives; while *Spiriferina*, D'Orb., not ascending above the Lias, first appears in the St. Cassian strata. Among the other Brachiopods, *Waldheimia* and *Thecidium* are Mesozoic; and *Koninckina*, Suess, and *Amphiceina*, Laube, are peculiar to the strata in question, and are transition forms between the Palæozoic and the Mesozoic typical genera. Among thirty species described, ten are new. Only a small number of the fifty species described by Count Münster and Klipstein have proved admissible, many of them being merely young forms of established species. The Bivalve-fauna bears a more general character, including however representatives of the typical Triassic genera, *Cassianella*, Beyr., *Myophoria*, Bronn, and *Hörnesia*, Laube. This last genus, named after Dr. Hörnes, comprises the *Gervilliæ* of the "Muschelkalk," bearing the type of *G. socialis*, Schloth, and differing from the genuine *Gervilliæ* by the peculiar structure of their hinge, and by a more or less lengthened septum going through the cavity of their umbones. Only about half the number of species established by Count Münster and Klipstein proved to be admissible after close examination, many of them having been established on mere fragments, not offering any decisive characters, or on figures of questionable accuracy. Of seventy Bivalves described by Dr. Laube, only eight are new. [COUNT M.]

# TRANSLATIONS AND NOTICES

OF

# GEOLOGICAL MEMOIRS.

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## *On the* DISCOVERY *in* HAINAUT, *below the* SANDS *referred by* DUMONT *to the* THANET SANDS, *of a* COARSE LIMESTONE *with a* TERTIARY FAUNA. By MM. F.-L. CORNET and A. BRIART.

[Note sur la découverte dans le Hainaut, en dessous des sables rapportés par Dumont au Système Landénien, d'un calcaire grossier avec faune tertiaire; par MM. F.-L. Cornet et A. Briart. Bulletin de l'Académie royale de Belgique, 2me série, tome xx. no. 11].

AT Tournay, Angres, and other localities in the southern part of Hainaut, the Thanet Sands (Landénien inférieur of M. Dumont) are seen overlying the Secondary formations, having at their base a glauconitic bed which contains numerous badly preserved fossils. Among these, however, there occurs abundantly an easily recognizable shell, the *Pholadomya Koninckii* of M. Nyst. MM. d'Archiac, Dumont, and Hébert considered this bed to be the lowest of the Tertiary strata of Belgium, and the equivalent of the "Glauconie inférieure" which forms the base of the Tertiary formation of the Paris basin.

The object of the authors is to refute these opinions by proving that there exists in Hainault, at a lower level than the glauconitic beds of Tournay, &c., a fossiliferous bed, of which the described species belong to a Tertiary stage of the Paris basin, superior to the "Glauconie inférieure" of M. d'Archiac.

At Limbourg, in the environs of Heers, M. Dumont discovered some marly and glauconitic beds lying below his "Landénien inférieur;" to these he assigned the name "Heersien," and classed them with the Cretaceous formation of Belgium. M. Hébert, however, from palæontological and stratigraphical evidence, considered them to be Tertiary, and Sir C. Lyell suggested the creation of a new system, in which should be included the pisolitic limestone of France, and the stages "Heersien" and "Landénien inférieur" of Belgium.

From this and other discoveries, the existence in Hainault of these intermediate beds had long been suspected. At the beginning of this year, M. Goffint sank a well on the confines of the town of Mons, near the Obourg station, to the depth of 68 feet, when water was reached. It presented the following section, in descending order:—

1. Grey sand, containing fragments of flint. 3 feet 6 inches to 4 feet.
2. An irregular bed composed of fragments of flint and phthanite. 4 inches to 8 inches.
3. Yellow ferruginous sand, containing grains of glauconite. 8 inches to 12 inches.
4. Fragments of flint and of coaly phthanite. 4 inches to 6 inches.
5. Very glauconitic sand, very green, and a little argillaceous in the lower part, but coloured and soft in the upper part; it contains fragments of phthanite. 15 feet 3 inches.
6. Very ferruginous red sand, containing limonite and numerous masses of a

rock of the texture of sandstone, very slightly calcareous, of a red colour on the outside, but a whitish grey in the fresh fractures: this rock contains numerous fragments of indeterminable fossils; its present position seems to be the result of a reconstruction. 8 inches to 12 inches.

7. Yellowish or white limestone of a coarse texture; some of its bands are compact, others very friable; in it occur certain beds, and detached fragments, of a very hard white rock, ¾ inch to 5 inches thick, entirely soluble in acids, and some of them containing numerous cavities full of a pulverulent lignitic matter.

The appearance of some of the bands of the limestone reminds one of the "tuffeau" of Ciply and Maestricht; but the difference in their mineralogical texture is easily detected. The palæontological evidence, however, leaves no doubt in this respect. An enormous quantity of fossils, in a perfect state of preservation, has been procured from all the beds of the limestone, and even from the beds and detached fragments of the harder included limestone. From 140 to 150 species have been collected, of which a great number appear to be new. Of the known species, not one is Cretaceous; "all belong to the Tertiary beds above the Glauconie inférieure of M. d'Archiac and the Sables de Bracheux of the French geologists."

The following is the list of the fossils which the authors have determined:—

| Gasteropods. | Lamellibranchs. |
|---|---|
| Turritella intermedia, *Desh.* | Cytherea multisulcata, *Desh.* |
| —— imbricataria, *Lam.* | Cardita planicosta, *Lam.* |
| Voluta spinosa, *Lam.* | Crassatella compressa, *Lam.* |
| Ancillaria buccinoides, *Lam.* | Corbula striata, *Lam.* |
| Mitra terebellum, *Lam.* | Corbis lamellosa, *Lam.* |
| Cerithium unisulcatum, *Lam.* | Arca biangula, *Lam.* |
| Melanopsis buccinoides, *Fér.* | —— modioliformis, *Desh.* |
| Buccinum stromboides, *Lam.* | Tellina rostralis, *Lam.* |
| Nerita Caronis, *Brong.* | —— donacialis, *Lam.* |
| Natica perforata, *Lam.* | Lucina mitis, *Sow.* |
| —— epiglottina, *Lam.* | |
| Monodonta Cerberi, *Brong.* | |

The greater number of the species which appear to be new belong to the genus *Nematura*, and some others to the genera *Ancillaria* and *Auricula*.

The authors then describe and compare several sections in the neighbourhood of Mons, by which they endeavour to prove that the glauconitic sand (no. 5) met with above the fossiliferous limestone of the well of M. Goffint represents the base of the Landénien inférieur, and corresponds to the beds of Angres and Tournay with *Pholadomya Koninckii*.

Detailed sections at Ciply, Nimy, and other localities are given, a complete section of which would represent the beds in the following ascending order, resting upon an eroded surface of the chalk:—

1st. A very glauconitic sand, slightly argillaceous. In its lower part the grains of glauconite are comparatively small and numerous, and are imbedded in a matrix of a whitish-blue substance, which gradually becomes softer towards the upper part, while the grains of glauconite become larger and less numerous. To the south-west of Mons it contains *Pholadomya Koninckii*, more or less abundantly, and at Ciply a fossil of the genus *Arca* has been discovered.

2nd. Grey sand, slightly glauconitic, coloured yellow in some places. It is impossible to draw a sharp line of demarcation between this and the lower bed, the passage of the one into the other being characterized by an insensible diminution of the glauconite and the white matrix, leaving nothing but a mixture of grains of quartz with a few of glauconite, which gives to the rock a greenish-grey appearance.

3rd. Blue ferruginous clay, variegated with yellow.

4th. Very ferruginous yellow sand.

A section between Mons and Ath, obtained some years ago by M. Lebreton-Dulier while sinking a shaft in a search for coal, is described as affording evidence of the greatest importance. After passing through $3\frac{1}{4}$ feet of black sand (surface-soil), and 26 feet of grey sand containing some grains of glauconite, 20 feet of very green sand was reached, reposing upon the débris of rocks, of which reliable specimens were not obtained.

This green sand is in its mineralogical character identical with that overlying the "calcaire grossier" of M. Goffint's well (no. 5 of section, p. 11); it rested upon a soft greyish-yellow limestone, containing at different depths thin beds of hard white limestone. This limestone was 305 feet thick, and contained fossils of which eight species have been identified with those obtained from the well of M. Goffint; they belong to the genera *Nematura, Melanopsis,* and *Cerithium.*

The absence of *Pholadomya Koninckii* from the glauconitic sand to the north-east of Mons is ascribed by the authors to the softness of the "white matrix" (see p. 12) in that district. This softness decreases towards the south-west; and near Angres and Tournay, in that direction, *Pholadomya Koninckii* is abundant.

The authors then trace the several beds which they have described from the cemetery at Mons to about forty-four yards to the north of the road to Charleroi, where they underlie the beds characteristic of the "Panisélien" system of M. Dumont, which are there seen *in situ.* Upon this they remark that "the glauconitic bed of our sections, and, with greater reason, the limestone with the Tertiary fauna, which it overlies to the north-west of Mons, are inferior to the 'Panisélien' system and to the sandy and argillaceous beds which form the base of it—beds which we refer, according to the geological map of M. Dumont, to the 'Landénien' and 'Yprésien' systems."

The "calcaire grossier" of the well of M. Goffint seems to occupy a vast depression or hollow in the chalk, and to correspond in its palæontological character to some parts of the upper sands of Soissonnais (sables supérieurs du Soissonnais) and the "Calcaire grossier" of the Paris basin.

In conclusion, the authors point out other localities, in the neighbourhood of Mons, where the same disposition of beds is known to occur.

In reference to this subject M. d'Omalius d'Halloy, who, in conjunction with M. Dewalque, reported on MM. Cornet and Briart's paper to the Academy of Sciences of Brussels, has communicated a note to the Geological Society of France*, in which he discusses the question whether the fossiliferous deposit discovered by them be not comparable with the "Colonies" of M. Barrande. He concludes that their discovery adds a new system to the Eocene deposits hitherto known in Belgium, namely the "Calcaire grossier of Mons," which underlies all the others, and which may be considered the precursor of the Calcaire grossier of the Paris basin in a district where that formation is not represented. He also remarks that the existence of this small Eocene basin of "Calcaire grossier of Mons," following the small basin of tufaceous chalk of Ciply, is a new indication in favour of the formation of calcareous deposits by causes which are perpetuated or reproduced in the same localities. [A. S.]

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### *On the* ENVIRONS OF TOKAY, HUNGARY. By Professor J. SZABÓ.

[Proceed. Imp. Geol. Instit. Vienna, September 1865.]

THE whole of these environs belong to the Tertiary period. The eruptive rocks are trachyte and rhyolite; those of sedimentary origin are the results of decomposed or disaggregated rhyolite; and last in the series comes the soil producing the well-known wines. The ascending order of the trachytes, as to their geological age, is:—Andesitic trachyte (Baron Richthofen's "grey trachyte"); amphibolic trachyte (v. Hauer's and Dr. Stache's "genuine" or "red trachyte"), less extended than the first variety, but forming important and lofty mountain-groups in the south portion of the chain between Eperies and Tokay; Beudant's "Trachyte micacé amphibolique," the extreme link of the amphibolic trachyte near Vissegrad, is wanting in the Kegyallia or viniferous hill-range of Tokay. The rhyolites differ from the trachytes proper by the crystallized quartz of primary formation, and by the nature of the felspars entering into their composition, which contain a large proportion of silica combined with lime and soda. Sanidine is but of subordinate occurrence. The rhyolites evidently owe their origin to submarine eruptions having taken place after the trachytes had been completely formed. The two rocks, although once in mechanical contact, are in no way connected as to their mode of formation. The marine shells included in the rhyolites make it probable that their eruption began contemporaneously with the deposition of Leithakalk, and ended with the beginning of the Cerithium-beds (consequently before the eruption of the basalts of Northern Hungary, which are frequently in contact with rhyolites and include fragments of them), while the trachytes may be supposed to belong to the Oligocene or even the Eocene period. The varieties of rhyolite are:—

*a.* Trachytic rhyolite, dark-coloured, porphyroid, passing into perlite, sphærulite, and white tufaceous rhyolite. This is the type of original rhyolite before its chemical and physical alteration by

* Bull. Soc. Géol. de France, 2[me] série, vol. xxiii. pp. 11–13.

contact with sea-water, which, in the course of time, alters it into vitreous clear-coloured varieties, then into pumice, and finally into a white vitreous powder, which, mixed with larger fragments of these and the preceding products of alteration, constitutes a pumice-conglomerate. The vitreous varieties give rise to obsidian- and perlite-porphyries.

*b.* Lithoid rhyolites, the substance of the upper portion of a rhyolitic volcano, seem to have been produced by a later eruption, beginning with vitreous substances, and passing upwards into genuine lithoid lavas. Dark colours are of rare occurrence among them; the included particles of quartz and felspar diminish to a very small size, and sometimes the substance appears homogeneous. The lower portions are homogeneous obsidian, the result of rapid solidification; or genuine perlite, sometimes with a nucleus of obsidian. Sphærulites of radiated or dendritic structure are segregated from the rhyolites of the Hagyallya.

*c.* Sedimentary breccias and tuffs, as mere agglomerations near the places of eruption, and at some distance from them more or less stratified with marine shells, as *Cerithium lignitarum*, *Arca*, and *Pecten.* These strata, solidified by infiltration, are Beudant's "millstone porphyries." The younger tufaceous strata, subsequently solidified by access of silica, lie nearly horizontally, and contain species of *Cerithium* and *Cardium* of the Cerithian strata.

*d.* Rhyolitic trass, resting on the primary volcanic tuffs, effervescing with acids, and partly decomposed into clay. The non-volatile substances contained in the water of the sea, beneath whose level these rhyolites have been raised, have had a chemical action on them. In the first place, the oxide of iron has been converted into a soluble substance, sesquichloride of iron, which, having been washed out, left rocks of gradually paler tints, until the uppermost of them became completely white. Then an addition of sodium may have made them more fusible; and the sulphur of the pyrites which was originally included in them, and of which traces still occur, may have been oxidized into sulphuric acid, still occurring in the white varieties of rhyolite (probably in the form of a mechanical aggregation of sulphates and silicates). When submitted to red heat and to decomposition under the action of water, these white rocks treated with hot water give a considerable proportion of alum. An extensive upheaval took place at the end of the rhyolitic period; and in consequence of it, several closed freshwater basins, excavated in rhyolitic breccias and tuffs and receiving the waters of siliciferous thermal springs, were formed around the margin of the group of rhyolitic islands. The lowermost deposit in these basins is a stratum of silicified mud, with specimens of *Planorbis* deprived of their calcareous shell. Then follows quartzite, with plenty of silicified trunks of trees and other vegetable fragments, all transported by waters from without,—or menilite, easily decomposed by water, the soluble variety of silica occurring in the upper strata under the form of white, loose, and very thin layers composed of *Diatomaceæ*, with fine impressions of leaves on their planes of contact.

The productive soil around Tokay offers three distinct varieties:—A. Argillaceous soil, immediately originating from the superficial decomposition of trachyte, without any organic remains, not effervescent with acids; this soil is the prevailing one, and gives the best and strongest wines. B. Rhyolitic tufaceous soil, less fit for viniculture than A. C. Diluvial loam-soil, occurring to some extent only on a hill next to Tokay, producing wines of inferior quality.

[Count M.]

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## Eozoön *in* Austria. By Professor Hochstetter.

[Proceed. Imp. Geol. Instit. Vienna, January 1866.]

In South-western Bohemia an extensive system of strata, in which metamorphic schistose rocks prevail, extends from the "Böhmerwald" and "Bayrische Wald" to the north banks of the Danube. This system, hitherto ranked among the Azoic rocks, is unconformably overlain by the Ginetz beds, containing M. Barrande's "Primordial fauna," and by Pribram Greywacke, in which Dr. Fritsch has found traces of Annelids. Prof. Hochstetter, after long and laborious search, succeeded in finding, in the crystalline limestone of Krummau, agglomerations of calcareous spar and serpentine, which have been declared by Dr. Carpenter, to whom specimens had been sent for examination, to be undoubted remains of *Eozoön.* Prof. Hochstetter thinks the lenticular nodules partly composed of calcareous spar and serpentine, so abundant in the vicinity of the graphitic beds of Schwarzenbach and Mugerau, to be possibly of organic origin. Prof. Gümbel, of Munich, has lately ascertained the existence of *Eozoön* in the crystalline limestones of the "Bayrische Wald."

Prof. Hochstetter correlates as follows the pre-Silurian or Eozoic strata of the "Böhmerwald" and the frontier-mountains between Bohemia and Bavaria, with the analogous formations in England and North America:—

| Bohemia. | England. | North America. |
|---|---|---|
| *a.* Ginetz strata with M. Barrande's "Primordial fauna." Pribram Greywacke. | Upper Cambrian. | Taconic system, or Potsdam Sandstone. |
| *b.* Pribram slates with traces of Annelids. Primordial argillaceous slate. | Lower Cambrian (Longmynd group). | Huronian system. |
| *c.* Micaceous slate. | ? | Upper Laurentian system. |
| *d.* Prof. Gümbel's "Hercynian" gneiss-formation. | Sir R. I. Murchison's "fundamental gneiss" (partly). | Lower Laurentian system. |
| *e.* Prof. Gümbel's "Bojic" gneiss-formation. | do. | —— |

[Count M.]

# TRANSLATIONS AND NOTICES

OF

# GEOLOGICAL MEMOIRS.

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## *The* FAUNA *of the* LOWER OLIGOCENE TERTIARY BEDS *of* HELMSTÄDT, *near* BRUNSWICK. By HERR V. KOENEN.

[Die Fauna der Unter-Oligocänen Tertiär schichten von Helmstädt bei Braunschweig. Von Herrn v. Koenen. Zeitschrift der Deutschen geologischen Gesellschaft, Band xvii. pp. 459–534, 1865.]

THE author begins his Memoir with an historical notice of the discoveries respecting these middle Tertiaries from the time of Münster and Goldfuss to the day when Beyrich introduced the term "Oligocene" between the Eocene and Miocene of Lyell, for beds, the whole series of which only occur in North Germany, where they are purely marine, and therefore can in that region only be fully studied and understood. He then proceeds to point out what he considers a want of due appreciation of the Oligocene system on the part of Sir Charles Lyell, who places the Headon and Bembridge beds in the Eocene, and the Lower Oligocene, on the other hand, in the Miocene system. He calls attention to his Memoir published in the Quarterly Journal for 1864, p. 98, in which he has shown that the Headon series is the exact equivalent of the Lower Oligocene, inasmuch as out of 56 marine species, 6 are peculiar to the Headon series, and of the remaining 50, 43 occur in the Lower Oligocene, 23 being peculiar to it, whilst only 21 species occur in the Upper Eocene (Barton). He then shows that every one of the 152 species from Edeghem, as quoted by Nyst, occurs in the *Black Sand* (Lower Crag) of Antwerp ('Système Diestien' of Dumont), and that consequently it is incorrect to separate the Edeghem beds from the *Black Sand* of Antwerp.

Herr v. Koenen then points out the vast increase of material which has been obtained for the better knowledge of the Oligocene beds, since Prof. Beyrich first began his excellent work on the shells of the North German Tertiary beds, but which he has so long left incomplete. These fossils have been obtained chiefly from the Middle Oligocene of Söllingen, and the Lower Oligocene in the neighbourhood of Magdeburg. Other localities are also mentioned, most of which had been already alluded to by the author in a Memoir published in the 'Zeits. d. Deutsch. Geol. Ges.' 1863. p. 612, on the extent of the fossiliferous beds of this formation. The green sands and yellow clays of Helmstädt were then pronounced by the author to be Lower Oligocene. Somewhat later Herr v. Strombeck, after a careful investigation of the beds in question, came to the same conclusion, that they were Lower Oligocene. But in order to remove the possibility of a doubt, Herr v. Koenen undertook the palæontological question by carefully working out the fauna of the Helmstädt beds. Numerous collections, both from German localities, and from Belgium and England, were placed at his disposal, and he particularly alludes to Mr. Edwards as having afforded him the greatest assistance.

The following section of the stratification at Helmstädt is taken from Herr v. Strombeck's work, and is derived from a shaft sunk to the brown coal about half a mile to the west of Helmstädt.

| | ft. | in. |
|---|---|---|
| (*a*) Soil | 6 | 5 |
| (*b*) Gravel | 3 | 1 |
| (*c*) Green sand | 30 | 8 |
| (*d*) Green clay with sand | 28 | 4 |
| (*e*) Grey calcareous sandstone | 4 | 2 |
| (*f*) Green marly sand | 11 | 8 |
| (*g*) Grey clayey sand with iron pyrites | 10 | 10 |
| (*h*) Brown coal | 20 | 0 |

giving a total thickness of 95 feet 2 inches *above* the brown coal. The fossils occur chiefly in bed *f*, except a few in *e*, but these are identically the same as in *f*. The hard stone *e* is also petrographically the same as that which occurs sometimes in single blocks, sometimes in tabular masses near Lattorf, Calbe, Eggersdorf, Neu-Gottersleben, Aschersleben, Wolmirsleben, &c., with typical Lower Oligocene fossils.

After describing the extent of the Brown Coal beds from Helmstädt to Westeregeln, &c., he refers to some grey-yellow clay beds south of Helmstädt, which from their fossil contents, *Cassis coronata*, Desh., *Crassatella Woodii*, v. Koenen, *Pecten corneus*, Sow., *Isocardia multicostata*, Nyst., *Cardita latisulca*, Nyst., *Ostrea Queteletii*, Nyst., and *Ostrea ventilabrum*, Goldf., must also be considered as Lower Oligocene. The author then endeavours to correct the errors in the nomenclature adopted by Prof. Giebel in his 'Fauna der Braunkohlen Formation von Lattorf,' owing to his want of proper means of comparing the Lattorf fossils with those of other localities; and he adds corrected lists of the fossils published on the four plates of Prof. Giebel's work, and warns geologists against the too hasty adoption of Giebel's names, and defends Mr. Edwards against the unfair charges and attacks brought against him by Prof. Giebel.

Herr v. Koenen then proceeds to give a full and critical description of the 122 species (omitting five species of corals) which have been found at Helmstädt, pointing out their analogues or identical forms in other districts, and showing where the same species occur in other Oligocene formations, or in older or younger beds; amongst these are seven species of *Cancellaria*, 13 of *Fusus*, 4 of *Conus*, 22 of *Pleurotoma*, 5 of *Voluta*, 4 of *Leda*. This is followed by a tabular statement of the whole Molluscous fauna of Helmstädt, from which he deduces the following conclusions. "If we deduct from these 128 species the doubtful *Nautilus imperialis*, Sow., and the 17 species hitherto peculiar to Helmstädt, we have a remainder of 110 species, of which 100 are known to occur in other Lower Oligocene localities, whilst only 31 are known as Upper Eocene and 30 as Middle Eocene fossils. There can therefore be no doubt that the beds of Helmstädt are also Lower Oligocene, the more so as of these 100 species 59 occur only in the other Lower Oligocene, or in younger beds, but not in older ones. The number of species which otherwise occur only in the Middle Eocene, but not in the Upper Eocene, is only four, namely *Cancellaria subangulosa*, Wood, var. *rotundata*,

v. Koenen, *Pleurotoma turbida*, Sol., var. *ligata*, Edw., *P. attenuata*, Sow., and *Solarium pulchrum*, Sow. He then alludes to the difficulties occasioned by the anomalous occurrence of certain forms in two distinct beds, when they are wanting in the intermediate bed; and he concludes with the hope that, although some modifications may hereafter be rendered necessary, in consequence of more perfect materials for comparison, the labours of future explorers will be facilitated by the work which he has already done, and the careful comparison he has made. [W. J. H.]

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## *On the* NUMMULITIC STRATA *of* NORTHERN ITALY *and the* ALPS, *and on the* OLIGOCENE *of* GERMANY. By M. E. HÉBERT.

[Note sur le terrain nummulitique de l'Italie septentrionale et des Alpes, et sur l'oligocène d'Allemagne; par M. Ed. Hébert. Bull. Soc. Géol. de France. Deuxième série. Tome xxiii. pp. 126–144.]

The Tertiary deposits of the Northern Apennines have been subdivided by the Marquis Pareto,* in the following manner:—

EOCENE.

1. *Étage Nicéen.*—The Nummulitic limestones of Nice and the Alps, overlain by great deposits of macignos and flysch.
2. *Étage Ligurien.*—Grey macignos, with alternations of limestones and argillaceous schists.
3. *Étage Modénais* or *Calcaire à Fucoides.*—The upper part of the last stage where the limestones predominate.

MIOCENE.

1. *Étage Bormidien.*—Beds of Dego, Carcare, &c., with *Nummulites intermedia*, with the intercalated lignites and lacustrine beds of the horizon of Cadibona. M. Pareto ultimately classed in this division all the Nummulitic strata of the Vicentin and the Véronais, except Monte Bolca.
2. *Étage Langhien.*—The marly grey sands, molasse, and ophiolitic sands of the Colline de Turin, characterized by fossils of the Faluns of Bordeaux.
3. *Étage Serravallien.*—Marly, grey, and yellow sands, &c.

M. Hébert considers it now possible, upon palæontological grounds alone, to arrive at a more precise, and even a more detailed classification that that of M. Pareto. In 1854, M. Renevier and the author showed that it was necessary to detach from the great Nummulitic mass certain beds at Saint-Bonnet and Faudon, in the High Alps, in the Diablerets in Switzerland, and at Pernant, Entrevernes, &c, in Savoy, which are overlain by the variegated sandstone and macignos to which the name of "Flysch" has been given. These beds, to which the term "Terrain Nummulitique supérieur," was applied, are more recent than the other beds of the Nummulitic series, and contain fossils characteristic of the Paris "Calcaire grossier" and "Sables de Fontainebleau." M. E. Sismonda adopted this distinction, and in the following year discovered a still more recent Nummulitic series in the valley of Bormida.

* Bull. Soc. Géol. France. Tome lxxi. p. 245.

M. E. Sismonda referred all these groups to the Eocene, considering the middle one as the equivalent of the Eocene of the Paris Basin. M. Pareto*, however, clearly showed a separation between the Flysch and the "Calcaires à Fucoides" on the one part, and the upper Nummulitic zone on the other; there is also an incontestable relation between the true Miocene and this upper zone, which overlies, at Sassello and at Carcare, lignites with *Cyrena Brongniarti*, Bast. (*C. convexa*, Brong.), and *Cerithium margaritaceum*, Brocc., and which he considers the equivalent of the lignites of Cadibona.

From this it results that the great Nummulitic system of the Alps and Northern Italy presents three groups of different ages, namely, the Nummulitic formations (1) of Nice, (2) of the High Alps, and (3) of Bormida, of which the two lower groups are Eocene, and the upper one Miocene.

Two or three years ago the author procured a series of fossils from the Vicentin, and while grouping them according to their localities, was struck with the difference and the independence of the faunæ so separated. From an examination of these fossils he has concluded that in the Vicentin there are different beds corresponding to the different stages of the Tertiary series of Paris, namely:—

1. The beds of Priabona (Valle di Boro) are the equivalents of the Biarritz, that is of the Lower, Eocene. To this level also belong, on the one side Bolca, and on the other Brandola, and some other localities of Monte Berici, and probably also Val Rovina, and Monteglosso, near Bassano, to the north-east of Salcedo.

2. San Giovanni Ilarione and San Pietro Mussolino are synchronous with the "Calcaire Grossier Inférieur."

3. Villagrande, near Ronca, is contemporaneous with the "calcaire grossier supérieur," including, perhaps, the "sables de Beauchamp."

4. Castel Gomberto (Monte Grumi, San Valentino), Montecchio maggiore (la Trinità), Monte Carloto near Monteviale, Monte Postale, and, further north, Salcedo to the north of Bregauze, and Sangonini near Monte Sumano, and to the north-east Schio, correspond exactly to the horizon of Gaas and the lower part of the "Sables de Fontainebleau."

There is between Ronca and Castel-Gomberto a considerable gap, which is filled up in the Alps by the limestones with *Nummulites striata* and *N. contorta*, the Flysch, and the "Calcaire à Fucoides." These deposits, then, become synchronous with the gypsum, and represent the Upper Eocene. The system of the valley of Bormida presents a remarkable admixture of the fossils of the Lower Miocene of Castel-Gomberto, and of the "Sables de Fontainebleau" with the middle Miocene fossils of Touraine and of the Superga. This system is, then, posterior to that of Castel-Gomberto, and as it is anterior to that of the Superga, it must be placed upon the level of the "Calcaire de Beauce," of which it constitutes the marine equivalent.

The author then gives it as his opinion that the mountain masses to the north, in the Vicentin and the Véronais, and to the south, in the Ligurian Apennines, which form the great basin of the Po, have been during the Tertiary period subjected to an oscillatory movement, which alternately elevated the northern and depressed the

* Bull. Soc. Géol. France, 2e Sér., tome xii. p. 370.

southern part, and *vice versâ*, during which the deposition of the several beds was taking place.

In the long succession of faunæ and physical phenomena described by M. Hébert, it is between the Nummulitic fauna of the High Alps and that of Castel-Gomberto that the greatest difference is manifested, and it is there where M. Pareto, incorrectly as the author thinks, places the limit between the Miocene and the Eocene.

An intimate relation exists between the beds of Castel-Gomberto and Salcedo, and the Upper Nummulitic beds of the Bormida, and between these latter and the true Miocene of the Superga, and of Léognan, or of Touraine.

An altogether analogous succession unites together, in Aquitaine, Gaas and Léognan, and M. Hébert considers that at present it does not appear necessary to add to the three great divisions of the Tertiary a fourth—the Oligocene,—which is included in his Lower Miocene.

If in the north of Europe this Oligocene presents great differences from the Miocene (Middle Miocene), it only shows that the upper part of this group is not generally represented by a freshwater formation; but the continuity is found again in the south, and there it is not possible to admit the Oligocene. There is not then sufficient reason to change the ternary division of the Tertiary strata, and the best line of demarcation between the middle and lower group will remain that which, in a general manner, M. Élie de Beaumont has indicated, namely, below the Fontainebleau sands, and which the author has attempted to define more clearly by fixing it between the freshwater marls above the gypsum, and the marls with *Cyrena convexa* and *Cerithium plicatum*, &c., below the Calcaire de Brie.

A paper by M. Beyrich, published in 1858, in the "Berichte" of the Academy of Berlin*, is then noticed by M. Hébert, who says that the author has, in some instances, given to his statements a meaning which was not exactly intended. For instance, his opinion that although the sea of the Faluns of Touraine differed as much from the sea of the Fontainebleau sands, as these from the sea of the "Calcaire grossier," it was preferable to adhere to the ternary division, has been rendered altogether differently in the German text.

M. Beyrich has placed the Fontainebleau sands as the equivalent of his Middle Oligocene, and the gypsum of Montmartre as synchronous with the Lower Oligocene, which would be represented in Belgium by the lower beds of Limbourg. This classification, M. Hébert thinks, cannot be justified by facts. First of all, in the Paris basin the gypsum belongs certainly to the lower part:—

(1) By the marine bands intercalated with its lower beds, of which the fauna is identical with that from the marls with *Pholadomya Ludensis*, which belong to the Beauchamp sands; (2) by the freshwater beds above the gypsum, the fauna of which approaches nearer to that of the Saint-Ouen limestone, situated below the gypsum, and the marine marls with *P. Ludensis*, than of that of the Brie limestone; (3) by the contained Mammifers, which it would be difficult to associate with those from the Beauce limestone, this being the consequence of classing the latter as Upper Oligocene, and the gypsum as Lower Oligocene.

* See also Quart. Journ. Geol. Soc. vol. xx. Part 2, Miscell. p. 5.

In the second place, the fauna of the Lower Oligocene, as far as the author was able to judge in his journey to Latdorf, seemed to be singularly analogous to the fauna, not of the first marine beds of the Fontainebleau sands, but to those of Morigny, near Étampes, superior to the marine marls of Montmartre. From Latdorf about forty species were obtained, and the author has not been able to establish the identity of one of them with Eocene forms. While admitting that the fauna of the Lower Oligocene may be anterior to that of Morigny, he considers that there is still enough margin between this zone and the gypsum in which to class it, without separating it from the Lower Miocene; for in the Paris basin, between the horizon of Morigny and the freshwater marls above the gypsum, which M. Hébert considers as the upper limit of the Eocene, there are, (1) sands and marls with *Natica crassatina*, *Deshayesia cochlearea*, Brong., &c. (2) Freshwater limestones and "meulières" of Brie. (3) Green and yellow marls with *Cyrena convexa*, Brong. sp., *Psammobia plana*, Brong. sp., *Cerithium plicatum*, Lam., *C. trochleare*, Lam., *Bithynia plicata*, d'Arch. and de Verneuil, sp.

There is not sufficient reason to place the Lower Oligocene below the last of these.

The lignites upon which the marine beds of Latdorf rest, and generally the Lower Oligocene, may, the author admits, *possibly* correspond to the gypsum, although it is impossible to assign a definite place to it until after the discovery in it of organic remains. He also thinks that the beds of Limbourg may be ranged with the Middle and Lower Oligocene of M. Beyrich, but considers that too much haste has been shown in identifying the Lower Oligocene of Belgium and Germany with the Upper Eocene of England, especially with the Barton clay.

The idea of a general catastrophe putting an end to the Eocene fauna, which had been attributed to the author by M. Beyrich, is denied, and a more gradual operation, such as accompanies all general movements of the surface, is maintained to have been the cause. The author then gives a Table showing the correlation of the beds belonging to the Lower Miocene in France, Germany, and Belgium.

| | | France. | Germany. | Belgium. |
|---|---|---|---|---|
| Lower Miocene. | Upper bed ... | Beauce limestone. | Upper Oligocene . | |
| | Middle bed... | Sands of Étampes. | Middle Oligocene. | Upper Limbourg. |
| | Lower bed | Brie limestone and marls with Cyrenæ ........... | Lower Oligocene | Lower Limbourg. |
| Upper Eocene ...... | | Gypsum ...... | ? Lignites of Latdorf, &c......... | Missing. |
| Middle Eocene (upper bed) ......... | | Beauchamp sands | Missing ............ | Missing. |

M. Hébert attempts to show that it is more probable that the Middle Oligocene of the basin of the Rhine, and of Switzerland is related to the beds of Tongres and of Maestricht than, as M. Beyrich considers, to those in the environs of Orléans, and he denies that he, in conjunction with M. Renevier, ever asserted that the Nummulitic strata of the High Alps are contemporaneous with the "Sables de Fontainebleau;" but, on the contrary, that he had refererd them to the gypsum.

Lastly, M. Hébert says he is still of opinion that the Barton clay is synchronous with the lower part of the Beauchamp sands, and the Headon sands with the upper part. The upper part of the beds of Colwell Bay belong to the Fontainebleau sands, and the fossils of the gypsum are found between these two horizons in the freshwater formation of Hordwell. No new reason has been shown for classing the gypsum in the Lower Oligocene.

The conclusions at which the author has arrived are these:—that the Lower and Middle Tertiary series, regarded in the north and south of Europe, present their maximum of difference, both palæontological and stratigraphical, between the gypsum and the base of the Fontainebleau sands on the one part, and between the Flysch and the beds of Castel-Gomberto on the other; and that it is there where the limit between the Eocene and the Lower Miocene, or Oligocene, should be placed. This last is allied much more with the Miocene, properly so called, or Middle Miocene, than with the most recent Eocene beds.

At the epoch of the gypsum the sea retired from the north, where, in the opinion of the author, there does not exist any marine equivalent of the beds with *Palæotherium*, and advanced to the south, where it penetrated to the Alps, and occupied a part of Switzerland, but without communicating with the depression already existing in the valley of the Rhine. Afterwards, when at the commencement of the Miocene epoch, the sea extended to the north of Germany, it withdrew from the Alps to the Vicentin gulf. On both sides, it seems well proved that during the period which this study embraces, it was at this time that occurred the greatest differences in the general distribution of sea and land in Europe. [A. S.]

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## *On the* Occurrence *of* Eozoon *in the* Primary Rocks *of* Eastern Bavaria. By Prof. Gümbel.

[Ueber das Vorkommen von *Eozoon* in dem ostbayerischen Urgebirge. Von Herrn Gümbel. Sitzungsberichte der königl. bayer Akademie der Wissenschaften zu München. 1866, I. Heft 1. pp. 25–70. 3 plates.]

Prof. Gümbel introduces the special subject of his memoir by a concise exposition of the facts relating to the discovery and determination of *Eozoon*, including its structure, mineral condition, and geological position. He then describes the geological features and relations of the older rocks of Bavaria, which he arranges in descending order as follows:—

1. Hercynian clay-slate.
2. Hercynian mica-schist.
3. Hercynian gneiss.
4. Bojic gneiss.

The Hercynian gneiss is considered to be equivalent to that of the Danube, and both are stated to abound in layers of graphite, which the author thinks is important as proving the existence of organic life at the time of their deposition. The Hercynian and Bojic gneiss-formations together are held to represent the Lower Laurentian system of Canada; the Hercynian mica-schist, the Upper Laurentian or Labrador series; and the Hercynian clay-slate, the Huronian of Canada and the Cambrian of England. Prof. Gümbel then describes the mineralogical characters of the Hercynian gneiss, and afterwards shows that a stratified ophicalcite occurring near Steinhag, exhibits structures corresponding with those of the Canadian *Eozoon* in addition to other appearances which he also believes to be of organic origin, and some of which he compares to the sections of certain Bryozoa.

The occurrence of a *second species of Eozoon*, to which he gives the name *Eozoon Bavaricum*, has been discovered by him in a rock consisting of a granular aggregation of calcite, serpentine, and a white hornblendic mineral, arranged in flakes or stripes. The rock belongs to the Hercynian Clay-slate formation, supposed to be of Huronian or Cambrian age, and the specimens examined were obtained from near Wunseidel and Thiersheim, and between Hohenberg and the Steinberg, especially the last-named locality. It exhibits:—(1) A thin band almost entirely calcareous, and traversed by a network of straight lines, or, when treated with acid, divided by band-like ribs into irregular cell-like spaces, the calcite filling which is seen to be granular. (2) Thicker calcareous portions abounding in tufts of fine tubes, exactly as in *Eozoon*; these tubes end at the serpentinous portions (3), which have generally the same form as in the *Eozoon* from Steinhag before described, but are much smaller. In decalcified examples they may be seen to possess the same vaulted margins as *Eozoon*; their breadth averages ·1 millim. and the diameter of the tubes ·01 millim. Generally these serpentine bands pass into an adjoining portion (4), of one-half the width, or less, made up of very much twisted lamellæ, consisting of serpentine or a whitish mineral, and possessing highly vaulted and deeply channelled outlines. Prof. Gümbel considers that on the whole these characters undoubtedly prove the affinity of this more recent and very much smaller form to the group *Eozoon*; but as the last-mentioned structure (4) differs from what has been observed in *Eozoon Canadense*, he gives it the distinctive name of *Eozoon Bavaricum**.

In conclusion Prof. Gümbel describes certain structures which appear to indicate with greater or less probability the presence of *Eozoon* in the pargasite of Pargas in Finland, in the coccolite-limestone of New York, in ophicalcite from Tunaberg, in a granular limestone containing chondrodite, hornblende, and garnet, from Boden in Saxony, in a blackish serpentinous limestone from Hodrisch in Hungary, and in ophicalcite from Reichenbach in Silesia.

[H. M. J.]

* Dr. Carpenter has lately recognized the similarity of the Connemara Eozoonal structures to those of *Eozoon Bavaricum* (*supra*, Part 1, p. 228). This observation is of considerable interest when viewed in connection with the relative geological age of certain Eozoonal rocks, more especially the probable Cambrian date of *Eozoon Bavaricum*, the Lower Silurian position of the Connemara serpentine, and the Laurentian age of *Eozoon Canadense*.—Edit.

# TRANSLATIONS AND NOTICES

OF

# GEOLOGICAL MEMOIRS.

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## *On the* Explorations *made during the* Winter *of* 1865–66 *in the* Caverns *of the banks of the* Lesse. By M. E. Dupont.

[Étude sur les fouilles scientifiques exécutées pendant l'hiver de 1865–66 dans les cavernes des bords de la Lesse, par M. E. Dupont. Bull. de l'Acad. Royale de Belgique, 2me série, tome xxii.]

*Caverns of Pont à Lesse.*—Several little caverns occur in the commune of Anseremme, about a quarter of a mile down the river, from the castle of Pont à Lesse. They are upon the right bank of the river, and about 30 to 40 feet above its level. One of the principal of them presented the following section in descending order:—

1. Greyish-yellow earth, 2¾ feet.
2. Dust, 9 inches.
3. Black earth containing human bones, bones of animals, numerous land shells, with abundant fragments of pottery, some pieces of flint, ashes, &c., 1¼ foot.
4. Yellow clay, 2 inches.
5. Grey earth, sometimes encrusted with stalagmite. Human bones, bones of animals, as in bed No. 3, flint, numerous fragments of pottery, ashes, and coals, and plates of psammite. 2¾ feet.
6. Yellow clay, 5 feet.
7. Traces of yellowish-white pure sand.

The yellow clay with angular fragments of limestone (No. 6), which is only separated from No. 7 by traces of sand, is easily recognized as the equivalent of the argillaceous deposit which overlies the whole province, being the ordinary yellow clay with blocks (*argile jaune à blocaux*) forming the base of the upper stage of the Quaternary formation of this region, and containing in other cases the remains of man, and of a fauna of the age of the Reindeer. The superposed beds are consequently posterior to that age. The occurrence in them of a very coarse pottery indicates a pre-Roman date, a determination which is confirmed by the presence of fragments of flints and of two worked flints, together with a little flint arrow-head "*à ailerons,*" so characteristic of the age of polished stone.

Remains of this age are found at two levels. The first is only separated from the "argile à blocaux" by masses of limestone coming from the partition of the cavern. It furnished fragments of grey pottery with grains of unburnt calcareous spar, not modelled with the hand, some plates of baked flint, two worked flints, a flint arrow-head, a fragment of the tusk of a wild boar pierced with a hole, ashes, and coal, some burnt bones, plates of psammite, and some rolled flints. It also contained human bones, together with bones of the Wild Boar, Goat, Stag, Heath-cock, Water-rat, and three vertebræ of a large fish (? Pike). *Helix nemoralis, Helix lapicida,* and *Unio batavus* were also found associated with them. The author remarks that the occurrence of human bones in the midst of the remains of the repasts of men is at present inexplicable, and rejects the hypothesis that it may indicate cannibalism on the part of the inhabitants of the cave.

In the beds overlying the "argile à blocaux," which, M. Dupont considers, occupies the place of the loess, an almost complete human skeleton of enormous dimensions was found; the contour of the grave in which it had been buried could be distinctly traced: and afterwards five other skeletons were found in a common grave. Neither arms nor any other object by which their age could be determined were discovered; and, excepting that they are posterior to the age of polished stone (for the graves are dug in the deposit which overlies remains of this age), no period can be assigned to them.

Between Chaleux and the castle of Walsin occur several caverns, three of which the author describes.

*Trou des Blaireaux* (Trô des Tassons).—After passing through a yellow earth almost without blocks, an unstratified yellow clay with blocks is reached. Besides some ashes and a rudely cut block of baked flint, bones of the following species were found:—Horse, Elk, Fox, Otter, Badger, Wild Cat, and Heath-cock, the bones of the Badger being particularly numerous. Below this was a bed of alternating veins of clay and sand, with two beds of gravel. This sandy argillaceous deposit is certainly the "Lehm."

*Trou de l'Hyène.*—This cavern is nearly opposite the "trou des blaireaux," upon the opposite bank of the Lesse; it has two openings, is about 12 feet above the river, and presents the following section:—

1. Mould formed by dead leaves, and containing bones of the Fox and Fowl.
2. Yellow clay, containing bones of the Reindeer and the Horse, as well as two worked flints.
3. Thin and non-continuous bed of stalagmite.
4. A sandy argillaceous deposit of a greyish-yellow colour, with traces of stratification and rolled pebbles.

Numerous bones are found in this bed, belonging principally to the following species:—*Hyæna spelæa,* Great Bear, Fox, Horse, *Elephas primigenius* (milk tooth), *Rhinoceros tichorhinus,* Ox (two species ?), and Reindeer.

The most abundant remains belong to the Hyæna, Rhinoceros, Reindeer, and the Horse; and nearly all show traces of a strong carnivore, except the *Hyæna,* from which it may be inferred that this cavern was the den of that animal, the other bones being the débris of its repasts. The results attained by the exploration of this cavern are of the highest importance; for by them we are enabled to assign the place of the great Quaternary mammifers to the stratified sandy argillaceous beds or Lehm, they evidently having lived immediately before the deposition of these strata. On the one side the stratified sandy argillaceous beds occur, as well in the caverns as in the subaërial formation of the province of Namur, between the great deposit of rolled pebbles on the one hand and the argillaceous deposit with blocks on the other.

But, as in the valley the deposit of rolled pebbles is characterized by the abundant remains of *Elephas primigenius*, these beds may be named the beds with *Elephas primigenius* (couches à *Elephas primigenius*). On the other side, the deposit of yellow clay with blocks, which is the equivalent of the *diluvium rouge* of the Paris basin, contains the fauna of the Reindeer properly so called, the characteristic of which is the absence of extinct species, and the presence of a series of animals which are at present banished to colder climates. These facts confirm, in the author's opinion, his division of the Quaternary formation into three stages:—

Étage supérieur à *Cervus tarandus*.
Étage moyen à *Ursus spelæus*.
Étage inférieur à *Elephas primigenius*.

*Trou de la Naulette*.—This cavern is on the left bank of the Lesse, about 60 yards up the river from the "trou des blaireaux." It is 27 feet above the river, is more than 40 yards long, and has a breadth in the middle of 12 yards. At the entrance to the cavern was a thick deposit of yellow clay with blocks, containing bones of the Horse, Reindeer, &c., which thinned out so rapidly that at 4 yards from the entrance there was not more than a trace of it. There a falling in of part of the roof had completely hidden the Quaternary deposits. Towards the extremity of the cavern, some well-stratified sandy argillaceous beds were laid bare, not overlain by the clay with blocks. A sinking made here presented the following section:—After passing through 9 feet of sandy clay and yellow sand, followed by 14 inches of yellow clay with fallen stones (*a*), cones of stalagmite, and bones of ruminants, 4½ feet of alternating beds of clay and stalagmite were reached. This was followed by sandy clay and sand, about 4 feet in thickness, which contained at its base the head of a Wolf and some vertebræ. In this bed (*b*) nearly all the bones mentioned hereafter were found. Below this, beds of sandy clay and sand were reached, followed by a gravelly sand, until traces of red clay were discovered.

The bone-bearing beds occurred at two levels. The upper one (*a*) contained some bones (especially single rami of the jaw) of an undetermined Ruminant.

The lower level (*b*) furnished, however, the most important series yet obtained from the caverns on the banks of the Lesse. The bones were not numerous, but were in an admirable state of preservation. The principal species were the Wolf, *Ursus arctos*, Fox, Badger, Bat, Marmot, Water-rat, *Elephas primigenius*, Rhinoceros, Horse, Reindeer, Wild Boar, Chamois, Common Stag, Sheep, and a fish. But the great importance of the discovery consisted in the presence in the midst of the bones of a human jaw and cubitus, and of a bone with a hole artificially produced. The association of the human remains with the rest of the bones was beyond a doubt.

The author then gives a detailed description of the human jaw and cubitus, and compares the former with the one discovered associated with remains of *Elephas primigenius* and *Rhinoceros tichorhinus* in the grotto of Arcy by M. de Vibraye, and with a jaw of the age of the Reindeer which came from the "trou de Frontal," with both of which, notwithstanding that the latter is of a much more recent geological age, he declares it to have a most intimate connexion.

Several bones, associated with these human remains, seemed to bear traces of the hand of man, especially a fragment of a bone which may be referred to a ruminant. The hole which is pierced is evidently artificial, the sides of the incision being very sharply cut. The sides of the fragment appear cut with a sharp instrument, unless, as M. de Quatrefages suggests, it be a particular mode of fracture. [A. S.]

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*On* THREE CAVERNS *in the* VALLEY *of the* LESSE EXPLORED *during the months of* MARCH *and* APRIL 1866. By M. E. DUPONT.

[Étude sur trois cavernes de la Lesse explorées pendant les mois de Mars et d'Avril, 1866, par M. Edouard Dupont. Bull. de l'Acad. Royale de Belgique, 2me sér. tome xxii.]

*Trou de Praule.*—The cavern of Praule is situated on the left bank of the Lesse, about 600 yards up the river from Furfooz. It is easy of access, and about 98 feet above the level of the river. The cave is 19½ feet broad, and has a length of 11 feet in the centre, its mean height between the rocky floor and the roof being little more than 6½ feet.

Upon the calcareous soil is a thin bed of sandy stratified clay, with rolled pebbles and gravel in non-continuous veins—the characteristic of the *Lehm,* or middle stage, of the Quaternary formation of Namur. The deposit yielded a humerus and a canine of a Great Bear, which, the author considers, confirm the application to this *Lehm* of his name of "*Étage à Ursus spelæus.*" These beds are overlain by yellow clays with blocks (argiles jaunes à blocaux), which contain, especially at the base, worked flints and bones of the Bear, Wolf, Fox, Horse, Reindeer, and Goat. The flints worked in the form of a knife are few, and are derived from the Chalk. The bones are probably the remains of repasts of men, as is generally the case in deposits of this nature in the caverns of the banks of the Lesse. These facts prove, in the author's opinion, that the *argile à blocaux* should be referred to the age of the Reindeer, and is relatively anterior to the deposition of the vast covering of clay. To the beds thus characterized, which form the upper stage of the Quaternary formation of the province, M. Dupont gives the name of "*Étage à Cervus tarandus.*"

*Trou des Allemands.*—The shelter furnished by a sloping dolomitic rock, under which the Bohemians established themselves during their wanderings, constitutes this cavern. Shelters of this kind are very numerous along the banks of the Lesse, and are generally slightly raised above the river-level. The following is the section presented by one near the route from Hulsonniaux to Celles, in ascending order:—

5. Rolled pebbles of Ardennaise origin cemented by gravel.
4. Yellow clay with dolomitic blocks.
3. Loess.
2. Alluvium formed of alternating veins of sands and clays, like *Lehm*.
1. Like No. 2, but *remaniés* and mixed with vegetable detritus. From this bed the author obtained some flint knives and a little sandstone hache, polished and with an irregular surface.

*Nutons des Gendron.*—The cavern of Nutons des Gendron is situated on the right bank of the Lesse, about 1½ mile (in a direct line) from the Furfooz cavern. It is excavated in a schistose bed with alternating calcareous bands, belonging to the "Psammites of Condroz." The length of the cave is 15 yards, and it has a breadth at the opening of 2½ yards. At the entrance is a mould formed by the decomposition of leaves, below which is found yellow clay with blocks of schist, without bones or works of art. The mould at a distance of 8 yards from the entrance was overlain with stalagmite, and contained human bones which belonged to no less than seventeen skeletons. Although the bones were broken, the workmen were able to observe that fifteen of the skeletons were arranged longitudinally along the cavern in six rows of two or three, varying according to the width of the cavern, with two skeletons placed transversely, the heads of the longitudinal skeletons being towards the mouth of the cave. A very small splinter of chalk-flint in the shape of a plate was found, together with three fragments of coarse pottery.

On the slope of the escarpment, immediately below the entrance, two great blocks of transported schist were dug up, one measuring 5 feet by 2¾ feet, the other 3½ feet by one foot.

Among the human remains were found bones of the Fox, Badger, Fowl, &c. The workmen also found a modern metal button with inscription, but without a date.

After having noticed the great number of human bones, especially fragments of the upper and lower jaw, and given detailed descriptions of the bones, the author states as his opinion that the remains are in a sepulchral cavern. The exact age, however, to which they belong is difficult to determine. The skeletons belong to a period posterior to the age of the Reindeer, because in the province of Namur remains of that age are always found below the yellow clay, the mould in this instance being above. M. Dupont therefore concludes that the skeletons were deposited in the cavern at an epoch posterior to the age of the Reindeer and anterior to the Bronze age, and refers them to the Polished-Stone period (*âge de la pierre polie*). [A. S.]

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## *On a* New genus *of* Cephalopods. By Chev. F. von Hauer.

[Proceed. Imp. Acad. of Vienna, December 14, 1865.]

This genus, for which the author proposes the name of "*Choristoceras*," bears a shell similar in form to that of *Crioceras*, with the lobular ornamentation characteristic of *Ceratites*. The first specimens of *Choristoceras Marshi* were brought to Vienna by Mr. O. C. Marsh, F.G.S., of Newhaven; subsequently Prof. Suess received a greater number of them; and lately Mr. Hinterhuber, an Imperial Mining Engineer entrusted by the Imperial Geological Institute with the task of examining the locality of the specimens found in Austria, ascertained their occurrence in a stratum resting on undoubted Kössen strata and overlain by "Adneth" (Liassic) limestones. Similar forms occur among the specimens referred to "*Crioceras*" from the Bavarian Alps, described by MM. Gümbel and Schafhäutl; but their determination must remain uncertain until their lobular ornamentation becomes better known. [Count M.]

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### *On* Remains *of the* Marmot (Arctomys marmota, *Gmel.*) *in* Styria.

[Proceed. Imp. Acad. Vienna, 8th and 22nd March, 1866.

The remains of this animal, which has never been known in Styria, as far as historical records or traditions go, consist of a jaw, found at the junction of the Parschlug and Mürz valleys, among some indeterminable fragments of bones; it was recognized as belonging to the species in question by Prof. Hyrtl (see Imp. Geol. Instit., Annals, xiv. 1864, Proceedings, p. 33). In the beginning of 1866, Prof. Oscar Schmidt discovered again, in the neighbourhood of Grätz, about two hundred feet above the river Mürz, an old den of Marmots, with the skeletons of four individuals, belonging to three different generations. These animals must be supposed to have lived in Styria during a portion of the Diluvial period, when the extension of glaciers in the higher Alpine regions drove away the Alpine flora and fauna to seek shelter and food in lower, and consequently more congenial, regions. [Count M.]

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### *The* Gasteropods *of* St. Cassian. By Dr. Laube.

[Proceed. Imp. Acad. Vienna, May 11, 1865.]

The Gasteropod-fauna of St. Cassian possesses many species analogous to forms found in the Carboniferous Limestone, and is particularly interesting as being a "Limit-fauna," comprehending representatives of a number of undoubtedly Palæozoic genera associated with others whose full development took place afterwards in the course of the Mesozoic Period; and the number of species occurring also in other localities is but small. The types of two new genera have lately been discovered among the Pectinibranchiate Gasteropods of St. Cassian, namely (1) *Euchrysalis*, having a chrysalid-like form, with smooth whorls, long-slitted mouth, and very prominent lips, and (2) *Ptychostoma*, resembling *Pleurotoma* by the peculiar slit on its mouth and by the lines of growth taking the form of the letter V on the sides of its smooth polished whorls. Dr. Laube describes 117 species, among which 22 are new. [Count M.]

# ALPHABETICAL INDEX

TO THE

## PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

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[The fossils referred to are described, and those of which the names are printed in italics are also figured.]

THE END.

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