THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

VOLUME THE FOURTEENTH.

1858.

PART THE FIRST.

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

LONDON:

LONGMAN, BROWN, GREEN, LONGMANS, AND ROBERTS.

PARIS:—FRIED. KLINCKSIECK, 11 RUE DE LILLE; BAUDRY, 9 RUE DU COQ, PRES LE LOUVRE; LEIPZIG, T. O. WEIGEL.

SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.

MDCCCLVIII.

List

OF THE

OFFICERS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

Elected February 19, 1858.

President.

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

Vice-Presidents.

John J. Bigsby, M.D.
Hugh Falconer, M.D., F.R.S.
Leonard Horner, Esq., F.R.S.L. & E.
Sir R. I. Murchison, G.C.St.S., F.R.S. & L.S.

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

Foreign Secretary.

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

Treasurer.

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

COUNCIL.

John J. Bigsby, M.D.
W. J. Broderip, Esq., M.A., F.R.S. & L.S.
Prof. Charles Daubeny, M.D., F.R.S. & L.S.
Thomas Davidson, Esq., F.R.S.
Hugh Falconer, M.D., F.R.S.
Thomas F. Gibson, Esq.
R. A. Godwin-Austen, Esq., B.A., F.R.S.
William John Hamilton, Esq., F.R.S.
Leonard Horner, Esq., F.R.S.L. & E.
T. H. Huxley, Esq., F.R.S.
Col. Henry James, R.E., F.R.S.
Sir Charles Lyell, F.R.S. & L.S.
Prof. N. S. Maskelyne, M.A.
John C. Moore, Esq., M.A., F.R.S.
Sir R. I. Murchison, G.C.St.S., F.R.S. & L.S.
Robert W. Mylne, Esq.
Prof. John Phillips, M.A., LL.D., F.R.S.
Major-General Portlock, LL.D., F.R.S.
Joseph Prestwich, Esq., F.R.S.
Samuel Peace Pratt, Esq., F.R.S. & L.S.
Prof. A. C. Ramsay, F.R.S.
Warington W. Smyth, Esq., M.A., F.R.S.
Alfred Tylor, Esq., F.L.S.

Assistant-Secretary, Curator, and Librarian.

T. Rupert Jones, Esq.

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PART I.—ORIGINAL COMMUNICATIONS.

LIST OF THE FOSSILS FIGURED AND DESCRIBED IN THIS VOLUME.

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

GEOLOGICAL SOCIETY OF LONDON.

ANNUAL GENERAL MEETING, FEBRUARY 19, 1858.

REPORT OF THE COUNCIL.

The Council, in laying their Annual Report before the Members of the Geological Society, have the pleasure of congratulating them on its continued efficiency and prosperity. They have the satisfaction of stating that there has been an increase of nine in the number of Fellows. Twenty-nine new Fellows have been elected, and six, who were elected in the previous year, have paid their subscriptions, making an addition of thirty-five ordinary Fellows. The loss which the Society has suffered from deaths amount to twenty, and from resignations six, making a reduction of twenty-six ordinary Fellows. One Honorary Member and four Foreign Members have been elected, and three Foreign Members have died. The total number therefore of the Geological Society at the close of 1856, was 868 Members, and at the close of the past year it consisted of 877.

The Council have to report that the current expenditure of the Society has exceeded the income by the sum of £62 8*s.* 8*d.*, but in this expenditure is included the sum of £208 11*s.* 6*d.*, incurred during the previous year for printing the last part of the 7th Volume of the Transactions, the Journal, and Supplementary Catalogue. The ordinary income during the past year has therefore exceeded the expenditure by £146 2*s.* 10*d.* The Exchequer Bonds for £200, purchased in 1855, have been sold and added to the balance of the Society's Bankers.

The amount of the Funded Property of the Society remains the same as at the close of 1856, viz. £4578 19*s.* 2*d.*, which includes £500, the amount of the late Mr. Greenough's Legacy, bequeathed for the purpose of defraying the expenses incidental to his donation of Books, &c., of which about £50 has already been disbursed and temporarily liquidated out of the ordinary expenditure of 1856 and 1857.

The Council have to announce the completion of the 13th volume of the Quarterly Journal and the publication of the 1st part of volume 14.

They have further to report that a temporary engagement has been made with Mr. J. Wetherell to assist in the Museum and Library.

Amongst other donations received since the last Anniversary, the Rev. Mr. Haughton, on the part of the Dublin Geological Society, placed at the disposal of the Society, sixty sets of portions of their Journal, which the Council have chiefly distributed to those Foreign Institutions which receive the Quarterly Journal.

The Council beg to state that they have lately commenced the gratuitous circulation of monthly Abstracts of the Proceedings of the Society, both to resident and non-resident Fellows, a measure which the Council has adopted with the view of more rapidly communicating to the Fellows the substance of the papers read before the Society.

They also have to inform the Fellows of the Society that in June last they received a request from Sir Wm. E. Logan, F.G.S., Director of the Geological Survey of Canada, on the behalf of the American Association, that a Member should be named to represent the Geological Society of London at their Annual Meeting at Montreal, accompanied with an intimation that a free passage, there and back, was at the disposal of the Society. The Council gladly availed themselves of the generous offer, and requested Professor Ramsay to be the representative of the Society at the American Meeting in August last.

The Council have anxiously considered how the Geological Map of England, prepared by the late Mr. Greenough, and by him bequeathed to the Society, may be made more available for the purposes of Science. No alterations have been made to that Map for nearly 20 years, while during that period our knowledge of the geology of our country has been steadily progressing. They have therefore come to the resolution of placing the Map in the hands of a Special Committee of nine Members, who are empowered to revise the Map, and to lay down upon it such alterations as recent investigation suggests.

They are of opinion that there cannot be a more legitimate mode of applying a portion of those funds, than to the perfecting of that Map, and therefore propose that the expense incident to the revision should be defrayed from the legacy of £500, bequeathed to the Society by the late Mr. Greenough.

In conclusion the Council beg to state that they have this year awarded two Wollaston Medals: the one to M. Hermann von Meyer, for his numerous publications on Palæontology; the other, together with the balance of the proceeds of the Wollaston Donation Fund, to Mr. James Hall of Albany, in testimony of the admiration entertained by the Geological Society of London for his geological labours in the field in North America, by which the nature and chronological superposition of the Palæozoic rocks of a large part of North America, and especially of the State of New York have been accurately defined and mapped. Also for his labours in general Palæontology, by which he has collected and classified a great series of North American organic remains from the lowest Silurian of New York to the tertiary mammalia of the Western States inclusive; and for his valuable works, published and in progress, on the Geology and Palæontology of New York, the publication of part of which has already been of the highest value to European geologists, especially in affording them the means of comparing the general structure of the rocks and the succession of life in the Palæozoic rocks of Europe.

Report of the Library and Museum Committee.

Library.

Of the books and pamphlets selected as duplicates from those bequeathed by the late Mr. Greenough and from the Society's Library, nearly all have been distributed as directed by the Council, according to the recommendations of the Special Committee. The Royal Geographical Society, the Geological Survey, and London University College have received about 450 volumes, and the Geological Society of Dublin have selected 30 volumes. It is proposed, in compliance with the application of Professor Oldham, that the majority of the remainder shall be presented to the Calcutta Library of the Geological Survey of India.

In accordance with the recommendation of the Library Committee of last year, a fair copy in manuscript has been made of a Catalogue of the additions of books to the Library.

The books, maps, prints, &c. received during the past year have been, as far as necessary, bound or mounted, and arranged in their respective places on the shelves in the Society's Library, or in the Map-cases and Portfolios.

The printing of the Index* prepared by Mr. Ormerod is in progress: four sheets are in the press, and it is expected that the whole will be completed by Lady Day next. We are happy to be able to state that nearly 100 copies have been subscribed for; and as a limited number is to be printed, it is suggested that those Institutions and Fellows who are desirous to obtain a work so indispensable for the advantageous use of the Society's publications should at an early date add their names to the list of those intending to take copies.

The number of British and Foreign Institutions to which the Quarterly Journal of the Society is presented, and from most of which their publications are received, has increased during the past year and now amounts to above 100. The papers bearing on Geological Science which are contained in such publications, as well as in the purchased Scientific Journals, continue to be noticed in the bibliographical list printed in the Quarterly Journal.

* Classified Index to the Transactions, Proceedings, and Quarterly Journal of the Society.

Museum.

The specimens presented during the last year to the Museum have been for the most part arranged in their respective drawers. They include series of rock-specimens and fossils: from St. Thomas's, presented by Dr. Hornbeck; from Bulgaria and the Grecian Archipelago, presented by Captain Spratt; from Asia Minor by Major Garden; from Chili by Mr. Bollaert and Dr. C. Forbes; from South Africa by Dr. Rubidge; and from Nagpur by the Rev. M. Hislop, who has continued to add to the magnificent series of fossil plants from that district, which it is hoped will ere long be described by some of our palæontologists.

Amongst the British specimens, Mr. Statham's polished section of one of the typical species of Devon Coral, the boulder from the chalk of Croydon, presented by Dr. Young, lately described by Mr. Godwin-Austen, Mr. Pettit's Clathraria from Leighton, and specimens of the Woodocrinus from Mr. E. Wood, of Richmond, may be mentioned as valuable additions to the Museum. Mr. Harris of Charing has sent a large supply of the fossiliferous ironstone of the North Downs; and the fossils are being carefully worked out and mounted.

Prof. H. D. Rogers has kindly superintended a partial re-arrangement of the North American series of fossils. He has also added to it a number of the wanting species, and has kindly promised to make a farther revision of the collection next year. We hope that other Fellows of the Society may be induced to follow the example of Prof. Rogers in undertaking the arrangement and description of the collections above noticed.

The Assistant-Secretary reports that he has received valuable aid in the work of the Library and Museum from Mr. J. Wetherell, whose services the Council engaged in April last, and that he has found him very attentive to his duties.

In accordance with the recommendation made by the Museum Committee last year, the Society's Collection of Foraminifera and Bryozoa was placed in the hands of W. K. Parker, Esq., who has, at a slight expense to the Society, sorted and carefully and beautifully mounted the specimens, on mahogany slips, many with glass covers, so that after some farther attention to the naming of the specimens, they will be commodiously arranged for study.

N. S. Maskelyne.
T. F. Gibson.
R. W. Mylne.
W. W. Smyth.

Comparative Statement of the Number of the Society at the close of the years 1856 *and* 1857.

	Dec. 31, 1856.		Dec. 31, 1857.
Compounders	128		126
Residents	189		188
Non-residents	485		497
	802		811
Honorary Members	13		12
Foreign Members	49		50
Personages of Royal Blood	4—66		4—66
	868		877

General Statement explanatory of the Alteration in the Number of Fellows, Honorary Members, &c. at the close of the years 1856 *and* 1857.

Number of Compounders, Residents, and Non-residents, December 31, 1856			802
Add, Fellows elected during former years, and paid in 1857	Residents .. 2		
	Non-residents 4— 6		
Fellows elected and paid, during 1857	Residents .. 9		
	Non-residents 20—29		
			— 35
			837
Deduct, Compounders deceased		5	
Residents „		5	
Non-residents „		10	
Resigned		6	
			— 26
Total number of Fellows, Dec. 31st, 1857, as above..			811
Number of Honorary Members, Foreign Members, and Personages of Royal Blood, December 31st, 1856....			66
Add, Foreign Members elected 1857			4
			70
Deduct, Foreign Members deceased		3	
Honorary Member „		1	
		—	4
		As above	66

Number of Fellows liable to Annual Contributions at the close of 1857, with the alterations during the year.

Number at the close of 1856		189
Add, Elected in former years, and paid in 1857		2
Elected and paid in 1857		9
Non-residents who became Residents		6
		206
Deduct, Deceased	5	
Resigned	6	
Compounded	3	
Became Non-resident	4	
	—	18
As above		188

Deceased Fellows.

Compounders (5).

Charles Barclay, Esq.
F. G. Bell, Esq.
James Morrison, Esq.
G. S. Nicholson, Esq.
Prof. J. Royle, M.D.

Residents (5).

H. J. Brooke, Esq.
Earl of Ellesmere.
Earl Fitzwilliam.
Charles A. Monck, Esq.
G. H. Saunders, Esq.

Non-residents (10).

William Bald, Esq.
Rev. William Dansey.
Lieut.-Col. G. Eliot.
Damiano Floresi, Esq.
Major T. B. Jervis.
W. T. Laverack, Esq.
Very Rev. W. D. Conybeare.
E. W. Rundell, Esq.
Rev. Christ. Sykes.
Joshua Trimmer, Esq.

Honorary Member (1).

Rear-Admiral Sir F. Beaufort.

Foreign Members (3).

M. Alcide D'Orbigny.
M. P. A. Dufrénoy.
Prof. A. H. Dumont.

The following Persons were elected Fellows during the year 1857.

January 7th.—William Peace, Esq., Haigh, near Wigan; W. H. Baily, Esq., Walcot Place, Kennington Road; and Joseph D. Rigby, Esq., Priory Lodge, Kew.

—— 21st.—Charles Greaves, Esq., Old Ford, Bow; George A. Ibbetson, Esq., Brook Street, Hanover Square; and Charles F. A. Courtney, Esq., Ramsgate.

February 4th.—Edwin Lees, Esq., Worcester; and Prof. W. Thomson, LL.D., Belfast.

—— 25th.—John Calvert, Esq., Ballydehot, Cork.

March 11th.—Charles Napier, Esq., Adelphi; and John Brown, Esq., Barnsley.

—— 25th.—Rev. John Montague, Leamington; and William Sowerby, Esq., Darlington.

April 8th.—Rev. Henry Brass, B.A., Brompton, Chatham.

—— 22nd.—Thomas Alfred Yarrow, Esq., Old Broad Street.

May 6th.—Lieut.-General John Briggs, Clayton, Sussex; Captain G. H. Saxton, Madras; and Arthur Abbott, Esq., Hitchin.

—— 20th.—Lieut. Henry Thurburn, Madras; and James Salter, Esq., Montague Street.

June 3rd.—William Reed, Esq., York.

—— 17th.—Capt. Charles P. Malony, Madras; and George Robbins, Esq., Bath.

Nov. 4th.—Robert White, Esq., West Cowes, Isle of Wight.

—— 18th.—Isaac Fletcher, Esq., Cockermouth; Edward Saunders, Esq., George Street, Hanover Square; Josh. Cooksey, Esq., West Bromwich; William Colchester, Esq., Dovercourt, near Harwich; and John Evans, Esq., Hemel-Hempstead.

Dec. 2nd.—James Templeton, Esq., Exeter; Edward Meryon, M.D., Clarges Street; Christian L. Bradley, Esq., Richmond, Yorkshire; Major A. C. Cooke, R.E., Perth; James Ross, Esq., Canonbury Park; and John Mansell, Esq., Dorsetshire.

—— 16th.—Dr. Eugene Francfort, Clapham Road; Charles Wright, Esq., Wigan; and John W. Woodall, Esq., Scarborough.

The following Persons were elected Foreign Members.

Jan. 21st.—M. Edouard Lartêt, Paris.

May 6th.—Professor Goeppert, Breslau.

—— 20th.—Professor Geinitz, Dresden.

Dec. 16th.—D. H. Abich, St. Petersburg.

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

British Specimens.

Specimen of Polished Coral from Devon; presented by J. L. Statham, Esq.
Specimen of Marl Slate with Lingula Credneri; presented by R. Howse, Esq.
Series of Fossils from the Tertiaries, Chalk and Wealden of the Isle of Wight, in Mahogany Glazed Case; presented by R. White, Esq.
A Skull of *Bos longifrons* from Waltham, and some fossils from the London Clay; presented by N. Wetherell, Esq.
Granitic boulder, &c. from the Chalk of Croydon; presented by Dr. J. Forbes Young, F.G.S.
Fossiliferous Ironstone from the North Downs; presented by William Harris, Esq., F.G.S.
Cast of a Bone from the Crag, and a rock-specimen from the Harwich Well; presented by S. V. Wood, Esq., F.G.S.
Specimens of Asterias from the London Clay; presented by Prof. Tennant, F.G.S.
Specimens of Clatharia from the Iron Sand of Leighton; presented by C. Pettit, Esq.
Crystals of Carbonate of Iron from Virtuous Lady Mine, Devon; presented by Capt. Lord.
Two Specimens of Woodocrinus from Yorkshire; presented by E. Wood, Esq., F.G.S.

Foreign Specimens.

Specimens of Fossil Fruits, &c. from Nagpur; presented by Rev. S. Hislop.
Specimens of Rocks from St. Thomas; presented by Dr. Hornbeck.
Specimen of Iron Ore from Missouri; presented by J. Colquhoun, Esq., F.G.S.
Specimens of Fossils, &c. from Bulgaria, &c.; presented by Capt. Spratt, F.G.S.
Specimens of Rocks and Mineral Waters from Erzeroum, &c.; presented by Major R. J. Gordon.
Specimens of Coal from Chili; presented by W. Bollaert, Esq.
Fossil Plants and other Specimens from North Africa; presented by Dr. Rubidge.
Fossils and Rock-specimens from Central India; presented by Rev. S. Hislop.
Specimens of Coal and Fossils from Valparaiso; presented by Dr. C. Forbes, R.N.
Silurian Fossils from the United States; presented by Prof. H. D. Rogers, F.G.S.

Charts and Maps.

169 Charts published by the Dépôt de la Marine; presented by the Director-General of the "Dépôt de la Marine."

Horizontal Sections; Sheets 41 and 42, of the Geological Survey of Great Britain.

Comparative Vertical Sections of the Purbeck Strata of Dorsetshire.

Index to the Colours and Signs employed in the Geological Survey of Great Britain; presented by the Director-General of the Geological Survey of Great Britain.

Geometrical Projection of Two-thirds of the Sphere, by Lieut.-Col. James, R.E.; presented by the Author.

Geological Map of the Duchy of Hesse-Budingen District; presented by the Middle Rhine Geological Society.

Map of the Principal Features of the Geology of Yorkshire, by John Phillips, Esq., 1853 (2 copies); presented by the Author.

Chart of Renkioi British Hospital, and part of Country adjacent; presented by Alfred Tylor, Esq., F.G.S.

Reconnoissances in the Dacota Country, by Lieut. G. K. Warren; presented by the Author.

Colton's Township Map of the State of Wisconsin.

Map of Madison and the Four Lake Country; presented by the Wisconsin State Historical Society.

Particulars of an Artesian Well at Praça St. Paulo, Lisbon, by Baron D'Enscheque; presented by F. Braithwaite, Esq.

Two Stereoscopic Photographs of Fossils, and Four Photographs illustrating the Geology of the Dorsetshire Coast; presented by Wm. Thompson, Esq.

Two Engravings of Mars and Saturn; presented by the Hon. East India Company.

Section from the North of Scotland to the Adriatic; and

Prospetto Meridionale dell' Etna, M. Gemmellaro; presented by Sir Charles Lyell, F.G.S.

Plan of Madison, the Capital of Wisconsin; presented by the State Historical Society of Wisconsin.

Small Engraved Portrait of the late Daniel Sharpe, Esq.; presented by F. Sharpe, Esq.

The following List contains the names of the Persons and Public Bodies from whom Donations to the Library and Museum were received during the past year.

American Academy of Arts and Sciences.

American Association for the Advancement of Science.

American Geographical and Statistical Society.

American Philosophical Society.

Anciola, Signor A.

Andrew, W. P., Esq.

Ansted, Prof. D. T., F.G.S.

Appel, Dr. A.

Art Union, London.

Asiatic Society of Bengal.
Atlantis, Editor of the.
Athenæum Journal, Editor of the.

Baillière, M. J. R.
Barrande, M. J., For. M.G.S.
Basel, Natural History Society of.
Berlin, German Geological Society at.
Berlin, Royal Academy of Sciences of.
Berwickshire Naturalists' Club.
Binney, E. W., Esq., F.G.S.
Blake, W. P., Esq.
Bland, Thos., Esq., F.G.S.
Bollaert, W., Esq.
Bonaparte, M. le Prince Ch.
Boston Natural History Society.
Boué, Dr. Ami, For. M.G.S.
Breslau Academy.
British Government.
Brodie, Rev. P. B., F.G.S.

Cambridge Philosophical Society.
Canadian Journal, Editor of the.
Carter, H. J., Esq.
Chemical Society of London.
Civil Engineers' Journal, Editor of the.
Collomb, M. E.
Colquhoun, J., Esq., F.G.S.
Coode, John, Esq.
Copenhagen, Royal Society of.
Cossio, Signor E. de.
Critic, Editor of the.

Dana, Prof. J. D., For. M.G.S.
D'Archiac, M. le Vicomte, For. M.G.S.
Darmstadt Geographical Society.
Daubeny, Prof., M.D., For. M.G.S.
Daubrée, M.
Davidson, Thos., Esq., F.G.S.
Dawson, J. W., Esq., F.G.S.
Delaharpe, M. Ph.
Delesse, M. A.
Dennis, Rev. J. B., F.G.S.
Deshayes, Prof. G. P., For. M.G.S.
Devalque, M. G.
Dijon, Academy of Sciences of.
Dublin Geological Society.
Dublin Natural History Society.
Dundonald, Earl of.
Dyson, Rev. Wm.

East India Company, The Hon.
Élie de Beaumont, Prof. L., For. F.G.S.
Elliot Society of Natural History, Charleston.
Emmons, Ebenezer, Esq.
Erdmann, Herr A.

Ferguson, W., Esq., F.G.S.
Fitton, W. H., M.D., F.G.S.
Forbes, Dr. C., R.N.
Fournet, M. J.
France, Geological Society of.
Franklin Institute of Pennsylvania.

Garden, Major R. J.
Geinitz, Dr. Hans Bruno.
Geological and Polytechnic Society of the West Riding of Yorkshire.
Geological Survey of India.
Geological Survey of the United Kingdom.
Gillis, Lieut., LL.D.
Girard, C., M.D.
Göppert, Prof. H. R., For. M.G.S.
Guiet, M. E. L.

Hall, James, Esq., For. M.G.S.
Halle Society of Natural History.
Hamburg Society of Natural Science.
Hamilton, W. J., Esq., For. Sec. G.S.
Harkness, Prof., F.G.S.
Harris, W., Esq., F.G.S.
Hartung, Herr Georg.
Haughton, Rev. Prof. S., F.G.S.
Hébert, M. E.

Heidelberg Natural History Society.
Helmersen, Col. G. von, For. M.G.S.
Hennessy, Prof. H.
Henry, Joseph, LL.D.
Hislop, Rev. S.
Hogg, J., Esq.
Holmes, Prof. F. S.
Holmes, Rev. J. I.
Hornbeck, Dr.
Howse, R., Esq.
Huxley, Prof. T. H., F.G.S.

Indian Archipelago Journal, Editor of the.
Institute of Actuaries.
Institute of Civil Engineers.
International Association.
Ives, Lieut. J. C.

Jackson, E. W., Esq., F.G.S.
James, Col. Henry, F.G.S.
Jones, T. Rupert, Esq., F.G.S.
Jones, Rev. W. A.
Jenzsch, Dr. G.

Lancashire and Cheshire Historic Society.
Lapham, J. A., Esq.
Laurent, M. C.
Lea, J., LL.D.
Leeds Philosophical Society.
Leidy, J., M.D.
Liége, Société Royale des Sciences, de.
Linnean Society.
Literary Gazette, Editor of the.
Liverpool Literary and Philosophical Society.
Lombardy Institute.
Lord, Capt.
Lyell, Sir Charles, F.G.S.
Lyons Hydrometrical Commission.

MacAdam, James, Esq., F.G.S.
Madras Exhibition.
Madrid Royal Academy of Sciences.
Manchester Philosophical Society
Marcou, M. Jules.
Martin, P. J., Esq., F.G.S.
Microscopical Society.
Middle Rhine Geological Society.
Mitchell, Rev. W.
Moscow Naturalists' Society.
Murchison, Sir R. I., F.G.S.
Museum of Practical Geology.

Naumann, Dr. C. F., For.M.G.S.
New York, State of.
Nicol, Prof. James, F.G.S.
Neuchatel Société des Sciences Naturelles.

Owen, D. Dale, Esq.

Paris, Academy of Sciences of.
Paris, École des Mines de.
Paris, M. le Directeur-Général du Dépôt de la Marine de.
Paris, Muséum d'Histoire Naturelle de.
Parker, W. K., Esq,
Pettit, C., Esq.
Philadelphia Academy of Natural Sciences.
Phillips, Prof. John, F.G.S.
Photographic Society.
Pick and Gad, Editor of the.
Pictet, Prof. F. J.
Prestwich, J., Esq., Treas. G.S.
Provincial Magazine, Editor of the.

Ramsay, Prof. A. C., F.G.S.
Ray Society.
Reeve, L., Esq., F.G.S.
Rennie, G., Esq., F.G.S.
Rogers, Prof. H. D., F.G.S.
Royal Academy of Belgium.
Royal Academy of Munich.
Royal Astronomical Society.
Royal Cornwall Polytechnic Society.
Royal Dublin Society.
Royal Geographical Society.
Royal Institution of Cornwall.
Royal Institution of Great Britain.

Royal Observatory, Edinburgh.
Royal Society of Edinburgh.
Royal Society of London.
Rubidge, Dr.
Ruskin, J., Esq., F.G.S.

Schmidt, Dr. C.
Schmidt, Herr F. J.
Schrenk, Herr A. G.
Sharpe, F., Esq.
Shumard, B. F., M.D.
Silliman, Prof., M.D., For. M.G.S.
Sismonda, Prof. A., For. M.G.S.
Sismonda, Prof. E.
Smith, C. R., Esq.
Smithsonian Institution.
Smyth, R. Brough, Esq., F.G.S.
Society of Arts.
Sorby, H. C., Esq., F.G.S.
Spratt, Capt. T. A. B., F.G.S.
Statham, J. L., Esq.
Statistical Society.
St. Clair Deville, M. Ch.
St. Louis, Academy of Sciences of.
Stockholm Royal Academy of Sciences.
St. Petersburg Academy of Sciences.
St. Petersburg Mineralogical Society.
Suess, M. Edouard.

Tate, Geo., Esq., F.G.S.
Taylor, R., Esq., F.G.S.
Tennant, Prof. J., F.G.S.
Thompson, Wm., Esq.
Trimmer, J., Esq., F.G.S.
Tuomey, Prof. M.
Turin Royal Academy of Sciences.
Tylor, A., Esq., F.G.S.
Tyndall, J., Esq.
Tyneside Naturalists' Field Club.

United States Coast Survey.
United States Patent Office.

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

Warren, Lieut. G. R.
Warwickshire Natural History and Archæological Society.
Wetherell, N., Esq.
White, R., Esq.
Wiesbaden, Natural History Society of.
Wisconsin, State Historical Society of.
Wilkins, E. P., Esq., F.G.S.
Wood, S. V., Esq., F.G.S.
Wurtemberg Natural History Society.

Young, Dr. J. Forbes.

Zigno, M. Achille de.
Zoological Society.

List of PAPERS *read since the last Anniversary Meeting, February 20th*, 1857.

1857.

Feb. 25th.—On the occurrence of an Earthquake at Crete, by H. Ongley, Esq. (From the Foreign Office.)

———— On some remarkable Mineral Veins, by Prof. D. T. Ansted, F.G.S.

March 11th.—On *Dichobune ovinum*, by Prof. Owen, F.G.S.

———— On some Fossil Mammalia from Purbeck, by Hugh Falconer, M.D., F.G.S.

March 25th.—Palichthyologic Notes, No. 9, On some Fish-remains from the neighbourhood of Ludlow, by Sir P. G. Egerton, Bart., M.P., F.G.S.

———— Note on the beds near Ludlow, containing Fish-remains, by Sir R. I. Murchison, V.P.G.S.

———— On the occurrence of Mastodon Bones in Chili, by Bollaert, Esq.; communicated by Professor Owen, F.G.S.

April 8th.—On the species of Mastodon and Elephas found fossil in England, by Hugh Falconer, M.D., F.G.S. (Part I.)

April 22nd.—On a Fossil Crustacean from the Lias Bone Bed, by C. Gould, Esq.; communicated by J. W. Salter, Esq., F.G.S.

———— On a Fossil Crustacean from the Coal Shales, by Prof. Huxley, F.G.S.

———— On the Geology of Strath, Isle of Skye, by A. Geikie, Esq.; communicated by Professor Ramsay, F.G.S.

May 6th.—The Silurian Rocks of Norway as described by M. T. Kjerulf, and those of the Baltic Provinces of Russia, by Prof. Schmidt, compared with their British Equivalents, by Sir R. I. Murchison, V.P.G.S.

May 20th.—On a new Fossil Mammal (*Pliolophus vulpiceps*) from the London Clay, by Professor Owen, F.G.S.

———— On some Plant Remains in the Old Red of Caithness, by J. W. Salter, Esq., F.G.S.

June 3rd.—On the species of Mastodons and Elephants occurring fossil in Great Britain, by Hugh Falconer, M.D., F.G.S. (Part II. Elephants.)

June 17th—On some comparative Sections of the Oolitic Series in Yorkshire, by Prof. J. Phillips, F.G.S.

———— On the Oolites of Gloucestershire and Wilts, by Prof. James Buckman, F.G.S.

———— On the Geology of Malaga, Spain, by Prof. D. T. Ansted, F.G.S.

———— On the Geology of the Dobrutcha, by Capt. T. A. B. Spratt, R.N., F.G.S.

———— On the Freshwater deposits of the Levant, by Capt. T. A. B. Spratt, R.N., F.G.S.

———— On the Gravels at Taunton, by J. Pring, Esq.; communicated by S. R. Pattison, Esq., F.G.S.

———— On a new Fossil Fish from the Keuper, by Sir P. Egerton, Bart., M.P., F.G.S., and the Rev. P. B. Brodie, F.G.S.

———— On the Geology of the Crimea, by W. H. Baily, Esq. F.G.S.

———— On the New Red Sandstone of Loch Greinord, by Prof. James Nicol, F.G.S.

———— On the Boulder Clays of Norfolk, by Joshua Trimmer, Esq., F.G.S.

———— On an entire Hind-Foot of an Iguanodon, by Prof. R. Owen, F.G.S.

———— On a large Femur of an Iguanodon, by T. F. Gibson, Esq., F.G.S.

Nov. 4th.—On the Correlation of the Triassic and Permian Rocks of the Odenwald and Schwarzwald, and of Central England, by Edward Hull, Esq., F.G.S.

——— On the extinct Volcanos of Victoria, Australia, by R. B. Smyth, Esq., F.G.S.

Nov. 18th.—On some Estuarine Deposits on the upper part of Shotover Hill, by Prof. John Phillips, F.G.S.

——— On the Extent, Mineral Characters, Fossils and Relations of the Palæozoic Basin of the State of New York, by J. J. Bigsby, M.D., F.G.S.

Dec. 2nd.—On the Structure of Crystals, as applicable to the determination of the Aqueous or Igneous origin of Minerals and Rocks, by H. D. Sorby, Esq., F.G.S.

Dec. 13th.—On the genus Neuropteris, by C. J. F. Bunbury, Esq., F.G.S.

——— On the Boring through the Chalk at Harwich, by Joseph Prestwich, Esq., Treas. G.S.

——— On a Granitic Boulder from the Chalk at Croydon, and on other extraneous rock-fragments found in the Chalk, by R. A. Godwin-Austen, Esq., F.G.S.

Jan. 6th.—On Pteraspis, a Genus of Fossil Fishes, by Prof. Huxley, F.G.S.

——— On a new Species of Plesiosaurus, by Prof. Huxley, F.G.S.

——— On the Coal-beds of Valparaiso, by Dr. C. Forbes; communicated by Prof. Ansted, F.G.S.

——— On an upthrow of Crabs in the Harbour of Payta, by Dr. C. Forbes; communicated by Prof. Ansted, F.G.S.

Jan. 20th.—On the Emanation of Ammonia from Volcanos, by Prof. Daubeny, M.D., F.G.S.

——— On some of the Granites of Ireland, by the Rev. Prof. Haughton, F.G.S.

——— On the Classification and Stratigraphy of the Palæozoic Rocks of the State of New York, by J. J. Bigsby, M.D., F.G.S.

February 3rd.—On the whole succession of Rocks in the Northern Highlands, from the oldest Gneiss, through Strata of Cambrian and Lower Silurian Age, to the Old Red Sandstone, inclusive, by Sir R. I. Murchison, V.P.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 William Hopkins, Esq., and R. Godwin-Austen, Esq., retiring from the Office of Vice-President.

2. That the thanks of the Society be given to R. W. Mylne, Esq., retiring from the Office of Secretary.

3. That the thanks of the Society be given to S. Beckles, Esq., S. R. Pattison, Esq., William Hopkins, Esq., Lord Ducie, and Prof. Owen, retiring from the Council.

4. That the thanks of the Society be given to Major-Gen. Portlock, LL.D., retiring from the Office of President.

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

OFFICERS.

PRESIDENT.

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

VICE-PRESIDENTS.

John J. Bigsby, M.D.
Hugh Falconer, M.D., F.R.S.
Leonard Horner, Esq., F.R.S.L. & E.
Sir R. I. Murchison, G.C.St.S., F.R.S. & L.S.

SECRETARIES.

Thomas Davidson, Esq., F.R.S.
Warrington W. Smyth, Esq., M.A.

FOREIGN SECRETARY.

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

TREASURER.

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

COUNCIL.

John J. Bigsby, M.D.
W. J. Broderip, Esq., M.A., F.R.S. and L.S.
Prof. Charles Daubeny, M.D., F.R.S. and L.S.
Thomas Davidson, Esq., F.R.S.
Hugh Falconer, M.D., F.R.S.
Thomas F. Gibson, Esq.
R. A. Godwin-Austen, Esq., B.A., F.R.S.
William John Hamilton, Esq., F.R.S.
Leonard Horner, Esq., F.R.S.L. and E.
T. H. Huxley, Esq., F.R.S.
Colonel Henry James, R.E., F.R.S.
Sir Charles Lyell, F.R.S. and L.S.
Prof. N. S. Maskelyne, M.A.
John C. Moore, Esq., M.A., F.R.S.
Sir R. I. Murchison, G.C.St.S., F.R.S. and L.S.
Robert W. Mylne, Esq.
Prof. John Phillips, M.A., LL.D., F.R.S.
Major-General Portlock, LL.D., F.R.S.
Joseph Prestwich, Esq., F.R.S.
Samuel Peace Pratt, Esq., F.R.S. and L.S.
Prof. A. C. Ramsay, F.R.S.
Warrington W. Smyth, Esq., M.A.
Alfred Tylor, Esq., F.L.S.

Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Banker's, 1st of January 1857, on the Wollaston Donation Fund	30	7	0	Award to S. P. Woodward, Esq.	30	2	0
Dividends on the Donation Fund of 1084*l.* 1*s.* 1*d.* Red. 3 per Cents.	30	19	3	Cost of Engraving Wollaston Medal, awarded to M. Barrande		5	0
				Balance at Banker's (Wollaston Fund)	30	19	3
	£61	6	3		£61	6	3

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

SEARLES WOOD, ALFRED TYLOR, } *Auditors.*

Feb. 9, 1858.

Valuation *of the Society's Property; 31st December,* 1857.

Property.	£	s.	d.	£	s.	d.	Debts.	£	s.	d.
Due from Messrs. Longman and Co., on Journal, Vol. XIII.				76	18	2	Balance in favour of the Society	4657	15	6
Due for Subscriptions to Journal				54	12	0				
Due for Authors' Corrections in Journal				8	6	0				
Balance in Banker's hands				248	5	7				
Balance in Clerk's hands				12	1	9				
Funded Property, 4578*l.* 19*s.* 2*d.* Consols, at 90				4121	2	0				
Arrears of Admission Fees (considered good)	86	2	0							
Arrears of Ann. Contributions (considered good)	50	8	0							
				136	10	0				
				£4657	15	6		£4657	15	6

[*N.B. The value of the Mineral Collections, Library, Furniture, stock of unsold Transactions, Proceedings, Quarterly Journal, and Library Catalogues is not here included.*]

Feb. 9, 1858. JOSEPH PRESTWICH, *Treas.*

INCOME.

	£	s.	d.	£	s.	d.
Balance at Banker's, January 1, 1857	124	14	0			
Balance in Clerk's hands	8	17	8			
Exchequer Bonds, invested out of Income 1854	199	15	3			
				333	6	11
Compositions received				94	10	0
Arrears of Admission Fees	54	12	0			
Arrears of Annual Contributions	53	11	0			
				108	3	0
Admission Fees of 1857				266	14	0
Annual Contributions of 1857				574	7	0
Dividends on 3 per cent. Consols				130	15	10
Dividends on Exchequer Bonds....................				7	6	3
Publications:						
Longman and Co., for Sale of Quarterly Journal in 1856	68	12	6			
Sale of Transactions	26	8	3			
Sale of Proceedings	1	1	8			
Sale of Journal, Vol. 1–6..................	13	14	6			
,, Vol. 7....................	3	0	0			
,, Vol. 8....................	6	4	6			
,, Vol. 9....................	4	17	6			
,, Vol. 10	5	14	0			
,, Vol. 11	15	5	6			
,, Vol. 12	60	5	6			
,, Vol. 13*..................	131	16	4			
				337	0	3
Sale of Library Catalogue				2	19	
Sale of Geological Map of England (Greenough)				12	19	
				£1868	1	9

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

Feb. 9, 1858. SEARLES WOOD, ALFRED TYLOR, } *Auditors.*

	£	s.	d.
* Due from Messrs. Longman and Co., in addition to the above, on Journal, Vol. XIII.	£76	18	2
Due from Fellows for Subscriptions	54	12	0
Due from Authors for Corrections	8	6	0
	£139	16	2

Year ending December 31st, 1857.

EXPENDITURE.

	£	s.	d.	£	s.	d.
General Expenditure :						
Taxes	42	4	0			
Fire Insurance	3	0	0			
House Repairs	8	4	10			
Furniture Repairs	12	10	10			
New Furniture	20	9	8			
Fuel	35	18	0			
Light	30	13	1			
Miscel. House expenses, including Postages	51	11	7			
Stationery	21	1	5			
Miscellaneous Printing	30	10	9			
Tea for Meetings	23	7	3			
				279	11	5
Salaries and Wages :						
Assistant Secretary and Curator	200	0	0			
Clerk	144	7	0			
Assistant in Library and Museum	32	10	0			
Porter	101	8	0			
House Maid	38	3	0			
Occasional Attendants	12	0	0			
Collector	22	2	0			
				550	10	0
Library (including printing Supplementary Catalogue)*				128	7	3
Museum				15	12	9
Diagrams at Meetings				19	2	8
Miscellaneous Scientific Expenses				12	0	1
Publications :						
Geological Map of England	8	11	0			
Transactions	0	12	8			
Transactions, Vol. VII., Pt. 4	51	0	6			
Proceedings (Abstracts)	5	15	11			
Journal, Vols. I.–VI.	1	2	1			
,, Vol. IX.	0	6	3			
,, Vol. X.	0	15	11			
,, Vol. XI.	0	16	10			
,, Vol. XII.	102	12	6			
,, Vol. XIII.	428	11	4			
				600	5	0
Exchequer Bonds, loss on sale				2	5	3
Balance at Banker's, Dec. 31, 1857	248	5	7			
Balance in Clerk's hands	12	1	9			
				260	7	4
				£1868	1	9

* Nearly £50 has been expended on the Greenough Bequest during 1856 and 1857, which has to be returned to the credit of "Library" out of the Funded Property of that bequest.

Estimates *for the Year* 1858.

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Due for Subscriptions on Quarterly Journal (considered good)	50	8	0			
Due for Authors' Corrections	8	6	0			
				58	14	0
Arrears (See Valuation-sheet)				136	10	0
Ordinary Income for 1858 estimated:						
Annual Contributions (180 Fellows)				567	0	0
Admission Fees				160	0	0
Compositions				63	0	0
Dividends on 3 per Cent. Consols				133	7	4
Sale of Transactions, Proceedings, Geological Map, Library Catalogues				20	0	0
Sale of Quarterly Journal	250	0	0			
Due by Messrs. Longman and Co. in June, for sale of Journal in 1857	76	18	2			
				326	18	2
Due to Library on account of Mr. B. Greenough's Bequest				50	0	0
				£1515	9	6

JOSEPH PRESTWICH, Treas.

Feb. 9, 1858.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
General Expenditure:						
Taxes	43	0	0			
Fire Insurance	3	0	0			
House Repairs	20	0	0			
Furniture Repairs	10	0	0			
New Furniture	40	0	0			
Fuel	35	0	0			
Light	30	0	0			
Miscellaneous House Expenses	50	0	0			
Stationery	20	0	0			
Miscellaneous Printing	26	0	0			
Tea for Meetings	24	0	0			
				301	0	0
Salaries and Wages:						
Assistant Secretary	200	0	0			
Clerk	120	0	0			
Assistant in Library, &c.	35	0	0			
Porter	90	0	0			
House Maid	33	4	0			
Occasional Attendants	12	0	0			
Collector	23	0	0			
				513	4	0
Library, New Books, &c.	40	0	0			
Museum	40	0	0			
Diagrams at Meetings	15	0	0			
Miscellaneous Scientific Expenses	10	0	0			
Publications: Quarterly Journal	430	0	0			
„ Transactions	5	0	0			
„ Abstracts of Proceedings	50	0	0			
				590	0	0
Balance in favour of the Society				111	5	6
				£1515	9	6

PROCEEDINGS

AT THE

ANNUAL GENERAL MEETING,

19TH FEBRUARY, 1858.

Award of the Wollaston Medal and Donation Fund.

The preceding Reports having been read, the President, Major-General Portlock, addressed the Meeting as follows:—

The Report of the Council has pointed out that its Members have on this occasion awarded two medals, thinking it desirable to mark, without delay, their high appreciation of the great merits of two most distinguished men, who, labouring in countries very distant from each other, have contributed largely to our knowledge of the ancient Natural History of the earth.

The first Medal has been assigned to a veteran Palæontologist, Hermann von Meyer, who commenced his labours twenty-three years ago by investigating the principle of determining the order and classification of mineral deposits by their natural-history relations. From that time he has been engaged in an uninterrupted course of Palæontological inquiries of the most varied nature, and he has become one of the leading authorities upon the subject in Germany. Sixteen years ago he was associated with Germar, Count Münster, and Professor Unger in that important work 'Beiträge zur Petrefaktenkunde,' or Contributions to the Knowledge of Fossils, which was rich in every branch of organic remains, whether animal or vegetable; and I find in the fifth part the description of a species of Pterodactyle, *Pterodactylus Meyeri*, discovered by Von Meyer himself, and named by Münster after his able coadjutor. Fossil Fishes and Fossil Plants were equally the subject of discussion in this able work, which extended to seven parts. He was associated with Plieninger in describing the palæontology of Würtemberg, and he is now engaged with Dunker in publishing a general 'Palæontographica,' which has already recorded many interesting discoveries in this most rich and fascinating science. It will, I am sure, therefore, be felt that we are only doing justice to the claims of a man who has produced no less than 57 treatises upon Palæontological subjects, not one of which can be considered undeserving of respect and attention.

Sir C. Lyell,—It is with great pleasure that I place the Medal in your hands, requesting that you will convey to M. Hermann von Meyer our high appreciation of the value of his labours, and our gratification at conveying it to him through one so fully able to value the services of a great Palæontologist.

Sir C. Lyell thus replied:—

Mr. President,—It will give me great pleasure to take charge of the Medal which has been awarded by the Geological Society of London to my friend M. Hermann von Meyer.

The importance of his Palæontological labours is now, as you have truly stated, universally acknowledged; but for my own part, I confess that I should scarcely have been aware of their vast extent had I not enjoyed opportunities of visiting Frankfort from year to year, and seeing the author engaged in his preparations for those monographs on fossil reptiles with which he has enriched our science. I see that one of the most splendid of these elaborate treatises, which contains I believe descriptions and illustrations of about 80 species of Triassic Reptiles, is now lying on our table—a work of which it is not too much to assert, that it would have secured a very high reputation for its author had it been the only labour of his life. For this and for his other publications, M. von Meyer has executed all the drawings with his own hand, and has done them all on transparent paper, so that his lithographer, when transferring them to stone, has not had to reverse the figures—a process during which the spirit and accuracy of the originals are often found to suffer.

Allow me, Sir, in conclusion, again to express to you the satisfaction I feel at being requested to transmit this well-earned tribute of our esteem to one of the most distinguished of our Foreign Members.

The President proceeded:—

The Council has awarded the second Medal to Mr. James Hall, of New York, as a testimonial of its high opinion of his merits as a palæontologist and geologist. Twenty-one years ago Mr. Hall exhibited his taste for palæontology by describing two species of Trilobites belonging to the genus *Paradoxides*, a genus very remarkable in its conformation, and which our friend Mr. William Rogers has lately discovered in a highly metamorphosed rock, long considered a crystalline schist, near Boston. His notes upon the geology of the Western States soon followed as a testimony to his love of pure geology; but the palæontology of New York proved him to be worthy of the respect of all lovers of natural science. He has gone steadily forward, and we are now indebted to him for an accurate knowledge of the geology and palæontology of the great State of New York, which is in itself equal to a large kingdom in magnitude. The last of his works, "Descriptions of New Species of Palæozoic Fossils from the Lower Helderberg, Oriskany Sandstone, Upper Helderberg, Hamilton, and Chemnung groups," published last year, is full of descriptions of new species; and, although I am myself prone to hesitate respecting new species when closely allied to previously known species, the work proves the continued energy and ability of Mr. Hall in his favourite study.

To me it has always appeared, that the history of any of the past epochs of the earth's history may best be studied in countries which have not undergone any great disturbance during its continuance. In England, from its insular position, it is easy to observe that numerous disturbances must have interfered with the tranquil course of events, whilst in large continents, such as America, and a large portion of the continent of Europe, such as Russia, &c., little comparative disturbance may be looked for, and the succession of organic existences may be supposed to have gone on under the influence of ordinary and natural causes alone. Such considerations as these are the more interesting at the present moment as Sir R. Murchison has lately been enabled to establish the Silurian age of certain rocks in Scotland, by the discovery in them of Silurian fossils, not of the English type, but of the American type, amongst which may be mentioned the genus *Maclurea*, so called after one of the first writers on American Geology, the well-known Mr. Maclure. This curious fact adds to our interest in the award of this Medal, which we wish to be considered as a testimony of the high respect which our Society entertains for the labours of American geologists, and especially for those of Mr. James Hall. I should have felt much pleasure in transmitting the Medal through Professor Ramsay, who during the last summer represented our Society at the Meeting of American Naturalists in Canada; but in his absence, I naturally turn to you, Sir Roderick Murchison, as the natural leader on every question relating to the Silurian Formation, and who would have been our representative in America had you not found it necessary, from ill-health, to decline the pleasing duty in favour of Professor Ramsay, who may be considered almost your pupil. Let me then request you to undertake the task of conveying the Medal to Mr. James Hall, and expressing our high respect for him and his labours. The Council has added the proceeds in the hope that the sum, though small, may be of use to Mr. Hall in the publication of his fossils.

In reply Sir R. Murchison said:—

Sir,—Although I am unexpectedly called upon, through the accidental absence of Professor Ramsay, to receive the Wollaston Medal for Mr. James Hall, I beg to assure you, that no one of my countrymen can more truly rejoice than I do in the adjudication of the highest honour this Society can bestow, to so eminent an American geologist.

In my earnest desire to have visited the United States and Canada last summer—a desire which was alone frustrated by the state of my health,—my chief gratification would have been to have examined, under the guidance of James Hall, those great expanses of the Silurian and other palæozoic rocks of the Western Continent which he has so truthfully and ably described; for it is he who has shown us that, however widely separated by the Atlantic, the fossil remains of the earliest traceable living things in the New World have, like the present inhabitants, the strongest relationship with the old country. Permit me, Sir, also to say, that the high estimate of the merits of our medallist, which I have imbibed, both from a study of his own works and by reference to the opinions of Lyell, De Verneuil, and Logan, has been much strengthened by the animated reports of Professor Ramsay, who since his return has lost no opportunity of recording the deep sense he entertains of the very important services rendered to Geological science by the arduous and meritorious researches of James Hall.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT.

Proceeding now to the more special duty which devolves on your President this day, I have once more to perform the melancholy task of recalling to your memory the names of those Fellows of our Society who have been removed from amongst us, by death, during the year; and it is with sorrow that I find how erroneous was the hope I entertained last year, that the very magnitude of the losses I then commemorated would insure me from having to dwell in the present year, for any length of time, upon so sad a subject. It was indeed scarcely to be expected that we should have been, as a large Society, entirely exempted from the common lot of humanity; but the blow has fallen most heavily upon us, and amongst our losses we have to record the names of men distinguished in almost every branch of literary or scientific lore.

The first I shall notice was indeed a patriarch of our science, one of those illustrious men who assisted at the very birth of Geology amongst us, one who was long looked up to as a sure guide in the path of truth and science. You will at once perceive that I allude to the late Dean Conybeare, who last came amongst us only a very short time before the summer recess, when he appeared to take as lively an interest as ever in the proceedings of the Society he had once cheered by his frequent attendance, and adorned by his labours; and as he was going away he assured me that it was always with pleasure and satisfaction he came to meetings from which duty and distant residence could alone keep him away.

It has been justly said that he was one of a race of clergymen, and those men of intellectual eminence. His grandfather was Dean of Christchurch and Bishop of Bristol, the friend of Bishop Berkely, and the author of a work distinguished even in an age of deep thinkers and profound theologians, and entitled 'The Defence of Revealed Religion.' The Bishop's only son, Dr. William Conybeare, Rector of Bishopsgate, left behind him two sons, both of whom were eminent men. The elder, John Josias, Vicar of Bath Easton, was an accomplished scholar, no inconsiderable chemist, a sound geologist, and filled with credit the University offices of Professor of Poetry and of Anglo-Saxon, as well as that of Bampton Lecturer: he promoted the revival of Saxon literature, and left behind him, on his death in early life, a volume of translations which it was his brother's office to complete and edit. That brother, the second son of Dr. William Conybeare, was the illustrious object of this notice, William Daniel Conybeare: he was born in June 1787, and in due time sent to Westminster School, where he received his early education. From Westminster he proceeded to Oxford, and entered Christ Church in the same year as his fellow collegian Sir Robert Peel, taking a first class in classics, in which he was classed with Sir Robert, and a second class in mathematics, in which he was classed with Archbishop Whately. Until he took his M.A. degree, he continued to reside at the University, pursuing various studies, and assisting by his exertions to lay the foundation of Geology, which was then only a rising science. At the early portion of the present century, an indifference, such as we can now scarcely understand, as to the cultivation of the natural sciences prevailed at Oxford; but, in the midst of the consequent general neglect, a small band of individuals, residents of the University, were united in the effort to keep alive a taste for at least one branch of natural science, and succeeded in enlisting others in its cause.

The first lectures given at Oxford on Mineralogy, which was then as a study not accurately distinguished from Geology, were, it is believed, those delivered by Sir Christopher Pegge, then Regius Professor of Medicine; and although it may not be possible, either from written records or from the personal testimony of any one now living, to form an accurate opinion of the merits of those lectures, it may be fairly assumed that they were not destitute of attractiveness, as the same individual delivered long afterwards lectures on Anatomy, remarkable for an elegance and a fluency of diction which have caused them to continue fresh in the recollection of many. Sir Christopher Pegge was succeeded by Dr. Kidd, who for several years gave courses of lectures at Oxford on both the allied sciences, Mineralogy and Geology, and collected around him a knot of persons interested in similar pursuits, who formed themselves into a little club of Oxford Geologists. This club included amongst its members the late Dr. Buckland, the two brothers Conybeare, the late Rev. Philip Serle, of Trinity College, afterwards Rector of Addington, Oxford, and many others, who, though less vigorously devoting themselves to geological research, were still, from their eminent qualities and high character, most instrumental in keeping alive the growing interest for the new science, and in raising the character of the club so high, that some of the early members of the Geological Society of London, then in its infancy, amongst whom were the late Mr. Greenough and the present patriarch of our science, Dr. Fitton, were in the habit of paying an annual visit in Whitsun-week to the University, in order to explore, under the guidance of the geologists of Oxford, the physical structure of the rocks in its neighbourhood; whilst, on their part, they thus judiciously enlisted local inquirers in the service of general geology.

The venerable Principal of Magdalen College, Dr. Macbride, is the only survivor, at Oxford, of this memorable club, and he preserves at an advanced age the vigour of his faculties, and exhibits all his former interest in the progress of learning and of science; but of non-residents, there still survive Archdeacon Hony, now Prebendary of Sarum, and Mr. Philip Duncan, who now resides at Bath: the latter and his brother, Mr. John Grant, were Fellows of New College, were honoured by the degree of D.C.L., and were remarkable, not only for their love of natural history, but for their zealous support of every philanthropic and scientific object. The Rev. William D. Conybeare was, however, in the first rank of this little body, and stood so high in the estimation of all its members, that Dr. Buckland, when first lecturing as the successor to Dr. Kidd, expressed in the warmest terms his sense of the obligations he owed to him for the information he had imparted on points relating to geology, and his persuasion that it would not have been fitting for him to offer himself to fill the office of lecturer on that subject, had Mr. Conybeare been desirous to occupy it. Let me add here, that another equally eminent individual, the founder of the new school of geology at Cambridge, as Dr. Buckland was of that of Oxford, has assured me, with a similar frankness, so characteristic of Professor Sedgwick, that he too looked upon Dean Conybeare as his early master in geology.

In 1814 Mr. Conybeare married, and retired from the University, the scene of his early triumphs, to undertake the quiet work of a country curacy, and nine years afterwards removed to the vicarage of Sully in Glamorganshire, on the presentation of the late Evan Thomas, Esq., his brother-in-law; but, whilst holding the curacy of Banbury and Lectureship of Brislington, near Bristol, he had been mainly instrumental, in conjunction with Sir Henry Delabeche, in founding the Bristol Philosophical Institution and Museum, and it was at that time he received a visit from the great French geologists, M. Elie de Beaumont and M. Dufrénoy, who came for the purpose of acquiring a knowledge of the secondary rocks of England, as a standard of reference for those of France; and he so impressed them, whilst acting as their companion and guide in an exploration of the neighbourhood, with a deep sense of his geological knowledge, that they were prepared on their return to cooperate with Cuvier in obtaining the election of Mr. Conybeare as a corresponding member of the Institute, for Geology. Nor must it be supposed that this excellent man neglected his sacred duties whilst storing his mind with the richest treasures of geological research, as it was during his residence at Sully that he delivered, gratuitously, at the request of his friend Dr. Prichard, a course of theological lectures at Bristol College, of which institution he had become a visitor.

In 1836 he left Sully and went to Devonshire, having presented himself to his family living of Axminster, and, whilst there, preached, at the request of the authorities of the University of Oxford, the Bampton Lecture for 1839. The living of Axminster he resigned after a few years, on being called by his friend Bishop Copleston to the care of the Cathedral of Llandaff. Here he continued zealously to carry on the good work of restoration which had been commenced by his predecessor Dean Bruce Knight; and, as at all times in his life, was ever ready to distribute the rich and varied stores of his mind for the benefit of his fellow-men, in whatsoever station of life they might have been. This venerable, much-loved man, and admired philosopher, left Llandaff to attend the death-bed of his eldest son, and, whilst pausing in his return, at the house of another son, was stricken with pulmonary apoplexy, and died on the morning of the 12th of August, after an illness of only three hours, in the 71st year of his age.

Such is the general picture of the life of a truly estimable man; and I shall now add to it a very brief notice of his most characteristic works, premising, however, that, even before the peace of 1815 had opened the Continent to British geologists, Mr. Conybeare had formed, from the imperfect data then within his reach, a sound opinion as to the identity of the Jura limestone with the oolitic formations of England, an anticipation which he had afterwards the gratification, in conjunction with Dr. Buckland and Mr. Greenough, of verifying. The versatility of the genius of Dean Conybeare led him to examine and describe the lesser points connected with organic remains, as well as the greater; a circumstance in which he strongly resembled his friend and fellow-labourer Dr. Buckland. For an exemplification of this peculiarity of his mind, I shall refer to his paper published in the year 1814, in the second volume of the Transactions of the Society, and therefore one of his early contributions to Palæontological Science. It was entitled, "On the Origin of a remarkable Class of Organic Impressions occurring in Nodules of Flint." Mr. Parkinson had described them as "small round compressed bodies, not exceeding the eighth of an inch in their longest diameters, and horizontally disposed, connected by processes nearly of the fineness of a hair, which pass from different parts of each of these bodies, and are attached to the surrounding ones; the whole of these bodies being thus held in connexion." Mr. Parkinson considered that these bodies were the works of polypes, and he therefore classed them with corals of some unknown genera; and Dr. Buckland, who had directed his attention to them simultaneously with Mr. Conybeare, considered that the moulds in which the siliceous casts had been formed were the work of parasitic insects, the thin hair-like appendages having been the passages of entry first made by the insects, and the larger flattened bodies the cavities afterwards excavated, the object of the excavation having of course been to obtain nourishment from the body thus eaten into, whether a shell or any other. This observation of Dr. Buckland was communicated to Mr. Conybeare, but not until he had completed his own researches, and arrived at the same virtual conclusion,—namely, that "these cellules were the works of animalcules preying on shells and on the vermes inhabiting them." In arriving at this conclusion, Mr. Conybeare was guided by the examination of various fragments of shells, still preserved in contact with the siliceous matter which had subsequently been infiltrated into the cavities produced by the boring animal. These appear to have been portions of shells distinguished by a striated texture, and were stated by Mr. Conybeare to resemble in structure the recent *Pinna marina*, as the genus *Inoceramus* does; but in addition to these, Mr. Conybeare found them connected with other shells, and even with an *Echinus* and a *Belemnite*. Though

Mr. Conybeare spoke with diffidence of his having brought before the Society a paper on such minute palæontology, it cannot be doubted that the interest connected with the discovery of the existence and workings of minute marine animals at so remote an epoch is of a very high order. The flints and other siliceous deposits of the chalk and other geological epochs, have indeed been striking examples of the effect of judicious investigation in rendering the most obscure objects the means of throwing light upon natural phænomena.

Mr. Conybeare was fully aware of the necessity of studying physical as well as organic phænomena in connexion with geological science; and it is truly surprising how often the intimate connexion of the physical geography of remote epochs with their natural history is overlooked. His description of the land-slip which occurred on the coast of Culverhole Point, near Axmouth, in December 1839, was ably illustrated by a series of lithographic plates from the drawings of the present Lieut.-Colonel Dawson; and the magnitude of the results was well expressed by the following words:—"Although this convulsion can only be ascribed to the less dignified agency of the land-springs constantly undermining the sub-strata, yet, in the grandeur of the disturbances it has occasioned, it far exceeds the ravages of the earthquakes of Calabria, and almost rivals the vast volcanic fissures of the Val del Bove on the flanks of Ætna." Without doubt these phænomena are very striking and interesting in themselves; but they become still more so when we reflect, as Mr. Robert Mallet has taught us to do, that they ought not to be confined to the existing epoch alone, but should be sought for in the stony records of past ages. The paper on the Hydrographical Basin of the Thames, written with a view to determine the causes which had operated in forming the Valleys of the Thames and its tributary streams, is equally valuable as tending to maintain the value of attending to physical geography in geological investigations. His examination, also, of the Theory of Mountain-chains, then recently propounded by M. Elie de Beaumont, as well as his remarks on the phænomena of geology which most directly bear on theoretical speculations, are proofs of the truly philosophical and enlarged view he took of his favourite science.

In noticing the works of Dr. Buckland, I have already detailed the importance of the paper which was compiled by him in conjunction with Mr. Conybeare, on the Bristol and South Welsh Coal-fields; one, as I then observed, of those elaborate and comprehensive papers which were the fitting work of the first pioneers of geological science, and the difficulty of which can scarcely be appreciated in these times when the foundations of the science have been fairly laid, and geologists have only to improve or correct the details. His remarks on the sections of the Antrim and Derry coast were also a conjoint work, and of much interest.

Another and equally remarkable work was that undertaken in conjunction with the late Mr. William Phillips, namely, the 'Outlines of the Geology of England and Wales,' as it may be considered the first systematic work on the subject; and, though geology has been since more specialized and studied in minuter detail, this work will always be regarded as a striking proof of the ability and knowledge of the authors.

It was, however, in 1821 (April 6) that Mr. Conybeare communicated to the Society that remarkable Palæontological paper which excited so much interest at the time, and established in the most satisfactory manner the propriety of establishing a new genus of *Reptilia*, forming an intermediate link between the *Ichthyosaurus* and Crocodile, to which Mr. Conybeare gave the name of *Plesiosaurus*.

The discovery of immense vertebræ of oviparous quadrupeds in the Lias near Bristol had attracted the attention of Mr. Conybeare, who quickly recognized the difference between those belonging to the *Ichthyosaurus* and others, which evidently, in his opinion, were portions of a different animal. With a singular acumen and rare sagacity, he placed the detached vertebræ in their proper position, and finally established his new genus, for which he adopted the name *Plesiosaurus*, as expressing its near approach to the order Lacerta.

For the whole group of animals which approximate, on the one hand, to the Crocodiles in general organization, and yet have been provided with such specific organs as were necessary to enable them to live, at least principally, in the sea, Mr. Conybeare proposed the name *Enalio-sauri*, as a classic appellation for the whole order; and he observes of the genera composing it, that even the *Ichthyosaurus*, which recedes most widely from the forms of the Lizard family, and approaches nearest to those of fishes, exhibits in its osteology a beautiful series of analogies with that of the Crocodile, and which widely remove it from fishes.

In this paper he then described in the minutest detail the osteology of the *Ichthyosaurus*, and exhibited a knowledge of anatomy which excited the admiration of every one. He then examined with equal care the relics of the new genus, which, although at that time not complete, were sufficient to enable Mr. Conybeare to conclude that the vertebral column recedes from that of the *Ichthyosaurus* in all the points in which the latter approaches to the fishy structure, and that the invertebral substance must have been disposed much as in *Cetacea*; and that, from the locking together of the articulating processes, it must have had much less flexibility than in the *Ichthyosaurus* or in fishes. In examining also such portions of the paddles as could be arranged in order, he comes to a similar conclusion in another direction, namely, that the paddles of the *Plesiosaurus* are intermediate in character between those of the *Ichthyosaurus* and the Sea-turtles; and thus in every respect he laid a sound foundation for his new genus.

It is to be remarked that this paper was given as the joint production of Mr. Conybeare and Sir Henry Delabeche, to whom Mr. Conybeare most liberally ascribed a full share of the merit of the discovery; but, allowing Sir Henry every praise for his assistance in that discovery and in all the geological details, I believe the sagacity and skill exhibited in the osteological details and reasonings have always been ascribed to Mr. Conybeare.

In a second paper, read May 3, 1822, Mr. Conybeare was enabled to describe much more fully all the relations of the genera *Ichthyosaurus* and *Plesiosaurus*, from the discovery of other remains, both of the *Ichthyosaurus* and *Plesiosaurus*, by his coadjutor Sir Henry Delabeche. A very minute examination of the teeth, especially, enabled him to point out that those of the *Ichthyosaurus* were more intimately related to the teeth of the Crocodile than to those of other *Lacertæ* (an opinion then at variance with the opinions of some anatomists), whilst at the same time, in other respects, the analogy was in the other direction, for Conybeare observes, "in pursuing, however, the history of the teeth of the *Ichthyosaurus* to the last stage, we quit these analogies with the Crocodile, and arrive at another point wherein the *Ichthyosaurus* resembles the other *Lacertæ,* in common with many of the *Mammalia* : this is, the gradual obliteration of the interior cavity in old age, by the ossification of the pulpy nucleus." In conjunction with Sir H. Delabeche he brought up the number of species to four, determined from the teeth ; and in his further consideration of the genus it is right to notice the following remarks, proceeding from him after noticing a difference in one character of the fossil Crocodile, when compared with the recent, as stated by Cuvier :—"I am persuaded, from every circumstance, that a much nearer approximation to the structure of the older lacertian genera will be found in the fossil than in the recent Crocodiles ; interesting links in the chain of Saurian animals will be thus supplied, and it will probably be found that many of the points in which the *Ichthyosaurus* differs from the recent type are only instances of its agreement with the fossil."

The researches of Sir H. Delabeche had not at this time led to the discovery of a complete skeleton of the new genus *Plesiosaurus* ; but additional portions of it were found, including a very perfect dental bone of the lower jaw, whilst a tolerably perfect head was discovered by Mr. Thomas Clarke in the Lias of Street, near Glastonbury.

The investigation of these new relics of the *Plesiosaurus* led Mr. Conybeare to the following conclusion : "On the whole then, the manner in which the ribs of the *Plesiosaurus* articulate throughout, by a single head, to the extremity of the transverse processes of the vertebræ only, the structure of the humero-sternal parts, and the characters derived from the head, approximate this animal most nearly to the *Lacertæ.* By its teeth, on the other hand, it is allied to the Crocodile ; while its small nostrils and multarticulate paddles are features in which it resembles the *Ichthyosaurus*." This able paper he concluded with words characteristic of his natural modesty, after pointing out the difficulty of rendering anatomical details at once scientifically accurate and yet attractive to a general audience : "I need not add how much these difficulties will be increased in the hands of a writer who must acknowledge that, while intruding on the province of the comparative anatomist, he stands on foreign ground, and, using almost a foreign language, is frequently driven to adopt an awkward periphrasis, where a single word from the pen of a master would probably have been sufficient."

However some may at the time have been inclined to throw doubts upon the deductions of Conybeare, the ability and accurate discrimination of the author were publicly recognized by the great Cuvier, who hastened to advocate his admission to the French Academy as a Corresponding Member for the Science of Geology; and I am sure that all living palæontologists will follow the example of the late well-known, and at that time so highly respected, Mr. Clift, in recognizing the great merits of Dean Conybeare, and considering him one of the principal founders of the science in this country.

At the present moment it would be tedious and unnecessary to pass in review the whole of the long series of Mr. Conybeare's geological works, nineteen in number; and I shall point your attention therefore solely to that able "Report on the Progress, Actual State, and Ulterior Prospects of Geological Science," which he presented to the British Association in 1832, at its meeting in Oxford, in which he treats the subject with the combined powers of the scholar and man of science, pointing out the remarkable analogy in the views of Leibnitz to those of many modern speculators on physical geology; the opinions of Hooke in respect to the hypothesis of the elevation of our continents by volcanic agency; the masterly observations of Smith, first made known in 1799, which, although not the first to originate the doctrine of a regular distribution of organic remains, yet reduced to certainty and order what had been before vague and conjectural; the gradual rise of the Tertiary Geology from its foundation in the admirable 'Memoir on the Basin of Paris,' by Cuvier and Brongniart, published in 1811; the establishment of the Geological Society in 1808, and the labours of all the great men connected with it, including, amongst many others, Greenough, Buckland, Sedgwick, Fitton, Murchison, Delabeche, Phillips, Scrope, Daubeny, and Lyell, together with those of foreign geologists, including the great Von Buch and Boué. That Report alone is sufficient to prove his masterly acquaintance with the history of his favourite science, and with all its bearings, whilst it marks the liberal spirit with which he entered into all geological inquiries. The advance of geology since that Report has been enormous; and, if a period of twenty years from the publication of Cuvier and Brongniart had done so much in raising Tertiary Geology to a high position, may we not say that the result of the next twenty-five years has been still more remarkable, and has richly rewarded the continued and judicious researches of some of our most distinguished geologists, such as Lyell, Forbes, Prestwich, and Austen, whilst the elevation to which the Silurian system has arrived by the persevering exertions of Murchison is a monument of progress which we can scarcely hope will be equalled in that peculiar branch of geology in future times.

The zeal of Dean Conybeare for geology never forsook him; and when obliged to visit Madeira on account of the health of his youngest son, he visited the Peak of Teneriffe, and studied the other volcanic phænomena of the neighbouring islands. How deeply must we regret that his last days were embittered by sorrow for the death of another son, from whose funeral he was returning at the time of his death! But so excellent a man, prepared for death by the strict performance of every christian duty during life; requires not the commiseration of those who survive him; although all who recollect his air of gravity and of sincerity, which always made his words effective in commanding attention and respect, and in bringing home conviction to the minds of his hearers, must feel how heavy a loss we have experienced.

The next person whom I shall notice, though unquestionably not possessed of the same extensive range of intellectual acquirements as the illustrious individual of whom I have just spoken, was yet a most active, intelligent, and valuable member of our Society. Mr. Joshua Trimmer was the eldest son of Joshua Kirby Trimmer (who was the eldest son of Mrs. Trimmer the well-known authoress), and was born at North Cray in Kent, on the 11th of July, 1795. When he was about four years old his parents removed to Brentford, Middlesex, in order to be near the authoress, who resided in that parish. Under the roof of that venerable and widowed relative, much of the early childhood of the subject of this memoir was passed. The attention of the authoress was first particularly drawn to this grandchild by accidentally hearing him explain to a younger member of his family, rules of christian conduct to be observed through life—rules which, being entirely approved of by Mrs. Trimmer, were scrupulously followed out by himself in his own life. His docile disposition and inquiring mind gained her especial notice and affection, and he was held up by her to her various juvenile descendants as one whom they would do well to endeavour to resemble. It was indeed recorded of him, in the published life of Mrs. Trimmer, "that Sunday was to him a day of perfect felicity; and whether he sat with his book under a tree, or examined with his venerable grandmother the beauties of the plants and flowers, his countenance shone with delight; and in the winter, when such pleasures could not be recurred to, the day was still one of enjoyment, and never wearied him."

His taste for the science of geology was innate: his aged mother, who survives to mourn his loss, well remembers that at a very early age, when he used to accompany her and the authoress in their walks, his chief delight was to ramble to the side of a river or of a canal in search of shells, which he would bring to the authoress that she might name them; and frequently when at home he would invite his mother's attention to the organic formations on oyster-shells, expressing the strongest desire to learn their natural history. Though the favourite study of his life appears to have originated with himself, his daily converse with the venerable Mrs. Trimmer, who was emphatically "the child's friend," confirmed his early tastes, and assisted in training his mind for that keen observation and searching inquiry which so characterized his subsequent geological pursuits; and it is worthy of remark, that these two relatives in their separate writings, directed as they were to widely different subjects, arrived at the same inductive conclusion with reference to eternal truth. The authoress, in a little publication entitled

"The Knowledge of Nature, for the instruction of Children," has this remark: "It is evident from the construction of every part of nature, from the noblest to the most insignificant, that they are all most admirably formed; they must therefore have been the work of some wise, powerful Being, infinitely our superior;" whilst the closing words of her grandson, in his work on "Practical Geology and Mineralogy," are, "The structure of the earth, as well as the mechanism of the heavens, proclaims the Divinity of the Hand which made them. The one tells of power and wisdom displayed through the immensity of space, the other tells of the same attributes displayed through the immensity of time; and thus every bone and shell and leaf disinterred from the dust of the earth leads our thoughts towards eternity and the world of spirits, and tells us that, though all things visible are subject to change, they are the work of one invisible and eternal Being, 'the same yesterday, today, and for ever.'"

About the year 1806, young Trimmer was placed as a pupil with the Rev. William Davison, at that time Curate of New Brentford. Under that highly talented preceptor, he pursued his classical and mathematical studies with such diligence as to gain the esteem of his preceptor, which he retained until his decease in the year 1852.

When about nineteen years of age, he superintended for his father some copper-mines in North Wales; whilst thus employed, he gained a practical knowledge of mineralogy. After several years he undertook for his father the management of a farm in Middlesex; and, being thus engaged for some years, he acquired during that period a portion of that knowledge of soils which in after-life he so prominently connected with geology. During this period of his life he continued to reside with his parents, and his evenings were not unfrequently spent in Scriptural study. When engaged in other reading, the poet Spenser was his especial favourite; and his intimate acquaintance with every page of the "Faërie Queene" may have furnished him in part with that great command of language, so frequently evident in his writings. In prose-writing his model was Addison, the elegance of whose periods he admired: not unlike that author, he wrote with the greatest facility, never pausing for ideas or for language to express them; and it was not his habit to reconstruct any sentence he had once written: he composed also with ease in poetry, and gave expression to his thoughts in flowing and harmonious verse, and at an early age translated from the Italian a considerable portion of Tasso's "Jerusalem delivered."

In the year 1825 he was again in North Wales, working for his father some slate-quarries, one of them situate at Bangor, and the other two between Snowdon and Caernarvon. At the latter town he established, by means of public subscriptions, a museum, to which he gave many valuable organic remains, some of which he had met with when occasionally visiting Ireland, but the greater part he had long been engaged in collecting from the ossiferous deposits at Brentford. Whilst working these quarries, at which employment he continued for some years, he resided chiefly in the Vale of Nantlle, where he was occasionally visited by his friend the late Dr. Buckland, whom he would at such times guide with enthusiastic ardour over the Snowdonian range, pointing out to him from time to time the erratic blocks and marine shells on which he founded his opinion that they were not deposited, as had been supposed, by melting icebergs on the floor of a sea, which after long submergence had been converted into dry land by movements of elevation, but that they were spread by marine currents of extraordinary energy and short duration over the surface of pre-existing land, and over land covered with ice. This opinion, however, he subsequently modified by accepting coast-ice as being probably an efficient agent in these circumstances.

About the year 1840 he ceased to reside in Wales, and was for some time afterwards employed in the Government Geological Survey of England. He then returned to reside in his native county, Kent, in which he continued until the time of his decease. The last few years of his life were entirely devoted to writing on agricultural subjects in connexion with geology, more especially on the drainage of lands, in which he insisted on the following points:—

1. The important influence exercised by the superficial deposits on the distribution of soils.

2. The division of those deposits into erratic tertiaries, or Northern drift, and warp-drift.

3. The division of the erratic tertiaries again into lower and upper erratics,—the lower erratics consisting of boulder-clay, possessing peculiar characters found in no other marine strata; the upper erratics composed of rolled gravel and sand, approaching more the characters of ordinary tertiary strata, but distinguished from them by certain marked peculiarities.

4. The distinctness of the warp-drift, a deposit which generally forms the surface-soil, and its subsequent origin to that of the erratic tertiaries; its presence in those districts where the erratic tertiaries are absent, and its diffusion over their denuded surface where they are present.

5. The indented surface of the beds, whether of the erratic tertiaries or of the older strata, on which the warp-drift rests, presenting a series of irregular ridges and furrows.

6. The suggestion that the contradictory statements which abound respecting the superior efficacy of deep or shallow drains, of drains at wide or narrow intervals, of drains following the fall of the ground, or crossing it, might perhaps, in many cases, be reconciled by observing whether the drains were parallel or transverse to these natural furrows and ridges.

Among the numerous publications of Mr. Trimmer may be mentioned the following, which strongly mark the bent of his mind, and the practical objects he more especially had in view:—

1. On the Diluvial or Northern Drift of the Eastern and Western sides of the Cambrian Chain, and on its connexion with a similar Deposit on the Eastern side of Ireland, at Bray, Howth, and Glenismaule. 2. On the Origin of the Soils which cover the Chalk of Kent. In two parts. 3. Practical Geology and Mineralogy, with an Introductory Discourse on the Nature, Tendency, and Advantages of Geo-

logical Pursuits. 8vo, with two hundred illustrations. 4. Practical Chemistry for Farmers and Landowners. 5. Proposals for a Geological Survey, specially directed to Agricultural Objects. 6. On the Geology of Norfolk, as Illustrating the Laws of the Distribution of Soils. 7. An Attempt to estimate the Effects of Protecting Duties on the Profits of Agriculture. 8. Supplement to the same. 9. On the Agricultural Geology of England and Wales. Prize Essay. 10. Notes on the Geology of the New Forest, in relation to its capabilities for the growth of Oak, and for cultivation. 11. On the Agricultural Relations of the Western Portion of the Hampshire Tertiary District, and on the Agricultural Importance of the Marls of the New Forest. 12. On the Southern Termination of the Erratic Tertiaries, and on the Remains of a Bed of Gravel on the Summit of Clevedon Down, Somersetshire. 13. On the Erratic Tertiaries bordering on the Penine Chain. In two parts. 14. The Keythorpe System of Land Drainage; its Principles, Efficiency, Economy, and Opponents. 15. On the Geology of the Keythorpe Estate.

He was in the midst of preparing another work for the press, to have been entitled 'Soils, Subsoils, and Substrata; or, The Geology of Agriculture,' when, whilst walking in London, he was seized with an illness which after a few days terminated fatally, on the 16th of September, 1857.

The catalogue of Mr. Trimmer's works is sufficient to show that he was a most zealous, active, and practically useful geologist. When first I had the pleasure of becoming acquainted with him, he was distinguished as an enthusiastic advocate of the diluvian theory of the drift, considering that great waves had been lifted up and carried over the pre-existing dry land, scooping out channels and depositing marine debris; but this advocacy of a peculiar theory in no way interfered with his examinations, which were always made with care, and detailed with honesty. In June 1831 and January 1832, he communicated two short notices to our Society, on diluvial phænomena, as he then considered them, noticing the discovery of marine shells in diluvial sand on the summit of Moel Tryfane, near Caernarvon, 1000 feet above the level of the sea, and again, on a visit to Runcorn, the discovery of marine shells in a singular deposit, forming part of the banks of the Mersey. It consists of a series of beds:—

1st. Yellow sand, with some pebbles, but no shells, 3 to 6 feet thick;

2nd. Decayed vegetable matter, $\frac{1}{2}$ to 3 inches thick;

3rd. A bed 14 feet thick, to high-water mark, containing fragments of new red sandstone and erratic pebbles of various crystalline and other rocks, associated with a few blocks, of great weight, up to a quarter of a ton; and in this bed he found portions of shells belonging to *Cardium*, *Turritella*, and *Buccinum*, and he ascribed this phænomenon to an irruption of the sea.

In 1838, at the meeting of the British Association at Newcastle, he pointed out the occurrence of marine shells covering the vestiges of terrestrial phænomena in Cefn Cave in Denbighshire, and again alluded to his former discovery, having also communicated the results of both discoveries to the Geological Society of Dublin,—a body to which he was much attached, and by whom he was much respected. Perhaps no one ever laboured with more zeal and with more ability to discover all the phænomena connected with drift-deposits, or to reduce them to a diluvial origin; but, as time went on, he appears to have fallen into the more general views entertained on the subject, and, though he probably greatly modified his original opinions, many of his discoveries were of great use to other geologists, and have been noticed with respect by them, as, for example, by Mr. Conybeare, in his Report on Geology. In 1841, he published his work entitled 'Practical Geology and Mineralogy,' a work of very considerable merit, and especially remarkable for the sound and liberal views which he sets forth on that long-disputed subject, the description of creation in Genesis. "The assailants of revelation," he observes, "usually assume, and too many of its defenders argue on the assumption, that we have reason to expect a system of physical science in the sacred writings; but the slightest consideration of the purpose for which they were given must convince us that such a revelation would have been quite at variance with their professed object. That object was to make man acquainted with his relations to his Creator, with his original state, his present condition, his future hopes." Would that those who still keep up the argument, whether friends or enemies of science, would adhere to this view of the object of Scripture, and neither embitter the minds of their opponents by acrimonious disputations, nor endanger the cause of true religion by injudicious assertions!

Our late friend, for I must emphatically call him so, was frequently engaged of late in discussing the origin of the sand-pipes of the chalk; and his papers are so recent that all must recollect how steadily he maintained their production by the wearing action of the sea, in opposition to that by the eroding action of water charged with carbonic acid. In this, as in most other geological phænomena, every form of sand-pipe cannot perhaps be explained by any one cause; and it would therefore be unwise to reject *in toto* any reasonable cause, correct in principle, because incapable of explaining every effect. The wisest plan is to adopt a give-and-take principle, and to ascribe each separate effect to its own natural and efficient cause.

The very useful manner in which Mr. Trimmer had latterly applied his extensive knowledge of drift-formations to practical draining, obtained for him the patronage of Lord Berners of Keythorpe as a large and scientific agriculturist, and must cause him to be deeply regretted by that important and valuable class of society, the practical farmers: it had, indeed, been his principal object through life to make science an instrument in promoting the welfare of mankind; and his own predilection for the theory of currents, whether passing over the surface of dry land, or at the bottom of a sea, producing a furrowed surface, led him to resort to such furrows as a natural system of drains. We shall long remember him as an enthusiastic yet unprejudiced geologist, and as a simple-minded, frank, and honourable man, the worthy descendant of the friend of some of our childish days, Mrs. Trimmer.

As a man of very high intellectual acquirements, and as one who filled the office of Secretary of our Society in 1837, Dr. Royle deserves to be long remembered with respect and affection by us all. It has always been the pride of our Society to know that its officers were distinguished for their high position amongst men of science; and it is not necessary now to enforce the great truth that mental superiority in any one branch of natural science cannot fail to exercise a beneficial influence on the cultivators of every other great collateral branch. But though Dr. Royle has fully merited our warmest encomiums for his botanical researches alone, he deserves them also for the aid he has given towards the advancement of a knowledge of the geology of India, although he does not appear to have professed himself exclusively a geologist. As a proof of this I may cite a memoir on the geological features of the Himalaya Mountains, which forms part of his great work "Illustrations," to be hereafter mentioned. This memoir was accompanied by some extensive sections,—namely, one across the Himalaya Mountains; one from Saharunpore to the Source of the Jumna; one through the Great Coal-field of Bengal; and the last through the Central Range of India; so that this essay was a most valuable attempt to reduce to order, under the correcting influence of his own personal observation, the many scattered observations which had been previously made, on the structure of the Himalaya Mountains and Bengal Coal-field, but which, like the Report of Captain Herbert, having been buried in the official archives of Bengal, had been almost forgotten.

As might have been expected, Dr. Royle did not neglect Fossil Botany, and he figured in the "Illustrations" the two new genera from the Coal-field of Bengal, *Vertebraria* and *Trizygia*, the former of which is still very obscure in respect to its affinities. Connected also with his brief memoir of the Sewalik Hills, he figured some of the most interesting of their mammalian remains; and being Secretary of our Society whilst the well-known investigations into the curious fauna of that district were in progress, which have since redounded so much to the honour of Dr. Falconer and Sir Proby Cautley, he was most enthusiastic in his efforts to encourage his friends in their labour by rapidly bringing the results under the notice of men of science throughout Europe, thus performing an office which Dr. Falconer has himself so lately imitated in respect to Mr. Beckles and the Purbeck Fossils. Dr. Royle also published figures of some of the fossil mammalia from the elevated plateau of Thibet, behind the Snowy Mountains,—a matter so important in respect to the determination of the geological age of the Himalaya Chain, that it deserves the attention of every one who shall hereafter endeavour to perfect the geological examination of this magnificent and interesting region.

I am sure the Society will appreciate my feelings when I say that I have freely availed myself of the materials afforded me by Dr. Falconer (who succeeded Dr. Royle in the charge of the Botanic Garden, and was his most attached friend), not only in placing before you his geological claims, but also the following general sketch of his truly valuable life; for who can be considered a better judge upon such subjects?

John Forbes Royle, M.D., F.R.S. & L.S., Officer of the Legion of Honour, and a Vice-President of the Royal Society, was the son of an officer in the Royal army, who had served in India. He was born in that country and educated for the medical profession in Edinburgh, where he obtained the diploma of Surgeon. He received soon afterwards an appointment as Assistant Surgeon in the E.I.C. Service, and in 1819 proceeded to Calcutta on the Medical Staff of the Bengal Army, being first attached to the Artillery at Dum-Dum. For two or three years afterwards he was moved from station to station in Bengal and the North-Western Provinces, and whilst discharging the medical duties, which the exigencies of the service demanded from him, he availed himself of every opportunity afforded by frequent change of locality to acquire a knowledge of the natural productions of the country; among which, Indian plants engrossed the first place in his attention, and drew him into correspondence with Dr. Wallich, the eminent Danish botanist, at that time Superintendent of the Honourable Company's Botanical Gardens at Calcutta. A vacancy having occurred in the charge of the Botanical Gardens at Saharunpore, Dr. Royle was, fortunately for science, selected by Government as the best-qualified candidate, and appointed Superintendent in 1823. No station in India is more happily situated than Saharunpore for the cultivation of the natural sciences. Eastward of Delhi, elevated 1000 feet above the level of the sea, near the extreme northern limit of that part of the great plain of India which is included in the valley of the Ganges, within a few miles of the Sewalik Hills, and within easy range of the great chain of the Himalayas, the position commands alike the tropical flora and fauna of the plains of India, and the temperate climate of the Snowy range, and every variety between the two. Dr. Royle possessed the acquirements proceeding from education and self-culture,—the energy of character and the ardent love of science, which at once impelled and enabled him to avail himself to the utmost of these advantages.

The Public Garden, supported by a native endowment, and laid out, after the simple native plan, with abundance of fruit-trees and common flowering plants, was entirely remodelled by the new Superintendent, after the most approved plan of English landscape-gardening; a large addition was made to the number of species grown, whether indigenous or exotic; a scientific arrangement was adopted. A conservatory was erected, an ample stream of running water was introduced, which fell into an artificial lake; in short, by many refined alterations a tame oriental garden was speedily converted into a beautifully planned and useful scientific establishment, the whole having been the creation of Dr. Royle. To compensate as much as possible for the restriction imposed upon his time by the medical duties he was obliged to perform, he despatched parties of plant-collectors in successive years to the various mountain-provinces in the neighbourhood, across the Snowy Range over the Thibetian boundary, and as far westward as the valley of Cashmeer. By these means he amassed a rich and valuable herbarium; but his natural bent was most strongly exhibited in the investigation of the properties of plants and their application to the wants of men; and for a considerable time he supplied the hospitals of Bengal with indigenous drugs, as substitutes for the expensive articles imported from Europe. He devoted himself with great success to the identification of the articles in the bazaars of the East with the medicines familiar to the Greeks, as described by Dioscorides and Theophrastus. He investigated the agricultural resources of the plains of India, with a view to the improved culture and introduction of various grains and of plants yielding fibres and other useful products; and he endeavoured to direct attention to the capabilities of the valleys and slopes of the Himalaya for the growth of tea, which has since been so successfully carried out. Dr. Royle's principal work, "The Illustrations of the Botany of the Himalaya Mountains," is a storehouse of valuable facts and information, bearing on these and other allied subjects.

The favourable situation of Saharunpore provided other tempting fields of natural investigation, which his ardent zeal would not permit him to neglect. Single-handed he undertook the, for a tropical climate, severe task of taking hourly observations of the thermometer and hygrometer, and of the barometer on a single day in each month throughout the year, besides the regular ordinary observations twice a day; and by these means obtained excellent data for determining the meteorological conditions of the climate, and fixing one of the standard stations by which the range of mean temperature over the continent of India has been ascertained. He made collections of the mammalia, birds, reptiles, and insects of the northern plains and mountains of India, in themselves so valuable and extensive, that they furnished materials for two important and distinct memoirs by eminent British naturalists, upon the fauna of India, contained in "The Illustrations." During the various journeys through the Himalaya mountains, he carefully collected specimens of all the rocks he met with, marked the direction, and measured the inclination of the strata,—ascertained the elevation of the successive ridges, and the depressions of the intervening valleys, by barometrical measurement, and recorded the whole of the observations with such care, that, gleaning materials from other sources, and aided by Sir Henry Delabeche, he was enabled to produce a very respectable approximative geological section across the chain of the Himalayas, from the plains of Hindostan to the Snowy Range, which was brought out in his 'Illustrations.' All these varied and extensive researches were condensed within the comparatively short period of eight years. Gifted by nature with a strong frame, and a healthy constitution that never failed him, and which sickness never touched, he toiled from first to last as an earnest and ardent investigator of every natural object which came before him.

India has not always escaped that political reaction which hurries men in authority from reckless expenditure into sordid parsimony. It was thus that the first Burmese and other wars had thrown the finances of India into such embarrassment, that Lord William Bentinck was called upon to push retrenchment to the utmost possible limit. So urgent indeed was the demand upon him, that it is said he meditated the abolition of the Botanic Garden of Saharunpore; but such was the display of honest sterling work performed, and of most useful results obtained, which Dr. Royle placed before the eyes of the Governor-General, that Lord William Bentinck was spared the reproach of committing what would have been considered an act of Vandalism, and this most valuable institution was preserved,—a service for which his memory will always be regarded with gratitude by Indian naturalists.

Whilst this peril seemed to hang over one of the most cherished objects of his scientific life, Dr. Royle meditated a retirement from the service, as he could not have borne to remain in India after science had been so degraded; but as his energy, and, let it be added, the speaking testimony of his scientific labours, had averted the danger, he bore with resignation those reductions of pay and emoluments which affected him in common with other medical men, and remained in India till 1832, when he returned to Europe with a large and valuable natural-history collection. From that time to 1840 he devoted himself with characteristic energy to the investigation of the materials he had collected, and to the preparation for publication of his great work, the 'Illustrations of the Botany and other branches of the Natural History of the Himalaya Mountains:' a work which is distinguished equally by the large amount of original information it contains, and by the accurate research and comprehensive views it exhibits. On his return he became a member of all the great chartered scientific societies of London, and was named a Vice-President of the Royal Society, and latterly for several years he was Secretary of the Horticultural Society, for the welfare of which institution he felt a lively interest. The well-known ability with which he had investigated the medical botany of India, led to his appointment to the chair of Materia Medica and Therapeutics at King's College on its first foundation; and, as a member of the Royal Asiatic Society, he, with his habitual energy, soon introduced to the notice of that learned body a new branch of inquiry, in consequence of which a committee was formed to investigate the productive resources of India. The 'Transactions' of the Society, which had been before devoted chiefly to essays on the Languages, History, Mythology, Archæology, and Numismatics of the East, were thus enriched by a series of valuable papers on interesting commercial subjects by Dr. Royle. The interest which was now awakened in the manufacturing districts respecting the raw products of India led to so many inquiries for information, that the Directors of the East India Company were induced to establish a special department for the express purpose of spreading knowledge upon such subjects; and Dr. Royle, who had previously resigned his post as surgeon without any pension or other reward, having most wisely been placed at its head, he entered at once upon an enlarged sphere of public usefulness, suited to his great talents and vast stock of acquired information. He was instrumental in leading to the formation of a museum at the India House, for the reception of the most important portion of the immense collections of Indian products, both raw and manufactured, which had been imported for exhibition at the great Expositions, of London in 1851, and Paris in 1855, by which the benefit and instruction to be derived from their examination will be perpetuated. To perfect this noble design Dr. Royle devoted his utmost energies, and the very day before his death, though still labouring under sickness, he attended at the Museum to urge on the work; but, alas! it was his last effort, and, suddenly cut off on the next day, the 2nd of January, 1858, in the 59th year of his age, the East India Company lost one who, whether at home or abroad, had done more than most of its servants to promote its true interests, by rendering them essentially coincident with those of mankind.

Besides the works so often alluded to, Dr. Royle published many other essays, either separately or in the Journals of learned societies, principally botanical and bearing on the medical and commercial products of plants; and it may well be said that he was eminently a scientific philanthropist. Besides his general connection with so many of the most important Scientific Societies of London, he was a Member of several Foreign Natural History Societies, amongst which may be named the Academia Cæsarea Naturæ Curiosorum; and for his exertions in rendering the Indian Collection at the Paris Exhibition in 1855 as perfect as possible, he was honoured by a first-class Jury Medal, and by the insignia of an officer of the Legion of Honour.

In reflecting on the last years of so distinguished a man, it must be a great comfort to know that he was most happy in having married a lady of highly cultivated mind, who, in the bitterness of her sorrow at the loss of her husband, has the consolation of feeling that she was the source of his greatest happiness, and a participator in his intellectual labours. He has left, besides his widow, two sons and a daughter to mourn his loss and venerate his memory; and let me add, that their feelings will be shared by the numerous friends to whom he was endeared by kindred feelings and by moral worth.

Of several of our lost members little information of any material importance can be obtained, though they have all exhibited at some period of their lives a strong desire to advance the progress of science. Mr. Laverack for example, while an undergraduate at Cambridge, placed himself within the circle of attraction of Professor Sedgwick's Lectures, and manifested a taste for geology by his close attendance at the Woodwardian Museum, then being put into order; but it is not known that he had any opportunity in after life of undertaking original investigation.

Mr. G. H. Saunders likewise exhibited an early taste for geology, and is known to the Society as having contributed a Sketch Map intended to illustrate the position of a bed of fossil shells exposed to view in a cutting of the Panama Railway; the specimens he had forwarded to the Society, and they were found by Mr. Moore to possess much interest in regard to the distribution of tertiary fossils over the Central American area.

Mr. Floresi was a native of Sardinia, and ranked in his own country amongst the nobility, being Marquis d'Arcaes; but, as an Italian refugee, he only made use of his family name. For some time he was manager of a portion of the Mexican mines, which were worked under the direction of Mr. John Taylor; and he was on his way to Central America to report on mines in the Province of Guatemala, when he was attacked with fever at Panama, and died, to the great regret of his employers, by whom he was considered a most amiable and upright man. His son has since taken charge of some Mexican mines which belong to a different body of proprietors.

Mr. William Bald was an eminent Civil Engineer and Surveyor. He was born in Burnt Island, Fifeshire, and was educated at the parish school there until he arrived at his twelfth year, when he was removed to a school at Edinburgh. After completing his ordinary education, he was apprenticed to Mr. Ainslie, C.E., of Edinburgh. He commenced his professional career in this line in 1803, and he had much experience in making railways, and in the improvement of rivers and harbours. His abilities, being fully recognized, led to his employment in Ireland, where he was directing engineer in improving the navigation of the River Boyne and in forming quays at Drogheda; and was engaged to carry bills through Parliament for the improvement of the navigation of the River Suir, and of the River Moy, both in that country. It was during the time of his residence in Ireland, that he was employed in 1811, by a Royal Commission appointed to ascertain the situation and extent of the great bogs of Ireland and the practicability of draining and improving them, and to survey and report on the extensive bogs of the county of Mayo. His reports on their situation, extent, and improvement formed part of those valuable public documents, 'The Bog Reports,' which were presented to Parliament, and printed in the years 1811, 1812, 1813. The very interesting information which these Reports contain on the peculiar condition, circumstances, and origin of the large accumulations of bog, which are so remarkable in Ireland as to constitute what may be almost considered a distinct geological formation, has caused them to be consulted by every one desirous of studying the history of bogs; and when the curious phænomena connected with them, such as the occurrence of two or three layers of tree-stumps, the "escars" or long ridges of gravel, the beds of marl, and the numerous relics of the great fossil Deer, the *Megaceros Hibernicus*, are considered, it cannot be doubted that the authors of these Reports have laid before naturalists, and especially geologists, ample materials for reflection. This was not the only great Irish work in which Mr. Bald was engaged, as he was employed about the year 1810, by the grand jury of the county of Mayo, to make a territorial survey of that county, which he afterwards completed in a most accurate and satisfactory manner. This map was laid down and drawn on a scale of 4 inches to a mile; and I remember well my visit to the Court-house of Castlebar, some thirty years ago, to look at the map, which was then, as now, suspended in a large room, and justly considered a topographical work of the very highest order. That the triumph it then achieved was well-merited, may be judged from the honourable testimony which that able judge, Sir Richard Griffith, Bart., known to us all as one of our oldest and most able members, has recently borne to its excellence in the following words addressed to me on the subject:—"Though slightly faded, the mountain-ranges, hills, and other, even very minor, features of the country have been so carefully and faithfully represented by drawing and shading, as to present one of the most striking and effective maps I have ever seen on so large a scale, and in pictorial effect little inferior to the magnificent map of the mountains of North Wales, long since executed by Mr. Dawson, father to the present Colonel Dawson, R.E." This warm and frank expression of approbation, bestowed by a Civil Engineer of such eminence as Sir Richard Griffith, himself the author of the highly-valued Geological Map of Ireland which will long be an object of emulation to the Government Geological surveyors, to his former associate and acquaintance, seems peculiarly appropriate, as it is not too much to say that the map of Mr. Bald was in its time a fitting object of emulation to the Government National Surveyors, whether Engineer Officers and men, or Artillery Officers for some time associated with them, or Civilians who formed so large a portion of their hard-working staff, although it is much to be feared they shared more in the labours than in the honours and advantages of their military comrades.

Independently of the merits of his map of Mayo, Mr. Bald deserves to be remembered with respect by the Officers of the Ordnance, or, as it should now be called, the National Survey, for the manly and frank manner in which he gave his evidence in their favour, when the propriety of confiding the charge of the Irish Survey to the Ordnance was under discussion before a Committee of the House of Commons. The opinions of Civil Engineers and Surveyors were much divided; but Mr. Bald allowed no private interests to blind him to the advantage of a uniform system, carried on with the regularity and precision which military discipline enforces and ensures: but, while I say this in justice to the liberality of Mr. Bald, let it not be supposed that I am the advocate of monopoly or exclusion in any department of the public service.

When Mr. Bald left Ireland, he was employed for a time as a draftsman at the Admiralty, and then, by the Corporation of Glasgow, as Engineer for the improvement of the navigation of the Clyde by the erection of embanking-walls to circumscribe its channel, and by dredging to deepen it—reports of which operations were drawn up by him and printed. He was in this manner the recognized Resident Engineer to the Trustees of the River Clyde from 1839 to 1845, in the summer of which year he was engaged by the Chamber of Commerce to examine the River Seine in France, from Hâvre-de-Grâce to Rouen. I have been unable to learn anything of the last years of Mr. Bald's life, and I must therefore here close my remarks upon a man, whose talents, which reflected so much credit upon his profession, were employed on objects both useful and interesting to geologists.

The very eminent Mineralogist and Crystallographer, Henry James Brooke, was born at Exeter on the 25th May, 1771, his relatives being engaged in the manufacture of broad-cloth; and after having received an ordinary scholastic education, he studied for the Bar, but was induced from the favourable prospects which appeared before him, to abandon that profession and to engage in the Spanish wool-trade in London, for which object he spent nearly two years in Spain: it is, however, justly asserted that the active study of the law had, like that of mathematics, the effect of framing his mind to precise habits of thought and expression, the effects of which became apparent in all his subsequent acts and observations. In the year 1812, soon after he had become a resident of London, he turned his attention to the subjects of Mineralogy, Geology, and Botany, but more especially to the two former sciences, for which he had a peculiar predilection. He was elected a Fellow of the Geological Society in 1815, of the Linnean in 1818, and of the Royal in 1819, on the Council of which Society he served in 1842-44. Though devoting his leisure hours to scientific pursuits, Mr. Brooke did not neglect his ordinary duties, and assisted the late Mr. Henry Hase, Cashier of the Bank of England, in establishing the London Life Assurance Association; and, as the Spanish wool-trade began to decline, Mr. Brooke sought a pursuit more congenial to his taste in the establishment of companies to work the mines of South America; but, as these undertakings were too often marred in their prospects of success by difficulties abroad, he accepted the office of Secretary of the London Life Association, in forming which he had assisted; and after several years' service, such was the appreciation of the advantages he had conferred on that body, that on his retirement a liberal annuity was granted to him by the society.

Though interrupted for some time in the pursuit of his favourite sciences, by the consequences of a serious accident he experienced by being knocked down by a horse suddenly turning a corner near his residence, Mr. Brooke was not a man to be satisfied with idleness, and for recreation's sake he formed a large collection of shells, which he afterwards presented to the University of Cambridge. Not thinking the study of the simple envelopes of organic bodies sufficiently intellectual, he then took to the collection of engravings, having himself early in life made considerable progress as an amateur artist; and some specimens of rare excellence were presented by him to the national collection in the British Museum. This interruption of his scientific labours was only of short duration, and being usually blessed with excellent health, he continued to pursue his favourite studies with unabated activity until a short time before his death on the 26th June, 1857, at the good old age of 86 years.

Of his works, the 'Familiar Introduction to Crystallography' was the first systematic treatise which in this country brought that delightful branch of science into notice: it was based on the system of Haüy, and adopted therefore an unnecessarily large number of primary forms: but at the same time the relations of the various existing plane surfaces of crystals were traced out with a clearness which was a great improvement on preceding systems. In the subsequent Treatise on Crystallography, published in the 'Encyclopædia Metropolitana,' Mr. Brooke simplified the former one, and reduced the number of primary forms to six, which correspond with the six systems adopted by Continental Crystallographers. Mr. Brooke discovered and described thirteen new mineral species.

Mr. Brooke applied the reflective goniometer to the determination of the crystalline forms of artificial salts, and in the 'Annals of Philosophy' for 1823 described no less than fifty-five laboratory-crystals thus determined. He was the author of the article "Mineralogy" in the 'Encyclopædia Metropolitana,' and was associated with Professor W. H. Miller in the reproduction of the well-known treatise of the late Mr. Phillips. His last work was on the general relations and geometrical similarity of all crystals belonging to the same system; it formed the subject of a paper read before the Royal Society, and was in the press at the time of his decease. With a liberality equally characteristic both of Mr. Brooke the elder and the younger, the valuable and almost unique collection made by the father during half a century, has been presented by the son to the University of Cambridge,—a generosity which has wisely adopted the most efficient method of perpetuating the memory of a man who had so successfully endeavoured to simplify the study of that branch of Mineralogy which of all others is most full of interest; for assuredly crystallization seems to afford a sort of link between organic and inorganic nature, by showing that not only in composition, but also in external form, lifeless and inert matter has been subjected to definite laws by creative Intelligence and Power.

Francis, Earl of Ellesmere, a Knight of the Garter, Lord-Lieutenant of Lancashire, and during the year 1854-5 President of our sister Society, the Geographical, was one of those eminent individuals who in our day have shed lustre over the high order of nobility to which they belong, by their literary and scientific acquirements, just as their ancestors, in olden time, did by martial qualities. It is indeed a characteristic of the present age, which is principally due to the establishment of societies devoted to special branches of scientific inquiry, that men of the highest social position do not disdain to emulate men of a lower grade in the endeavour to obtain the first places in the ranks of science. Lord Ellesmere was the second son of the first Duke of Sutherland, and of that gifted lady the Duchess Countess of Sutherland. He was born in 1800, and died on the 18th February, 1857, being therefore cut short in his distinguished career at the comparatively early age of 57. As a geographer of a high order, Lord Ellesmere has received an affectionate and eloquent tribute from the pen of our own Sir Roderick Murchison, the President of the Geographical Society, in his Annual Address to that most useful and prosperous Society; and I can do no better than glean from him what is necessary to justify the high estimation in which we have always held that estimable Nobleman.

For a large portion of his writings, Lord Ellesmere adopted the Quarterly Review as the medium of communication to the public. It appears that between the years 1834 and 1854, he was the contributor of no less than fifteen articles, many of which were directed to geographical research, others to the fine arts of which he was an able connoisseur, and some to biography, or to military exploits, as the spirit of chivalry was as alive in him as in the breasts of his warlike ancestry. His accounts of the works of the Dutch authors Meiglan, Fischer, and Doeff, and especially his vivid picture of the manners and usages of the Japanese, have been justly praised as having thrown a charm over geographical science, and rendered even its minute details attractive. The lively interest he displayed in the romantic expedition of Sir James Brooke, his analysis of Arctic and Antarctic researches, and his account of the travels of Castron among the Lapps not only prove the pleasure he derived from perusing the narratives of voyagers and travellers, but also his ability in estimating the value of their results. Many must remember the stately figure, and the courtly yet courteous manners, of this type of the true English nobleman, when, opening the halls of the palace of his family for the reception of the leading men of science, he collected, as it were, the living gems of intellect within a frame-work enriched by those of past ages as displayed in his rich collection of the works of the great masters of art; as well as the dignified manner in which he presided over the Geographical Society: he exhibited indeed every quality which is calculated to adorn a nobleman of such high social position, and to render him a fitting leader of his fellow men. The versatility of his talents has been already noticed; but it may be added that he possessed the soul of a poet; for who but a poet could attempt to transfuse the spirit of a Goethe and Schiller into the English language?—and unquestionably the soul of a soldier, as, in addition to the papers in the Quarterly Review, he translated 'Clausewitz's Campaigns in Russia,' the 'Sieges of Vienna by the Turks,' and the 'Last Military Events in Italy.' This latter aspect of his character was strikingly marked by the strong attachment and respect he always manifested for the great Duke of Wellington; and his singular ability for military science may be judged from the sound judgment he has exhibited in his Preface, or, as it may be called, Introduction to Clausewitz's "Campaign of 1812."

His thorough knowledge of the fine arts is well known; and his general acquaintance with science, as well as his earnest desire to apply it to the practical amelioration of the condition of his fellow creatures, was publicly manifested by his address to the British Association, over which body, at its meeting in 1842, at Manchester, he presided as President, being then Lord Francis Egerton. His generous support of men of genius, and his domestic virtues, flowed from the highest qualities of the human heart; and I need do no more than quote the expressive words of one of his intimate friends, as given by Sir Roderick Murchison:—"His calm exterior and tranquil manner covered a deep-seated enthusiasm for the honour of his country, for the progress and amelioration of his species, and for all that is grand and noble in sentiment or in action."

Rear-Admiral Sir Francis Beaufort, K.C.B., D.C.L., F.R.S., F.R.G.S., Corr. Inst. France, was one of those remarkable men who in these days have afforded to the world a most powerful illustration of the fact, that the highest cultivation of the intellect is quite compatible with the nautical knowledge and habits which enter into the composition of a first-rate seaman and an able navigator. If indeed the example of Lord Ellesmere has shown how much the highest order of nobility may be adorned and elevated by scientific and literary tastes, we may also affirm that much of the dignity which has been associated with the names of Beaufort and of Graves, and with those of Admiral Smyth and Captain Spratt, fortunately still living, and of many other illustrious seamen and navigators, is due to the happy combination in their characters of high scientific attainments and of great practical skill.

Francis Beaufort was born in 1774, and was an Irishman of French extraction. His father, the Rev. Daniel Augustus Beaufort, was Vicar of Collon, in the county of Louth, and was directly descended from an ancient and noble French family. Francis was the second son, and the heir of some of the talents and tastes of his father, who numbered amongst his good deeds the best map of Ireland, previous to the Ordnance Survey, and an able Memoir on Ireland; but it may be added that those who have read the able essay upon the Round Towers of Ireland by one Miss Beaufort, and the kind-hearted and cheerful books written for the benefit of children by the Misses Beaufort, who are so well known and so highly appreciated in Dublin, must further acknowledge that the tastes and virtues of a whole family were embodied in the Admiral.

Though only thirteen when he went to sea, Francis had already many of the requisites of an able officer. On his first voyage, which was with Captain Lestock Wilson, in the 'Vansittart,' East Indiaman, as a "guinea-pig"—that is, in virtue of the payment of a hundred guineas,—he was remarkable for his skill in observation, and the amount of his nautical knowledge; so that he afforded valuable assistance to his commander in surveying the Strait of Gaspar, in the Sea of Java. His perilous adventures began thus early. The survey was just completed when the 'Vansittart' struck upon a rock off the Island of Banca (not very far from the spot where the 'Transit' went down last autumn), and through the hole stove in her bottom daylight and sea poured in alternately. An effort was made to keep the ship afloat until the flat shore of Sumatra could be reached; but even the hope of a landing on Banca was presently given up, and she was run aground on an island seven miles from Banca. The crew escaped in the boats, and, with the loss of six lives and one boat, reached two English ships after five days' rowing, with great suffering, on the open sea, close to the line. This adventure happened in August 1789.

His name had already been for two years on the books of His Majesty's ship 'Colossus'; but on his return from the East he joined the 'Latona,' Captain Albemarle Bertie, and afterwards the 'Aquilon,' in which he was engaged in the memorable action off Brest, of the 1st of June 1794, during which ten of the enemy's ships were dismasted and seven taken, and after which Lord Howe brought into Portsmouth six French ships of the line, which the King and Royal family came to inspect at the end of the month. They went on board the 'Aquilon' to sail round the fleet, and thus young Beaufort made, probably, his first acquaintance with royalty. He was for some years the sole surviving officer of that great battle. He followed his captain, the Hon. Robert Stopford, to the 'Phaeton,' in which ship he was serving when Vice-Admiral Cornwallis made his celebrated retreat from the French fleet on the 17th of June 1795. In this ship, afterwards commanded by Captain James Nicholl Morris, he assisted at the capture and destruction of many of the enemy's ships, and of nine privateers and other vessels. It was in May 1796 that he obtained his rank of Lieutenant, and in October 1800 that his first great opportunity of distinguishing himself occurred. While cruising off the coast of Malaga his commander observed that a Spanish polacca, the 'San Josef,' and a French privateer brig, had taken refuge under the fortress of Fuengirola; and at night the young lieutenant was sent in command of the 'Phaeton's' boats to board the 'San Josef.' The French brig intercepted the launch; but the other crews did their work without its aid. The resistance they encountered was desperate; but they obtained their prize, with the loss of one man to thirteen of the enemy, Beaufort, however, receiving no less than nineteen wounds. This made him a commander, with a small pension.

The two next years were spent on shore, but not in idleness. Miss Edgeworth tells us that they were "devoted, with unremitting zealous exertion," to establishing a line of telegraphs from Dublin to Galway, an object of great importance as long as the west of Ireland was perpetually liable to invasion from continental enemies. He received the thanks of Government for his efforts, declining any other acknowledgment.

Once more at sea, he was heard of from the East first, and then the West. As commander of the 'Woolwich,' 44, he convoyed from India sixteen Indiamen in 1806. In 1807 he was surveying the River La Plata; and he afterwards went to the Cape and the Mediterranean. In 1809 he was hovering about the enemy's merchantmen on the coast of Spain and at Quebec, being in command of the sloop-of-war 'Blossom.' In 1810 he obtained his post rank, and the command of the 'Fredericksteen' frigate; but before he joined he was employed in protecting the outward-bound trade to Portugal, Cadiz, and Gibraltar, in accompanying two Spanish line-of-battle ships to Minorca, and in acting for some months as captain to the

'Ville de Paris,' a first-rate, in the fleet off Toulon, commanded by Sir Edward Pellew.

It does not appear to be on record in which year of his life it was that he so nearly perished by drowning, and underwent the remarkable experience of the intellectual condition under such a crisis, which he afterwards recorded in a letter, at the request of Dr. Wollaston. He described himself as "a youngster, at Portsmouth, in one of the King's ships." He was not himself impressed as others were by the remarkable character of his sensations; but he saw the importance of every such record, and made it accordingly. Interesting in itself, the story is extremely valuable as coming from one as singularly truthful in recording experience as skilled in detailing it. One of his most striking accomplishments was the power of expressing what he meant. The effect of this power was seen wherever he went, in the harmony he seemed to establish by the clearness of his ideas, and the graphic manner in which he expressed them. All the disputings and perplexities which accompany the rule of men of confused mind and speech were extinguished by Beaufort's mere presence; and he at once made every one aware of their own, as well as of his views and objects.

This power of rendering the most abstruse subject easy of comprehension, a power possessed by very few, was strikingly exemplified in the letter to Wollaston, published in Sir John Barrow's Autobiography, which describes that peculiar psychological condition of the human frame at times when it hovers, as it were, between life and death, or is on the point of yielding up the united existence of body and soul, and assuming that alone of the soul. Few have doubtless experienced this condition under the same circumstances as Admiral Beaufort, by being snatched from drowning at the very moment when the soul was about to assume its undisputed empire; but many have passed through a corresponding state at times when, fever having reduced the powers of the body to a *minimum*, and elevated those of the soul to an unnatural and unbalanced sway, sleep is dispelled from the weary eyelids of the body, and the phantoms of past words, thoughts, and acts come rushing unbidden, and too often unwelcome, upon the mind's eye. At such moments the past is reflected upon with pain or with pleasure, in proportion to its relation to evil or to good, and doubtless in reference to its bearing upon the future; and hence the natural reflection of Admiral Beaufort,—

"May not all this be some indication of the almost infinite power of memory with which we may awaken in another world, and thus be compelled to contemplate our past lives? or might it not in some degree warrant the inference that death is only a change or modification of our existence, in which there is no real pause or interruption? But, however that may be, one circumstance was highly remarkable—that the innumerable ideas which flashed into my mind were all retrospective. Yet I had been religiously brought up, my hopes and fears of the next world had lost nothing of their early strength, and at any other period intense interest and awful anxiety would have been excited by the mere probability that I was floating on the threshold of eternity; yet at that inexplicable moment, when I had a full conviction that I had already crossed that threshold, not a single thought wandered into the future, I was wrapt entirely in the past." In several passages of the deeply interesting statement of Admiral Beaufort will be observed an idea which was afterwards powerfully elaborated by Mr. Babbage in the Ninth Bridgewater Treatise.

When he took the command of the 'Fredericksteen,' in 1811, he was on the road to fame as an author. Sir. J. Barrow tells us that Beaufort was selected out of the whole Mediterranean fleet to survey an unknown portion of the coast of Syria. The result of this errand was, not only a capital survey, but a historical review of the country, as illustrated by its remains of antiquity. Beaufort's 'Karamania' was, as a book of travels, sound, substantial, and learned (thanks to the good classical education his father had given him), and full of interest at once for the man of science and the scholar. It was this book, with its discoveries and verifications of ancient sites, which had prepared the way for the researches of Fellows, Spratt, and Forbes, and more recently of Charles Newton, in Asia Minor, the result of which has been that the Halicarnassian Marbles have become part of the treasures of the British Museum.

After much hazardous service against the pirates in the Greek waters, Captain Beaufort went to work on the survey of Syria, in the course of which he underwent extreme danger. In June 1812, his party were surrounded by armed Turks led by a crazy dervish, and he was wounded in the hip-joint so seriously that the wonder was that he ever walked again. It was a severe struggle for life itself; and when his ship was paid off, in the next October, he was still undergoing much pain from the exfoliation of the bone. He solaced his enforced leisure by work, preparing for the Admiralty such a set of charts of the coasts of Asia Minor, the Archipelago, the Black Sea, and Africa, as had never before been seen at the Admiralty. They were so drawn, finished, and arranged as to be fit for transference to the copper without any aid from the hydrographer or his assistants. Such is the testimony of Sir John Barrow, who recommended him to Lord Melville for the post of Hydrographer.

This was in 1829. In 1823 Captain Hurd had died, and Captain Parry was requested by Lord Melville to fill the post temporarily, which he did twice, if not three times. After the resignation of the Duke of Clarence as Lord High Admiral, Lord Melville again became First Lord, and one of his objects was to fill the office of Hydrographer with the best man that could be found, who should hold it permanently. There were many applicants; but by 1829 two names only remained for choice—and one of them was not an applicant, Captain Peter Heywood. Lord Melville therefore requested Sir John Barrow and Mr. Croker to advise him. Sir John Barrow had, as we have seen, selected Beaufort out of the whole Mediterranean fleet for the survey in Asia Minor; and that survey having been so ably completed, he naturally named for the office of Hydrographer the accomplished officer who had so much distinguished himself.

For twenty-six years Beaufort was at the Admiralty as Hydrographer; and very early in that period he had made his office the model on which Copenhagen and St. Petersburg constructed theirs. Everywhere hydrography took a new form and existence, through the life which he put into his work. There is not a geographical discoverer, nor a zealous professional student in any naval service in the civilized world, who does not feel under direct obligation to Beaufort for his scientific assistance given through his works, or more special encouragement by his personal aid and counsel: those, indeed, who remember the enthusiasm with which Commander Wilkes, of the United States Exploring Expedition, used to speak of the friendly assistance afforded by Captain Beaufort, in preparing for that important enterprise, cannot doubt of the appreciation in which he was held by his professional brethren of all nations.

It has been no small benefit to the world that the most accomplished hydrographer of his own or any time was at our Admiralty for six-and-twenty years, always ready to avail himself of any chance of increasing general knowledge, and ever genial and generous in assisting every man of any nation who devoted himself to geographical discovery or the verification of glimpses already obtained. His name is attached to several stations in newly-discovered lands and seas; for instance, it will be uttered in all future times by voyagers passing up either the eastern or western shores of the American continent to the Polar Sea; but even when not expressed, it is invisibly connected with almost every other modern enterprise of geographical discovery; for he gave a helping hand to every scientific adventurer who applied to him, and no one thought of instituting scientific adventure without applying to him.

When he entered the Admiralty, nearly thirty years ago, he found his own department a mere map-office. His friends well remember what a place it was—small, cheerless, out of the way, altogether unfit and inadequate. The fact is, nobody but the *élite* of the naval profession had any conception of the importance of the office—of the true functions of the hydrographer. Maritime surveying on an extended scale was only beginning. We were not yet in possession of the full results of the labours of Flinders, Smyth, King, and Owen; and Sir Edward Parry's view of his office was, that it made him the Director of a Chart Depôt for the Admiralty, and the supporter, rather than the guide or originator, of maritime surveys. Becoming conscious that the times were requiring something more than he could give, he wisely resigned. The manner in which Captain Beaufort was appointed, without solicitation on his own part, and simply because the best judges considered him the fittest man, encouraged him to lay large plans, and to indulge high hopes. He began a great series of works, in which he intended to comprise, gradually and systematically, all the maritime surveys of the world, —our own coasts, still shamefully obscure, being destined for a thorough exploration in the first place. He designed and began what Lieutenant Maury has since achieved. His instructions to surveying officers show how extensive were his purposes as to deep-sea soundings so long ago as 1831; and the object was never lost sight of, though he was baffled in the pursuit of it. Whatever depended on his own energy was done, throughout his whole term of office; but he had to endure the affliction, often experienced by highly qualified servants of the Government, of not being able to excite a sympathy in his views amongst those in power, or amongst those who, keeping watch over the public purse, sometimes arrest the progress of what would conduce to the public interest. It is indeed no small mortification to compare our Hydrographical Establishment with that at Paris, where the Dépôt de la Marine might be taken for the office of the greatest maritime power in Europe; or with those at St. Petersburg, Copenhagen, and Washington; but the annual amount of shipwrecks, and the number of lives lost through want of that knowledge which Beaufort would have established a quarter of a century ago, gave rise to a severer grief, which weighed heavily on his heart, and was probably the most painful experience of his life. The universal spread of education, and the more scientific tone which it has assumed, will, it is hoped, rectify this evil, by satisfying the Members of Government, as well as our Legislators, that expenditure on such objects can never be money thrown away; and we trust therefore that the able successor of Beaufort, Captain Washington, to whom I am indebted for most of the materials of this memoir, will be secured from the anxieties and mortifications which his predecessor experienced.

Captain Beaufort was so restricted in his office that he had no subordinate who could be a comrade in his labours; and all that he had at heart was done by his own hand. Disappointed in some of his hopes, and pinched in his official expenditure, he applied the full forces of his strong will to make the best of the hard circumstances of the case. His industry, of constitutional origin, and sustained by principle, appeared something miraculous under this stress. Day by day for a quarter of a century he might be seen entering the Admiralty as the clock struck; and for eight hours he worked in a way which few men even understand: for many years he rose at five, and worked for three hours before his official day began. The anecdote of his connexion with the maps of the Society for the Diffusion of Useful Knowledge has recently gone the round of the newspapers; and all the world knows that, in order to get these maps sold at sixpence instead of a shilling, he offered to superintend their preparation. As if he had not enough to do in his own function, he gave the world that set of maps, so valuable that no ship in the United States navy is allowed to sail without them; and it is his doing, that they are in a thousand houses which they would never have entered but for their cheapness.

This is one of his innumerable charities. There was no sort of charity in which he was not just as liberal and as wise. There was no pedantry in his industry, any more than in his knowledge. He never seemed in a hurry. While too seriously engaged for gossip, he had minutes or hours to bestow where they could really do good; he had conscientious thought to spare for other people's affairs, and modest sympathy in their interests, and intrepid advice when it was asked, and honest rebuke when it was deserved and might be effectual. His unobtrusiveness was perhaps the most striking quality of his manner, to observers who knew what was in him. His piety, reverent and heartfelt, was silent, as he preferred that that of others should be. His domestic affections were unconcealable; but spoken sentiment was quite out of his way. His happy marriage (with the daughter of his first commander, Captain Lestock Wilson) ended in a mingling of pain and privilege which touched the hearts of all witnesses. Never was so much understood with so little said. She died of a lingering and most painful disease, making light of it to others as long as possible, though the full truth was known to both; she kept her young children about her, with their mirth wholly unchecked, to the latest possible day; and the few who looked in on that sacred scene saw that it was indeed true that, as she said, she had never been happier than during that painful decline. As for him, there was not the slightest remission of public duty, while his domestic vigilance so powerfully assisted in smoothing her passage to the grave. Now that both are gone, it is right to present this feature in the character of the man so long before known as hero and as *savant*. He came out from the long trial so much changed that it seemed doubtful whether he would ever regain his health and buoyant cheerfulness. He lived, however, to see his children fulfilling, each his own career of labour and honour: one son in the church, another as Legal Remembrancer (Attorney-General) in Calcutta, and a third as a judge in Bengal. By his second marriage, with a sister of Maria Edgeworth, he secured a friend to himself and his daughters for many of the latter years of his life.

Among his public labours were those of the successive offices of Commissioner of Pilotage, entered upon in 1835, and of Member of the Royal Commission to examine into the state of the Tidal Harbours in the United Kingdom, in 1845. In 1846 he became Rear-Admiral on the retired list rather than surrender his office; but he never liked his "yellow flag," and the mortification of his retirement was but slightly solaced by the honour of the Knighthood of the Bath, conferred in 1848. The sudden expansion of railway-projects so increased his work that his health began to fail, but not till he had reached an age at which few men think of work at all. Early in 1855 he was obliged to retire and go home to a sick bed to suffer with fortitude the pangs of a painful and incurable disease. He was the same man to the last,—active and clear in mind, benevolent and affectionate at heart, and benign in manners. His activity never interfered with his profound quietude and peace; and his quietude and peace deepened, as his mind brightened, to the last.

He was short in stature; but none of those who were personally acquainted with him will forget his countenance, which could nowhere pass without notice. Its astute intelligence, shining honesty, and genial kindliness revealed the man so truly that, though he never lauded himself, few were so correctly estimated, and so highly valued. He was attended in his last hours by his adoring children, and died in the midst of them on the 17th of December, 1857. Whilst deploring his loss, society should be thankful that such a man was spared so long for the benefit of mankind. Although most of the preceding record is but the echo of the tribute already paid to this great man by one of his most distinguished friends, I have thought it due to the members of this Society to preserve it that they all may be able to dwell on the character and merits of one who has shed so much lustre on this and other scientific societies. May the officers both of army and navy be encouraged to imitate so bright an example, and not be deterred from doing so by the senseless dread of becoming *too learned*!

Thomas Best Jervis, Lieut.-Colonel E.I.C. Engineers, F.R.S., F. Geol. S., F. Ast. S., F.L.S., F.A.S., F. Geog. S., M.I.C. Eng., Cor. M.N.H.S. Boston, Soc. Ethnogr. Paris, &c. &c., was the second son of John Jervis, Esq., civil servant of the E.I.C., who, having for some time held a high post at Madras, was transferred to Jaffnapatam, on the north of the island of Ceylon, where Thomas Best Jervis was born, August 2, 1796. Lieut.-Col. Jervis throughout life valued himself less upon his ancestry, although his family is most ancient and respectable, than on the fact that several of his relatives had been eminent for their patriotism, learning, and integrity. The head of the family, James Jervys, Esq., possessed the property of Chatkyll, in Staffordshire, in the fifteenth century; and Colonel Jervis would recount with satisfaction the fact of King Charles having been protected and hidden after his retreat to the oak, by Miss Lane, one of the staunch royalist members of the family. In later times the celebrated divine, Bishop Hooker, and the Earl of St. Vincent (Sir J. Jervis), have nobly maintained the honour of the family. On his mother's side Colonel Jervis was descended from a Polish family of the name of Ritzo, who had been for generations in the royal household of the Georges, whom they accompanied from Hanover. Baron Grimm's family still reside in Prussia, where the present Dr. Grimm is physician to the king of Prussia, and one of the principal medical officers of that country.

George, Thomas, and John, the three sons of Mr. John Jervis, were sent home to England at a very tender age, in accordance with the necessity imposed by the tropical climate, for their education, and were consigned to the care of their uncle Chief-Justice Thomas Jervis, of the Chester circuit. Thomas was first transferred to a maiden aunt, Miss Jervis, at Lichfield, an excellent Christian person, from whose watchful care he acquired that deeply-rooted principle which was always one of his most marked characteristics. The first school he went to was kept by a *Dame*; and, being there taught along with little girls, he was thoroughly grounded in English grammar, and other subjects too often neglected or omitted at boys' schools. From hence he probably derived an habitual gentleness of disposition, so that he had an uncommon tenderness of feeling, even towards the brute creation, never liking to inflict pain even on an insect. From Lichfield he was placed at a school at Rugely (Staffordshire), and subsequently sent up to town to Judge Jervis, whose wife, having children of her own, always treated the three "India boys" with comparatively little ceremony. Thomas was sent to Mr. Delafosse's excellent classical school at Richmond, and, having to trust entirely to his own exertions for getting on in life, early showed an eager thirst for knowledge; so that, instead of wasting his youth in play, he studied with the greatest attention, and was soon one of the most proficient in the school for his classical knowledge, taking great delight in Greek and Latin poetry. He now became very desirous of acquiring a knowledge of other subjects then so much neglected at classical schools, as is still too frequently the case in great seminaries: he procured some books on elementary mathematics, and studied them diligently, making himself by his zeal a favourite with the principal. During the holidays, which he spent with his uncle, he still pursued his studies by himself, and spent his allowance of pocket-money in procuring little French books, a pencil, or something similar, exhibiting an energy in the pursuit of knowledge uncommon in a lad of his age, though shared in a measure by his two elder brothers. He now persuaded his cousins to teach him a little French and drawing, and he always remembered with gratitude the simple lessons of one of them who thus assisted him. Hence he was sent to Addiscombe College to study for the East India Company's service, in which for several generations his family and relatives had passed the best years of their life. He had here a better opportunity of studying the languages, French, Hindustani, &c., and under the able professors of that establishment he mastered the elements of mathematics, becoming, as he advanced in knowledge, enraptured with the subject, which he followed up to the day of his death with unwearied delight. After having remained the requisite time, he passed a most honourable examination for the Engineers, being one of the foremost of the cadets of the year (and there was no lack of talent among the candidates for the Engineer service); and he was sent to Worcestershire, under Colonel Mudge, R.A., to work on the Ordnance Survey of England: the part he surveyed was the town and neighbourhood of Bromsgrove, since engraved on the 1-inch scale.

He now embarked in the fleet which was despatched to convoy the merchantmen sailing for Bombay, and he arrived at that port in May 1814. Immediately after his arrival he entered on the responsible duties of his profession, and had the control of large sums of money, £28,000 having been spent by him in erecting civil and military buildings; and at one time he had five thousand natives under his orders, whom he had to instruct in bricklayers' and masons' work. To make up for the scarcity of limestone, he examined the beach, and, finding that there was a considerable bed of recent shells in the neighbourhood, he persuaded old women and children and infirm villagers, by liberal offers, to collect them in baskets; and so great was the quantity obtained, that the kilns were filled and the building rapidly erected. He was appointed interpreter to Major-General Keir, in Guzerat, in December 1817; temporary Assistant to the Superintending Engineer at the Presidency in February 1819; and Executive Engineer, Southern Concan, in September 1819.

In 1820 he requested to be appointed to survey the Southern

Concan. The Chief Engineer considered "the offer creditable to the activity of the officer;" and Lieut.-Colonel Kennedy recommended that he should be permitted to commence on the proposed undertaking, as being in all respects highly qualified for executing such a work; and the Governor in Council authorized his being employed in making the survey whenever he could be spared from his other duties as Executive Engineer. He was thanked by letter on the 5th December 1820, by Mr. Pelly, the Collector and Magistrate in the Southern Concan, for the admirable internal organization of his department, and was then placed at the disposal of the Commander-in-Chief, to be employed on an expedition against the pirates in Arabia.

His Report on Weights and Measures was noticed as "highly creditable to his talents and philosophical researches," and obtained a special acknowledgment from the Government, dated July 1822, which expressed their approbation of the ability and research it displayed.

In 1824 Lieut.-Colonel Sutherland, Deputy Surveyor-General, bore testimony to the value of Lieut. Jervis's services as a Trigonometrical Surveyor, and in the same year the Government expressed its approbation of the "zeal and diligence he had displayed in the preparation of certain Revenue and Statistical papers;" and in June 1826, noticed in terms of approbation his "able and intelligent Report on the State of Education in the Concan."

In 1829 the Commander-in-Chief (Sir Thomas Bradford) submitted to Government, Captain Jervis's application to be appointed Deputy Surveyor-General of India, on the death of the Surveyor-General, with his Excellency's warmest and most unqualified recommendation that it should be complied with. "Captain Jervis," his Excellency adds, "was employed under the late General Mudge, from whom he has the highest testimonials, in the grand Trigonometrical Survey of England in 1812. His Excellency conceives him to be the most qualified person that could possibly be selected for the situation to which he aspires."

He was appointed Inspecting Engineer of the Surat division in December 1829; Superintending Engineer at the Presidency in 1830; in the same year Acting Inspecting Engineer in Guzerat; afterwards Executive Engineer in Ahmednuggur, and Acting Executive Engineer in Belgaum, in March 1831.

The Government expressed their satisfaction at the zeal and energy he had displayed in prosecuting his researches, and for information he had afforded respecting slate-quarries discovered in the Southern Mahratta country. In 1833 the church built by him at Belgaum was stated to reflect great credit on his taste; and the following extract from a letter addressed to Captain Jervis, dated 8th August, 1831, will show the high estimation he had then acquired:—"The Governor in Council, highly appreciating the value of your labours, and desirous of securing to the Government and the public all the benefits that can be derived from them, accepts your offer to prepare a copy of your Statistical Memoir of the Concan in a complete state and form for publication."

In February 1835 the Government reported that Captain Jervis had completed his statistical reports and memoir on the revenue-system of the Concan, and had furnished a volume of beautifully executed maps and plans, "which reflect great credit on him." In 1835 also the acknowledgments of Government were conveyed to him for his "curious and interesting volume on Weights and Measures;" and the Governor in Council stated that he considered Captain Jervis deserved great credit for having devoted his spare time and distinguished talents to the illustration of so difficult a question.

He was appointed Superintending Engineer at the Presidency in May 1835; and member of a committee to take into consideration the best plan for the construction of a causeway between Bombay and Colaba in October 1835; and the Government subscribed for fifty copies of his Statistical and Descriptive Memoir of the Western Coast of India.

On his quitting India on furlough to Europe in 1836, Government expressed "the high sense which they entertained of his character, professional skill, and talents. Before his departure he drew up a code of instructions, at the request of Sir Thomas Bradford, the Commander-in-Chief, in three languages,—English, Hindustani, and Mahratta. In 1837 the Court of Directors awarded him a donation of 10,000 rupees as a testimony of the high sense which the Court entertained of the value of his labours in conducting the geographical and statistical surveys in the Concan. In 1838 the Court expressed their approbation of "the zeal evinced by him for the advancement of the objects of the Survey of India by making himself fully acquainted with the details of the system which is pursued upon the Irish Survey;" and about the same time he was appointed to superintend a series of tide-observations to be made upon a uniform principle at various points of the coast of India. He returned to his duty in October 1839, and was appointed Superintending Engineer, Northern Provinces, in March and May 1840.

On his retirement from the service in December 1841, the Governor in Council stated that "he will have much satisfaction in bringing to the notice of the Court of Directors the services of Major Jervis in the several branches of his particular profession, and also as an officer eminent for his general science and research;" and the testimony borne to his services by the Bombay Government was creditable to him and most satisfactory to the Court of Directors.

In 1830 Captain Jervis married Miss A. S. Paget, daughter of William Paget, Esq., M.D., 48th Regiment; and this lady, having been the intimate friend and coadjutor of Mrs. Ibbetson the botanist, was an able assistant to Captain Jervis in his description of the indigenous flora of the Concan, as she made water-colour drawings of almost all the flowering plants and trees of the Province: the work he then projected has not however been published.

Whilst in London, Major Jervis drew up a statement of the scientific researches which he deemed to be desirable in Shedda; and this comprehensive report was considered so valuable and so important, that a memorial was addressed to the East India Company on the 14th of July 1838, signed by His Royal Highness the Duke of Sussex, as President of the Royal Society, and many of the most illustrious members of that and other Societies, urging that the Government in India might be directed to forward in every possible way his views; and no one expressed himself with more characteristic and generous warmth in his favour than Sir Roderick Murchison. About this time Major Jervis had been appointed Surveyor-General of India in succession to the present Colonel Everest; but, finding after his return to India that that officer had no intention to retire so soon, he gave up his hopes of being ever able to carry out his favourite project, and retired, as has been stated, from the service, in January 1842.

Whilst in India his discovery, and application to useful purposes, of lithographic stone, and his examination and description of the slate-quarries he had first discovered in the Western Ghâts, and his report to Lord Clare and the Governor-General of India on the geological structure of that portion of Western India which lies between the 15th and 19th degrees of north latitude, were all important scientific services; and on his return home the activity of his mind did not relax, and he spent his time in educating his own family, seeking to find some congenial employment that might keep his faculties in full exercise.

In 1843 he began to set up with his private funds a lithographic press, for the purpose of promoting the education of the natives of India, whom he loved to his dying hour, and wished to see enlightened. The productions of his press were all of a useful character; and the first thing he did was to prepare forms for the E.I.C. for the collection of revenues, the management of the marine engines of the navy, and a variety of other forms, which he furnished, by the highly scientific processes he adopted, at a very moderate charge. Among the various papers which Major Jervis proposed to the Indian Government is one which is of great importance, as it urged the adoption of properly lithographed post-office-orders in India. In writing to Lord Hardinge, March 24, 1845, Major Jervis says: "A Government post-office-order and letter of advice, in the opinion of General Morrison, formerly in the Supreme Council, several of the most eminent judicial authorities lately in India, and many of the members of the Court of Directors, would go further to suppress murders, crimes, and misrule consequent on the transmission of money by private hands than any other thing."

The few maps and papers printed by Major Jervis at his private press were equal to the best of the day, according to the testimony of many able geographers; and Mr. Greenough thus writes, "Your map of the Duskrooe Purgunnah is admirable both in design and execution: would that the whole of India were laid down on your model!" (December 6, 1844); Sir G. Rennie says, "I could not have conceived the perfection to which the lithographic art had arrived till I saw these specimens, although we have have had much experience in our dealings with the trade for railway and other maps" (January 21, 1845); while with regard to the maps of

India in the vernacular languages, which Major Jervis was desirous of making for the missionary-schools, had funds permitted, Mr. Davis, the best Chinese scholar of all Europe, speaking of the Plan of Pekin, was pleased to say that it was the *finest specimen* of Chinese writing he had ever seen, and he would compare it with the *native Chinese.* Nor was the encouragement of native female education a trifling object aimed at by Major Jervis, who felt how important the example of mothers must be in after life to the rising generation.

At the commencement of the Russian war, Colonel Jervis examined the materials forthcoming to enable the allies to gain a knowledge of that country, and early fixed upon the magnificent map of the Crimea which had been prepared by General Mukhin and the Russian staff. He obtained permission to trace it himself at a Continental library, and, having completed it and translated the names into English, brought it to England to lay it before the Duke of Newcastle, along with other rare documents not to be procured in England. After urging the subject long and frequently, and impressing upon the Government the absolute necessity of having *geographical* information for the troops, his Grace permitted him to furnish two or three copies of each of these documents, officially, to commence with. In *ten days*—less time than he could have sent to Vienna for another copy of the Austrian map of Turkey—he produced, entire in twenty-one sheets, two hundred copies at the service of the Government! The map of the Crimea was also ready before the army left Varna; and by it Lord Raglan mentions that he made his flank movement by MacKenzie's farm. Soon after, the Government sent copies of these maps to the general-officers; and in alluding to this subject, Colonel Jervis wrote thus to the Duke of Newcastle:—(1854.) "I believe it is not generally known that the present is the *first war in which the British forces have been supplied with the most needful help to success, correct and suitable land-maps.* To your Grace and Lord Raglan's acceptance of my services is ascribable, as well as to the exertions of the Hydrographer at the Admiralty, Admiral Sir F. Beaufort, and his coadjutor Capt. Washington, R.N., that the army has been furnished with the earliest and best information of the distant countries in which they are now engaged. This service as regards the army has been honourably recognized by the principal Staff-Officers, the Commander-in-Chief, and many distinguished personages in France and England; nor least by her most gracious Majesty the Queen, the Emperor of the French, and the Ministers of War and Marine." In an unknown country, on a conflict so momentous, geographical information must be inestimably valuable.

Much of this important service was carried out at his own cost and by his own and his son's labour; and he pressed upon the Government in very emphatic terms the advantage which would be derived from the establishment of an office in connexion with the army, similar to that of the Hydrographical Office connected with the navy.

After some months, Colonel Jervis procured from the French Government 1476 maps of the choicest kind, and offered these as a nucleus for the new office. Soon after, he was appointed, March 1855, to be the Director of the Topographical and Statistical Depot of the War Department, with one assistant to attend to the details of working, &c., and, to act as his deputy in his absence, his son, Mr. W. P. Jervis, all other assistants being merely hired by the week. This was almost the last work of the Duke of Newcastle, and will doubtless be remembered as one of the greatest improvements in the organization of our army, for the first step taken by Colonel Jervis was to impress the Minister with the importance of attaching to his office a set of intelligent officers who should form a topographical corps, and accompany the troops in the Crimea, Asia Minor, and indeed in every campaign. The first corps sent out under Colonel Jervis, and equipped with instruments, &c., went to Erzerum, where they surveyed the whole sources of the Euphrates on a large scale, and the plain and town of Erzerum, sketching in the hills, &c.: this survey was afterwards employed in connexion with the frontier-survey from Ararat to the coast. Lord Panmure did not sanction a topographical corps for the troops at Sevastopol, though the Engineers of the Turkish Contingent were regularly supplied with instruments and materials from the Topographical Depot, and sent home some valuable maps. It may however be observed that the propriety of attaching a scientific corps to the Crimean army had been submitted to Lord Raglan by a different person, and that the project would have been carried out had not insurmountable difficulties appeared in the way. Lieut.-Colonel Jervis had the merit of originating the important establishment of a Topographical Office in the War Department, and he did much with limited means; we must not however condemn the higher authorities for not at once raising such an establishment to its utmost elevation, as no men in power can neglect the necessary economy of public money. It cannot be doubted that the Topographical Office will go on improving in excellence and importance, and that the remembrance of its first head will be long associated with it. The works of Lieut.-Colonel Jervis on geographical and other scientific subjects were very numerous; and I may mention especially, as proofs of his labour or ingenuity, his model of Sevastopol, which is in the War Department (it is 14 feet by 10, on a scale of ten inches to a mile, with true altitudes, and was coloured skilfully by the kindness of Mrs. Colonel Jervis), and a new system of projection for maps, called by him "cycloidal," and which has been employed in his official maps of the Caucasus (two sheets) and the S.W. of Asia, Circassia, the Caspian, &c.; of these, nine sheets are more or less completely engraved and issued.

Lieut.-Colonel Jervis is now gone; but we may fairly say that the East India Company has seldom possessed an officer of more energy and ability, that his services at home were very valuable, and that in every respect he was a most kind and estimable man, fulfilling all his duties, as a loyal subject, a faithful husband, and an affectionate father, in the most exemplary manner.

George Weare Brackenridge, F.S.A., was born on the 4th of January, 1775, in Hanover County, Virginia, at that time still subject to the British crown. He was the eldest son of George Brackenridge of Winash, Brislington, who was a Scotchman by descent, though born at Bristol, where his family had recently settled, and of Sarah, youngest daughter of Francis Jerdone, Esq., of Louisa County, Virginia, and formerly of Jedburgh, N.B. The father of Mr. Brackenridge had settled in America as a planter and merchant; but, entertaining conscientious scruples on the principles and propriety of the American revolution, he returned to England, and placed his son at the school of Dr. Estlin, at Bristol, where he was initiated in the mysteries of commercial pursuits, and became ultimately the senior partner in a leading and long-established West India firm. As a man of business he was characterized by high principles of honour and integrity, and by habits of accuracy and punctuality. He exhibited at an early age a taste for science and literature, and in spite of the demands of commerce upon his time, rendered more absorbing by the distractions of the revolutionary war, he found leisure for inquiries into mediæval antiquity and more than one branch of natural history. He formed a good collection of the *Coleoptera*; and his cabinet of organic remains, which in the early days of geological science was of much repute, is still of value for its specimens of fossils connected with the strata of the West of England. He was very accurate in his examination of fossils, and brought under the notice of Mr. Sowerby a specimen of Ammonite, remarkable for the striking and peculiar form of the lip, which was found at Dundry, near Bristol. Before arriving at his fiftieth year, Mr. Brackenridge abandoned his commercial pursuits, and purchased the residence of Brislington. He had before, like many of our leading men of science, found it possible to exercise the faculties of his mind during many a leisure moment on objects of more stirring interest than the dry details of business; but he now gave himself up to the full gratification of his refined tastes, collecting much more largely than he had done before, fitting up his library in the Tudor style, and enriching it with richly-cut furniture, and with fine specimens of stained glass. As an antiquary, he devoted much attention to the investigation of the architectural features of Bristol, that picturesque old city, where he had passed so much of his early life, and to the preservation of many of its ancient relics.

He assisted most liberally in procuring the best illustrations for 'Collinson's History of Somersetshire,' which work must therefore be looked upon as bearing testimony to his love of topographical research.

Having for the last twenty years of his life spent the summer and autumn at Clevedon on the Bristol Channel, he liberally promoted the building of a new church on Clevedon Hill, contributing the greater portion of the building-fund, and adding a permanent endowment: his son was appointed its first minister in 1839, when the church was consecrated. Though, from his retired and domestic habits, he was not generally known in his neighbourhood, he was valued by those who did know him for the kindliness of his disposition, his great powers of conversation, and the many sterling qualities of his character. He married, Nov. 11, 1800, Mary, youngest daughter of Robert Burt, Esq., of Bristol, and of Tracy Park, near Bath, who died March 20, 1855. He was not long left behind her, as he died February 11, 1856, at his house at Brislington, near Bristol, aged 81.

Charles William Wentworth Fitzwilliam, fifth Earl Fitzwilliam, K.G., was best known to the world as an enlightened liberal politician, but his claim on our respect is founded upon his desire to promote the intellectual advancement of his fellow men, as manifested by the fact that since the year 1833 he filled the office of President of the Yorkshire Philosophical Society. He has been succeeded by the Earl of Carlisle, but the services of twenty-eight years' presidency are not likely to be forgotten by the members of the Yorkshire Philosophical Society.

As a soldier myself, I cannot pass by the name of Colonel W. G. Eliot in silence, though I have been unable to obtain any specific notice of his life. The officers of our military and of our naval profession should be encouraged to enter upon a study which is so capable of being made valuable in practice; and the very fact of joining our Society proves that regard for science which it is our object to inculcate and to cherish.

I have now to notice the distinguished foreign members whom it has been our misfortune to lose during the past year, and I shall begin with M. André Hubert Dumont, who was so well known to many of our leading members, and whose career, though short, was productive of great results. He was born in 1809: and such was his earnest pursuit of his favourite science, that at the age of twenty (in 1829), he produced his first geological essay on the "Geological Constitution of the Province of Liege," and addressed it to the Royal Academy of Belgium, by which body it was crowned with honour. Ten years afterwards the merits of this work obtained for M. Dumont the award of the Wollaston Medal from our Society. In 1834 (April 5) he was chosen a corresponding member of the Belgian Academy, and in 1836 (Dec. 15) he was admitted a regular member. About the same time, at the recommendation of the Dean of the Academy, and of the late M. Cauchy, also a member of the Academy, M. Dumont was named, by the Government, Professor of Mineralogy and Geology to the University of Liege, and was requested to undertake the difficult and important task of drawing up a geological map of Belgium; and it is much to be feared that, honourable as that work must be considered to his native country and to himself, the labour and anxiety connected with its preparation were fatal to his health.

In 1852 his Memoir on the Rhenish and Ardennes Formations, including the Ardennes, Brabant, Condroz and the Rhine, shared with De Koninck and Van Beneden the first great quinquennial prize in the natural sciences decreed by a jury selected from the Academy. In January 1855 the Academy selected him as its director for the year 1856, and he had only completed his year of office two months when he was snatched away by death; and it may be considered a touching incident, that the only survivor of those members who assisted at the foundation of the Academy, M. D'Omalius d'Halloy, came to Belgium to bid adieu to Dumont, whose early progress he had encouraged, whom he loved as a son, and by whom he was revered as a parent. For twenty years his life was devoted to the preparation of the geological map, during which time he shrank from no labour either of body or mind, exploring every spot in Belgium, and not allowing a single geological fact of importance to escape his attention, so that his inquiries extended from the primary to the tertiary formations inclusive. The merit of the map cannot be disputed, even though doubts may be entertained as to the nomenclature made use of; and we may adopt the following words of one of his eulogists without reserve: "Though he was, perhaps from a natural disdain for ordinary means of success, too careless about popularizing his ideas beyond the class he taught, his maps will retain their value, even though it may be necessary to change his nomenclature; and they are so manifestly stamped with the character of exactness and reality, that it may be expected that the divisions which he has adopted will be hereafter taken as general types of formations: indeed they have already been adopted in Germany for many formations, so that they have already obtained a place in geological science." The failure of his health forced M. Dumont to travel; and he discovered on the shores of the Bosphorus, and on the mountains of Spain, formations equivalent to those he had recognized on the plains of the Ardennes and of Condroz; and it was then that he conceived the idea of forming a geological map of Europe, a map which has appeared, and must be looked upon as one of the first serious attempts to establish on a large scale the geological correlation of the various countries of Europe.

Like our late friend Mr. D. Sharpe, to whom he was well known, he was snatched away in the very prime of life, and at a moment when still greater advances in geological science might have been reasonably expected from him. The University and the Government of his country had however done much in that brief time to testify their estimation of him. Many of his academical honours have been already noticed; but it may be mentioned that he was a Commander of the Order of Leopold, a Knight of the Order of Conception of Villa-Viçosa of Portugal, and of the Polar Star of Sweden, whilst he was a member and one of the founders of the Royal Society of Sciences of Liege, Member of the Society of Sciences, Arts and Belles Lettres of Hainault, Honorary Member of the Central Society of Agriculture of Belgium, of the Association of Engineers, formed on the model of the School of Mines, and of the Society of Emulation, Member of the Academies of Naples and Turin, formerly President of the Geological Society of France, Member of the Imperial Society of St. Petersburg, of the Society of Naturalists of Moscow, Corresponding Member of the Society of Physical, Chemical, and Agricultural Sciences of France, and since 1841 a Foreign Member of our Society, the loss of whom will be deeply regretted by many of our members, and by none more than Mr. Austen and Mr. Prestwich, both of whom were intimately acquainted with him personally and knew well his worth.

The preceding observations are sufficient to prove how fully M.

Dumont had earned the high character for unwearied zeal and energy in geological research, ascribed to him not merely by his own countrymen, but by the geologists of all Europe: some further remarks on his writings are, however, necessary to give a clear idea of his great and varied talents, as well as of that independence of mind which led him perhaps sometimes to an excessive dread of being shackled by systems. The Memoir on the Geological Constitution of the Province of Liege was his first great work, and gained the prize offered by the Academy of Brussels for the essay which should best fulfil the following conditions: "describe the Geology of the Province of Liege; point out the mineral species and accidental fossils which are there found, the localities where they occur, and the synonyms of all substances already known and which have been before described." There were two other competitors for this prize; and the epigraphs attached to the papers of Dumont and of his next ablest opponent, who gained a silver medal, are as follows: that of the second competitor was a passage from Baillet to this effect,—"few systems and many facts, ought to be the motto of a Naturalist," a sentiment which well defines the views of Dumont himself, whilst his own epigraph, "the relative age of the primordial rocks cannot be determined with certainty from their inclination," may be taken as the expression of the results of his labours.

M. Dumont adopts the nomenclature of D'Omalius d'Halloy for "Terrains" or Formations, and that of Alexandre Brongniart for Rocks. The primordial formations of the province of Liege he describes as occurring in basins, the stratification as conformable, and the rocks as divisible into three groups, which, in conformity with the views of D'Omalius, he designates the Schist- or Slate-group, the Anthracitiferous group, and the Coal-group; the coal-group resting on the anthracitiferous group, and that upon the slate-group.

Describing his rocks from below upwards, he enumerates in the slate-group: 1. Diallage-slate, consisting of a paste of talc with lamellar diallage disseminated; 2. Red Slate, consisting also of a talcose base, with red grains of (?) peroxide of iron; this and the preceding belong to the "Steaschiste" of Brongniart; 3. Common Clay-slate; 4. Quartz- and talc-slate; 5. Granular Quartz; 6. Talcose Conglomerate and Puddingstone; 7. Freestone or Diorite of Brongniart.

These rocks might be considered as forming parts of one great whole, the varieties being consequent on the accidental presence of certain mineral elements in different parts of the series at the time when crystallization was induced in the mass by metamorphic action; but M. Dumont divides them into two systems: the Inferior comprising the Diallage-slate, the Granular Red Slate, the Talcose Puddingstone, and a little Clay-slate; whilst the upper system principally consists of common Clay-slate and of Granular Quartz, including in some parts Talco-quartz-slate and Greenstone: but this arrangement, if invariable, would be quite consistent with the theory of a simultaneous metamorphic change through the whole mass.

The several rocks which have been named as constituting the Slate-formation are not irregularly distributed, but are arranged in definite order. The whole formation in the province of Liege is divided into three distinct portions by the Anthracitiferous formation: on the South-east it occupies the whole region of the Ardennes, and is there covered only by its own debris, except in one locality, where a small band of the "Penean" (the Permian of our nomenclature) comes to the surface; at the North-east it is almost entirely covered by secondary strata, whilst in the centre of the great Anthracite-basin it occurs in discontinuous bands parallel to the lateral edges, which have thus been lifted up like islands in the centre of the great depression. Had this elevation been carried sufficiently far, the Anthracitiferous formation would have been divided into two parts; but it has stopped short of a complete separation, the lower quartz-slate of the Anthracitiferous formation covering it in many places, though the limestone immediately above the quartz-slate is completely divided into two principal basins by the quartz-slate. In the Ardennes alone is the lower system of the Slate-formation found, and it there forms a single band, whilst the upper system occurs as two bands, one to the north and the other to the south of the lower system. It is unnecessary here to follow M. Dumont in his very careful and able examination of the mineral character and products of these rocks; but it may be said that the symmetrical arrangement of the rocks forming the lower system, in the following order from below upwards—Diallage-slate, Red Slate, Common Slate, Talcose Puddingstone—on each side of an anticlinal axis, proves that the lower system here forms a saddle-shaped elevation, just as the upper system appears to do in the centre of the basin, with this difference, however, that it is not covered, as the upper system partially is, by the next series in regular order of superposition. Passing over the local descriptions of the Slate-formations, the Anthracitiferous formation is next in order, and is divided by M. Dumont into four systems, namely: 1st, Slate, Sandstone, and Conglomerate, called the Lower Quartz-slate; 2nd, Limestone and Dolomite, called the Lower Limestone; 3rd, Slate and Sandstone, called the Upper Quartz-slate; 4th, Limestone and Dolomite, called the Upper Limestone: and in both the limestone-divisions the Dolomite occurs, though not always present, between two beds of common limestone. M. Dumont, in his remarks upon the order of superposition of these rocks, states that the lower quartz-slate-system graduates, at its junction with the slate-system of the Ardennes, so imperceptibly into the slates, that it is scarcely possible to mark distinctly the line of separation, and he refers this system to our Old Red Sandstone; but he does not in this Essay effect a correlation of the three remaining systems of the Anthracitiferous formation with English formations, nor do I think that the list of fossils he gives would alone have enabled a geologist to decide on the true position of the Anthracitiferous and Coal formations of Liege; as, for example, in the fossils of the Lower Quartz-schist appear the names *Productus hemisphæricus*, *P. comoides*, *P. concinnus*, and, in the Upper Limestone System thereof, *Calymene Tristani*, *C. macrophthalma*, whilst in like manner *Spirifer attenuatus* is recorded as occurring in the Upper Quartz-schist below the Coal-field, and in the Penean or Permian formation above it I do not mention these palæontological obscurities with an intention to detract from the great merits of M. Dumont's Essay, but simply to show how impossible it is to determine the relative ages of the strata of the earth without an appeal to the fossils, or, in other words, to the Natural History, of each successive epoch. M. Dumont detailed with the utmost ability the mineral structure and the physical peculiarities of the province of Liege, and his work became a natural basis for the future researches of himself and others; but a district so much undulated by disturbance was not to be satisfactorily unraveled by such a system of investigation alone. The identification, however, of the Lower Quartz-schist of the Anthracitiferous formation with the Old Red Sandstone, and the determination of two successive limestones, the lower and the upper, were important steps towards the final establishment of the Devonian as a true formation.

In his subsequent memoirs on the rocks of the Ardennes and of the Rhine, M. Dumont observes that in his preceding work he had proved the accuracy of M. D'Omalius d'Halloy in dividing the primary strata of the North of France into the Slate, Anthracitiferous, and Coal formations; and he then adds that subsequently Sir R. Murchison had proposed for the same formations the names of Silurian, Devonian, and Carboniferous,—denominations which, having been adopted by many French geologists, had replaced those of D'Halloy. M. Dumont also admits that the undulations and disturbances of the four systems into which he had divided the Anthracitiferous formation produce such indefinite alternations of the calcareous, schistose, and quartzose divisions, as to render their study very difficult, though he states that by *purely geometrical* considerations he succeeded in demonstrating the existence of two calcareous deposits within the Anthracitiferous formation, and adds that Murchison had arrived at the same result in England, having allocated the Lower limestone to the Devonian, and the Upper to the Carboniferous formation. Without doubt the labours of M. Dumont were in this respect most valuable, as affording a proof of the just claim of the Old Red Sandstone to be considered part of a true formation, and his observations correct; but his subsequent remarks are not equally well-founded, when he speaks of the difficulties which those first-rate geologists, Sedgwick and Murchison, experienced in determining the precise boundary between the Cambrian and Silurian formations, as proofs of the insufficiency of a study of organic remains to settle such questions. This idea he endeavours to strengthen by pointing out the differences of opinion which have existed in respect to the quartz-schist of the Ardennes and of the Rhine, which Sedgwick and Murchison had placed in the Silurian, whilst M. C. F. Roemer had considered, from the study of organic remains, that the quartz-schist of the Rhine belonged to the Devonian, and MM. D'Archiac and De Verneuil, from their examination of the ancient fossils of the Rhenish Provinces, had placed the grey slates of Nieder-Prüm in the Silurian, though, in M. Dumont's opinion, above the red grits of the quartz-schist-system of the Anthracitiferous formation; and he then concludes that Palæontology had proved insufficient, and proceeds to establish the divisions of the ancient Schist-formations by his own *geometrical method.*

He divides his memoir into two parts, the first treating of the Ardennes, and the second of the Rhenish strata, and adheres to the same principles of subdivision which characterized his first work; adopting for the Ardennes the following systems from below upwards: 1st, the Devillian, 2nd, the Revinian, and 3rd, the Salmian, the names being all derived from special localities; and for the Rhenish, 1st, the Gedinnian, 2nd, Coblentzian, 3rd, the Ahrian, also local names. The Ardennes and Rhenish formations are all composed of quartz-slates, quartz rocks, grits, &c., and underlie the Anthracitiferous formation, which M. Dumont subsequently subdivided into three systems, the Eifelian, the Condrusian, and the Coal, so that the Devonian was here confounded with the Carboniferous in one formation characterized merely by its carbon constituent. M. Dumont exhibited the same mineralogical skill in the examination of all these rocks, and the same care in describing his different systems, which, as they closely resemble each other, must have caused him great trouble. The various contortions of rocks he notices are also sufficient to indicate the complexity of the district; but he manifestly considers the question of fossils as one of secondary importance. M. Dumont in 1838 referred to his former determination of the correlation of the Eifel formation with the Anthracitiferous formation of Belgium, and stated that he had subsequently visited Wales in company with MM. D'Omalius d'Halloy and De Verneuil, in order to determine in a similar manner the correlation of the English and Belgian strata; and he comes to the conclusion that the divisions established by Sedgwick and Murchison, as Cambrian and Silurian, correspond with the Slate and Anthracitiferous formations of D'Halloy: on this supposition he considers the Slate-formation of Belgium as the representative of the Cambrian formation, and the Anthracitiferous formation as including the whole of the Silurian system and the Carboniferous formation in the following order:—

Anthracitiferous Formation.	Upper Limestone.	Limestone ...... Dolomite ...... Limestone......	Carboniferous Limestone.	
	(Old Red, supposed to be absent in Belgium.)			
	Upper Quartz Slate.	Grit..............	Upper Ludlow.	Silurian System.
		Limestone	Aymestry Limit.	
		Slate with subordinate Limestone	Lower Ludlow.	
	Lower Limestone.	Limestone ...... Dolomite ...... Limestone	Wenlock Limestone.	
	Lower Quartz Slate.	Grey Fossiliferous Schist	Wenlock Strata.	
		Schist and red Grit, conglomerate Grit, Quartzite, Schist ...	Caradoc and Llandeilo.	
	Slate Formation.	Upper............ Middle .... Lower	Cambrian System.	

M. Dumont adds that it is doubtful whether the Old Red exists at all in Belgium, so that he abandons his former conclusions; and as he adds, that, though the divisions established by Murchison on fossil evidence in England were good for that country, they would be found palæontologically different in Belgium and other countries, it is quite evident that he had not then succeeded in establishing, by his system of examination, the true age of the Belgian rocks, and that the ultimate application of the English system was necessary to reduce this important geological district into order, It is indeed with regret that we observe so able a man persevering in ignoring the well-known names of Silurian and Devonian and adhering to that of Anthracitiferous, which must perplex rather than inform the geologist; but, making a fair allowance for his high respect for his old master in the science of geology, D'Halloy, which manifestly interfered with his examination of the older rocks, it is evident that however able in many respects his classification, more especially that of 1852, was, it is gratifying to turn to his researches on the Tertiary strata. Here his judgment was less shackled; and I freely quote the following practical observations with which that profound Tertiary geologist, Mr. Prestwich, has favoured me.

M. Dumont now directed his attention to the Tertiary strata, which until that time were in a most perplexing state of confusion. Without any clearly-established order of superposition, with fossils belonging to upper beds placed in the lowest beds, and with no accurate sections, it was impossible for foreign geologists to establish their correlation with the Tertiary strata of the adjacent countries. One equivalent deposit only had been distinctly recognized, viz. the relation of the Brussels Sands to the Calcaire Grossier of Paris; but all previous descriptions of the beds above and below that group were full of inaccuracies and very incomplete. This in part was owing to the want of natural and artificial sections, arising from the flatness of the country and the scarcity of building-stones in the Tertiary series. In 1839, in a report to the Royal Academy of Brussels, M. Dumont gave his first sketch of the classification of the Belgian Tertiaries, dividing them into a series of "systems" distinguished by local names. This plan he from time to time enlarged and improved, still retaining the original groundwork, and finally establishing ten principal groups, of which the following is a list:—

1. Scaldisian System. 2. Diestian System.	Pliocene.
3. Bolderian System. 4. Rupelian System.	Miocene.
5. Tongrian System. 6. Laeckenian System. 7. Bruxellian System. 8. Paniselian System. 9. Ypresian System. 10. Landenian System.	Eocene.

To establish the correlation of these groups, M. Dumont visited the Tertiary districts of France and England, and published a table of equivalent strata, showing great ability and sagacity; but unfortunately the data on which the synchronisms are based, both with respect to organic remains and physical structure, are not given. The main points on which M. Dumont throughout insists are the breaks in the sequence, corresponding with certain movements of elevation. The fuller descriptions and lists of fossils were reserved for a larger work, of which unfortunately his early death has deprived science. A table embodying his most recent views was published in the Journal of our Society for 1852.

To the great and extensive deposit of loamy drift which covers so much of Belgium, he applied the term of "Limon Hesbayen," being a portion of his "Système diluvien," which again was a section of the "Terrains Quaternaires." The deposits arising from hot springs, evolutions of vapour, and gases, he proposed to designate as of "Geyserian" origin, in contradistinction to rocks of igneous and sedimentary origin.

It will be observed from the preceding remarks, that, whilst recognizing the great value of a purely mineralogical examination of a country, both as regards a correct determination of the true causes of metamorphism and with a view to trace out the physical forces which have contributed towards the present constitution and distribution of mineral strata, I have endeavoured to show that no perfect knowledge of the successive epochs of the earth's history can be acquired without the study of its fossils, or in other words, of its natural history. Neither of these modes of inquiry should be neglected, as it is quite evident that any one taken alone can give but an imperfect notion of the whole subject. M. Dumont directed his efforts, and they were great and most skilfully conducted, to the mineral mode of investigation; but there is little doubt that he would, had his life been spared, have ere long given more attention to the palæontological mode of inquiry, as being the only one which can make the works of the geologist a philosophical history, and not a mere dry account of isolated facts.

I do not consider it necessary to dwell on M. Dumont's mineralogical essays, or on his description of Louisiana; but the paper which he read to the Academy of Brussels on the 22nd November 1834 deserves especial notice, as it refers to that much-vexed question, the origin of the volcanic craters of the Eifel. These he enumerates as craters of elevation, craters of eruption, and lake-craters; and he observes that the conical mountains, known in the Eifel as volcanic, have generally *no* appearance of a crater. They have a circular base, a summit more or less pointed, and tolerably uniform slopes: they are, for the most part, formed on one side by scoriaceous matter, and on the other by inclined beds of compact lava or tephrine, similar to that which extends into the plains in a more or less horizontal sheet, whilst at the foot of the inclined beds is often found a *trainée* of large blocks of the same description. These conical mountains, M. Dumont calls "cones of elevation", and he explains the facts described in the following manner. The compact lavas and the tephrines were already formed, had been spread in uniform sheets over the surface, and cooled before the scoriaceous matter had been forced upwards and exposed to view. The pressure from below upwards, exerted by this matter on the upper sheet of lava, first fissured it in a star-like form, over an extent of ground proportional to the force, the radii of the sector-like spaces proceeding from the point of application of the force; the scoriaceous matter then forced its way through by lifting up that portion of the sectors which offered the least resistance, escaping by the opening formed, and completing the cone, of which the elevated sector formed only a part. The blocks scattered over the ground at the foot of the sector were detached and projected at the time of the elevation. The mode of formation of elevation-craters, M. Dumont derives from the preceding explanation: when, for example, the sum of the areas of sectors raised constituted but a small portion of the circumference, the result was a conical mountain only; but when the larger portion or the whole of the sectors had been uplifted, the scoriaceous matter could no longer fill up the cavity formed, and a true crater of elevation was then the result. As an example, M. Dumont quotes the crater north of Mayen, near Ettringen, where the beds of tephrine which are horizontal in the quarries of Mayen are observed to be tilted up, whilst the scoriaceous lavas are seen to underlie them and to fill up several vertical fissures which correspond to the radii of the sectors. M. Dumont adds that there can be no doubt from a consideration of these facts, as to the mode of formation of this kind of crater. Of craters properly called craters of eruption, M. Dumont states that the only well-characterized one he has observed is that near Gerolstein, which is situated on the summit of a calcareous hill, and has a well-marked excavation, containing scoriaceous lavas. It would appear, then, according to this explanation, that when the flexibility of the strata is sufficient to yield to the pressure without being broken off, either a cone or a crater of elevation will be formed; but when inflexible, the mass of the rock is torn away, and a true crater formed, round which the scoriaceous matter would be then arranged. The lake-craters, though apparently proceeding in the first instance from the uplifting and rupture of a portion of the rocky crust of the earth, do not generally exhibit any appearance of true volcanic rocks, the place of the scoriaceous lavas being here supplied by agglomerates, the paste of which is dried mud, and the imbedded nodules fragments of the fissured schists and grits of which the borders of the crater consist. The volcanic bombs found in connexion with these craters, M. Dumont considered as having been projected through the mass of mud at the time of the eruption, the granular structure of the bombs being analogous to that which a vitreous substance strongly heated, and then suddenly cooled, would assume. This is an interesting view of a very obscure subject, and, though in a certain degree speculative, may be fairly considered as one of the most systematic explanations of the formation of craters which has, up to the present time, been attempted*.

* Whilst this address has been passing through the press, the subject has been

I trust what I have said will be deemed sufficient as affording an ample proof of the great and varied abilities of our deceased member, whose zeal and energy in the prosecution of his favourite science was such that Mr. Prestwich has estimated that he *walked* no less than 15000 miles whilst examining the geology of Belgium; for it was his rule to form his judgment entirely upon his own observations. He is gone; but his great labours will never be forgotten, and his excellent social qualities will be long and affectionately remembered.

M. P.A. Dufrénoy was born on the 5th September, 1792, and was therefore sixty-five years of age at the time of his lamented death. His mother, Madame Dufrénoy, was a lady of great literary acquirements and a poetess of considerable eminence, having founded her style upon classic models, the native language of Virgil and Horace being familiar to her. Amongst other works she wrote a poem on the last moments of Bayard; and its beauty merited and obtained the approbation of the French Academy, by which distinguished body it was crowned. This excellent woman, at a time when she had long suffered from illness, wrote the following touching lines, commemorative at once of her feelings of affection, and of her confidence in the future fame of her beloved son:—

> "Oui, mon fils, oui, ma noble idole,
> De mon été qui fuit, ton printemps me console.
> Eh! comment du passé garder le souvenir,
> Quand les mâles vertus de ton adolescence,
> Et tes savants travaux, suivis avec constance,
> Répondent de ton avenir!"

The recollection of this highly-gifted mother was always fondly cherished by her son, who was never weary of dwelling upon her high qualities as a wife and mother. Nor was he less fortunate in his marriage, as his wife, a daughter of M. Jay, was a fitting companion for such a man, and, after bestowing the necessary maternal cares on her three sons, of whom she was justly proud, was ever ready to assist her husband in his labours by correcting proofs, by translating works written in foreign languages, or by making drawings as illustrations of his own works. This amiable woman survives her husband, and must be an object of admiration and of respect to all men of science.

In 1803 M. Dufrénoy was a schoolfellow of M. Valenciennes, the celebrated ichthyologist, at the Lyceum of Rouen, where both the young friends acquired a taste for the study of the natural sciences; and, although they cultivated different branches, were often in communication with each other on scientific subjects, and finally became colleagues at the Museum of Natural History, and fellow members of the Academy of Sciences. Having completed his literary and

again discussed by one of our greatest and most philosophical geologists, Sir Charles Lyell, who considers the elevation-theory as untenable. This is not the place to enter into a discussion of his facts or arguments; but I may venture to say, that the force which was sufficient to raise the semi-liquid lava to a great height, and there to erupt it, must have been also sufficient to fissure and uplift the consolidated crust of the earth.—J. E. P.

scientific studies at the Imperial Lyceum, he entered the Ecole Polytechnique in 1811, and having attained a very high place in that institution, so well known for the high standard of education it maintains, he became one of the Corps des Mines in 1813. Soon after the establishment of a School of Mines, M. Dufrénoy was enlisted in its management; and it is justly said that its prosperity has been mainly due to the prudence and ability with which he has managed its concerns. He quickly associated himself with M. Elie de Beaumont, who bears the warmest testimony to his worth, both as a Professor and a Director:—"He was always," M. de Beaumont observes, "clear and solid, and knew how to fix attention on the most dry subjects, or to render the most difficult easy of apprehension: perhaps, indeed, crystallography had never an interpreter more successful or more elegant in his mode of explanation. As a Director he will ever be considered a model. With all his modesty, gentleness, constant desire to be strictly just, and indefatigable efforts to be useful, he always exercised his power with such judgment, that during 40 years passed at the School of Mines, the most perfect order was preserved. He never spoke harshly, and yet no one would have thought of disobeying him. Every one would have been grieved at the very thought of annoying him, and he constantly lived as it were amongst a body of friends." In 1823 he commenced, in conjunction with M. Elie de Beaumont, the important work of a Geological Map of France, and that at a time when the geology of France had been the subject of no detailed works, so that almost everything required to be founded on new observations. In less than twenty years this great work was finished, and is now considered by geologists of every country as an example worthy of imitation in all similar works, whilst it is a frequent work of reference to the practical agriculturist and other industrial agents of France.

It is to be observed that before commencing this great work, the two young friends visited England, which had become classic ground for geologists, in order to study there the Secondary formations, and it cannot be doubted that, whilst obtaining information on the one hand, they must have been instrumental in communicating it on the other. The publication of the "Metallurgical Voyage to England" was indeed a most valuable addition to our knowledge, as at that time there was no work extant in the English language which gave so complete an account of our mineral riches and of our industrial establishments for working them. He afterwards visited England on a special mission to examine the improvements which had been introduced into our foundries, and at the Universal Exposition of Industry in 1851 he was the delegate from France, when he was elected Vice-President and Reporter of a Commission composed of representatives of all nations. As a geologist, his labours were various and important, either conjointly with Elie de Beaumont, or independently by himself; it is said, indeed, that his works had a powerful influence in rendering geology popular in France, and that he deserves to be ranked amongst the first founders of the Geological Society of that country.

His researches in Auvergne, where he demonstrated the alternate disposition of tertiary lacustrine and volcanic strata, and those on the volcanic strata of the neighbourhood of Naples, where he distinguished between the trachytes and pumice of the Phlegræan fields and the ancient lavas of Somma, as also between those ancient lavas and the recent lavas of Vesuvius, are proofs of great sagacity and judgment. It is to be observed, however, that he shared with M. Elie de Beaumont and M. Dumont in the belief of the theory of uplifted craters, and endeavoured to explain the mathematical laws of those forces which have produced the elevation of volcanic cones,—a task for which his mathematical education at the Ecole Polytechnique had eminently qualified him: indeed such an education seems indispensable for all those who intend to deal with the phænomena of physical geology. His work, again, on the age and composition of the formations of the West of France is one of much ability, his principal object having been to determine the geological position of the principal iron-mines and of the rocks generally of the Eastern Pyrenees.

His work on Mineralogy is very extensive, and is one of great merit: it explains not only the physical and chemical properties of minerals, but also their geological relations; and a very good judge has particularly extolled his critical acumen and his fidelity, remarking that "it is much more common in these times, to find mineralogists ready, on very slight grounds, to establish new and ill-defined species, than disposed to efface from the nomenclature substances which have no right to figure there. It is, in fact, easy to assume the merit of having given a name to a substance without having taken the trouble to study it sufficiently for an accurate definition; but it is a long, difficult, and ungrateful task to demonstrate the errors of others." How true is this remark, and how applicable to the examination and determination of organic fossils!

So highly were the talents of M. Dufrénoy appreciated, that he was consulted on many difficult subjects extraneous to his ordinary duties, such as the purification of the Sologne and the management of the mineral waters of Vichy and Plombières; and it may be asserted that he was during his whole life the enthusiastic friend of science, and the successful promoter of every useful application of scientific knowledge.

M. Alcide D'Orbigny, Professor of Palæontology at the Museum of Natural History in the Jardin des Plantes, was remarkable for the vast magnitude, as well as for the interesting character of his palæontological works, intended as they were to embrace the whole field of geology in France, and, of course, comparatively to notice the relations of the ancient inhabitants of all portions of the earth whilst describing those of his native country. M. D'Orbigny was born at Couëzon (Loire Inférieure), and has been in succession Travelling Naturalist for the Museum of Natural History, Secretary of the Natural History Society, Member of the Central Commission of the Geographical Society, Assistant of M. Cordier in the Geological Course, and latterly placed in the chair of Palæontology which had been created expressly for him. He was a Knight of the Legion of Honour.

M. D'Orbigny commenced in 1826 his travels for the Museum, under the auspices of the government. As a student at Rochelle, M. D'Orbigny passed his earlier years on the sea-shore, and employed much of his time in examining the natural productions thrown ashore by the waves. Before he had attained the age of twenty-two, he presented to the Academy a work which was attended with great success, as the committee appointed to examine it reported that, from the great number of new species he had made known, he deserved to be placed in the first rank of original observers. In 1826 he proceeded, as Travelling Naturalist for the Museum, on a voyage to South America, where he explored, with equal perseverance, courage, knowledge, and success, Brazil, Buenos Ayres, the frontiers of Patagonia, and the Republics of Chili and Bolivia, from the shore of the Pacific Ocean to the centre of the continent: he afterwards went through the Republic of Peru, and, when he returned to France, had visited all that portion of the earth from the 11th to the 12th degree of latitude, and from the Pacific to the Atlantic Ocean.

As the product of this voyage, M. D'Orbigny brought home most extensive collections and manuscripts, numerous drawings of objects of natural history, and everything necessary to illustrate the geography, the languages, the ethnology, and archæology of this part of America: historical manuscripts, thirty-six vocabularies of the American language, a collection of animals containing 7000 species, of which many were new, and one of about 2300 species of plants, as well as much information respecting the geology of the countries he visited, were amongst the results of his labours, and were embodied in the great work entitled, "Voyage dans l'Amérique du Sud," published under the sanction of the Minister of Public Instruction. He also superintended the publication of another work, "Voyage pittoresque dans les deux Amériques;" and his labours were appreciated by the Geographical Society of France, which awarded him its annual prize in 1836. As an active, intrepid, and persevering traveller, he had thus made his way over an immense extent of country, from Brazil and Peru to Patagonia, in eight successive years, sometimes navigating previously unknown rivers, sometimes penetrating virgin forests, resting on the loftiest plateaux of the Andes, or in the plains of Patagonia, frequently finding himself amongst contending tribes, and being obliged to take part in their conflicts.

M. Alcide D'Orbigny, who had thus studied nature under all its varied forms, now devoted himself to a task not less deserving of the admiration of posterity, as he thenceforth consecrated his life to the study of Palæontology, a science which had only sprung into existence in the nineteenth century, and which has already enabled the geologist to study the ancient natural history of the several epochs of the earth's history, and to determine by that clue the true *relative* age of the mineral deposits with which the fossil relics of animals and plants, long since removed from observation as existing genera and species, are associated. It has been justly said that what he succeeded in accomplishing, in this new branch of science, was so vast as to be almost beyond the intelligence, and, I may add, the physical powers of any one man; and, as a proof, I will at present mention his Foraminifera of Cuba, of the Canaries, of Meudon near Paris, and of Vienna; his studies on the Crinoids, his "Prodrome de Paléontologie," his "Course of Stratigraphic Geology," and especially his "Palæontology of France," which has extended to fourteen volumes, and contains 1400 plates of French fossils.

M. D'Orbigny was removed by death only four years after he had been chosen Professor at the Jardin des Plantes, and before he had had time to complete his great palæontological works, though it is believed that he has laid the foundation of a palæontological collection worthy of France. I have on a former occasion spoken of the nomenclature introduced by him into geology, which, although founded in great measure upon that previously adopted in England, deserves, from its simplicity, and in many respects its euphony, the ready reception which it has obtained on the Continent. In respect to his great work on the Palæontology of France, I am aware that many English palæontologists consider that he has been sometimes too hasty in the creation of new species; but this error, I fear, is common to a large portion of palæontologists, and will not be entirely remedied until naturalists have made their comparisons, not with drawings, but with actual specimens. Making, however, every deduction on that account, the works of M. D'Orbigny must ever stand forth as a memorial of the most persevering industry and of a high order of intellect, in confirmation of which opinion I will briefly but more particularly notice some of his numerous works.

In doing so I shall principally confine myself to the notice of such works and opinions of D'Orbigny as affect materially either the philosophy or the practice of geological science. Such papers as his Monograph of the new genus of Gasteropods to which he gave the name *Scissurella*, or his description of two species of the genus *Pteroceras*, found in the jurassic limestone of La Charente Inférieure, or his essay on the beaks of fossil Cephalopoda, in which he divides the Rhyncholites into two divisions, belonging to different genera, one being the beaks of *Nautili*, and not of *Sepiæ*, as had been before supposed,—an idea supported by the anatomical description, by Professor Owen, of the *Nautilus Pompilius*,—or his note on the genus *Caprina*, his tabular view of the class Cephalopoda, his memoir upon a second living species of the family of Crinoids, to which he gave the generic name *Holopus*, and many other of his papers, are sufficient proofs of his great knowledge of, and accurate judgment upon, almost all branches of natural history; but others speak the language of a philosopher on such subjects.

Every one will doubtless remember the different opinions which were once entertained on the true position, amongst organized beings, of the Foraminifera, some naturalists having, from the resemblance of form, allotted them to the Cephalopoda: after a careful examination of the animal portion as well as of the shelly covering of these minute, often microscopical, bodies, he disproved the earlier notion of their alliance to the Cephalopods, which he had himself at first adopted, and proposed a general classification of the Foraminifera, founded upon the form of their shells, placing them amongst the Radiata, close to the Polypes. In this great and important inquiry he described and figured 118 new species from the Island of Cuba and from the Antilles, and afterwards 43 species from the Canaries, of which 33 were peculiar to those islands. Nor was it to living Foraminifera that he confined his attention, as he described and figured 54 species from the white chalk of the Paris basin, all, with the exception of three or four, new, and then again those which had been discovered by M. von Hauer in Austria, ending by the following statement of the geological distribution of Foraminifera :—

	Genera.	Species.
Palæozoic strata	1	 1
Jurassic strata	5	 20
Cretaceous strata	34	 280
Tertiary strata	56	 450
Existing epoch	68	 1000

So that it would appear that the genera and species were few in number and simple in structure at first, and increased both in number and complexity of structure from formation to formation, until they had obtained their maximum of development in the present seas. M. D'Orbigny even considered that this gradual advancement from simple to compound was more distinctly manifested in these minute beings than in any others, and that they are in consequence the best fitted for determining with precision the relative ages of geological strata. The following ten living genera, *Gromia, Rimulina, Conulina, Vertebralina, Caudenia, Pavonina, Robertina, Cassidulina, Uniloculina*, and *Cruciloculina*, M. D'Orbigny named as not having been as yet discovered in a fossil state; and he gave the following view of the climatal distribution of the Foraminifera, which cannot fail to be very suggestive to the palæontologist also. Torrid Zone, 375 species; Temperate Zone, 350; Frigid Zone, 75: so that, as in Mollusca, the seas of hot climates are more productive of species of Foraminifera than those of colder regions.

M. D'Orbigny traces the history of these bodies from their first discovery in 1731 to the present time; and as a proof of the importance of the office they may have played in the formation of some geological strata (the houses of Paris and the pyramids of Egypt being in part built of rocks composed of Foraminiferous shells), he states that little more than an ounce in weight of the sand of the Antilles yielded 480,000 of these shells. M. D'Orbigny concluded, from his examination of the Foraminifera of the Paris basin, that they had lived in a hot climate, and had not been subjected to the wearing action of any current.

In explaining the distribution of the Foraminifera of South America, M. D'Orbigny points out how varied the groups are, under the influence even of chorographic differences,—the Foraminifera of the southern shores of the Pacific differing from those of the southern shores of the Atlantic, and both from those of the equatorial region of the Antilles, from which fact he deduces the conclusions, that in the same sea, and in connexion with the same continent, different faunæ may exist at very small distances from each other; and further, that Tertiary basins, although different in their faunæ, may have been formed simultaneously, just as the material deposits are necessarily widely different in character at localities by no means very remote. Unquestionably the reasoning is good, and equally applicable to the geological deposits of all ages of the world*.

In his essay on the distribution of the Acetabuliferous Cephalopoda, he states, in reference to their present distribution, that 15 out of 16 genera are found in hot countries, 10 in temperate regions, and 6 only in cold; and he also concludes, from his inquiries, that these forms are more complicated as they inhabit hotter regions, and further, that it is probable the fossil genera lived under a high temperature. Taking account of this view of the subject, it is interesting to observe the other statement of M. D'Orbigny, that the Acetabuliferous Cephalopoda appeared first in the jurassic formation, when they were represented by the *Belemnites* and 6 other genera, including the existing genus *Sepia* and three other living genera, simultaneously with the vast numbers of *Ammonites*; that all disappeared except the genus *Belemnites* in the Cretaceous epoch, being represented, however, by different species; and that in the Tertiary strata, the *Belemnites* disappeared entirely, being replaced by the genus *Sepia* appearing for the second time, and the genus *Beloptera*, which appeared, only to pass rapidly away, as it is no longer a living genus. These are unquestionably very remarkable facts, and have on the one hand a tendency to support the doctrine which M. D'Orbigny so strongly supports, of the destruction of one creation and the production of another again and again at successive epochs, whilst, on the other, they may induce a pause in the decision of the palæontologist, as it seems difficult to conceive that any such genera as *Sepia*, *Sepioteuthis*, &c., could have been created so far back as the Jurassic age, and then have totally

* It must not be assumed from my remarks on D'Orbigny's labours in the *Foraminifera*, that I consider him to have arrived at his final results *per saltum*. Far from it, as in 1826 his object, as so well explained by Férussac, was simply to separate the microscopical *Cephalopoda*, as he then considered them to be, from the Siphoniferous genera with which they had been confounded. De Haan had previously proposed such a separation, and founded upon it his *Siphonoides* and *Asiphonoides*; but D'Orbigny felt that there were other differences, and therefore proposed his more distinctive term *Foraminifera*. His 'Prodromus,' published at that time, was founded upon this view of the subject, and remained the standard of classification until Desjardins, in 1835, gave many reasons, deduced from careful observation, for separating the *Foraminifera* from the Mollusca entirely, and forming of them a totally distinct class, to which he gave the name *Symplectomères*. Desjardins therefore gave the impulse which has since led to the correct classification of these microscopical but most interesting animals, which have been shown, by the examination of the deep-sea soundings of the Atlantic, to be as active now as in ancient epochs in laying the foundations of future strata.

disappeared, to be *again created* in the Tertiary and existing epochs. I must again maintain that it is more natural to conceive that the link of connexion between the dead and the living has been kept up, although hitherto the region of their habitation, during the long period of time elapsed, has been veiled from observation.

I shall not attempt further to follow the able author of no less than fifty distinct treatises, some of vast magnitude and interest, and all full of ingenuity and knowledge; but I may notice him as the author of that nomenclature which is gaining ground rapidly; and in doing so I will quote, as illustrative of his method, the distribution of the Bryozoa-Cellulina, which he thus details:—

		Genera.	Species.	
Terrains Crétacés.	Étage Néocomien	1	1	593 species.
	— Aptien	1	1	
	— Albien	1	1	
	— Cénomanien	11	26	
	— Turonien	9	17	
	— Sénonien	54	547	
Terrains Tertiaires.	Étage Suessonien	3	5	109
	— Parisien	12	24	
	— Falunien	40	75	
	— Subapennin	4	5	
Existing Fauna.		58	312	312

The Bryozoa-Centrifugina, which form the other division of the class, he discovered in almost all the geological formations, and he gives their numbers thus:—

	Genera.	Species.
In the Palæozoic	10	66
—— Triassic	0	0
—— Jurassic	32	93
—— Cretaceous	130	480
—— Tertiary	32	101
—— Existing epoch	26	80

And he concludes from the whole that there were *three centres* of development of the Bryozoa, the first two composed of B.-Centrifugina alone,—namely, one in the Carboniferous stage of the Palæozoic, and one in the Bathonian of the Jurassic,—and the other composed of both orders, Cellulina and Centrifugina, in the Senonian stage of the Cretaceous.

Having now, I trust, enabled every one to form a correct judgment of the great and varied abilities of M. D'Orbigny, in aid of whose researches the Society has twice awarded the proceeds of the Wollaston Fund, I will close my remarks with the following passage from the report of MM. Brongniart, Dufrénoy, and Elie de Beaumont, on his "Geology of South America," as it conveys a sentiment in which all our members will, I am sure, cordially concur:—

"The author's reserve, in treating upon a subject so vast and difficult, cannot but be approved, although no one can fail to perceive that the memoir of M. D'Orbigny has enriched science with a great number of new facts and with many ingenious speculations. New observations may hereafter lead to a modification of some of his theoretical views; but the merit will always be his of having considered a vast subject from a point of observation so elevated as must necessarily cause it to command attention, and lead the way to still further progress. We therefore propose to the Academy that it should express to the author the high satisfaction it has experienced in contemplating the indisputable advancement which has been made towards a knowledge of the geology of South America, by his courageous and persevering researches:"—let me also add, towards a knowledge of the geology of all parts of the earth; for his great works on the Palæontology of France deserve such a commendation.

Having now, I trust, faithfully performed my duty towards those illustrious members whom we have lost, and who during their lives were active either in promoting the progress of our own science or in advancing the general knowledge of mankind, I will turn to a work not so embittered by painful recollections, and proceed to estimate the labours of the past year.

The present Session has been characterized by the excellence and importance of its Palæontological papers: the first was contributed by Professor Owen, who exhibited and described an almost entire lower jaw, with the permanent dental series, wanting only four middle incisors, of an Anoplotherioid quadruped, from the collection of the Marchione s of Hastings, and now forming part of the Palæontological collection in the British Museum.

From the equality of height of the crowns of the teeth, and their general character, Professor Owen considered the animal as belonging to that group of the Anoplotherioid family which includes the genera *Dichobune* and *Xiphodon* of Cuvier, the animal being of the size of Cuvier's *X. gracilis.* The author then described in detail the dentition of the specimen, and pointed out its difference from that of *Dichodon,* and of *Xiphodon,* as also its agreement with that of *Dichobune*, with which genus therefore he associated it provisionally, in the absence of a knowledge of the molars of the upper jaw; and, after a comparison with the *Dichobune leporina* of Cuvier, he formed it into a distinct species, *Dichobune ovina,* from the size of the animal. The *Dichobune cervina* of his 'British Fossil Mammals' he transferred, on the suggestion of M. Gervais, to the genus *Dichodon.*

Professor Owen then compared the genus *Xiphodon* with the genus *Dichobune.* The first had originally formed part of the genus *Anoplotherium*; but the species *A. medium,* Cuvier, afterwards called by him *A. gracile,* was subsequently separated by Cuvier, and made the type of a new genus *Xiphodon,* as *X. gracilis,* to which Gervais (in 'Paléontographie Française') afterwards added the *Xiphodon Geylensis,* and described the dental series of both jaws of the typical species from a specimen obtained from the lignites of Debruge, near Apt. M. Gervais had given his reasons for considering the genus *Xiphodon* very approximate to *Hyopotamus*; but Professor Owen points out that both *Anthracotherium* and *Hyopotamus* differ from *Anoplotherium, Xiphodon,* and *Dichodon,* by the interrupted character of the dentition, which in the latter genera is continuous. The genus *Dichobune* had been also separated by Cuvier from the genus *Anoplotherium,* the species *A. minus* and *A. leporinum* having been transferred to this new genus, which is closely connected with the genus *Xiphodon*; it is, indeed, manifest that most able palæontologists have found it sometimes difficult to determine between such closely-allied genera, M. Gervais having in like manner transferred the species *Hyracotherium Robertianum* to the genus *Dichobune.* Professor Owen also made some interesting observations on the consequences of adopting the analogy of *Microtherium* or of *Anoplotherium* in determining the fore or back parts of the crown of the upper molar—an important point in settling the relations of a new genus,—he himself adhering to the *Anoplotherium.*

In respect to the first appearance of true Ruminants, Professor Owen remarked that the dentition of the upper jaw of the species *Anoplotherium murinum* and *A. obliquum,* referred by Cuvier to his genus *Dichobune,* must be known before the existence of true Ruminants in the Upper Eocene gypsum of Paris can be inferred. The following interesting remark closed his statement, and is worthy of careful attention; for, whilst it speaks of a formative force being transferred from one set of teeth to another, as an easy mode of effecting a transition, and shows how easily the Ruminant stomach might have been modified, it is impossible not to imagine how readily many transmutations might have been effected in the progress of time, without the aid of renewed creation. "No doubt the affinity of these small Anoplotherioids to the Chevrotains was very close; let the formative force be transferred from the small upper incisors to the contiguous canines, and the transition would be effected. We know that the Ruminant stomach of the species of *Tragulus* is simplified by the suppression of the psalterium, or third bag; the stomach of the small Anoplotherioids, whilst preserving a certain degree of complexity, might have been somewhat more simplified. The certain information which the gradations of dentition displayed by the above-cited extinct species impart, testifies to the artificial character of the order Ruminantia of the modern systems, and to the natural character of that wider group of even-toed hoofed animals, for which I have proposed the term Artiodactyla."

The next paper by Professor Owen was one on a small Lophiodont Mammal from the London Clay, near Harwich. Professor Owen first points out the rarity, and usually fragmentary condition, of the remains of mammals found in Eocene beds below the Binstead, Gypseous, and Headon or Hordwell series, either in our own country or on the Continent, and illustrates this position by referring to the fossil evidence upon which the genera *Pachynolophus, Dichobune, Pro-*

palæotherium (Gervais), *Macacus* or *Eopithecus*, and *Hyracotherium* have been established. This last-named fossil genus was founded upon "the portion of a cranium with the molar series of teeth;" and as he was enabled to determine a new genus, named by him *Pliolophus vulpiceps*, on "*an entire skull with the complete dentition of both upper and lower jaws, and a portion of the skeleton of the same individual, including the right humerus, the right femur, a great part of the left femur, the left tibia, and three metatarsal bones, apparently of the same hind foot*," and many other recognizable and important portions of the skeleton, he justly states that "it is the most complete and instructive mammalian fossil of the age of the London Clay which has hitherto been discovered, and its study is replete with interest. It was brought to the British Museum by Mr. Colchester, being imbedded in one of the Roman-cement nodules of the London Clay, near Harwich. The osseous tissue is fossilized, and partly impregnated with pyritic matter. It is well known how rich the cement-nodules are in fossils; and, a fragment having been chipped off the present one, the attention of the workmen was arrested by the appearance of what appeared to them the head of a fox. The specimen then came into the possession of the Rev. Richard Bull, M.A., vicar of Harwich, who placed it in the hands of Mr. Colchester to obtain the opinion of Professor Owen on its true character and relations. By him it was recognized as a new species, forming the type of a new genus, which he has named *Pliolophus*, meaning to imply that it was nearer to the Lophiodont-type than its close ally the *Hyracotherium*: the whole name *Pliolophus vulpiceps*, or Fox-headed Plioloph, expresses the peculiar form already alluded to.

It is unnecessary that I should enter into the anatomical details, worked out, as they have been, with the usual skill of Professor Owen; but I may mention some of the results. One portion of the cranium approximates the specimen to the carnivorous type, whilst in other respects it follows the rule of the Hog, *Hyrax*, and Palæothere—resembling, in the proportions of the zygomatic arches, the *Palæotherium* more than any existing mammal. In a similar manner its approximation on the one hand to, and its divergence, on the other, from several other genera, such as the *Rhinoceros*, *Tapir*, Horse, and *Hyrax*, *Anoplotherium* and *Hyracotherium*, are minutely investigated, as are also the similarly partial approximation and partial divergence in affinities as exhibited by a conjoint comparison of the skull and teeth of *Pliolophus* and various other genera. Professor Owen then states that *Lophiodon*, *Pachynolophus*, *Pliolophus*, and *Hyracotherium* form so many sub-generic modifications of the same natural family of Perissodactyle Ungulates, and that in the comparative simplicity of their premolars, and the progressive approach to the molar type of the Chæropotamoids, the *Pliolophus* and *Hyracotherium* both exhibit a tendency to a closer adherence to the general Ungulate type.

Professor Owen then observes that, "in stating that these modified

Lophiodonts are the most artio-dactyloid of the Perissodactyles, no particular hypothesis is advocated; there can be but one inference from this and the numerous analogous facts that have already been made known. So, likewise, in regard to the typical character of dentition as manifested by the number and kind of teeth, we find, in this last Eocene mammal which has come to light, a repetition of that remarkable adherence to a more general mammalian character. The older Oolitic mammals exemplify a tendency to a type of dentition of a still higher generality than the mammalian class." In this manner three genera of the Oolitic epoch resemble in their dentition the *general* Vertebrate type, whilst no less than 38 genera, belonging to the Eocene epoch, resemble in dentition the Mammalian Diphyodont type; but Professor Owen adds that "all general rules in organic nature have their exceptions, and differ in that respect from inorganic phænomena, in regard to some of the general laws of which no exceptions have been as yet discovered." If we consider this gradual change, from a more general type of vertebral organization to a more special type, to be the result of original creation, it seems difficult to understand the possibility of exceptions to any great law; but if it be considered only as the progressive modification of some type from a long series of ages of existence, it would seem quite natural and probable. The fact, however, though so strongly supported by Professor Owen, has been disputed in a paper, to be subsequently noticed, by Dr. Falconer, and the Professor has promised to consider at a future day the objection thus taken to his theory, which is unquestionably one of great importance in speculative Palæontology. A description of some of the bones of the extremities terminated this most interesting paper, and assisted to confirm the determination of the true position and affinities of *Pliolophus*, and most probably of *Hyracotherium*, also in the Ungulate series.

The bones of the hind foot of an Iguanodon, discovered by Mr. Beckles in the Wealden-clay of the south coast of the Isle of Wight, afforded materials for another short paper by Professor Owen. After stating the result of his investigation of these interesting relics, he observes,—"guided by the analogy of the number of phalanges in the toes of the hind foot of the Iguana, we may infer that the three toes that are normally developed in the hind foot of the Iguanodon, are the second, third, and fourth; that the first or innermost is represented by a rudimental metatarsal, which was concealed beneath the skin of the foot; and that the fifth or outermost was entirely suppressed;" a modification of the hind foot, he adds, which is interesting by its analogy to the tridactyle hind foot of the *Rhinoceros* and *Tapir*, and still more so by its correspondence in the varying number of the phalanges, and their progressive increase from the inner to the outer toe, with the foot of birds,—a fact which naturally suggests a caution in respect to the habit of referring the many large tridactyle impressions found in the Wealden and other formations, to the class of Birds.

A large femur, also found in the Weald-clay of Sandown Bay, Isle of Wight, was made the subject of a communication by Mr. Gibson, who stated that, though it had suffered much from pressure, Professor Owen had been enabled to state his opinion from a clay-model, that in all probability the bone was the femur of an Iguanodon, and if so, being the largest of its kind yet recorded, that it merited the attention of the Society.

Valuable as all these papers are, they afford only a small specimen of the continuous and successful efforts of the greatest Palæontologist of our day to enlarge our knowledge of the natural history of the earth at successive epochs; and it is most gratifying to know that the admiration we feel for such genius and skill is quite shared in by our Continental brethren; one proof of which may be derived from the following notice of a paper by M. Ed. Hébert, who has contributed an interesting memoir on a subject closely related to that which has engaged our attention, and, in the hands of Dr. Falconer, has produced such rich results. His principal object was to discuss the value of the genus *Coryphodon* of Owen, founded in 1846 upon a lower back molar, which in itself was very analogous to that of the Tapir, and consequently to that of the *Lophiodon*, but exhibited two transverse ridges instead of three, as in the *Lophiodon*. To this genus M. Gervais had correctly referred the *Lophiodon anthracoideus* of Blainville, considering, however, that the genus could only be considered a sub-division of *Lophiodon*. To determine the question of the validity of the genus, M. Hébert examines the dental formula, and shows that, whilst the lower molars differ little from those of the Lophiodons and Tapirs, the difference from each of these genera being about the same, the upper molars constitute a distinct type from those of all other Pachydermata,—the *Coryphodon* being more separated from them in this respect, than the Lophiodon, the Tapir, the Rhinoceros, and the Palæotherium are from each other. The canines, separated from the incisors by a space less long than in the Tapir, are powerful and characteristic, resembling those of no animal, living or fossil. The incisors are strong and regular, with blunt points, having a singular resemblance to those of *Anthracotherium*. M. Hébert concludes the comparison by observing that the formation of this genus from a single tooth is an example of the rare sagacity of Mr. Owen, and that, so far from any doubt being thrown on the validity of the genus *Coryphodon*, it cannot be doubted that future researches will bring to light new forms, intermediate between the *Coryphodon* and the *Lophiodon*. He has also determined the existence of two species of the genus, namely, the *Coryphodon eocænus* of Owen, found by M. Hébert in the lignite bed of the Soissonnais, and another called by him *C. Oweni*, from the conglomerate of the Plastic Clay, or lower in the series. The name *C. anthracoideus* is of course abandoned, as merging in *C. eocænus*. The *C. Oweni* was larger than the Tapir of India; and the *C. eocænus* must therefore have been an animal of large stature. M. Hébert then gives a tabular view of the mammiferous fauna of the Lower Tertiaries of France :—

Mineral Condition.	Physical Formation.	Mammifera observed.
Gypsum	Fluvio-lacustrine	Fauna very rich; Anoplotherium, Palæotherium, &c. the details not given.
Calcaire de Saint-Ouen	Lacustrine	Anchilopus Desmaresti, *Gervais*, wrongly quoted as from the Calcaire Grossier.
" "	Fluvio-Marine ...	Ossiferous conglomerate at the junction of these beds not yet studied.
Sables de Beauchamp..	Marine	None.
Upper Calcaire Grossier	Fluvio-Marine ...	Lophiodon Parisiensis, *Gervais*; Pachynolophus Duvalis, *Pomel*; P. Prevosti, *Gervais*; Dichobune Robertiana, *Gervais*; D. suilla, *Gervais*; and others, as yet undetermined.
Middle and Inferior Calcaire Grossier ...	Marine	None.
Conglomerate of Mont Bernon	Fluviatile ...	Pachynolophus Vismæi, *Pomel*. Several species of Lophiodon not yet described; Carnivores.
Soissonnais Sands. Upper, or of Cuisse Lamotte.........	Marine	None.
Soissonnais Sands. Lignites	Saltmarsh ...	Coryphodon eocænus, *Owen*. Paleonictis gigantea, *Blainville*.
Soissonnais Sands. Plastic Clay	....	None.
Soissonnais Sands. Conglomerate of the Plastic Clay	Fluvio-Marine	Coryphodon Oweni, *Héb.*; several other Pachyderms and Carnivores and a Rodent.
Soissonnais Sands. Inferior, or of Bracheux	Marine	Arctocyon primævus, *Blainville*.
Limestone and marl with *Physa gigantea*	Lacustrine ...	None.
White Sands of Rilly-la-Montagne	....	None.

Old-established labourers in Palæontology have not failed to contribute their quota towards the advancement of palæontological science; for example, Sir Philip Egerton has supplied an interesting paper on Fish Remains from the neighbourhood of Ludlow, which deserves special attention. He justly states the difficulty of the subject, and observes that little has been discovered, since Agassiz determined the Ichthyic affinities of the Cephalaspid remains in England, to have enabled even that great naturalist to advance a positive opinion as to their true place in the scale of nature. Agassiz, whilst referring two species, namely *Cephalaspis Lewisii* and *C. Lloydii* to the genus which he had originally founded on *C. Lyellii*, indicated the possibility that they might hereafter become the type of a new genus; this change has been effected by Dr. R. Kner, who formed the genus *Pteraspis*, a genus accepted by Professor Huxley and Mr. Salter, though on different grounds to those on which Kner's determination was made. With, therefore, every necessary reserve upon so difficult a point, Sir Philip has been able to establish, even from the imperfect materials furnished him, no less than three new species, namely *Cephalaspis*

Salweyi, *C. Murchisoni*, *C. ornatus*, restoring therefore to the genus a stability equal to that it had formerly obtained,—and one new genus and species, *Auchenaspis Salteri*, founded on a specimen perfect in every respect, and yet in size not larger than a fourpenny-piece—a genus closely allied to *Cephalaspis*, but yet structurally distinguished from it.

It is curious and worthy of notice, that the ichthyological portion of this subject has also engaged the attention of Professor Huxley, who has already attained a high place in the ranks of our Palæontologists. Reviewing the question of the affinities of *Cephalaspis* and *Pteraspis*, in a paper read before our Society, he refers to the opinion expressed by Kner, that *C. Lloydii* and *C. Lewisii* should be separated from the other species belonging to that genus, and placed in a new genus, *Pteraspis*, which, however, he considered a genus of Cephalopods, and not of Fishes. Roemer again more recently expressed an opinion that the *Pteraspides* are Crustacea; but, after a careful microscopical examination of the shields of *Cephalaspis* and *Pteraspis*, Professor Huxley has fully established the ichthyic character of *Pteraspis*, whilst at the same time he proves its just claim to be considered a distinct genus; so that this paper was a valuable confirmation of that of Sir Philip Egerton.

The importance of this inquiry of Professor Huxley had been stated by anticipation, and with his characteristic modesty, by Sir Philip Egerton, who observed, towards the close of his remarks, "much remains to be done with reference to the structural anatomy and true affinities of this curious family—subjects far beyond my grasp, but which I trust ere long will be grappled with by Professor Huxley, who has already bestowed some time upon them, and than whom no one is better qualified for bringing the inquiry to a successful issue."

Associated with the specimens described by Sir Philip Egerton, were portions of jaws resembling *Plectrodus mirabilis* rather than *P. pleiopristis*, an Ichthyodorulite resembling *Onchus Murchisoni*, and another, hitherto undescribed, which differs from the genus *Onchus* as now restricted, and in some characters approximates to the spines of *Ctenacanthus* and *Erismacanthus*; Sir Philip, however, offers a proper caution as to a reliance upon the forms of spines in determining specific differences. Sir Roderick Murchison added a few useful remarks on the relative position of the Ludlow strata which had supplied the fossils described by Sir Philip Egerton, as a note to his paper. In the section of the railway-cutting north of Ludlow, some of the highest beds of the Ludlow Rock have been brought, by an up-cast, immediately in contact with the Old Red Sandstone, constituting a small insulated mass, which is younger than and distinct from the bone-bed of the Upper Ludlow Rock, described in the 'Silurian System;' for, whilst the bone-bed is overlaid by the Downton-Castle building-stone and other grey strata which constitute the lower portion of the tilestones, the Railway-band, about 6 feet thick, is conformably surmounted on the south-east by micaceous sandstone and red shale or marl. Though, however, higher in the series, this thin band still contains some characteristic fossils of the lower course, such as *Plectrodus*, *Onchus Murchisoni*, and *Lingula cornea*: it contains a large majority unknown in any inferior stratum, viz.—*Cephalaspis ornatus*, Eg., a species of which Sir Philip expresses a belief that future specimens may reveal further characters, and lead to its union with *C. Murchisoni*; *Auchenaspis Salteri*, Eg.; *Onchus* or *Byssacanthus*; *Pterygotus anglicus*, Ag., and *Eurypterus pygmæus*, Salter;—the last two fossils having been recognized by Mr. Salter, who will describe them in the Survey Decades. Sir Roderick points out the manner in which the strata are so obscured by drift, that they can only be discovered here and there in the river-bank, where the water is very low, and hence suggests that the Railway-band, though its intermediate range is concealed by detritus, may yet be discovered in the banks or in the bed of the Teme. A fossil-band, called the Grit-bed, composed of a whitish-grey micaceous sandstone, was discovered by Mr. Lightbody higher in the series: it contains several of the fossils which have been mentioned, together with fragments of crustacea and coprolites; and, as amongst its fossils some of those most characteristic of the lowest of the bone-beds are found, it might at first be supposed to exhibit, though associated with red and green marls, the last remnant of Silurian life, were it not that other fossils show that it marks a passage upwards into the Old Red or Devonian system, and forms, in fact, the uppermost layer of the tilestones, whilst the red marls, sandstones, and cornstones which follow, with the *Cephalaspis Lyellii*, *Pteraspis Lloydii*, &c., form the great overlying masses of Old Red Sandstone. The determination of the true generic position of fossils must always be an important element towards the accurate identification of strata; but with every aid there must be many difficulties in settling the true age of strata which are connected with a drift-period; and the observation, therefore, of Sir Roderick in respect to the tilestones of Shropshire and Herefordshire, "that they may be classed either with the Silurian or the Devonian, according to the *predominance* of certain fossils," is both just and philosophical.

A conjoint paper by Sir Philip Egerton and the Rev. P. B. Brodie contains an account of the discovery, by the latter geologist, of a new species of *Palæoniscus* in the Upper Keuper Sandstone, at Rowington, near Warwick, and a careful ichthyological description of it by Sir Philip. In this he points out the difference, as regards the remote position of the dorsal fin, which separates it from all the other known species of the genus except the little *P. catopterus* of Roan Hill, county of Tyrone, Ireland, formerly considered to belong to the New Red Sandstone, but now transferred, as other supposed portions of the same formation have been, to the Permian. Though the specimen was not perfect, Sir Philip considered it sufficient to prove that it was a true heterocercal fish, and not one exhibiting a transition between the heterocercal character of Permian and other earlier strata, and the homocercal character of the Liassic fish. The dorso-ventral scales are arranged in gentle curves, which give an appearance of much elegance to the species, which is named by Sir Philip

P. superstes, as being probably the last surviving representative of a genus "which occupied so important a place in the fauna of the Carboniferous and Permian epochs." The Rev. Mr. Brodie also states that "another and entire fossil fish has been obtained from the Keuper Sandstone, but that the possessor has not yet been persuaded to place it in the hands of a palæontologist for examination and description." He mentions also the discovery of more vegetable remains, amongst which are several which appear to be the *calyces of some flowering plant.* The occurrence of so many vegetable impressions in beds so closely associated with those containing the fossil fishes in this locality, and the similar occurrence of *Posidonia minuta,* now considered by some able palæontologists as a Crustacean (*Estheria*), seem to suggest a freshwater habitat for the genus *Palæoniscus*; and I will only add that the analogy in anatomical structure of extinct with existing fishes is not always sufficient to prove that the medium in which they lived must have been the same.

The next paper was one pregnant with interest, as it brought before us proofs of a terrestrial fauna in the Purbeck region, which had been previously represented only by the fossil mammifer named and described by Professor Owen as *Spalacotherium tricuspidens,* a small insectivorous form, referred with some hesitation to the Placental series. It was discovered by Mr. W. R. Brodie in one of the *dirt-beds* of Durdlestone Bay, Purbeck; and the same observer afterwards found other mammalian remains, also in a dirt-bed, which he forwarded to Professor Owen for description. Mr. Samuel H. Beckles, who had already gained much experience by his researches in Sussex and the Isle of Wight, now entered on the field, and being encouraged and assisted by the judicious advice of Sir C. Lyell, who has always maintained that the non-discovery of the remains of terrestrial animals is no decided proof that they had not existed, proceeded to Swanage to commence that close and steady search for mammalian remains which has resulted in the discovery of what would be considered a rich local terrestrial fauna, even in the present state of the earth, some reptilian remains having been mixed with those of the mammals. The whole collection has now been submitted to Professor Owen for his final examination and description; but in the first instance they were wisely sent to Dr. Falconer, who, being able—as a consequence, I am sorry to say, of frequent confinement to his house by ill health—to devote his immediate attention to them, was in a condition to give Mr. Beckles useful hints in the progress of his search. Dr. Falconer soon recognized no less than seven or eight genera of Mammalia, some of them unquestionably Marsupials, both predaceous and herbivorous, others, in Dr. Falconer's opinion, more probably Placental Insectivora, having affinities, more or less remote, to existing types. Having been requested by Mr. Beckles to describe one of the most remarkable genera, as a contribution to the Supplement of Sir C. Lyell's 'Manual,' then about to be published, Dr. Falconer favoured the Society with a more detailed statement of the result than was necessary for the former purpose.

The genus *Plagiaulax* (being an abbreviation of *Plagiaulacodon,* from *plagios*, "oblique," and *aulax*, "groove," in reference to the diagonal grooving of the premolars) has been established by Dr. Falconer; and he has been already enabled to distinguish two species, one named *P. Becklesii* in commemoration of the zealous discoverer of the specimens upon which it is founded, and *P. minor*. Dr Falconer points out that the coronoid process in *Plagiaulax* resembles more that of the predaceous Marsupials, and especially of the Ursine *Dasyurus*, than it does that of the herbivorous families, differing in a marked degree from the elevated strap-shaped coronoid of *Hypsiprymnus*, though at the same time being less elevated than in the predaceous genera whether marsupial or placental; but, after a more careful investigation of the question of affinity in every direction, he concludes that *Plagiaulax* may be considered as a marsupial form of Rodent, constituting a peculiar type of the family to which *Hypsiprymnus* belongs. The genus must have presented a form to which there is nothing exactly similar in living marsupials.

It may, he observes, for aught which can be asserted to the contrary, have had the volant habits of the Flying Phalangers, and have flitted from tree to tree among the Oolite forests by means of parachute-like folds of the skin. The species were probably herbivorous or frugivorous like the Kangaroo-rats; but there is nothing in their teeth to show that they were either insectivorous or carnivorous. The largest species was about the size of a squirrel, the other much smaller. Professor Owen has designated another form by the generic name of *Triconodon*, so that at present there are three described Mammalian Purbeck genera—*Spalacotherium*, *Triconodon*, and *Plagiaulax*. Dr. Falconer also points out the remarkable resemblance between the molar teeth of *Plagiaulax minor*, and those of the Triassic genus *Microlestes antiquus* of Plieninger; and this resemblance may help to settle the true character of the *Microlestes*, supposed by some to be predaceous, by others to approximate to an omnivorous or omnivoro-insectivorous type.

Dr. Falconer further remarks in respect to the speculative views of palæontologists,—that, whilst they do not consider that there is any satisfactory evidence of a progressive serial development from the lower to the higher forms, there has been another form of serial progression, namely, from the general to the special, the animals of the older period being more perfect in respect to an archetype, or, as it may be called, a normal type, whilst by degrees there is a divergency from this archetype, in order to assume a more special character, and to progress towards a special adaptation to new circumstances or conditions of life. Now *Plagiaulax* is, as Dr. Falconer observes, the oldest herbivorous mammal yet discovered; and yet, so far from adhering to the general archetype, it is far more specialized than are any of the Marsupials, whether fossil or recent, exhibiting characters, at the earliest epoch, which ought rather to have been found in animals of the existing epoch,—a fact, therefore, which is entirely at variance, in his opinion, with the theoretical views to which I have alluded in speaking of the paper of Professor Owen. The case is one of difficulty; and I will only repeat that it cannot be explained by the supposition of any exceptions to a primary law of nature or of organization.

Two other communications of Dr. Falconer were on the species of Mastodon and Elephant found fossil in Britain,—the first paper relating to the Mastodon-remains of the Norwich or Red Crag, all of which are referred, so far as present knowledge permits their identification, to one species—the *M.* (*Tetralophodon*) *arvernensis* of Cuvier and Jobert, a pliocene form. In a similar manner he examines the species of Elephants, and shows that, associated with the *Mastodon arvernensis*, occur *Elephas meridionalis* and *E. antiquus*, as well as *Rhinoceros leptorhinus* and *Hippopotamus major*,—an association the same as that of the Val d'Arno, or of the Subapennines; and this of course excludes the opinion which had been advocated by many, that there was really only one species of Elephant, *E. primigenius*, extending over both miocene and pliocene formations.

So far, indeed, from admitting only one species of Elephant in the deposits of Europe, and therefore assuming that the same species had been contemporary with two species of Mastodon, Dr. Falconer considers that he has fully established four distinct species, and further proved that the several species of Elephant, as well as the species of Mastodon, are limited to peculiar formations in so marked a manner as to justify him in ascribing a higher value to them and to other air-breathing animals, for determining geological epochs, than to the relics of Mollusca or other marine animals.

To effect so important an object as is implied by this deduction, it was manifestly necessary that the most careful scrutiny should be applied to the determination of the true characters both of genera and species. In treating of the Mastodon, Dr. Falconer had, for example, pointed out that the obscurity which had crept over the determination of the faunæ of the Miocene and Pliocene periods was the necessary result of the fusion of several really distinct forms, belonging to different geological ages, into one species—the *Mastodon angustidens*; and in like manner he shows that the same confusion has existed in reference both to the geographical range, and period of existence as a species, of *Elephas primigenius*, or the Mammoth, which, having been quoted as existing at the time of the deposition of both the lower and upper pliocene beds, and also, when the post-pliocene glacial gravels were distributed, must have continued its existence over a vast extent of time and space, in spite of the convulsions which had attended the elevation of the Alps, Apennines, and Pyrenees, and given rise to the present geographical contour of the European area. In order to unravel this confused jumble of many species into one, Dr. Falconer points out the peculiarities of dentition, and, assuming these peculiarities as permanent, or, in other words, as depending on an organic law, not on a mere casual modification, he explains the characters on which several subgenera have been established, and shows that, just as *Tetralophodon arvernensis* had been separated from *Mastodon* (*Trilophodon*) *angustidens*, so also must *Elephas* (*Euelephas*) *primigenius* be separated from *Loxodon meridionalis*, *L. priscus*, and *Euelephas antiquus*, however near to each other in some respects they may be.

By this reasoning, then, it appears that the following genera are grouped together in the older pliocene deposits of several important localities: viz. Piedmont and Lombardy—*Trilophodon Borsoni, Tetralophodon arvernensis, Loxodon meridionalis, L. priscus, Euelephas antiquus,* together with *Rhinoceros leptorhinus* and *Hippopotamus major.* In the Subapennine beds of the Val d'Arno, in Tuscany—*Tetralophodon arvernensis, Loxodon meridionalis,* with the same Hippopotamus and Rhinoceros. Near Chartres in France—*Loxodon meridionalis* with the same Hippopotamus and Rhinoceros. In the Crag deposits of the Eastern coast of England—*Tetralophodon arvernensis, Loxodon meridionalis, Euelephas antiquus,* associated at Cromer and other places in Norfolk, as well as in the Valley of the Thames, with *Rhin. leptorhinus,* and *Hipp. major*; so that the resemblance between the two extreme localities is even greater than between either of them and the intermediate.

On the north of the Alps, the regular characteristic fauna of the Pliocene epoch becomes confused by the introduction of species foreign to it, proceeding from the erratic drift, in some cases a glacial drift; and this has been the case also in proximity with the newer gravels of England, so that the *Euelephas primigenius,* the Mammoth of the Siberian glacial period, the *R. tichorhinus,* and the Musk Ox (*Bubulus moschatus*) of the Post-pliocene fauna have been accidentally mixed with the fauna of the Pliocene. Whilst, however, thus separating the fauna of the true Post-pliocene beds from that of the Pliocene, Dr. Falconer considers that the chronological subdivision of the Upper Tertiaries into Older Pliocene and Newer Pliocene or Pleistocene is untenable, as he considers too great a stress has been laid upon shell-evidence—at the same time stating that he is far from supposing that all the species of this remarkable fauna ranged equally throughout the area, as it is at least probable that some were peculiar to the south, and others to the north. The apparent restriction, indeed, of *E. primigenius* to the region north of the Alps, in Europe, and again to the Northern and Central States of North America, is a fact of great importance, whilst the occurrence of the Hippopotamus gives a fair indication of the climatal and physical conditions of the country.

A short paper of Mr. W. Bollaert, F.R.G.S., on the occurrence of bones of Mastodon in Chili, was communicated by Professor Owen, who states that the fragments of bone taken from the Lake of Taguatagua, 45 leagues south of Santiago de Chili, are parts of a femur and tibia of a *Mastodon,* probably *M. Andium,* Cuvier. Mr. Bollaert observes that few instances of the discovery of fossil bones on the western side of the Andes have been recorded, and that he had been unable to discover any traces of such bones, either on the Isthmus of Darien, where many railway-cuttings were in progress, or on his journey southward to Chili, until his friend, the British Consul at Santiago, Mr. George Smith, presented him with the above specimens which he had himself taken from the Lake Taguatagua. The lake is 2300 feet above the bed of the Pacific Ocean, and is surrounded by very high hills, called the Borbollon, of volcanic origin, the highest peak rising to the height of 7000 feet above the margin of the lake. It receives no streams from the mountains, but, being supplied from springs, is generally as full in summer as in winter, and appears to Mr. Smith to be the exhausted crater of a volcano. In cutting a ditch from the lake towards the mountains, the fossil bones were found at the depth of 30 feet, the first animal discovered being almost perfect, excepting the head, and another skeleton of smaller size being very near it. Mr. Smith found fossil branches of trees in the same trench; and as its width was only 12 feet, he naturally concluded that a wider excavation in the alluvial soil would have yielded the remains of other individuals, and in consequence suggests, "may not herds of these creatures have been destroyed whilst feeding on what at that time was an extended plain?" The teeth of one of these animals are in the museum at Santiago; and there can be no doubt that the skill of a Falconer would be enabled to determine whether, in South America also, there is a difference between the Mastodons of the East and West, the *M. Andium* having been found both east and west of the Andes, in Peru and Chili, and the *M. Humboldtii* in Buenos Ayres and Brazil, or entirely to the east. Without doubt, this wide distribution in the ancient fauna of a type of organization so comparatively restricted at present in its range, is one of the most curious natural-history phænomena which the researches of geology have brought to light.

In the class Crustacea, two additions have been made to our knowledge, both of which are interesting, as tending to approximate the faunæ of past epochs to that of the present,—a remark I have frequently on preceding occasions been led to make. The one is a Decapod from the Lias Bone-bed, described by Mr. C. Gould of the Geological Survey, to which it had been confided for examination by Mr. E. Higgins, of Birkenhead. Mr. Gould after describing carefully the specimen, investigates the affinities of the fossil individual to known genera and species, and points out in what respects it resembles, and in what it differs from, the several great divisions of the Macrura; he then states that, although there is an affinity in some respects with the genera *Nephrops* and *Scyllarus*, he does not think the evidence sufficient for assigning it to those or any existing genus of Macrura, and he therefore constitutes a new genus for its reception. The names assigned to it are *Tropifer lœvis*,—the generic term (from τρόπις, "keel") expressing the keeled character of the carapace, and the specific its general smoothness. The eyes are large and remote, and the abdomen flattened and sculptured.

The next was derived from the Coal-measures, and is the result of the examination, by Professor Huxley, of three specimens, two of which belong to Mr. R. S. Cooper, of Bilston, and the third, being the most perfect, to the Manchester Museum, which were obtained from the Coal-shales at Midlock Park Bridge. Professor Huxley describes minutely the structural peculiarities of the specimens, and explains the difficulty of even deciding "which end was the head, and which the tail, and whether the surface exposed to view was the ventral or the dorsal." Assuming the dorsal surface to be in view, his first impression was, that the form combined the characters of *several orders* *of Crustacea*. Taking, however, into account all the objections to so anomalous an interpretation, he next reversed his hypothesis, and assumed "the quadrate disk to be the head, the hemispherical disk to be the caudal extremity, and the exposed face to be ventral,—a supposition which, though still not free from difficulty, exhibited, on a comparison of the specimens with the *Mysis* or Opossum-shrimp of our own sea, such curious points of resemblance as could not be considered merely accidental; and he therefore concludes that the *Pygocephalus Cooperi*, which is the name he adopts, is probably more nearly allied, notwithstanding an approximation in some respects to the *Squillidæ*, to the *Mysis* than to any other existing form, that it is therefore a Podophthalmous Crustacean, and may safely be assigned a place among either *the lower Decapoda or the Stomapoda*, affording the first certain evidence of the existence of *Podophthalmia* at so early a period as the Carboniferous epoch.

In another paper, Professor Huxley described a new species of *Plesiosaurus*, procured at Street, near Glastonbury, and now in the Museum of Practical Geology, Jermyn-street. As this species will be described at length in the Decades of the Geological Survey, the object of Professor Huxley was principally to point out the peculiarities of the atlas and axis, and of the cranium of that genus. The species resembles most *P. Hawkinsii*, and is about the same size, being between seven and eight feet long; but it has 53 cervico-dorsal vertebræ, of which 30 are cervical, whilst in *P. Hawkinsii* there are 31 *cervical*, and at least 23 dorsal. The species is therefore characterized as having 53 cervico-dorsal vertebræ, by a cranium not more than $\frac{1}{12}$th of the length of the body, the 30 anterior vertebræ being fully, or more than, four times the length of the cranium. It has been named *P. Etheridgii*. The atlas and axis are (as stated by Professor Owen to be characteristic of the genus) anchylosed; but their structure is very different from that exhibited in the genus *Ichthyosaurus*, and more nearly resembles the corresponding parts of the Crocodile.

Professor Huxley then pointed out the many points of structural correspondence between *Plesiosaurus* and *Teleosaurus*, and questions the accuracy of the very backward position of the posterior nares ascribed to *Plesiosaurus*, which would be in opposition to such an analogy, as the posterior nares in *Teleosaurus* are far more forward than in *Gavialis*, and in the Gavial more forward than in the Crocodile. He thinks it therefore more probable that the so-called posterior nares of *Plesiosaurus* correspond with the deep fossæ on either side of a prominent median ridge visible on the under surface of the basi-sphenoid of *Teleosaurus*. Some other structural analogies between *Teleosaurus* and *Plesiosaurus* were noticed; and Professor Huxley stated that in many respects the *Teleosaurus* appeared to afford a link, before not noticed, between the long-necked *Enaliosaurus* and the existing Crocodile, a conclusion in the interest of which, when the relations of time are considered, the genus *Plesiosaurus* must manifestly share.

In respect to the ancient flora, Mr. Salter has submitted a notice of some terrestrial plants from the Old Red Sandstone of Caithness, the specimens being, however, merely fragments, and, as such, only capable of an approximate determination. The best have been lent for examination, by Mr. John Miller, of Thurso; and Mr. R. Dick has materially added to the discoveries. Similar plants have been found at Wick by Mr. C. W. Peach, and by Dr. Hamilton in Orkney. All the collections have passed under the observation of Mr. Salter. The fossils are preserved in hard, grey, sandy flag-stones, many of which are marked by Annelide borings; and it was suggested by the late Hugh Miller, that these strata had been accumulated on an extremely level muddy shore: some appear to have been fragments of large stems, occasionally three feet long, and are straight and finely fluted; others, which are curved and occasionally branched, were probably roots. They are highly bituminized, and divided by oblique lines, evidently due to mineral structure. From compression, the silex stands out in relief, and the resulting impressed lines may be mistaken for marks of organic structure, similar lines noticed by Dr. Hooker in calamites from near Lerwick having been ascribed by him to "pressure during silicification." The large stems are considered by Mr. Salter to have belonged to Coniferous wood, and the structure, or thick woody envelope, surrounding a central pith, to be allied to that of the *Dadoxylon* of the Coal-measures; and in confirmation of his opinion, Mr. Salter refers to the authority of Professor Quekett, who examined for him microscopically some sections, and found the ordinary Coniferous structure,—namely wood-fibres dotted with disks, which appear to have been in alternating double rows, as in the modern *Araucaria*. The dotted structure distinguishes the specimens from other fragments of fossil-wood without disks, described by Professor Unger. Some smaller branches, bearing branchlets at intervals, are referred to the same plants. Some of the supposed rootlets are marked by tubercles, as are the roots of many Conifera, and cannot, in Mr. Salter's opinion, be ascribed to marine plants. Of Lycopodiaceous plants, Mr. Salter names one *Lycopodites Milleri*; and the other he thinks may be *Lepidodendron nothum*, Unger, though not exactly agreeing with the figure given by Unger, which, however, appears to represent the cicatrices, not the leaves themselves. Professor Unger considered his plants as constituting a new type, and they came from the Upper Devonian of Germany, whereas the strata from which the fossils described by Mr. Salter were derived have been determined by Professor Sedgwick and Sir R. I. Murchison to belong to the Middle Devonian, and were associated with the genera of fishes *Dipterus* and *Diplopterus*. An interesting note was appended by Mr. John Miller, descriptive of the Devonian beds of Caithness, which had yielded these plants.

Mr. C. J. F. Bunbury, F.R.S., has taken advantage of an interesting fossil specimen of the genus *Neuropteris* from the Coal-measures of Lancashire, to throw some light upon the true character of that genus. He points out the extreme rarity of specimens of young half-expanded fronds of Ferns, showing the characteristic circinate vernation. Those hitherto figured have belonged to the genus

Pecopteris; but the present specimen exhibits a well-marked example of the circinate condition in *Neuropteris*, and proves that it did not belong to the Coniferous order. The only flowering plants which can be compared with Ferns in this respect are the *Cycadeæ*; and Mr. Bunbury admits the difficulty of deciding, in the absence of fructification, whether *Neuropteris* may not have belonged to that family, though it is far more probable, from all the observable characters, that these plants were true Ferns: the present specimen he considers to belong to *N. gigantea*. Mr. Bunbury concluded his paper by stating that the genus is principally characteristic of the Coal-measures,—no *genuine* species from a formation later than the Trias having come under his notice, whilst the Oolitic species referred to the genus by Lindley and Hutton do not agree with its characters. *N. Loshii* and *N. tenuifolia* appear, he observes, to be common to the Carboniferous and Permian systems; and he adds that the species have been too much multiplied by describing the ordinary and possible variations in the same frond as distinct species. I need not add that this short addition to our more critical knowledge of an important fossil genus of plants exhibits Mr. Bunbury's well-known botanical skill and accuracy of judgment.

Foreign palæontology.—Of all living animals, the Edentata are perhaps second only to the Marsupials in the interest attached to their organization and habits; but, unlike the Marsupials, they possess another claim to our admiration, in the fact that they have not as yet been traced beyond what may be considered the natural terrestrial range of their distribution. We can still study the wonderful organization and the singular habits of the Armadillo and the Sloth in the original cradle of the first birth of the order; and Professor Owen has pointed out to us that they are but the relics of a larger fauna characteristic of South America, and once enriched by the *Glyptodon*, the *Mylodon*, and the *Megatherium*. A memoir upon the *Glyptodon*, by Professor Owen, has appeared in our Transactions; and my object at present is to bring under your notice a memoir by M. L. Nodot of the Academy of Dijon, and published in its Transactions.

M. Nodot first reviews the history of the progress of knowledge in respect to the peculiar form of organization of the Edentata, and specially of the *Glyptodon*, and justly remarks that it was not till the great Cuvier had given so powerful an impulse to the study of fossil organic remains, that travellers began to bring home specimens of such relics from distant countries. We are all aware with what skill Professor Owen treated the investigation into the Osteology of the remarkable genus *Glyptodon*; and M. Nodot states correctly that he recognized and named, from specimens in the Museum of the College of Surgeons, four species, to which he added afterwards, without describing it, a fifth species; but M. Nodot adds that the number has now been, to his own knowledge, tripled. He then proceeds to describe these species, making a wise reservation when he observes that, not being acquainted with the descriptive characters of the three species named by Dr. Lund *Hoplophorus euphractus*, *H. Selloi*, and *H. minor*, it is possible that he may have sometimes applied new names to some of those species. He further observes that one of the four species described by Professor Owen was not, in his opinion, sufficiently known to be accurately determined, and ought perhaps to have been transferred to a separate genus.

M. Nodot had the advantage of examining a very valuable collection of remains of Edentata, brought home from South America in 1846, by Vice-Admiral Dupotet, and which his widow, in conformity with his wishes, conferred upon the Museum at his untimely death. The larger portion of his collections had been previously deposited in the Museum at Paris; but this generous contribution to the treasures of a provincial museum consists of 2000 fragments, more or less valuable, but which were all confusedly packed together in the chests containing them. The task of identification and restoration was necessarily very great; but M. Nodot carried it on vigorously and successfully, adopting as rules for preparatory selection—1st, the colour of the fragments; 2nd, the thickness of the fragments; 3rd, the peculiar markings or figured designs upon them; 4th, anomalous forms, tubercles, &c.; by which arrangement the whole number of fragments were reduced into 30 groups, and the examination greatly simplified, whilst M. Nodot was enabled by the same means to compare the specimens at Dijon with those at Paris, and thus to supply many deficiencies in the parts of the former by castings from analogous portions amongst the Paris specimens.

Having thus completed the reconstruction of his species, M. Nodot compares it with the *Glyptodon clavipes* of Owen, and notes the following differences:—

1st. The carapace or cuirass is much more convex than in *Glyptodon clavipes,* and resembles the form of a truncated pear more than of a cylinder,—a difference which may be sexual, but in that case would mark the specimen as having been a female.

2nd. Nearly all the osselets which compose the cuirass are hexagonal, whilst in *G. clavipes* they are pentagonal. Besides, the circular or ovoidal markings, situated on the front of the central line of the osselets in the *G. clavipes,* are on the posterior extremity in the Dijon species.

3rd. The tubercles which form a border to the carapace of *G. clavipes* are all alike in form and size, and are supported on two rows of osselets, whereas in the other species the tubercles are disposed in series of different forms, and several are articulated with only a single row of osselets, their edges being angular and imbricated, which gives a segmentary character to the sides of the animal.

4th. The carapace of the *G. clavipes* exhibits not a trace of an anterior or posterior buckler, whilst it is distinctly visible on the lower margin of each side of the carapace of the other.

5th. The tail of the *G. clavipes* is composed of pieces strongly articulated, and intimately connected together, which form a homogeneous and inflexible sheath, which envelopes the vertebræ of the tail, whilst in the other the tail is merely annulated and extremely flexible, both laterally and downwards, having also a series of supplementary tubercles articulated on the axial line of each ring, of which the probable object is unknown. On the basis of these distinctive characters, particularly on the flexibility of the tail, M. Nodot considers himself justified in establishing a new genus, to which he has given the name *Schistopleurum* (from *σχιστὸς, cut, πλευρὸν, side*), in reference to the segmentation, by which character it is approximated nearer to the genus *Armadillo* than to the *Glyptodon*. I do not think it necessary to follow M. Nodot into minuter details, from the consideration of which he has established three species of his new genus, *S. typus*, *S. gemmatum*, *S. tuberculatum*, and added to the genus *Glyptodon* five, viz. *G. subelevatus*, *G. elevatus*, *G. gracilis*, *G. quadratus*, *G. verrucosus*: but I may add, he considers that the genus *Hoplophorus* of Lund should be retained, as being distinct from the genus *Glyptodon* of Owen, being characterized by its club-shaped tail; and he therefore names the *G. clavicaudatus* *H. clavicaudatus*, which, however, appears objectionable, as a generic peculiarity cannot be properly used as a specific designation. This genus is remarkable for its great size, M. Nodot remarking that he has only observed two species, *H. euphractus*, and *H. Selloi*, both of which were of the size of an Ox; and it may well be understood how useful the short club-shaped tail must have been in supporting the weight, probably more than 4000lbs., of so large an animal, with its covering coat of mail. It is curious that all these three genera are linked together by the same dental formula, and by the same sculptured teeth, which led to the adoption of the name *Glyptodon*,—the number and kind of teeth being the same in both jaws, viz.: $\frac{8\cdot8}{8\cdot8}=32$, whilst the formula in the Armadillo is $\frac{9\cdot9}{8\cdot8}=34$. This group does not appear to have ever migrated from the regions of South America, although the Megatherium wandered more northwards; they formed therefore a local fauna of the highest interest, which is now only faintly represented by the Armadillos, including the genera *Dasypus*, *Tatusia*, *Xenurus*. M. Nodot considers, from the positions in which they are found, that they inhabited the Pampas, on the banks of rivers or of fresh-water lakes or pools, where they doubtless found an abundance of those plants which grow in damp localities and might have been easily scratched up by the slender yet rigid feet of these animals. It would be unwise to accept such large additions to so remarkable a group without strict scrutiny; but it is impossible to read the memoir of M. Nodot without the greatest gratification, and I may add that his views on classification, and on the plans of organization, are very ingenious. There appear to have been, he observes, three such plans,—the first, in which the body is equilibrated horizontally, the centre of gravity corresponding with the centre of the axis which passes through the length of the animal; the second, where the body is equilibrated vertically, the centre of gravity being behind the centre of the longitudinal axis; and the third, in which the organization is sometimes conformable to the first type, and at other times to the second.

These views are illustrated in reference to the Mammalia by the different modes of progression of various animals, as, for example, amongst the Carnivora, in which the Lion and the more humble Cat are well known to preserve in leaping a horizontal position, by extending forwards their necks and front limbs, and backwards their hinder legs and tail, and thus to maintain their equilibrium in that direction, which would be destroyed were the animal deprived of its tail, and amongst the Solipedes by the Horse, the neck, limbs, and tail of which are also thrown into a horizontal position in leaping. Well may M. Nodot observe that he cannot comprehend on what principle the English have adopted the barbarous practice of docking the tails of horses! In all such animals the tail is in great measure a counterpoise; but in those which are equilibrated vertically, it becomes one of the organs of support, as in the Marsupials, and still more strikingly in the fossil genera which have been the subject of M. Nodot's essay; and it is therefore curious that animals of so distinctive a type of organization should have been so restricted in distribution, both as regards space and time: and with this remark I shall close my notice of the valuable essay of M. Nodot, which I trust will attract the attention of some of our able palæontologists.

In my last Address, I commented at some length on the description of numerous species of fossil Chelonia found in Switzerland, by MM. F. J. Pictet and Alois Humbert, and which are relics of the organic life of the Mollasse or Tertiary epoch. During the last year the same naturalists have been able to record the discovery of a new species, found in the forest of Lech, near Moirans, in the Department of Jura, the locality being in the French territory. A portion of the carapace, probably the dorsal, was observed projecting beyond the surface of the rock, by the peasants, who reported to the priest of a neighbouring village that it was the impression of the breast of a man; and his curiosity being excited, he had it carefully extracted, and presented it to M. Girod, the Vicar-general of the diocese of Saint-Claude. M. Pictet has named the fossil *Emys Etalloni*, after M. Etallon, Professor of the Lyceum of Saint-Claude, to whom he was indebted for the opportunity of examining and describing it. M. Etallon, a zealous geologist, had also explored and studied the highly-fossiliferous rocks which surround that city; and from the result of his investigations, M. Pictet concludes that the flat on which Moirans has been built belongs to the Upper division of the Jurassic Formation, or Portland Oolite section,—the rock in which the specimen was imbedded having all the characters which distinguish the rocks of that stage in the Department of the Jura and of the Ain. M. Pictet adds that the data are not sufficient to bring it into relation with the Chelonian Limestone of Soleure.

The dimensions of this fine specimen are as follow:—

Carapace....	Length	1ft. 7½in.	Breadth 1ft. 5in.
Breastplate..	,,	1ft. 5⅓in.	

Depth and height between the upper face of the carapace and lower face of the breastplate .. 6¼in.

The carapace is nearly regularly oval—the anterior extremity being widely notched, and the posterior slightly acuminated: it is depressed as in the genus *Platemys*. The breastplate is solidly fixed to the carapace for about half its length, the free portions being both much narrowed, the anterior one subtruncated, and the posterior one acuminated.

M. Pictet describes in detail the bony pieces according to their respective positions, and as far as the condition of the specimen permits, and then, having made the most of his materials, discusses the affinities of the species. In respect to the genus, he considers that it belongs, without doubt, to the family of *Elodites* of Duméril and Bibron, but states that it is impossible to refer it more specially to any of the numerous genera of the family, as the generic characters of most of them are based on portions of the bony structure of the animal not preserved in the specimen, whilst, although clearly separated from some others by the solid manner in which the carapace and breastplate are joined to each other, there are not sufficient data for separating it from others. Under these circumstances M. Pictet thinks it prudent to retain for it the name of *Emys*, as originally defined by Alexander Brongniart, in 1803, when it embraced the whole family of *Elodites*. M. Pictet gives, however, the following diagnosis as a guide to palæontologists in estimating the value of the generic characters.

"Bony case flattened; breastplate extensively and firmly anchylosed with the carapace, without moveable pieces, perforated with two holes, narrow and subtruncated in front, terminated behind by a front not notched; a series of submarginal scales between the marginal scales and the sternal as well as the inguinal margins on each side; upper face of the marginal pieces very large, cut by the margino-costal impression very near its exterior edge."

In respect to species, M. Pictet considers that it approaches nearest to *Pleurosternon latiscutatum*, Owen, known only from the carapace; but he points out several striking differences which separate it from that species, although he thinks it probable that both species belong to the same generic type, and that the discovery of the breastplate of Professor Owen's species might lead to its removal from the genus *Pleurosternon*. He explains also the many points of difference between the *Emys Etalloni* and the *E. Menkei*, Roemer, and *Platemys Mantelli*, Owen. It is therefore an interesting addition to the fauna of the Upper Oolite period.

In addition to the work I have just noticed of MM. Pictet and Humbert, M. Pictet has published during the year the 6th, 7th, 8th, and 9th parts of his contributions towards Swiss Palæontology,—being a series of Monographs of the Fossils of the Jura and of the Alps. A brief abstract of the species described, and of the localities in Switzerland and in other countries where they have been discovered, will explain in the simplest manner the value of these portions of a very important work; and it may be fairly said that the fact of finding so many mollusca common to England, France, and the limited localities of Perte du Rhône and Sainte Croix, is of even higher interest than the discovery of new species. The 6th and 7th parts are devoted to Mollusca; and it will be noticed, in the abstract, that out of 25 species described, 3 only are new, the remaining 22 having been before named by preceding authors. This fact exhibits strongly the great caution with which MM. Pictet and Renevier have compared their specimens with the species of other countries, frequently with the specimens themselves, and proves that they have been free from that anxiety to make new species, which is too frequently a prevailing passion amongst palæontologists:—

"Terrain Aptien."

Cardium Bellegardense, *Pict. & Renevier.*—Yellow Marl of Perte du Rhône.

Cardita fenestrata (*Forbes*), *D'Orbigny.*—Lower Greensand, Lower Neocomian, Perte du Rhône.

,, Meriani, *Pict. & Renevier.*—Yellow marl, Perte du Rhône.

Opis neocomiensis, *D'Orb.*—Yellow marl, Perte du Rhône.

,, Mayori, *Pict. & Renevier.*—Yellow marl, Perte du Rhône.

Astarte Buchii, *F. Roemer.*—Yellow Marl of Perte du Rhône, and of Sainte Croix. Lower Neocomian, France.

,, obovata, *Sowerby.*—Lower Greensand of Isle of Wight, Hard Grit of Perte du Rhône.

,, laticosta, *Desh.*—Middle Neocomian, Yellow Marl of Perte du Rhône.

,, sinuata, *D'Orb.*—Aptian Lumachella of Marolles, Yellow Marl of Perte du Rhône, Red bed of Wassy, and L. G. of Peasemarsh.

Crassatella Robinaldina, *D'Orb.*—Lower Neocomian, Hard Grits of Perte du Rhône, Yellow Marl of Sainte Croix.

Trigonia Dædalea, *Parkinson.*—Blackdown and Haldon (Dev.), Lower Greensand (Forbes), Neocomian, Yellow Marl, Perte du Rhône.

,, nodosa, *Sowerby.*—Lower Greensand, Hard Grits of Perte du Rhône.

,, Archiaciana, *D'Orb.*—T. spinosa, *Sowerby.*—Lower Greensand, Hard Grits of Perte du Rhône and Aptian Formation of Pont (Lac de Joux).

,, ornata, *D'Orb.*—Neocomian in France, abundant in Yellow Marl of Perte du Rhône and of Sainte Croix.

,, caudata, *Agassiz.*—Blue Marls, Neocomian, Neuchatel; Lower Neocomian, France; Lower Greensand, England; Yellow Marls of Perte du Rhône and Sainte Croix.

,, aliformis, *Parkinson.*—Gault, France; Lower Greensand, England; Hard Grits of Perte du Rhône, and probably in the Gault of these localities and of the Savoy Alps.

,, carinata, *Agassiz.*—Neocomian Marls of Hauterive; Neocomian, France; Lower Greensand, England; Yellow Marl of Sainte Croix.

,, longa, *Agassiz.*—Neocomian, Neuchatel; Lower Neocomian, France; Hard Grits and Yellow Marl of Perte du Rhône, Trigonia Coquandiana, *D'Orb.*—Chloritic Chalk of Castellane, Lower Alps; Neocomian, Yellow Marl of Perte du Rhône.

Arca glabra, *Parkinson & Goldfuss.*—Greensand of Quedlimburgh and Aix-la-Chapelle, and, under various synonyms, Gault in France, and Lower Greensand, England, as also in Bohemia. Perte du Rhône.

,, Robinaldina, *D'Orb.*—Neocomian at Marolles, Lower Greensand of Isle of Wight, Yellow Marl of Perte du Rhône.

,, Raulini, *Leym. & D'Orb.*—Lower Neocomian, France; Lower Greensand, England; Yellow Marl of Perte du Rhône and of Sainte Croix and of the Presta. This species was first named by Leymerie as *Cucullæa Raulini*; and M. Pictet agrees with Edward Forbes in uniting to it *A. marullensis* and *A. neocomiensis* of D'Orb.

Nucula impressa, *Sowerby.*—Neocomian and Red Bed of Wassy, France, Lower Greensand, England; Yellow Marl of Perte du Rhône and of Sainte Croix. Several synonyms, such as N. Cornuelina, N. planata, N. subobtusa, are united to this species, as also N. subrecurva, *Phillips*, Speeten Clay.

Mytilus lanceolatus, *Sowerby.*—Neocomian, France; Lower Greensand, England; Yellow Marl, Perte du Rhône. Three species of *Sowerby* and two of *D'Orb.* are given as synonyms, but do not materially affect the geological deductions. Yellow Marl of Perte du Rhône.

,, sublineatus, *D'Orb.*—Neocomian, Turonian, and Aptian, France; Lower Greensand, England; Hard Grits of Perte du Rhône; Yellow Marl of Sainte Croix, Gault of Perte du Rhône and of Savoy. This species absorbs Modiola lineata, *Sowerby*, M. angusta, *Roem*, from the Hils conglomerate, Mytilus lineatus, *Sowerby*, M. asper, *Forbes*, &c.

Part 8 is devoted to the two orders Sauridia and Ophidia of the class Reptilia.

In the first, some bones of a head, collected at Mauremont by MM. De la Harpe and Gaudin, are, after a careful scrutiny, identified with *Crocodilus Hastingsiæ* (Owen) from the freshwater Eocene beds of Hordwell Cliff,—a species which Professor Owen has shown to form a passage between the true Crocodiles and the Caimans. The left branch of a lower jaw, found in the breccia of Saint Loup by Professor Morlet, has all the generic characters of a true Lizard, but is insufficient for specific determination. It must have belonged to an individual of the same size as the common European species, *Lacerta agilis*. Two bony osselets of a cranial plate are referred by M. Pictet to the genus *Placosaurus*, Gervais, which was established upon one such plate. The French specimen was found resting on the cranium, which it protected, and was obtained from the calcareous Palæotherian Marls of Sainte Radefonde, near Apt; the Swiss specimens were found by Professor de Morlet in the breccia of Saint Loup.

The bony osselets, as described by Gervais, were irregularly hexagonal, mamillated on the surface by blunted tubercles having no analogy with anything previously observed in reptiles. The characters of these osselets are quite in conformity with this description; they are irregularly hexagonal, protuberant, and covered with four concentric bands of smooth, rounded tubercles. As the diameter of these osselets is only about $\frac{1\frac{1}{2}}{10}$th of an inch, it is certainly a very curious fact that the *Placosaurus rugosus* of Gervais, founded upon the discovery in France of such minute osselets in direct contact with the cranium, of which, combined together, they formed a protecting plate or covering, should have been traced into Switzerland by means of the osselets alone, though in this case detached and isolated. If this identification be well-founded, it is only natural to expect that other vestiges of the *Placosaurus* may be hereafter discovered; and at all events such a fact is a striking illustration of the wisdom of the caution which Sir C. Lyell has given us, not to assume that certain animals have never lived because we have been unable to find their fossilized remains. Palæontology has done much to unravel the ancient natural history of the world, but it has yet much more to do. Of the other fossils described by M. Pictet, some were bones of a head, found by MM. Gaudin and De la Harpe at Mauremont, and which, though not without much difficulty, M. Pictet refers to a lost type of Saurians, closely related to the Iguanas. The reason of the difficulty in establishing this analogy is the striking resemblance of the inferior maxillary to that of an Ophidian; but, as the intermaxillary cannot be classed with Ophidian remains, the upper and lower maxillary evidently belonged to the same species; and as all the bones were so closely associated together, the inference seems well-founded, that they belonged to a pleurodont iguana, of the size of the living iguanas, characterized by a flattened muzzle shaped like a horse-shoe, the nostrils being large and widely-separated; by a series of small teeth on each pterygoid; by slender jaws armed with conical detached teeth, of which the anterior were very acute, thin, and slightly curved backwards. Having given these details, M. Pictet exhibits a wise reserve by refraining from giving a generic name to the animal until further discovery has provided more complete data. Four vertebræ, obtained by Professor Morlot in the breccia of Saint-Loup, are next noticed; two are comparatively large, and two smaller: the dimensions of the largest are, breadth, 1·02 in.; height, 1·06 in.; length, measured from one articulating surface to the other, half an inch nearly—and these in the smaller are similar in proportion, the height and breadth being nearly the same, viz. ·55 of an inch. M. Pictet states that the large vertebræ, compared with those of *Python molurus*, appear to exhibit an almost perfect identity, excepting that the vertebræ of the living serpent are a little wider and shorter than those of the fossil; the differences between the fossil and the vertebræ of a Python figured by Professor Owen, are, however, greater. He then points out the analogies of the fossil with the recent genus *Eryx* and the fossil genus *Paleryx*, observing that he would have classed the small vertebræ, if alone, with *Paleryx rhombifer* of Owen, but that the larger vertebræ seem to have belonged to a more robust serpent, and that on the whole he considers that, if all the vertebræ belong to the same genus, and that genus be *Paleryx*, the analogy of the genus is more with *Python* than with *Eryx*. At the same time there are, in the same deposit, smaller vertebræ, belonging probably to younger individuals of the same species, and which are more close in their resemblance to *Paleryx*. The discovery of this little nest of snakes in Switzerland, apparently the same as those of the Bracklesham Clay of England, is a most interesting fact as regards the distribution of fossils. Some Chelonian remains found by MM. Gaudin and De la Harpe at Mauremont close the number: they appear to show the former existence of a small Emys and of a small Land Tortoise, scarcely determinable; and at the same time they have afforded materials for the restoration of the carapace, and partly of the breastplate, of a species which is assigned to the new genus and species *Dithyrosternon valdense*, Pict. and Humb. It unites many of the characters of the Land Tortoises, associated with some of those of the Emys. The generic name implies that the shell has *two* moveable doors or valves. There are living genera which have the double valve, such as the Cistudo, where there is, however, no fixed portion of the breastplate between the valves, which simply move on a hinge; and the Cinosternum, in which the analogy as regards the two valves is complete, but in all other respects it fails.

Appended to the 9th part is a list of the Vertebrata of the Eocene Fauna found in the siderolite deposits of the Canton de Vaud.

Mammalia—Pachydermata.—1. Palæotherium medium, *Cuv.*—2. Palæotherium curtum, *Cuv.*—3. Plagiolophus minor, *Pomel*, Palæotherium minus, *Cuv.*—4. Rhagatherium valdense, *Pictet.* —5. Hyracotherium siderolithicum, *Pictet.*—6. Oplotherium. —7. Dichobune Campichii, *Pictet.*—8. Dichobune, species near to but a little larger than D. cervina, *Owen*; from isolated teeth.—9. Dichobune, smaller species, also from teeth alone.

Carnivora.—1. Amphicyon, species of the size of the Conguar; from teeth alone.—2. Cynodon, probably new species of the size of C. lacustris, *Gervais*, from teeth alone.—3. Indeterminable, of the size of the Ocelot.

Cheiroptera.—1. Vespertilio Morloti, *Pictet.*

Rodentia.—1. Theridomys siderolithicus, *Pictet.*—2. Sciurus.—3. Spermophytus?

Reptilia—Sauridia.—1. Crocodilus Hastingsiæ, *Owen.*—2. Lacerta. —3. Placosaurus rugosus, *Gervais.*—4. Saurian of extinct species, probably belonging to the group of Iguanas.

Ophidia.—1. Python.—2. Python or Paleryx.

Chelonia.—1. Dithyrosternon Valdense, *Pictet & Humbert.*—2. Cinixys?—3. Emys, large species.—4. Emys, small species. —5. Testudo, small species.

Most of these fossils were obtained by the labours of either MM. Gaudin and De la Harpe, or of Professor De Morlot; and as the illustrations, both of them and of the Mollusca previously noticed, are extremely well drawn and lithographed, the work may be justly considered highly creditable to the palæontologists of Switzerland and to Geneva, of the Academy of which city M. Pictet is a Professor.

I have already had occasion to notice the varied labours of Herman Von Meyer, whilst stating to you the grounds upon which the Council had awarded to him the Wollaston Medal; but it is right that I should briefly notice in more detail the later numbers of the 'Palæontographia,' a work which is the joint production of Dunker and Von Meyer. In the July number, the history of the discovery of reptilian remains is briefly but succinctly stated, from the time when the *Botryosaurus* of the Zechstein formation, a genus established by Von Meyer, was deemed the oldest or first reptile form of the ancient world, to the discovery, in 1847, by Von Dechen of remains which were distinguished from the fish-remains of the Coal Formation of Lebach, in Rhenish Prussia, and were rightly assumed to belong to Reptilia. The relics of the past which first attracted attention were Coprolites of a finger's length; but Von Dechen soon set the peasantry to search for all kinds of fossil remains, and five nodules containing reptilian relics were brought to light, from which Goldfuss established the genus *Archegosaurus*. Before, however, this positive determination of the existence of reptiles at so remote an epoch as the Coal formation, several geologists and palæontologists had suspected their existence; but either the actual age of the deposits, or the true nature of the fossils remained uncertain. The nascent expectation, however, that Reptilian remains would be found was a proof that old prejudices were beginning to give way; whilst their original depth may be understood from the fact cited by Von Meyer, that the first specimen of the *Archegosaurus* was found in 1777, and was long afterwards described as the head of a fish by Agassiz, who named this very specimen, even then the only one known, *Pygopterus Lucius*, evidently, therefore, considering it a fish: so sure is any long-admitted theory to interfere with the due appreciation of truth when it comes in an unexpected form. The imaginary boundary once passed, other Reptilian remains soon flowed in from the Coal formation. In 1848 Von Meyer proved that the cranium upon which Goldfuss had established his *Sclerocephalus Hauseri* belonged to a reptile, and not to a fish. In 1849, Jordan established a second species of *Archegosaurus*, *A. latirostris*, also from Lebach, where the first species, *A. Decheni* had been discovered. In 1853, Professors Wyman and Owen named some Reptilian remains found in Nova Scotia *Dendrerpeton acadianum*; another specimen, from the coal of the neighbourhood of Glasgow, Prof. Owen termed *Parabatrachus Colei*; and in 1854, Nova Scotia supplied him with the data for establishing his *Baphetes planiceps*. All these reptiles belonged to the remarkable family of *Labyrinthodonta*; and Von Meyer observes that the *Telerpeton elginense* of Mantel, though from the Upper Devonian, may be considered as belonging to the same *geological period*,—an opinion in harmony with the views of the present leading Irish geologists, who consider the Old Red Sandstone to be simply the base of the Carboniferous deposits; and I may add that I have repeatedly urged the probability of the lowest portion of the Devonian system belonging to the Silurian, and the upper to the Carboniferous.

M. Von Meyer then gives a detailed description of the genus *Archegosaurus*; and nothing can more strikingly exhibit the extensive range of the genus at the Carboniferous epoch than the fact that 271 specimens have passed under the inspection of M. Von Meyer, in addition to two specimens from England, and three others described by Goldfuss, Burmeister, or Jäger, which had not been personally examined by him: of these he has figured 102, and, having ascertained, from careful examination and comparison, that the embryonic condition and stages of growth of the animal may be recognized, he unites *A. medius* and *A. minor* of Goldfuss with *A. Decheni*, —an arrangement which reduces the genus to two species, *A. Decheni*, and *A. latirostris*. A short notice of *Apateon pedestris* and of *Sclerocephalus Hauseri* closes this section of the work,—both being of the Labyrinthodont type, but yet distinct from the genus *Archegosaurus*: the latter is from shale resting upon beds of coal; the former (*Apateon*) from the coal-shale of Münster-Appel, being the first specimen which carried the epoch of reptilian life back to the Carboniferous formation.

The other section of the work of Von Meyer, published during the last year, is devoted to the plants of the Chalk Formation of the Hartz, from Blankenburg and Quedlinburg. The interesting character of the Chalk flora, from the many points of approximation to the existing flora which it affords, is well known. M. Von Meyer reviews the works of his predecessors, and by description and illustration endeavours to reform anything which may have been defective in them. From the genus *Crednera*, Zenker, so remarkable for its hazel-like leaves, 11 species have been transferred to the genus *Ettinghausenia*, of Stiehler, which resembles the *Cistidæ*: these were all from the Blankenburg deposits. Those of the Long Mountain near Quedlinburg, have yielded, of Ferns, the species *Weichselia Ludoviæ*, Stiehler; of Pandaneæ, *Pandanus Simildæ*, Stiehler; of Cycadeæ, *Pterophyllum Ernestinæ*, Stiehler: and it may be added that the chemical examination of other specimens detected the former presence of organic vegetable bodies by the quantity, though small, of carbonaceous matter they contain. A description of the flora of the younger Brown-coal, by M. R. Ludwig, adds value to the work of Von Meyer, and displays, as usual, a still nearer approximation to the existing flora, as such names as *Vaucheria, Conferva, Potamogeton, Pinus, Taxus, Myrica, Arundo, Lobelia, Magnolia*, &c. &c. testify,—even our very recent discovery, *Victoria regina*, finding its representative in the genus *Holopleura* of Ludwig, to which he gives the specific name *Victoria*, from its near approach to the genus of that name.

It cannot be doubted that the brief notice I have given of a portion of a great work will add weight to what I have already stated in pointing out to you the great merits and services of those distinguished palæontologists, Von Meyer and Dunker. Many more names might be cited as a proof of the universal spread of enthusiasm about the history of the past world, such as Weber, Von Hauer, Von Hagenow, Schnur, in addition to those which have long become household words amongst men of science.

Of the latter, the distinguished countryman of Dumont, M. de Koninck, is still earnest in his endeavours to perfect the fauna of the Carboniferous epoch. In a paper addressed to the Belgian Academy, he notices the distribution of some of the Carboniferous fossils, stating that he had already determined the existence of more than 600 species. These he has grouped in three sections,—the first belonging to the Coal-formation, properly so called, the second to the limestone of Visé, and the third to the limestone of Tournay. In Belgium, the fossils of the first section are peculiar to the strata in which they are found; but in the other two groups some are found common to both, whilst others are characteristic of either one or the other limestone. M. de Koninck adds that the same facts may be observed in both England and Russia,—the fossils of the neighbourhood of Bristol and of Moscow being the same as those of the limestone of Tournay, whilst those of Newcastle, Glasgow, and Gosatschi-datchi in the Oural Chain are identical with those of Visé. Whilst, indeed, he observes, this existence of the same species at widely-separated localities is one of the great palæontological facts, it is not less curious to observe how localized some species are, though belonging to the same epoch (a fact, I may add, equally observed in recent natural history), as for example, *Spirifer striatus*, *S. rotundatus*, and *S. cuspidatus*, abundant in the Carboniferous limestone of the neighbourhood of Dublin, are not found at Hook Head, county of Wexford; and in the same manner, the limestone of Tournay has never furnished these Spirifers, though they are abundant in that of Dinant, which belongs to the other section. As an interesting notice of new discovery, he states that M. Dupont, to whom he was indebted for the latter remark, has also enabled him to state that 130 species of Mollusca are found in connection with the Spirifers, of which about 30 are new, including some magnificent specimens of *Cardiomorpha*, *Avicula*, and *Aviculopecten*, which M. de Koninck proposes to describe very shortly, as an addition to a fauna already so rich.

Before closing this brief notice of the labours of one of our most active foreign friends, I may observe that he submitted to the British Association at Dublin last year his description of a third species of the genus *Davidsonia*. In the generic name he had testified his recognition of the merits of one of our most able palæontologists, and in the specific he has borne testimony to those of another of our most able naturalist members, by adopting the term *Woodwardiana*. This Devonian genus he places in the family of Productidæ, from the existence of spines along the hinge, which separates it from the Strophomenidæ, whilst he does not think there is any reason for establishing a specific family under the appellation of Davidsonidæ. Every peculiar Devonian type must be considered an advantage gained, by those who maintain the independence of that formation.

It is right to observe that, whilst our knowledge of the fauna of the ancient world is daily increasing, new information respecting that fauna which is so closely connected with our own existence, and has been so long studied, is constantly flowing in upon us. Dr. H. A. Philippi, Professor of Natural History at the University of Santiago, in Chili, for example, describes a new species of the genus *Thysanopus* under the name *T. australis*, which he discovered on examining the stomach of a fish. He speaks of the discovery as remarkable, since the species already known to him was from the European seas: the editor, however, of Wiegmann's Archiv adds to this remark, that Brandt had enumerated 7 species of the genus, in Von Middendorf's Voyage. In either case the wide distribution of a genus comprising such minute species, eight lines in length, is a fact of much interest. Of another Crustacean of the order Stomatopoda, he forms a new genus *Hoplites*, and gives it the specific name *longirostris*. It was found in the Atlantic ocean, in 25° N. lat. and 22° 50′ West long. *Leucifer Zybrantsii*, Ph. is a new crustacean found in the same position by Captain Peter Zybrants, who commanded the ship which conveyed Dr. Philippi to Chili. *Alima valdiviana*, and *A. ctnura* are two new species of a genus not before traced to the American coast, and found in the harbour of Valdivia. The new genus *Euacanthus* is also established from a minute crustacean of the order Stomatopoda, and the new species *Megalopa valdiviana* from another three lines long. Of this latter, Dr. Philippi remarks with great justice, that even though his observations may not prove sufficient to determine the question whether *Megalopa* is a full-grown and perfect animal, or merely an immature condition of some other genus, the existence of that form of crustacean in the Chilian seas is not less a fact of great interest. Were I to go through the 12 new Echinodermata described by Dr. Edward Grube of Breslau, or follow Dr. Troschel in his analysis of the progress of discovery in natural history both in America and Europe, I should have no difficulty in establishing the fact that the time is still far distant when it will be possible to study the system of nature as one great whole, combining the extinct and the living: and so this fact, far from discouraging, ought to exercise upon every naturalist the most powerful and stimulatory influence; for who can tell what will be the ultimate result of man's researches and of man's unprejudiced reasonings upon them?

Physical Geology.—As the physical condition of the crust of the earth has been not only affected by the action of external force, including all aqueous and aërial agencies, but also by the action of internal forces, it becomes important to study whatever is calculated to throw light upon the processes of nature which, though unseen, are too often felt to be going on under our feet. Of all our members, Dr. Daubeny has most distinguished himself by his able advocacy of the chemical theory of volcanos; and although that theory may not be considered sufficient to explain all the phænomena, it is impossible to doubt that chemical action must be going on extensively in the interior of the earth, and that it is of the utmost importance to study the nature of that action. The paper by Dr. Daubeny on the Evolution of Ammonia from Volcanos, deserves therefore especial consideration, as it is evident that the volcano must be considered the discharging flue of the subterranean laboratory, and therefore the place where its gaseous products ought to be traced in their passage outwards. That ammoniacal compounds are found in the vicinity of volcanic vents is well known; but MM. Bischoff and Bunsen have endeavoured to prove that the production of ammonia is due to chemical action on the surface, and not within the crust of the earth, as, for example, in the celebrated hypothesis, that the hot lava, whilst overflowing the herbage, so far promotes its decomposition, as to set free its nitrogen, which uniting with the muriatic acid of the lava, became sublimed as sal-ammoniac. This theory, though ingenious, is shown by Dr. Daubeny to be inapplicable to many volcanic districts, in which, though the herbage is far too scanty to supply a sufficiency of nitrogen, the sal-ammoniac is not less in quantity; he therefore adopts, as in his opinion more probable, the theory of the formation of ammonia within the crust of the earth, and adduces, in support of his explanation, the affinity which certain metals are known to possess. For example, Wöhler and Rose have proved the existence of a compound of titanium with nitrogen; and Wöhler and Ste.-Claire Deville have shown that titanium absorbs nitrogen even from the air, and that heated titanic acid, when brought into contact with nitrogen, leads to the production of a nitride of titanium with so intense a chemical reaction as to generate light and heat, nitrogen in this case, instead of oxygen, acting as the supporter of combustion. Dr. Daubeny also alludes to the recently discovered fact, to which I shall again refer, that boron, like titanium, has the property of combining directly with the nitrogen of the air, and that the compound thus formed possesses the property of evolving ammonia under the influence of the alkaline hydrates. Dr. Daubeny further observes that we cannot fairly conclude, from the difficulty hitherto experienced in producing a direct combination of nitrogen and hydrogen, that such a combination would be impossible under the different circumstances of pressure, heat, &c. which may be expected within the crust of the earth: in fact, he considers that such circumstances might even be sufficient to induce the combination of hydrogen and nitrogen, and thus produce ammonia directly, although it has not been possible to do so in the laboratory of the chemist. Titanium is present in most volcanos, though Dr. Daubeny admits that it is not sufficiently abundant to account for the large quantity of sal ammoniac known to occur, and, I will add, for the continued production of it, unless, indeed, it be assumed that the titanium discovered outside the volcanic vent, and freed from the nitrogen with which it may have been combined, is only a small portion of that which has passed through the chemical decomposition, and still remains below the crust. Such a conclusion would not be unreasonable, as it is certainly quite consistent with sound speculation to deduce what is passing out of sight from that which can be actually observed. Boracic acid, however, is sufficiently abundant in many volcanos to account for the production of any amount of ammonia; and it only remains in those cases to determine whether the chemical reactions which have led to the production of ammonia took place actually within the volcanic crater, or during the process of eruption,—assuming in the first instance, that the combination of boron, titanium, or any other metal with nitrogen had at least been effected in the volcanic laboratory.

The paper by Mr. Robert Warington, F.C.S., read so far back as 1854, at the Liverpool meeting of the British Association, and published in the Edinburgh New Philosophical Journal, April 1855, is valuable, as it shows the actual circumstances under which both boracic acid and ammonia may be found. Mr. Warington founds his remarks on information from a friend who visited the island of Vulcano, twelve miles north of Sicily. The volcanic mountain is estimated to be 2000 feet in height, and its crater is about 700 feet deep. The area at the bottom, about 10 acres in extent, is paved, as it were, with small loose fragments of limestone; and the ground is so hot as rapidly to destroy the leather of the shoes. A thermometer thrust between the stones indicated a temperature between 250° and 500°; so that the conditions of the locality were peculiarly favourable for the study of the phænomena under consideration, as it is evident that there was nothing extraneous to interfere with the results. On looking down on the area, it appeared covered with a substance like finely-drifted snow, which was found, on examination, to consist of crystallized boracic acid. This incrustation, about an inch thick, being dug through with a pickaxe, a mass of red-hot fused lava, similar in appearance to the slag of a glass-house, spumed up, and was found to consist of fused saline matters forming a coherent mass of volcanic debris. "When the ground covered with boracic acid is dug down for about eight inches, a red-hot mass of sal-ammoniac is always found," as also sulphur. Now this is not a temporary phænomenon, as the boracic acid is constantly renewed when removed, and has become, together with sal-ammoniac and sulphur, a regular source of income to the proprietors, to whom it yields about £1000 per annum,—sulphur being obtained by fusing the stone of which the sides of the volcano are composed, sal-ammoniac from the lixiviation of the scoria or lava, and boracic acid, either at once from the surface, or by receiving the sublimed acid in open barrels filled with broom-twigs or other plants, placed there for its reception.

It will be observed from these observations, as Mr. Warington states, that the sal-ammoniac sent to him was obtained by the lixiviation of the fused mass; and its exact condition, therefore, in that mass he had no means of determining. On the boracic acid, however, which came to him as collected, he was enabled to experiment. The boracic acid having been boiled in diluted muriatic acid, the solution was subsequently decanted from the undissolved portion. This again was boiled in a weak solution of caustic potash, without yielding any trace of ammonia, but the residue being washed with distilled water, dried and fused in a tube of hard glass with caustic potash, gave strong evidence of the formation and liberation of ammonia. From these experiments, therefore, Mr. Warington concludes that the reactions are similar in character to those effected by Balmain in 1842, and by Wöhler. In them the nitride of boron was first obtained by heating borax and ferrocyanide of potassium (both anhydrous) to a dull red heat in a crucible; and this, being fused with caustic potash, gave out ammonia copiously, or, if heated in a current of steam to a moderate red heat, was entirely converted into boracic acid and ammonia. These experiments unquestionably explain the simultaneous presence of boracic acid and ammonia in volcanic craters, considering that nitride of boron had been previously formed in the interior of the volcanic vent, and then brought into contact with either alkaline bases under a high temperature, or with heated steam. The same may be said in respect to the reactions consequent on the formation of nitride of titanium, or of the nitride of any other metal within the volcanic vent. All these reactions are natural in their way, consistent with the circumstances of volcanic action, and confirmatory of Dr. Daubeny's views.

Admitting, then, the reasonableness of Dr. Daubeny's views, and those of Mr. Warington, as to the production of the ammoniacal compounds so generally found in connexion with volcanos, the source from which the nitrogen, presumed to be of internal origin, has proceeded, can only be conjectured. From the smoke-vents of lava-streams, as well as from those of the craters of volcanos, atmospheric air was evolved, in combination with other gaseous products; but it was often found poorer in oxygen, or, in other words, richer in nitrogen, than in a normal state, according to Deville,—whilst Palici states (as quoted in the Jahresbericht der Chemie of Liebig and Kopp) that the gas collected in the Lago di Naftia, in Sicily, on the 5th October, contained 17·4 volumes of oxygen, and 82·6 of nitrogen, and on the 22nd October, 5·0 of carbonic acid, 15·8 of oxygen, and 79·2 of nitrogen. From the same Journal we learn that C. Schmidt had examined the boracic-acid vents of Monte Cerboli in Tuscany. According to his researches, the boracic acid cannot be found in the mixed vapour and gas which issues from the vent itself, but in the shining mud which floats over its mouth, and there in combination with carbonic acid, ammonia, and a small quantity of sulphuretted hydrogen. In fact, salts of ammonia abound in the dark-grey mud of these mud-lagoons; and after, in the refining process, the greater portion of the boracic acid has been removed by crystallization, the residue, obtained from the mother-liquor when condensed by evaporation, yielded on analysis the following results—the first from a specimen obtained by M. Abich, and the second from one collected by M. Schmidt himself:—

	NH_4O, SO_3	MgO, SO_3	CaO, SO_3	KO, SO_3	NaO, SO_3	NH_4Cl	NH_4O	$\left.\begin{matrix}Fe_2O_3\\Al_2O_3\end{matrix}\right\}$	BO_3	Total.
Abich's Sp.	5·328	4·116	0·160	1·086	0·266	0·178	0·159	0·019	1·754	13·066 in 100
Schmidt's	9·667	1·843	0·102	0·419	0·515	0·109	0·614	0·011	3·094	16·373 ,, ,,

with a trace of oxide of manganese and of silicon.

Here the co-existence of ammoniacal salts and of boracic acid is again manifest; and it may be fairly assumed that they are the results of the same chemical reaction. In a letter to M. Elie de Beaumont, M. Bornemann mentions a case where the nitrogen is given out in a free state, and where it has apparently not gone through the first step of combination with boron, which appears to be essential for the production of ammonia.

In this letter he notices the gaseous and aqueous emanations in Sardinia, as supplementary to the labours of M. Deville. These he considers as the last exhibitions of volcanic action in Sardinia, where, although there are many remains of ancient volcanos, there are no true volcanic vents of gaseous matter,—the emanations proceeding from mineral waters or thermal springs, all of which are situated in close proximity to the ancient volcanic districts. These emanations are rich in carbonic acid and azote, and contain also some free oxygen. M. Bornemann concludes his notice by eulogizing the Geological Map, and work on Sardinia, of General Albert de la Marmora.

Perhaps no one has devoted more attention than M. Ch. Sainte-Claire Deville to the gaseous products of volcanic vents. In a former memoir he laid down the proposition that the physical and chemical properties of the gas-vents of any volcano are influenced, on the one hand, by the distance of the observed orifice from the initial point of emission, and on the other by the interval of time between the moment of observation and the initial moment of eruption. As this proposition implies variations in the nature of the gaseous emanations, corresponding to variations in their position and the time of emission, M. Deville has endeavoured to illustrate his position by a study of the chemistry and stratigraphy of the subject, so as to test in the laboratory the reactions which have taken place between the elementary substances recognized as existing in volcanic districts, and thereby to explain the observed modifications in the halogene sulphureous or carbonic emanations. These emanations he divides into two groups, according as the *motive substance*, or substance which gives rise to the chemical reactions, is either hydrogen or a haloid body such as chlorine or fluorine; and M. Deville points out the *antagonism* between these two classes of emanations: for, whilst chlorine and its congeners decompose water by absorbing its hydrogen, its oxygen being fixed by the alkaline metal which accompanies them, sulphur and carbon, when emitted in combination with hydrogen, produce a contrary effect, by giving out the hydrogen and reconstituting water at the expense of the oxygen of the air,—the equilibrium of the forces manifested in natural phænomena being thus preserved.

Along the course of a lava-stream it is also seen, in respect to the halogene and sulphureous emanations—and in this case M. Deville observed no other gases—that their transformations, explained on chemical principles, are influenced by the position of the gaseous vents, the characters of which vary according to their distance from the focus of eruption, and to the time which has elapsed since its commencement,—these two coordinates of time and space representing the variations of temperature under the influence of which, and by the instrumentality of the primary elements or constituents of the gaseous emanations and of the accessory elements either derived from the rocks through which they pass or from the air, the various products which M. Deville enumerates have been formed. Each order of emanation has therefore its peculiar products, which are, in M. Deville's opinion, merely modifications, under the influence of variable physical and chemical causes, of the same compounds, derived from the incandescent materials of the volcanic eruption.

The difficulty is greater when the inquiry is directed, not merely to the gaseous vents of the lava-stream, but to the vents of the volcanic cone itself, assumed, as they are, to communicate by a transverse fissure with the internal focus, as the variations then observed depend on causes similar to those which have produced in the interior of a vein the successive deposition of different substances. Generalizing the phænomena, an analogy is recognized between the gaseous emanations which succeed each other in a volcano during the course of a single eruption, and those which, in the series of ages of our globe, have predominated at each successive epoch. As, for example, when at the commencement of an eruption chlorine and fluorine are the gaseous emanations which proceed from the orifices of the lava, whilst phosphate of lime and oxidulated iron are fixed in the rock, can we not perceive an analogy between the workings of existing volcanic forces and those phænomena of emanation which under the influence of the same agents, chlorine and fluorine, have enriched the most ancient consolidated rocks with tourmaline, phosphate of lime, oxide of tin, or, in a word, with that galaxy of bodies, intimately connected one with another, which has been figuratively named the *penumbra of granite*?

M. Deville then endeavours to explain how the gaseous vents are distributed over the volcanic mass, and to prove that their positions can be referred to the great stratigraphical accidents of the country.

The effect of an eruption is to determine, on the cone, fissures the direction of which prolonged would sensibly pass through the centre of the crater; and in a volcano in a state of eruption, two kinds of operating agencies may be recognized; the one eccentric in connexion with the fissures produced by the eruption, or with the orifices of gaseous vents; the other central, at the summit of the volcano, or common centre to which all the fissures converge,—the first generally acting only during the duration of the eruption, whilst the latter acts variably but constantly. The object of M. Deville is to define precisely the functions performed by each, either in a period of tranquillity, or during the height of an eruption, or at the moment when the intensity of volcanic action retires from the fissures to the normal focus, and thus, by establishing the mutual connexion of one with the other, to obtain the means of predicting the effects to be expected from observations made during any particular form of eruption; as for example, in respect to the eruption of Vesuvius in 1856, M. Deville, from the facts he had observed, did not hesitate to announce the probability of a series of small eruptions from the summit of the volcano,—a prediction which was fully verified.

But it was yet to be determined whether the fissures, which perform so important an office in volcanic eruptions, are merely accidental and ephemeral, or are intimately connected with those powerful mechanical forces which have at various epochs broken the crust of the earth, and left everywhere ineffaceable marks of their action behind them; and in investigating this question, M. Deville determined, from numerous observed facts, that the planes of fissure penetrate the volcanic mass so deeply, and with such a permanency of direction, as to preserve a remarkable regularity, at successive great explosions of the eruptive forces.

M. Leopold von Buch had pointed out the tendency of volcanic vents to arrange themselves in lines corresponding to the direction of volcanic chains, or radiating from central volcanos; and M. Deville modifies the expression of this view, by stating that a central volcano always occupies a peculiar point, fixed by the intersection of two or more volcanic lines, and supports his opinion not only by the facts he had observed at several volcanic chains, but also by the theory of M. Elie de Beaumont, in itself directed towards a different object, and shows that, on the principle of a pentagonal network of lines of elevation, Etna occupies one of the summits of a rectangular spherical triangle, one side of which passes through Teneriffe, and the other connects Etna with the Eolian Islands, Vesuvius, and Mauna-Loa of the Sandwich Islands; so that the geographical distribution of volcanos, the manner in which the mechanical effects of earthquakes are exhibited, and the chemical peculiarities of gaseous emanations seem to correspond with general laws of stratification. M. Deville also points out—and the fact is important in reference to the general question—that in the Isle of Teneriffe each of the lines which cut the Peak of Teyde is characterized by the appearance of a peculiar kind of volcanic rock.

By this class of investigations the special phænomena of volcanos, which can be still observed, are put into relation with the more general phænomena of elevation by which the stratification of the earth's crust has been modified, and which can now no longer be observed; and a step is therefore made towards a physical history of the earth. M. Deville has continued through the year to detail the results of his researches, all of which have a bearing more or less in conformity with his theoretical views. In gas-vents, where there is neither vapour of water nor acids, the oxygen and azote proceeding from them are mixed in proportions not sensibly different from those of normal air,—whereas from vents which exhibit traces of vapour of water, or hydrochloric or sulphurous acid, the proportion of azote is in excess of that of oxygen; and this is the same, whether the vent is from a stream of lava or from a volcanic crater. In illustration, M. Deville gives the following results of the examination by himself and M. Felix Leblanc, of the gaseous emanations of Vesuvius and Vulcano, after abstracting from them the hydrochloric acid and the vapour of water:—

	Vesuvius.			Vulcano, Vents with flame.		Vulcano, Without flame.
	1.	2.	3.	1.	2.	
Sulphuric Acid	2·6	2·4	0·3	39·1	27·5	69 6
Oxygen	18·7	19·7	17·6	5·8	14·0	5·5
Nitrogen	78·7	77·9	82·1	55·1	58.5	24·9
	100·0	100·0	100·0	100·0	100·0	
Oxygen in 100 parts of the combined oxygen & nitrogen	19·3	20·2	17·6	9·6	19·4	18·8

Now, as the normal proportions of oxygen and nitrogen are 20 or 21 O and 80 or 79 N, it is evident that in few instances were the true proportions of normal air preserved, whilst in several the proportion of nitrogen was greatly in excess. The fact, therefore, that nitrogen appears in a portion of the gaseous emanations of volcanos, cannot be doubted; but, as oxygen appears contemporaneously with it, the question still remains to be answered, whether the atmospheric air, of which it appears to have once formed a part, has only been sucked into the mouth of the crater, or whether it has been carried, either in combination with water, or in any other state, deep into the interior of the earth or down to the very focus of volcanic action. It is somewhat remarkable, indeed, that the gases of Vulcano, which are accompanied with vapour, and contain air so poor in oxygen and so rich in nitrogen, are those which, as stated by Mr. Warington, deposit sulphur, boracic acid, and muriate and hydriodate of ammonia, exhibiting therefore so great an excess of nitrogen as almost to demonstrate that the reactions which gave rise to the production of ammonia and the collection of an excess of nitrogen must have been internal. The gas proceeding from the spring of Santa Venerina on the flank of Etna yields nitrogen entirely free from oxygen; and M. Deville states that he looks upon volcanos as vast chimneys into which, by means of the lateral fissures connected with them, the atmosphere is sucked in, and there freed by combustion of all or part of its oxygen, and that the emanations from vents in a plane of eruption exhibit a combustion less and less energetic as it recedes from the centre of activity, which corresponds with the view already enunciated,—namely, that in any one vent the intensity of action will diminish in proportion to the time elapsed since the commencement of the eruption, but in many contemporaneous vents the intensity will be in proportion to their distance fiom the focus of eruption or main crater. This notice of the labours of M. Deville will, it is trusted, convey an adequate idea of their importance, either as bearing upon the subject brought under our notice by Dr. Daubeny, or upon the still higher generalizations of physical geology. The operations of the volcanic laboratory may be investigated in the laboratory of the chemist, and, when once satisfactorily explained, afford a clue to the investigation of phænomena, of which the mode of production has long since been veiled from direct observation.

M. J. Durocher has directed his attention to another form of this interesting inquiry, and has studied with much attention the chemical constitution of igneous rocks for more than twelve years. Researches of this kind illustrate the manner in which the simple elements of the crust of the earth have been so combined as to produce rocks of considerable apparent, but little real difference. It is for this purpose that M. Durocher investigates with great care the atomic properties of the oxygen of the silica and of the bases of these *magmas*, the solidification of which has produced the igneous rocks. In the hornblendic series, the ratio of the oxygen of the silica to that of the bases exceeds 3 to 1, except in trachytic lavas and phonolites; so that, on the *magma* solidifying, it is resolved entirely into a crystalline mass, and the silica which is in excess becomes free in the form of quartz. In granite, the proportion between the oxygen of the alumina and that of the alkaline and alkali-earthy bases is, on the average, 3·7 to 1; and, as there is more alumina than is necessary to produce merely a felspathic mineral, the excess of alumina contributes to the production of mica. In normal granite there is about 35 per cent. of quartz, and 40 to 45 of felspar which has absorbed $\frac{3}{5}$ths of the alumina, the remaining $\frac{2}{5}$ths serving to produce the mica in the proportion of 20 to 35 per cent.; and M. Durocher observes that the *same magma*, on solidifying, may, through a variation of circumstances, take the form of a granite, sometimes more rich in felspar, and sometimes in mica and quartz. Where the oxygen of the alumina in the erupted mass was nearly three times that of the protoxides, very little mica was found, and a pegmatite more or less rich in felspar was the result. It is easy indeed to imagine how readily the variations of physical circumstances sometimes consequent on tranquillity, sometimes on disturbance, must tend to alter the distribution of the mineral elements, and thus to produce, on solidification, different results; it is curious also to observe how in the long series of events the alumina becomes proportionally diminished, and gives rise to newer forms of igneous rocks. M. Durocher states that, in the felspathic rocks of the tertiary and recent epochs, the oxygen of the alumina bears a proportion to that of the alkaline and earthy-alkaline bases of less than 3 to 1; so that all the *magma* cannot be changed into felspar, and part continues in the state of a paste, or forms other minerals less aluminous than felspar. These and many other variations in the resulting rocks produced by the solidification of the *magma* are described by M. Durocher, and the general atomic relations shown by tables; and this is the interesting conclusion of one of his papers, "the present essay has exhibited the physical, chemical, and geogenic relations which connect together the igneous rocks, however varied in their aspect. The clearness with which these relations have been unravelled confirms the proposition I have laid down, that all igneous rocks have been derived from *two mineral beds or layers*, situated below the crust of the earth—one characterized by its richness in silica, and the other, though poorer in silica and in alkalies, containing a very much larger proportion of alkaline earths and oxide of iron, and at the same time distinguished by very different atomic proportions. I have thus successively thrown light upon the mutual relations of eruptive products, on the generation of the minerals they contain, on the history of their emission, which I have simplified, and on their natural classification."

According to M. Durocher's view, silicium performs the same office in the mineral kingdom as carbon performs in the organic world, acting as a polybasic acid, and uniting with the oxides in very different proportions, so as to give rise to a great variety of combinations; and hence that the minerals which constitute rocks must depend principally upon the materials brought into chemical action. After comparing his own chemical analyses with those recorded in the works of other writers, M. Durocher concludes that the granites, eurites or felspathic and quartziferous porphyries, trachytes, phonolites, pearlstones, obsidians, pumice, and lavas, rich in vitreous felspar, were produced from the first of his *magmas*, whilst diorites, ophites, melaphyres, euphotides, hyperites, traps, basalts, and augitic lavas proceeded from the second.

M. Durocher also states that, if the different varieties of one type of rock, such as granite, be examined, there will be often found a greater difference in their elementary composition than in that of different species proceeding from the same magma; as, for example, those between granite and a trachyte or a pumice, and he then arranges in a tabular form the several species supposed to proceed from each magma; remarking that the differences are equally due to the conditions of pressure, temperature, and cooling as to mere elementary composition, and he adds that the magmas which have produced igneous rocks are similar to metallic baths containing in a state of fusion various metals, which on cooling give rise to alloys differing from each other according to the circumstances of solidification. He adds that, where the two layers or magmas are in contact, hybrid products are formed, or rocks which have petrographic and geological affinities, sometimes approximating them to the true rocks of one magma, sometimes to those of the other. The upper zone, rich in silica, and poor in earthy bases and in oxide of iron, has the least density, and its specific gravity differs from that of the lower as much as oil in this respect differs from water,—a circumstance to which is due the permanent separation of the two magmas. The solid crust, therefore, of the globe rests, in M. Durocher's opinion, upon a fluid zone composed of two distinct layers: the upper, which is the most refractory, being only semifluid or pasty; the second much more fluid and dense. It is to this second magma, so rich in oxide of iron, that he ascribes the eruptions of oxidulous iron which have appeared in the manner of igneous rocks in Italy, the Oural Mountains, and Scandinavia, being connected with hornblendic or augitic rocks; and in the upper bed he considers that light or volatile bodies would be concentrated, such as alkaline metals, fluor, boron, &c.: it is indeed amongst granite rocks proceeding from this layer that the fluor-silicates, boro-silicates, as mica, topaz, tourmaline, &c., have been usually found. There is of course much speculation in this theory of M. Durocher; but the attempt to penetrate through the mystery which hangs over the production of the great variety of igneous rocks, and to discover the mode in which nature worked in its internal laboratory, displays great ingenuity. In fact, geology has now arrived at such a stage that nothing short of a complete explanation of the great problem of the earth's history in all its relations, whether purely chemical, physical, or organic, will satisfy the philosophical geologist.

Geologists are all aware that the recognition, as an incontrovertible fact, of the increase of temperature in descending from the surface towards the centre of the earth, in whatever way the experiments may have been made, whether in Artesian borings, or in the shafts of mines, or by the examination of hot springs, was considered a certain proof of the existence of a source of internal heat, due to the retention of a portion of the original heat of the planet when in a state of igneous liquidity, by some part of the internal nucleus. When this theory was first propounded, many objections were urged in opposition to the fact itself, but when it had been satisfactorily proved that no accidental circumstances could account for the increase of temperature, the question appeared settled, and the theory was adopted without further hesitation. One remarkable circumstance had, however, been noticed, namely, that the rate of increase varied in different places, or in different deposits; and this fact has suggested, to our great physical geologist and former president, an *experimentum crucis*, to which he has subjected the theory. It is this,—that according to the ordinary law of the distribution of heat, the progressive increase of temperature from above downwards should be in an inverse proportion to the conducting power of the strata bored or sunk through. After a careful experimental examination of the subject, he comes to the conclusion that the rate of increase does not conform to this law, and, hence, that some other mode of explanation must be sought for, the fact remaining, as before, uncontroverted. It is hard to abandon a favourite theory so pregnant in deductions of great interest; and there can be no doubt that both the experiments and reasonings of Mr. Hopkins will undergo a rigorous examination; but should their accuracy be fully established, it will be better that we should be put upon a new scent and an active hunt, rather than be allowed to repose in an unwarranted confidence that we had solved so great a problem in the earth's history.

Another able investigator of the physical conditions of the earth is Mr. H. Hennessy, F.R.S., who, in a recent paper on the Physical Structure of the Earth, has brought forward additional developments and illustrations of the views he had already put forward in other publications. He quotes a result at which he arrived by a mathematical examination of the figure of a spheroid acted on by the abrasion of water, in order to show that the earth could not have acquired its present figure by the action of its watery envelope alone, as maintained by some distinguished philosophers.

Assuming, therefore, the earth to have been in a state of fluidity from intense heat, he proceeds to consider the way in which, according to known mechanical and physical laws, such a fluid mass may have passed into the actual condition in which we find our planet. He observes that the increase of density of the strata of the fluid in proceeding from its surface to its centre, consequent on the overlying strata compressing those included within them, would render the process of "convection" very different from that which takes place in a homogeneous and limpid fluid, such as warm water, and thus the principal oscillations of the fluid would be confined to the vicinity of the surface. As explanatory of the influence of the viscidity of the fluid, the consolidation of the surface of lava-streams is adduced, as it shows how a continuous solid covering may be gradually formed over matter still continuing in a fused condition beneath. The probably imperfectly consolidated, porous, or scoriaceous condition of the first-solidified portions of such a fluid mass would, as he has subsequently remarked, greatly facilitate the formation of a solid crust; and if the first superficial pellicle of the earth's crust had been formed in this way, it would manifestly be much more easily disintegrated and removed than the harder and more slowly consolidated crystalline masses beneath.

In further considering the physical and mechanical actions by which the earth's internal structure may have been effected, Mr. Hennessy strongly objects to the adoption of the supposition, regarding the fluid matter from which the crust of the earth has solidified, that the change of consistence of the earth's materials produced no change in their distribution. This hypothesis he rejects as improbable, and considers it more philosophical to base our views regarding the changes of state in the earth's materials upon the evidence afforded by those materials which come under our actual notice. The nature of the earth's internal structure appears to depend greatly upon the manner in which its fluid portions have passed into a solid state; and Mr. Hennessy points out that a consequence deducible from his views of the earth's structure, and from a result obtained by Mr. Hopkins, would prove the existence of considerable pressure and friction between the fluid nucleus of the earth and its solid envelope. The physical causes on which this pressure depends are shown to be involved in the gradual increase of density of the fluid towards its central portions. The connexion of these views with that portion of geological dynamics which embraces the study of the greater elevatory movements on the surface of our planet is briefly pointed out. Without implying the correctness of all the conclusions stated by M. Elie de Beaumont, Mr. Hennessy is satisfied that the eminent French geologist has shown such an amount of connexion between very widely distributed phænomena of elevation as indicates the operation of general and wide-spread disturbing agencies beneath the crust of the earth. But, instead of attributing, with De Beaumont and Humboldt, these phænomena to the successive collapse of the crust of the earth upon a more rapidly contracting nucleus, Mr. Hennessy refers it to the pressure he had before explained. Illustrating his views from the equilibrium of arches, he shows that a pressure acting in the direction required to produce subsidence of the earth's crust upon the nucleus, would be far more resisted than a pressure acting in the contrary direction. The action of an interior expanding elevatory force upon the crust of the earth appears to

Mr. Hennessy more calculated to produce symmetrical relations in the lines of fracture and elevation of that crust, than the squeezing or crushing actions that would accompany a series of great subsidences. The obvious connexion between the disturbances of the crust of the earth and its thickness has produced some remarks on that point. If gravity were rigorously perpendicular to the outer surface of the earth's crust, its thickness might be extremely small compared to the earth's radius, or the earth might be solid from its surface to its centre: the manner in which Professor Stokes has deduced Clairault's theorem shows, as remarked by Mr. Hennessy, that the variation of gravity over the earth's surface, and other great statical and dynamical results of the earth's structure, would be then precisely the same, whatever might be its internal constitution. But although gravity acts perpendicularly to the surface of the ocean, that does not prove its perpendicularity to the earth's solid crust; and reasons are adduced for coming to a different conclusion; whence Mr. Hennessy infers that we cannot at present consider the thickness of the earth's crust as an inappreciable fraction of the earth's radius. On the other hand, he considers Mr. Hopkins's estimate of the thickness of the earth's crust as not conclusive, because it essentially depends upon the hypothesis that the process of solidification of the earth was accompanied by no change in the distribution of its particles.

The very clear explanation of the views intended to be expressed in his late essays, with which I have been favoured by Mr. Hennessy, has enabled me to put other physical geologists in a position to estimate their value; and I have thus done justice to one who is following closely and with great ability in the footsteps of Mr. Hopkins. The purely physical investigation of the phænomena of the earth's crust cannot be in better hands than those of our former president and of his two Irish coadjutors Hennessy and Haughton, whilst there are many of our members who are quite capable of following Dr. Daubeny in the purely chemical investigation.

Amongst the phænomena which still require much elucidation are those of metamorphism; and it appears to me that we are at present allowing our foreign friends to make a monopoly of that class of research. M. Delesse has, for example, distinguished himself by his efforts to clear up the difficulties which hang over the subject of metamorphism; and I shall therefore briefly notice his 'Études sur le Métamorphisme' here, as a preparative for an abstract of his papers, which he has transmitted to me, and a translation of which I propose to insert in a future number of the 'Journal.'

M. Delesse rightly observes that the term "metamorphism," taken in its more general acceptation, comprises all the changes through which rocks have passed; and it may indeed be said that scarcely any rock or stratum can be studied in its original condition, as every one, whether it be a sandstone, a conglomerate, a shale, a schist, a limestone, a trap, or a granite, has undergone some modification,—consolidation being a process subsequent to deposition, and crystallization subsequent to some form of liquefaction. He then introduces the following classification as necessary to facilitate the study of so comprehensive a subject: viz., 1st, normal or general metamorphism, depending upon causes which have acted upon a grand scale, but generally in an imperceptible manner; 2nd, abnormal or special metamorphism, which depends upon partial causes, visible in their modes of action, and generally limited in extent. To this latter class of metamorphism, and more especially to metamorphism of contact, M. Delesse confines his attention at present, remarking that, though it is the most simple, it yet affords a vast field for inquiry; and in this restriction he acts wisely, as it cannot be doubted that the safest way to arrive at a correct conclusion as to the possibility of certain effects having been produced by the more obscure forces of nature, is to ascertain what those forces which can be observed almost in action, and which have some analogy (at least in results) with the forces which may be called into action in our laboratories, are capable of producing.

M. Delesse gives a goodly list of the various European and American authors who have in some one point of view or another, as M. Delesse observes, referred to the subject since the time when Hutton first brought it within the range of true science; but it must be admitted that many of these authors have merely referred to metamorphism as a matter of fact, and that some have occasionally assumed for it powers at variance with the laws, chemical and physical, of nature.

When a dyke or vein of intruded mineral matter can be so observed that the portion of the rock of deposition through which it passes exhibits the effect of its contact, whilst the portions distant from it retain their original condition, or rather their actual condition at the time of the eruption, there can be no reasonable difficulty in assigning the effect to its cause, though there may yet be a doubt as to the manner in which that cause had acted. One of the best methods of obtaining a clue to this very obscure question is to study the different effects produced on various substances by the same operating cause—bearing also in mind, that here, as in every exhibition of natural forces, action and reaction always accompany each other, the intruded rock acting upon the mineral matter through which it passes, whilst the latter reacts upon the intruded rock, the two forms of metamorphism being thus called by Cotta, direct and inverse, and by Fournet exomorphism and endomorphism,—citations which, it will be observed, I quote from M. Delesse. The effect of the direct action of the erupted rock is, however, generally greater than the inverse action of the rocks through which it passes, as its plastic state gives it a facility in penetrating and operating upon the more rigid materials of the enveloping rock, which the latter does not possess. Its action also is, doubtless, assisted (as suggested by M. Elie de Beaumont) by the filtration of water charged with mineral matter, or by the disengagement of gaseous and vaporous emanations from its mass. On this point, however, it is necessary that I should observe that the abstraction of certain portions of its elementary constituents from the intruded rock of eruption must

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necessarily induce a very great change in its ultimate condition, quite independent of the possible introduction into its mass of other elementary constituents derived from the enveloping strata. Here, again, the examination of the reciprocal effects produced by the passage of erupted rocks through various substances has the advantage of not only showing the difference of the results produced on the enveloping rocks, but also on the erupted rocks themselves, which, however different they appear in their final condition, may possibly be reduced to the same original by such inquiries. As M. Delesse observes, quoting an old proverb, "just as the workman is known from his work," so also from the study of metamorphosed rocks may be traced out the true history of the erupted rocks which have produced them.

M. Delesse begins his inquiry with direct metamorphism, or that change produced on the enveloping strata by the erupted rock, and limits himself first to the effects produced by the eruption of truly siliceous rocks, such as lavas, trap-rocks, and granites. The term lava is restricted to those flowing mineral masses anhydrous in composition and manifestly of igneous origin. Trap-rocks are hydrated mineral masses, the base of which is a hydrated felspar of the sixth system, anorthose, and which may be therefore called anorthose rocks: they include basalt, dolerite, hyperite, euphotide, trap, diorite, hornblende-rock, greenstone, kersantite, &c., to which are added "Sherzolithe" and serpentine. Granite-rocks contain, as an essential element, orthose felspar, and may be therefore called orthose-rocks: they include granite (as the type), syenite, protogine, porphyry, eurite, minette, and *even gneiss*. The family of trachytes, containing vitreous felspar, belongs to the orthose-rocks; but, as some of them are hydrated rocks, such as retinite, perlite, phonolite, and even obsidian, the metamorphism they have produced differs in character from that of granitic rocks, and they must therefore be classed with the trap-rocks. so that all hydrated volcanic rocks are grouped together as traps. The metamorphism produced by granitic rocks is not so easily traced out as that proceeding from the action of trap rocks, since it generally happens that the enveloping rocks are also crystalline, and that it becomes therefore no easy matter to determine the line of demarcation between the granitic nucleus and the granitic envelope, or to distinguish between the action of special and of general or normal metamorphism. M. Delesse therefore begins by explaining the metamorphic action of trap-rocks; and he investigates the effect produced on mineral substances such as the ores of iron, on combustible substances, on felspathic rocks, on limestones, and on siliceous and on argillaceous rocks, first citing the actual facts he has either observed himself in nature or in well-authenticated specimens, then describing the erupted rock and bringing into comparison the original and the metamorphosed condition of the rock upon which it has acted,—the principal mineralogical and chemical characters of all these being carefully determined, so that both the physical changes of structure and density, as well as the alteration of composition from the loss of particular elementary substances, may stand revealed. At this point it may be observed that M. Delesse soon convinced himself that the effect of heat as an agent of metamorphism has been much exaggerated, and even that porcellanite, so often assimilated as an igneous product to the vitreous slags of furnaces, which are produced by the action of beds of coal in a state of ignition, has only very partially owed its production to heat. Nor is this all, as he considers that the same remark applies to various other rocks, both metamorphic and eruptive, the formation of which has been exclusively ascribed to heat.

To solve a question of this kind, M. Delesse first submitted the various rocks to the action of heat in the laboratory, as the effects upon some substances may be very great, and upon others very slight. The prismatic structure which the lining of furnaces assumes by heat has often been noticed, as also the vitrified scoriaceous condition assumed by many substances; but all these bear about them marks of their origin which are easily recognized. As the action of heat necessarily varies with the composition of rocks, M. Delesse briefly notices the peculiarities of metamorphism which they exhibit: thus, combustibles lose their water and volatile constituents, and are converted into charcoal or coke, but are never by heat alone transformed into anthracite,—the temperature necessary for producing these effects being much less than is usually supposed, as the heat required for distillation of the bituminous matters ranges from 500° in turf and 572° in lignite, to 752° in coal and anthracite, or in all cases a temperature below red heat. On this point M. Delesse observes that, admitting the progressive increase of temperature in penetrating towards the interior to be at the uniform rate of 1° for 60 feet, the highest temperature above named would be possessed by a rock erupted from a depth of about $9\frac{1}{2}$ miles,—whilst the great change produced by the expulsion of the larger portion of the water of the combustible substances being effected at a temperature little above 212°, the eruption of a rock from a depth of $2\frac{1}{2}$ miles would be sufficient to produce such an effect. I need scarcely observe that this reasoning simply implies that an increase of temperature proportionate to the depth below the surface of the earth is an observed fact, and leaves untouched the question as to the true cause of that increase. It is only necessary to name the other agencies which M. Delesse cites as capable of abstracting the bituminous and volatile matter of combustibles, such as benzine, itself a product of the distillation of coal, alkalies and alkaline carbonates, and highly heated currents of water, charged with mineral and especially alkaline matter, traversing the beds of combustible matter when situated deep in the interior. M. Delesse indeed concludes from this latter fact, that the difference between lignite, coal, anthracite, and graphite is rather due to the metamorphic action produced by this aqueous action than to a simple dry distillation.

Pure calcareous rocks would lose by heat alone their carbonic acid, and be brought as caustic lime into a condition to undergo further change; but marls or impure limestones might enter into fusion, and thereby undergo a complete change. Sulphate of lime, even at a temperature of 248°, loses its water; and, if heated to a much higher temperature, does not regain it; so that it may be reasonably assumed that contact with an igneous rock of intrusion would change gypsum into anhydrite.

The action of heat upon siliceous rocks is somewhat different in character, and had been the subject of a previous essay of M. Delesse. Their fusibility diminishes with the increased amount of their silica; and they fuse either into a glass or into a scoria more or less crystalline, at the same time being diminished in density, and after fusion being readily acted upon by alkalies.

As prismatic sandstones are often found in contact with trap-dykes, M. Delesse has tried what the effect of the action of alkalies would be on a sandstone forming the lining of a furnace, and which had assumed a prismatic condition as the effect of heat. This sandstone was very quartzose and cellular, or melted only in some few points. When boiled in a concentrated solution of potash, 4·5 of the silica was extracted,—this experiment proving that, by the joint action of heat and the alkaline constituents of an igneous intrusive rock, the metamorphic effects would be considerable, as the rock is brought by the heat into a condition in which it becomes subject to the alkaline action.

It is manifest that hitherto M. Delesse has estimated the effects produced under the simplest aspect of the operations of natural causes; but, as in Nature the causes are complicated or combined (for example, in volcanos, where heat acts in the interior of the earth subject to the modifications due to pressure and the action of vapour and disengaged gases), he then proceeds to give examples of the alterations both of minerals and of rocks by subterranean ignition such as often occurs in coal-mines. The heat thus produced, and under such circumstances, has been found sufficient to volatilize the water, and disengage the carbonic acid of the argillaceous carbonate of iron, and to produce a considerable change in its physical characters, whilst combustible substances have also undergone material alteration in such a process. In this latter case, the carbon being dissipated, the ashes are sometimes too refractory to melt, as at Menat in Auvergne, where the ash proceeding from the spontaneous combustion of a bed of lignite is a schistose and pulverulent tripoli coloured red by oxide of iron, whilst in other cases they have melted and are vitrified. Considerable change may be effected also even where the combustibles are not burnt, as the observations of M. Drian, quoted by M. Delesse, prove—on such natural combustions at the Montagne de Feu near Lyons. The first alteration is indicated by the coal becoming iridescent; by a further change it becomes cellular and cavernous, as well as harder and more brilliant, and finally passes into a coke with metallic lustre: and such alterations have been extended to a distance of several yards from the ignited coal, the metamorphosis here produced being analogous to that observed in contact with trap-rocks. Siliceous rocks are acted upon nearly in the same manner as by ordinary calcination: they lose their water or other volatile constituents; they become, if argillaceous, agglutinated together, tinted of various colours, ribanded like jasper, still preserving traces of stratification, fragile, hard, and sonorous, of which porcellanite is an example: and if the temperature be very high, they are melted and form vitrified substances, just like the slags of a forge or furnace. These subterranean combustions yield also volatile and sublimed products like volcanos, as, for example, the combustible gases, vapour of water, specular iron, sulphur, hydrochlorate of ammonia, and other salts. It is right, however, to observe, that though the identity of the effects produced by artificial calcination with those produced by the combustion of beds of coal or lignite is fully established by these observations, it can hardly be said that the conditions are those of rocks exposed to intense heat under great pressure, and totally excluded from the air.

This latter case is more nearly represented by the effects produced by lavas, which is the next subject of the inquiries of M. Delesse, who names all those authors who had preceded him in such investigations. At the Puy de Montchié, in Auvergne, trunks of trees, more or less carbonized, are found imbedded in the volcanic debris which forms the base of the Puy. The charcoal thus formed is of a rich black colour, and of a metallic lustre; it is friable, very porous, light, and soils the fingers; it has preserved its original woody structure, and by MM. Lecocq and Bouillet is considered to have belonged to the birch. It is readily combustible; and its composition, as determined by MM. Lecocq and Bouillet, is—carbon, 52·50; white ashes, consisting of carbonate of lime, with traces of silica and alumina, 5·00; loss by ignition, 42·50; so that it is evident that the water and volatile matter had not been fully expelled by the igneous rocks, to the action of which the combustible body had been exposed.

The composition of another example of wood carbonized by lava, from Auvergne, M. Delesse found to be—carbon, 18·75; ashes, 46·48, consisting of carbonate of lime, 6·21, oxide of iron with a little alumina, 40·27; loss by ignition, 34·77. As charcoal formed artificially contains, when manufactured in damp air, not more than 20 per cent. of volatile matter, it is clear that, even in this example, calcination under such circumstances has only partially expelled the volatile matter of the wood, whilst both analyses show that the charcoal has been impregnated with mineral substances; so that the black or red charcoal, produced by the action of the lava which, as at Vesuvius where these effects may be studied, envelopes the wood or other vegetable substances, is in a much more advanced stage of metamorphosis than any artificially-formed charcoal. Felspathic bodies undergo very material change from contact with lava: thus the granite of the Roches Rouges, near the Puy, has assumed a prismatic structure; the fragments of granite of Denise, near the Puy (Haute Loire), imbedded in a volcanic scoria, have been partly melted, and have assumed a cellular structure, the cavities being due to the dissipation of the mica, which is the most fusible of the constituents of granite, whilst the quartz, which is the least, remains distinguishable.

Many other examples of the fusion, either partial or entire, of granitic rocks are cited, the effects being similar to that produced on granite in a glass-making furnace, the quartz alone resisting the action of the heat; but M. Delesse observes that, independently of fusion more or less complete, felspathic rocks become impregnated with "fer oligiste" and other sublimated products of volcanoes, and have, like other rocks, been sometimes attacked by acid vapours. In fact, metamorphosis, under such circumstances, depends on the action and reaction between the active rock and the rock acted upon, as also upon the effects produced by other agencies, due to the eruption of gases and vapours, simultaneously with the principal agent, the erupted rock.

In calcareous rocks it is remarkable that, though in general they are, by contact with lavas, rendered crystalline and granular, or in some cases highly saccharoid, like marble, they appear on other occasions to have undergone scarcely any alteration. This metamorphism, due to heat combined with pressure, has been well understood since the experiments of Sir James Hall, confirmed as they have been by those of several subsequent chemists: M. Delesse observes, however, that neither a great amount of pressure or of heat is necessary to produce it, and adduces as a proof the production of crystalline stalactites, and even beds of a similar limestone, without the aid of heat,—an example not, however, in my opinion, analogous, as in this case the molecules have been enabled to move by a previous solution of the body in water, whereas in the other the cohesive attraction between the particles required the action of heat to allow mobility. It appears to me, indeed, that the occasional absence of the effects of metamorphic action indicates that in such cases the pressure had not only prevented the escape of the volatile constituents, but had also neutralized the effort of heat to destroy the force of cohesion, and thus to allow the particles to move amongst themselves. If so, it is due to some modification in the circumstances, as yet to be explained by positive facts, though easily guessed at as a speculation. Other more complex effects, such as the introduction of magnesia into the rock, or (in the case of the saccharoid limestone of Somma, specially studied and described by M. Delesse) numerous minerals, are due to the reactions before noticed in respect to felspathic rocks, the limestone being originally marly or impure. Pure siliceous rocks, such as quartz, are acted upon in a similar manner to granite, but have been less affected. Fragments of quartz found imbedded in lava have become opake, and have been fissured, but rarely melted, and then chiefly on the surface. The presence of an alkaline solvent may, however, contribute to a mere perfect solution; and then the silica would be absorbed in the mass of the lava.

The effect of metamorphic action on argillaceous rocks is less complete, as the surface may be vitrified, and no alteration produced on the interior; still, however, gaseous matter has in some instances been expelled, and a cellular internal structure has been the result. M. Delesse then sums up the effects thus: either a calcination more or less complete; the assumption of a stony, cellular, or vitreous structure; sometimes a complete solution, probably partly due to the water combined with the rock.

I hope that what I have said will give a fair idea of the systematic and able manner in which M. Delesse has treated his subject advancing step by step from the simple to the compound, the laboratory of the chemist leading to Nature's present laboratory the volcano, and that again to the more recondite sources of metamorphism, viz. trap-rocks; but, as to follow him through the latter would require an inordinate space, I must merely content myself by observing that the same order is observed, and that every step of the investigation is illustrated by numerous examples, either based on the observations of others, or on his own, as well as by the chemical analysis of many of the products of metamorphism,—whilst the results are striking proofs of the value of M. Delesse's inquiries, and of the ability with which he has pursued them. In respect to combustible substances, he deduces from his inquiries that they appear under four aspects, corresponding to the different degrees of normal or general metamorphism, namely graphite, anthracite, coal, and lignite, and then illustrates the action of the trap-rocks upon each. New Cumnock in Scotland has afforded many illustrative specimens, originally collected by M. Boué, but analysed by M. Delesse, though here it is rightly assumed that the coal has passed through the several stages of metamorphism up to anthracite, and finally graphite, through the action of the trap, having become impregnated in the course of the change with a large amount of mineral matter. The lignite of Omenak in Greenland, collected during the recent voyage made by Prince Napoleon, and, where in contact with the trap, metamorphosed into anthracite, exhibits even more striking results, as by analysis it is found to consist of carbon 50·64, water and traces of bitumen 15·60, carbonate of lime 18·43, of magnesia 6·27, of iron 2·03, alumina 7·08; the anthracite having become useless as a combustible, being highly impregnated with mineral matter, sometimes in the form of veins. Whilst, however, these are the effects of contact with trap-rocks, M. Delesse points out, from various examples, that coal and anthracite, when *imbedded* in the trap, may have escaped such external metamorphism,—as an illustration of which, he cites the combustible, apparently a lignite, of Dellys in Algeria, observed by M. Ville, which, though imbedded in trap, has not passed into the state even of charcoal or of coke, as it would have done in contact with lava; but has been simply changed into a dry coal, which under distillation yields bituminous and ammoniacal matter.

M. Delesse deduces from this partial change a reason for considering the heat comparatively feeble; but I am more disposed to ascribe the differences of result to the more or less porous character of the enveloping trap, and the consequent greater or less facility with which the volatile ingredients might have escaped from the combustibles, although it is very possible that the heat in this case may not have been very excessive; and the impregnation with mineral matter indicates, as in other cases, that the metamorphism is due in part to other causes, and not to heat alone. The change produced is, indeed, of two different kinds, which point to differences of action, as, for example, the production of a more compact combustible, whether coal, anthracite, or graphite—the density being increased; or the production of a truly carbonized substance, in which more or less of the volatile matter has been removed, and its density diminished. M. Delesse offers some theoretical considerations on the subject of this description of metamorphism. The prismatic character so frequently observed he attributes to simple contraction or desiccation, not requiring a very high temperature, and he cites the fact, that some combustibles, when dried in the air, lose a part of their volatile constituents, and assume a prismatic character: the introduction of mineral matter he ascribes to filtration, aided in most cases by aqueous solution, and points out how the action of trap-rocks upon the usual sedimentary rocks of the earth's crust, all being more or less saturated with water, must produce streams of hot water, which, acting upon the rocks, will become charged with saline and alkaline matter, and thus become a powerful instrument of metamorphism, first by removing the volatile matter of combustibles, and then by acting chemically upon them through the instrumentality of the matter held in solution.

The action of heated water, penetrating either by fissures or through the pores of a rock, may often explain cases of metamorphism where no igneous rocks can be traced,—for example, in the Alps, as quoted by M. Delesse, where combustibles of the jurassic age have been converted into anthracite. Scotland and Ireland, as well as other countries, including North America, have afforded numerous examples of the effects produced on rocks of various geological ages and physical structure; but, tempting as the subject is when handled by M. Delesse, I shall now leave it, confidently trusting that some of the able chemical philosophers of our own Society and country will be induced, by what I have said, to give M. Delesse the gratification of knowing that he has kindled enthusiasm in the minds of those so fully qualified to follow his example. M. Delesse adopts the same system of inquiry as Bunsen and Senft* in Germany; and I hope that ere long we shall have our own chemical geologists, in Haughton, Galbraith, and others.

The papers or essays which I have hitherto noticed afford good examples of the purely chemical and physical modes of investigating the condition of the earth's surface; the one I am now about to notice introduces a new principle of examination, and is peculiar to our own member Mr. Sorby. The microscope has unquestionably done most important service in many delicate investigations connected with both inorganic and organic tissues; and all must remember the beautiful results displayed in the 'Odontography' of Owen, and in the works of Carpenter, Quekett, and Bowerbank: but it was reserved to Mr. Sorby to apply this powerful instrument to the examination of the internal structure of rocks, and to deduce from it many philo-

* We are indebted to Mr. J. Morris for an excellent abstract, in the 'Journal,' of the able work of Dr. Ferdinand Senft. It supplies what was wanting in the mineralogical classification of rocks by Brongniart, namely, their chemical analysis.

sophical conclusions of high interest. Mr. Sorby's application of the results of his inquiries to the explanation of the phænomena of cleavage is fresh in our recollection; and he has since pointed out the misapprehension of his views which even Professor Tyndall has shared with many others. Mr. Sorby intended to show that the compressive force, which he considers essential for the production of cleavage, acting upon the unequiaxial particles of mica, would lead to their arrangement in planes corresponding to those of the induced cleavage, and, consequently, that the cleavage in slate-rocks is more perfect in proportion as the quantity of mica present increases; and he further states, "there are scarcely any rocks whose particles are not unequiaxed, and I must still maintain that, other circumstances being the same, those have the best cleavage that are composed of particles whose length and thickness differ most." It is therefore not as being the primary cause of cleavage, but as influencing its degree of perfection, that Mr. Sorby cited the mode of arrangement of the particles of mica in slate and other rocks; and few will doubt that so far his reasoning is correct, as the planes of crystallization will naturally become coincident with the planes of cleavage. In his paper on the "Limestones of Devonshire," Mr. Sorby, in a similar manner, endeavours to show that the unequiaxed particles have by compression been thrown into planes, perpendicular to the direction of pressure, which have become the points or spaces of least resistance of Professor Tyndall, or those in which, according to my view of the case, the reaction to pressure exceeds the cohesive force, the planes in fact of least cohesion. In another paper, also of recent date, Mr. Sorby endeavours to prove that the terraces in the Valley of the Tay, north of Dunkeld, have been "formed by the combined action of the river and of the sea when it was at a relatively higher level;" and this idea he ingeniously supports by showing that the stratula of the bands of ripple-drift, or drift-bedding, dip on the whole along a mean line to one side, being that to which the current flows or in which the directing pressure is applied, just as in his previous experiments in the preceding paper,—a current therefore which alternately moves in two directions naturally giving rise to successive opposite dips of the stratula. Having ably maintained his views, Mr. Sorby judiciously adds, "it must not be supposed that I wish to make it appear that the terraces in all other valleys are due to the same cause,—as one set of circumstances may have formed some, and another set others. Nothing, in my opinion," he adds, "can be a greater obstacle to a correct interpretation of such phenomena, than to conclude that all things which appear *similar* are actually *identical* and have had a similar origin,"—remarks, in the truth of which I fully concur.

In the papers of Mr. Sorby which I have been noticing, the microscope was applied to the elucidation of the manner in which the constituent particles of rocks had been arranged, and thereby to the explanation of the true character of some important physical phænomena. In the paper which Mr. Sorby contributed to our proceedings during the present session, the same instrument has been applied to the examination of the "Microscopical structure of Crystals, with a view to the determination of the Aqueous or Igneous origin of Minerals and Rocks," which is one of the most abstruse and difficult questions in physical geology. As a general rule, it must of course be admitted that the molecules of any substance must be endowed with a power of movement before they can arrange themselves into any definite form; and, as regards mineral substances, it has therefore been always considered necessary that they should be in a state of solution before the elementary constituents, of which they are composed, could re-arrange themselves into a definite crystalline form. Taking, in the first place, notice of artificial crystals, since the whole process can in them be brought under actual observation, Mr. Sorby points out that, though the cohesive force of the particles is reduced to a minimum, it is not absolutely destroyed, and hence that, in the act of crystallizing, portions of the solvent surrounding them at the time of formation would be often caught up and enclosed within their solid substance. When, therefore, crystals are produced by sublimation, either air or vapour is imprisoned, which, on being condensed by cold, leaves apparently *empty cavities* or *air-cavities*; when the crystallization is from an aqueous solution, *fluid-cavities* are formed; when from an igneous solution, the crystals which separate themselves from the *fused-stone solvent* may be expected to catch up and entangle in their substance some portions of the mineral bath, which on cooling resume their original character, and produce what may be called *glass- or stone-cavities*. The differences between these several forms of cavities can be readily distinguished with suitable magnifying powers, and thereby afford the means of determining under what conditions the crystals had been formed: as, for example, crystals containing only fluid-cavities, from aqueous solution; crystals containing only *stone- or glass-cavities*, from igneous fusion; crystals containing both *water-cavities* and *stone- or glass-cavities*, from the combined influence, under great pressure, of highly-heated water and melted rock: and, further than this, that in the case of fluid-cavities, the amount of water present affords a datum for determining, from the amount of condensation it appears to have undergone since the original formation of the cavity, the temperature it possessed when entirely filling the cavity. In like manner, Mr. Sorby considers that empty cavities indicate that the crystals containing them have been formed by sublimation, unless there is reason to believe that the enveloping matter was sufficiently porous to allow the imprisoned fluid to escape, or that the cavities were merely bubbles due to fusion. The number of cavities may be expected to increase with the rapidity of crystallization, whilst a total absence of cavities indicates either very slow crystallization, or the cooling of a fused homogeneous substance. These general principles are then applied by Mr. Sorby to the study of natural crystalline minerals and rocks; and he deduces from them many highly interesting results: for example, that the *fluid-cavities* in rock-salt, in the calcareous spar of modern tufas, in vein-stones, in ordinary limestone, and in gypsum, indicate that these minerals were formed by deposition from solution in water, at a temperature not materially different from the present—a conclusion which equally applies to other minerals found in the veins of various rocks,—whilst the many fluid-cavities in the constituent minerals of mica-schist and the rocks associated with it show that the metamorphism to which they have been subjected was due, at least in part, to the action of heated water, and not alone of dry heat and partial fusion—a conclusion which should be compared with some of the deductions of M. Delesse.

The structure of the minerals in erupted lava shows that they were generally deposited from a mass in the state of igneous fusion; but as in some of the blocks ejected from volcanos, crystals are found which contain *water-cavities*, in addition to stone- and glass-cavities, it may be fairly assumed that they were formed under great pressure, when both liquid water and melted minerals were present, and that the minute crystals which the fluid-cavities of these aqueo-igneous minerals generally contain have been deposited on cooling from the highly-heated water which once filled the cavity. The minerals in trap-rocks appear to have been of genuine igneous origin, though they have been subsequently much altered by the action of infiltrating water, from which many other minerals have been also deposited.

The quartz from quartz-veins appears to have been rapidly deposited from solution in water, the temperature of which must, from the diminished volume of the water by cooling, have been considerable, about 329°; at a still higher temperature, mica, limestone, and probably even felspar were deposited, showing, as has been asserted by M. Elie de Beaumont, a passage from quartz-veins even to granite, and that the one therefore can scarcely be separated, as a rock of deposition, from the other as a rock of purely igneous fusion. Whilst, indeed, in the quartz of highly quartzose granite, the liquid-cavities are so numerous as to number millions even in a cubic inch, and the water they contain amounts to 1 or 2 per cent. of the volume of the quartz, so that they might be considered the result of an aqueous solution, both the felspar and quartz exhibit stone-cavities exactly similar to those in the crystals of furnace-slags or of erupted lavas, and therefore indicate the conjoint action of igneous fusion. The great conclusion which Mr. Sorby draws from this fact is, that granite is not a *simple igneous* but rather an *aqueo-igneous* rock, produced by the combined influence of liquid water and igneous fusion, under similar physical conditions to those existing, far below the surface, at the base or focus of modern volcanos. These deductions of Mr. Sorby are in conformity with the views of Scrope, Scheerer, and Elie de Beaumont; and he even agrees with them in considering it probable that the difference between erupted trachytic rocks and granite, both of which are included by M. Durocher (in the paper on which I have already commented) in the same class, as proceeding from the same *magma*, is due to the presence or absence of the water.

In whatever light we regard the paper of Mr. Sorby, whether as founding upon microscopical observations a new explanation of the conditions under which rocks have been formed, or as proving from them the intimate association of water with the constituents of minerals, independently of the simple water of crystallization, it cannot but be received by the Society as a striking exemplification of the zeal, originality, and success with which he carries on his researches in physical geology.

Cleavage.—In my last address I was necessarily obliged to enter at considerable length upon the subject of cleavage, in order to do justice to the labours of our late most distinguished and most lamented President, and I shall therefore refrain from anything more than a very brief reference to what has since then come under my notice. The report upon cleavage presented to the British Association in 1856, or anterior to my address, but published subsequently, has been divided into two sections: the first, of a historical and descriptive character, is that which has now appeared; the second, which will be theoretical, is reserved for a future period. With his usual ability Professor Phillips has corrected some errors of detail in the observations of his predecessors; and it may be said that he clearly establishes the following phases in the progress of a subject which he justly characterizes as English; viz., 1st, the recognition of the necessity of a great leading or general cause, instead of a partial or accidental one, by Professor Sedgwick; 2nd, the more perfect connexion of cleavage with pressure, by the methodical application of the phænomena of distorted shells to its explanation by Mr. D. Sharpe; 3rd, the illustration of many points connected with cleavage, by the microscopical investigations of Mr. Sorby; 4th, the experimental investigation of the effects of pressure in producing cleavage, by Professor Tyndall. The "fundamental generalization" of Professor Sedgwick, to use the expression of Professor Phillips, has been illustrated by many observers, and especially by the two brothers Rogers in their graphic account of the Appalachian chain in the United States; and I will only add, that whilst there can be no doubt that cleavage has, in many of the cases which came under the observation of Mr. Sharpe, been the result of pressure, it still remains to prove that pressure has been the only cause of cleavage—or at least that pressure has always acted in the same manner, in order to bring within the scope of calculation some of the examples cited by Professor Phillips, such as "waved cleavage," "cleavage varying *in its angle* according to the variation in the mineral composition of successive strata," &c. In my last address I gave my opinion as to the natural law upon which cleavage might be supposed to depend; and I must still say, that when Professor Sedgwick expressed the idea that the cleavage in mountain-masses is so regular as to appear like the results of enormous crystallization, he seems to have exhibited that keen appreciation of natural phænomena for which he has always been remarkable, and to have had in his mind the fact that crystals, being formed by the apposition of successive layers of molecules drawn together by the force of affinity, subsequently cleave in the direction of these layers—the cohesive force between the molecules of any one layer being greater than between the molecules of two adjacent layers. At the last meeting of the British Association, Professor Haughton illustrated his preceding calculation of the effect of pressure in distorting organic remains, by an ingenious model, which showed that as a general rule, there is not a greater extension of a distorted fossil in the line of the dip than in that of the strike of cleavage.

Glaciers.—The researches of Professor Tyndall on the properties of ice and the phænomena of glaciers having been alluded to in the preceding remarks, it seems to me desirable to offer a few observations on that interesting subject; for, though glaciers are not at present recognized as having at a comparatively recent epoch extended their action over a vast extent of the earth's surface, plain as well as mountain, they have been still more intimately connected with the general history of the earth, by the researches made, especially by Professor Ramsay, to detect traces of their past action, not merely *on* ancient rocks, but within the periods during which such rocks were deposited. The great difficulty in accounting for the progressive movement of glaciers, is to provide a sufficient force to put such ponderous masses into motion, and to keep it up notwithstanding the retarding force of friction. Some of the earliest investigators, as Saussure, considered the force of gravity as sufficient to produce motion, whilst the melting of the ice in contact with the earth reduced the friction to a minimum, or, in the words of Mr. Mallet, placed as it were liquid rollers under the ice. Anterior, however, to this mode of explanation, the Swiss philosopher, John Jacob Scheuchzer had advanced a totally different one in his 'Itinera per Helvetiæ alpinas regiones,' a work which was published by Vaudon of Leyden, in 1723, and dedicated to Sir Isaac Newton, then President of the Royal Society, of which Scheuchzer was a member. Scheuchzer observes that the movement of glaciers requires not to be explained by any miraculous agency, but is entirely dependent upon natural causes; for he adds, "Solet nempe aqua a tergo montium rupiumque glacialium defluens, vel in fissuris ipsis et interstitiis aliis glacialibus collecta, et utrobique conglaciata, quoniam amplius in hoc statu requirit spatium (contestantibus id experimentis circa frigus et glaciem institui solitis), undiquaque premere et eam quidem glaciei partem quæ liberum aërem respicit, et pascua declivia actu ipso propellere, et una cum glacie arenam, lapides, saxa etiam grandiora, quo ipso hyperbolica illa purgatio simul explicari et facile intelligi potest." All will remember the ingenious manner in which Agassiz, following Charpentier, adopted and applied this theory, by assuming that a multitude of capillary cracks are formed at night,—that water produced by the melting of the ice on the surface by the sun's rays during the day filters into the cracks, and is frozen and therefore expanded at night, when, by the expansive force of so many frozen seams of water, the ice is put in motion, new cracks are formed, and all is ready for a repetition of the same results. This theory was at first as popular as the simple gravitation-theory had at first been, when Professor James Forbes, considering it too hypothetical, entered upon the investigation of the subject, and, after most laborious personal researches in the Alps, guided and supported as they were by the light and vigour of his philosophical mind, brought forward facts and reasonings not merely to overthrow the hypothesis of Agassiz, but to prove that, however difficult it may be to reconcile the motion and the other phænomena of glaciers with the gravitation-theory so long as the glacier is considered to be composed of solid ice, his observations tended to show that all the phænomena are analogous to what might be expected in a moving semifluid or pasty liquid like lava, and hence that a glacier ought to be considered ice in this imperfect state of condensation. However difficult it has been to ordinary observers to convince themselves that the ice they saw before them with its lofty pinnacles and its huge crevices, and which they could split with an axe into angular fragments, was a semifluid substance, the theory of Forbes has yet for several years been received as a satisfactory explanation of the phænomena; but Professor Tyndall has now satisfactorily proved that the structure of ice (a structure which had been previously ably illustrated by M. Schlagintweit) is such that it can be readily crushed into its constituent particles, and again by pressure reconsolidated, so as to conform to all the variations of form of the mould through which it is forced. The comparison of the results of direct experiment at the laboratory of the Royal Institution with the actual phænomena of the glaciers themselves has convinced Professor Tyndall, and I may fairly say every one who has listened to or read his lectures upon the subject, that his explanation of the mode in which ice is enabled to pass through all the accidents of movement, and to change its form without losing its continuity, is as satisfactory as it is philosophical; but it must be evident to all, that the theory of Professor Tyndall explains all the phænomena of glacier-motion, but not the cause of that motion. Professor Forbes had this latter point in view when propounding his theory of semifluidity; and we must now look to Professor Tyndall, who stands, from his zeal, intelligence, and high mental training, in the foremost rank of Alpine observers, to clear up the only difficulty now remaining.*

Descriptive Geology.—The great zeal with which palæontological research has been pursued, and the vast accession to the numbers of extinct animals and plants, have necessarily required the cooperation of the most able naturalists with the geological explorer, in order to ensure a correct determination of the epochs of the earth's history by the peculiarities of their respective faunæ and floræ. The geologist

* On this point I think it right to refer to the paper of my respected friend the Rev. Canon Moseley, F.R.S., on the motion of glaciers, published in the 'Proceedings of the Royal Society,' and in which he adopts the facts of Forbes and Tyndall as being satisfactorily established. He considers the motion due to the successive expansions and contractions of the ice according to the variations in its temperature, just as in any other solid, and independent of the congelation of water which may have filtered into its cavities. This theory he illustrates by a curious fact, observed first in a scientific manner by himself, at the Cathedral of Bristol. The sheets of lead with which a portion of the building had been covered are observed to descend gradually down the inclined plane of the roof, even tearing out the nails by which they have been fastened to the rafters, and that solely by their successive expansion and contraction. This substitution of the simple principle of the contraction and expansion of the ice as a solid body, each tending to promote its descent on an inclined plane, for the hypothetical one of the expansion by congelation of water filtrating into either the crevices or cracks, is unquestionably very ingenious, although some of our able philosophers have considered it insufficient to account for phænomena exhibited on so large a scale. Mr. Moseley, however, is about to reply to the objections of Professor Forbes and others in a second paper on the subject.

now receives organic remains after they have been critically examined and described by the zoologist or botanist, and has only to apply them to the practical objects of his own science. Whilst, however, it is easy to allot to the palæontologist and to the geologist their respective tasks, it is not so easy to separate the objects of physical geology from those of pure or descriptive geology, upon the same principle that a perfect geographer may be expected to be conversant with both natural and physical geography: it is, indeed, the object of the geologist not only to determine the age of a deposit, but also the physical circumstances under which it was formed. The latter and truly philosophical branch of the subject has always been a favourite study of our able fellow-member, Mr. Godwin-Austen; and in the paper I am about to notice, he founds upon a simple fact a very ingenious speculation. The "fact" is, that in the chalk about two miles south of Croydon was found a boulder of granite, associated with other detritic materials. Prior to reasoning upon this fact, Mr. Austen gives a very reasonable definition of the term "extraneous," by which he understands that a fossil, or other body, is found in a position not in accordance with its original habits, or the place of its formation, as, for example, a "deep-sea mollusc amidst a number of the inhabitants of shallow water," or a boulder of granite in a chalk- or clay-deposit. This definition is sound and important, as it points out to the palæontologist the necessity of determining the natural habitats of fossils, as well as their names, and to the geologist the necessity of separating the extraneous from the native fossils, before he can make a satisfactory comparison between the deposits of different ages. Mr. Austen reviews the history of fragments of "extraneous" rocks previously found in the Chalk, and then proceeds to draw the conclusions, which, though I have named them speculative, I do not consider the less philosophical and important. All the fragments he has noticed appear to have been water-worn, and therefore must have been moved or acted upon by water. Some of them exhibit marks of the *Serpulæ*, &c., which attach themselves to bodies resting for a time on the lower or quiescent portion of the "marginal sea-belt," whilst others, more especially the smaller or shingly kind, from their smooth surface, would appear to have formed part of the upper portion, which, from its position, is subject to the constant disturbance of the waves. D'Orbigny and Edward Forbes, as quoted by Mr. Austen, were of opinion that the pure white chalk was the deposit of a deep and open sea; but Mr. Austen shows, from the application of such reasoning as I have here noticed, that every other form of sea-bed, from the abyssal to the marginal, existed in the Cretaceous period. On the one hand, for example, the presence of sand, gravel, and occasional boulders under the circumstances detailed by Mr. Austen have proved the existence of a marginal zone before the deposition of the upper portion of the chalk; and, on the other, the presence of forms of Bryozoa and of other fossils which when alive must have been fixed at the base, detached in the body of the chalk, show that such fossils are "extraneous" in the position where they are found, and must have been moved down from a more marginal locality, before they were imbedded. Many other examples are given of this forcible removal of fossils from their original locality, and their subsequent deposition in the deep-sea bed; but I need not follow Mr. Austen through the details of this inquiry, as no one will now hesitate to admit that all the means of transport which now exist, such as the tidal wave, floating ice, floating trees, sea-weed, &c., are as likely to have been in operation within the Cretaceous epoch. Some of these (as, for example, ice) may, as suggested by Mr. Austen, have been modified in their action by a difference in the physical circumstances of the then existing dry land and sea; but all may have more or less contributed to the results produced. I will only further observe that Mr. Austen investigates with great ingenuity the form and composition of the dry land of the chalk-period,—as, for example, he shows that the Cretaceous strata of many localities indicate littoral conditions, and therefore that the older rocks (whether gneissic, granitic, or slaty) which are now in close proximity to them must have even then been in the condition of land-surface. I shall not follow Mr. Austen in his attempt to trace out the coast-line during the Cretaceous epoch; and I will conclude my remarks on his paper by observing that he has appropriated to himself a class of research which is difficult in proportion to its apparent obscurity, but which he is likely by his skill and perseverance to place very high amongst the objects of the philosophical geologist.

A short paper by Mr. Prestwich again brings under our notice the ingenious speculations of Mr. Austen, and goes far to prove their accuracy. It refers to the recent borings for water at Harwich, in which the artesian well has been carried to the depth of 1070 feet, having passed through the superficial drift, the tertiary strata, chalk, upper greensand, and gault; but below these well-known strata, the normal rocks or deposits which ought to have appeared were deficient, and a mass denominated a black slaty rock appeared instead, as shown by the fragments brought up, and examined by Mr. Prestwich. In the Kentish Town well, the chalk was found to be underlaid by rocks which lithologically appeared to belong to the Triassic epoch, but the evidence was not considered conclusive: in the present case Mr. Prestwich considers the proof of the absence of a large portion of the normally underlying rocks to be satisfactory; and, though he is unable to satisfy himself whether the rock arrived at belonged to the Carboniferous or to the Silurian epoch, yet that the evidence in both the Kentish Town and Harwich wells is sufficient to warrant him in adopting, at least in part, Mr. Godwin-Austen's hypothesis of the extension of an underground tract of the older rocks, ranging from the mountains of the Ardennes in Belgium to the Mendip Hills in the West of England, and therefore breaking the continuity of the Lower Greensand under London. The actual form of this ancient palæozoic land, Mr. Prestwich considers to have been a broken ridge rather than a broad tract; and this is unquestionably the most in conformity with the probable elevatory cause of its existence. Even though Mr. Godwin-Austen may never have the gratification of hailing the discovery of a coal-deposit under London or in its neighbourhood, the penetrating powers of his mind have been fully established by these practical results.

One of the papers contributed by Professor Phillips has a close relation, in one respect, to those I have last noticed, as it endeavours to explain the physical conditions under which some of the strata of Shotover Hill, near Oxford, have been deposited. Tracing the history of discovery in respect to these deposits from 1722 to 1827, it appears that the sandy strata which on this detached hill rest on the Portland series, and with their associated ochres have received the general title of Ironsand, being by Conybeare referred to the Hastings group, had, until the latter date, afforded no organic clue by which the physical circumstances under which the deposits had been formed could be inferred. Dr. Fitton then ascertained the occurrence of Purbeck deposits at Whitchurch in Buckinghamshire; and about 1832, the Rev. H. Jelly discovered Paludiniform shells in the sands of Shotover; and this discovery, confirmed by Mr. H. E. Strickland, was published by Dr. Fitton in his well-known memoir "on the Strata below the Chalk." Mr. Strickland added a *Unio*; and Professor Phillips himself has still further added to the list of fossils which I will call physically characteristic. The word "Portland" is in the mind of most geologists associated with the idea of the "Portland Limestone;" but the words "Portland Rocks" have a much wider acceptation in this paper of Professor Phillips, and refer, not alone to a calcareous form of deposit, but to the green sands, clay-bands, and layers of subcalcareous concretions, rich in fossils, which here mark more than the age of a deposit; for, whilst the fossils *Pecten*, *Perna*, &c., mark the aggregate of 70 feet in thickness to have been marine, another overlying group of strata, about 80 feet thick, consisting of various coloured but not green sands, bands of clay, layers of peroxide of iron, and cherty masses, is as decidedly marked to have had a partially freshwater origin by *Unionidæ*, *Paludinæ*, and other mollusca, which, though some may be considered as possibly marine, mark distinctly at least the cooperation of fluviatile action, and, combined together, establish the existence of an estuary- rather than a lacustrine formation. Professor Phillips therefore infers that the Shotover Sands are a northern equivalent of the Hastings Sands; but, from the difference in the species of *Unionidæ*, he suggests the probability that the river which was the cooperating agent in producing the deposit was a different stream from that of the typical Wealden, and that its effects will be traced much further to the north-eastward. Without doubt, these deductions from facts are deeply interesting; but what a wide field they open for speculation, since, the course of the river being traced by its effects, its banks are yet to be discovered! I cannot help also observing that the species of *Unionidæ* appear to be remarkably local, or at least that the variations in form from one locality to another are so great as to render them admirable guides in distinguishing one estuary from another belonging to the same epoch, but not equally so for estimating the relative ages of deposits,—a remark which has been strongly impressed upon my mind by the great number of local species which that eminent conchologist, Dr. Lea of Philadelphia, has even recently established and described. The object of another paper of Professor Phillips was, in a great measure, to bring under the notice of geologists the great difference in mineral aspect, and the only partial agreement in fossils, of the oolitic regions of North Yorkshire and the South of England, and, whilst attempting to settle the real affinities of some of the calcareous beds in the Yorkshire series with some of the well-established members of the Oolitic group of the South of England, to facilitate the determination of the geographical range of the ironstone, coal, and limestone of Yorkshire, and of the physical conditions of the sea or estuary in which they were deposited. When I observe that, by the close examination of two great general sections, Professor Phillips has proved the existence in the lower oolitic series of five distinct plant-bearing bands of sandstones, of shales which occasionally yield coal arranged in three zones, of four calcareous bands, and of several layers of ironstone, it must be admitted that he has brought before us most remarkable alternations in the physical forces in action at the time; but he has gone still further, by describing the geographical range or distribution of these varied deposits, and tracing out the relation of the lines of deposition, called by him "isochthonal lines," with the general strikes and dips of the strata, or in other words the lines which mark the limits of each varying condition of the deposits, from marine to estuarine. I need not enter further into the details of this paper; but I may observe that, as Professor Phillips proposes to resume, at a future period, the discussion both of the geographical range of the fossils, and of the physical conditions of the sea-bed already glanced at in this paper, he affords us another proof of the high advance in geological science of the present day. At one time it was supposed that palæontology had entirely done away with the necessity of studying the mineral characters of deposits; but now we find that the mineral character is essential for the right understanding of the fossils, as indicating the physical conditions under which they have been deposited.

A portion of the same geological division of strata engaged the attention of Mr. A. Geikie, one of the members of the Geological Survey of Great Britain; and the results of his investigations are given in a paper on the Geology of Strath, Isle of Skye. The previous writers on this somewhat complicated district are enumerated, namely, Jamieson, Macculloch, Murchison, and Edward Forbes,—the first of the latter two writers having, however, been principally instrumental in determining the existence and limits of strata belonging to the lias, and the lower and middle oolite, whilst Edward Forbes, in seeking for the equivalents of the English lias and oolite, ascertained that the Oxford clay has its equivalent in Skye. The district examined by Mr. Geikie is a narrow belt, from three to six miles in breadth, which extends across the narrowest part of the island from sea to sea, and in area is about thirty square-miles. Including, as it does, the largest development of the lias in Scotland, and as, in its lowest and middle divisions, it attains a thickness of 1500 feet, it compensates for the small area by the important reflections to which it may well give rise in respect to its former physical conditions, as so deep a deposit in so small a space must be considered only a relic of a much greater whole; and we may well say, with Mr. Geikie, that the intricate and confused character of the geological structure of Skye gives to the liassic beds an additional and peculiar interest. Considering the state of knowledge at the time when Macculloch published his 'Western Islands,' and the imperfect maps he had to guide him in his researches, we may well excuse some errors in marking the limits of strata, even in so acute and able an observer; and it is therefore no real disparagement to him that others have since been able to discover and correct them.

As a fact it is remarkable, that the Lias in Scotland rests on either a metamorphic or palæozoic base, usually the Old Red Sandstone, and that it is confined to the northern counties, among the hypogene and older palæozoic districts. The lias of Skye is sometimes conformable and sometimes unconformable to the underlying red sandstone, a purplish-grey quartz-rock; but, as these rocks have hitherto yielded no organic remains, it cannot be positively determined whether they belong to the Old Red, the Silurian, or the later portions of the gneissose series of Central Scotland.

Mr. Geikie traces the limits of the sedimentary deposits, and describes their mineral character as well as their organic relations, and then in a similar manner notices the various igneous or erupted rocks, which have, without doubt, given rise to much of the complexity of the district. This paper is accompanied by a very valuable list of the fossils collected by Mr. Geikie from the lias, drawn up by Dr. Thomas Wright, who prefaces the list by a brief definition of the sense in which he understands the term "Middle Lias." He here repeats his former opinion, that the terms Upper Lias, Middle Lias, and Lower Lias, as used by English geologists, require modification, in order to place the "basic" beds in correlation with those of French and German authors,—modifications which in his opinion require the basic beds of the Inferior Oolite to be transferred to the Lias, as the "Upper Lias Sands," and the beds which, with the Marlstone, were the upper beds of the Lower Lias, to be considered the basic beds of the Middle Lias.

Following up this idea, Dr. Wright gives a table showing the condition of the lias-beds in France, Germany, Gloucestershire, and Skye, in which these alterations are exhibited. This is a disputed point, to which I shall again have to refer. I shall only further observe that Dr. Wright first gives a list of about 86 characteristic species of Mollusca and Radiata of Gloucestershire, and then compares those collected by Mr. Geikie, which are identified (as already-described species) with them. These are principally from the shales of Pabba, which Dr. Wright, as the result of the comparison, places at the base of the Middle Lias, under the Marlstone. As there are 25 of such Pabba species, the deduction is made from a more enlarged basis of comparison than in the case noticed in my last address, and is unquestionably treated with an evident desire to arrive at the truth. *Pleuromya Scotica, Gervillia Maccullochii, Pentacrinus robustus,* and *Isastræa Murchisonii* are new species added to the fossil fauna by Dr. Wright, who also states that the *Gryphæa Maccullochii* (Sowerby) is the true *Gryphæa Cymbium* of Lamarck: as determined from the observation and comparison of the Pabba specimens, it is in his opinion a Middle Lias species, both in England and France.

I have hinted in the preceding remarks that I should have again to notice the question, mooted by Dr. Wright, of a proposed modification of the position assigned to the sands of the Inferior Oolite by English geologists. I had then in view the paper by Professor Buckman on the Oolitic Rocks of Gloucestershire and North Wilts. It is gratifying to observe that the two important sections used as illustrations for this paper are the result of surveys made by the professors and students of the Royal Agricultural College of Cirencester, as they are thus a practical exemplification of the importance of combining geology with agriculture—a subject so forcibly dwelt on by our late friend Mr. Trimmer. After noticing the labours and reviewing the opinions of preceding writers on the Oolites, and more especially on the lowest part of the series, Professor Buckman declares himself opposed to the views of Dr. Wright, and considers that he has not produced sufficient evidence for associating the so-called "Sands of the Inferior Oolite" with the Lias. He admits indeed that some of the shells from the fossiliferous sands are peculiar, and have sometimes (especially a few of the Ammonites) a Liassic aspect, but at the same time contends that the greater portion of the fauna, including the local and non-migrating Mollusca, is *characteristically oolitic,* and that the two more characteristic Liassic Ammonites, on which especially Dr. Wright relied, were not merely "extraneous" fossils, to use the phrase of Mr. Austen, but actually obtained from the true Lias, far below the sands in question. The cause of this mistake is supposed by Professor Buckman to have originated from the decomposed state of the surface of the Lias here, and the fact that it is masked by an overflow of the sand from above, so as to have led Dr. Wright to think that the fossils were in the sand itself. Professor Buckman deserves much credit for the pains with which he must have instructed his pupils and laboured himself in working out the details of the whole oolitic series; and it appears to me that the question at issue between him and Dr. Wright is in itself instructive. To determine that a fossil is extraneous, it ought to be shown that the bed in which it is found is, from its physical characters, incompatible with the organic conditions of its existence. The physical conditions of the Liassic and Oolitic beds are different; and it might be expected therefore that they should have supported many organisms peculiar to each, independently of any question of age. Should, therefore, a bed exhibiting the physical conditions of the Lias appear immersed in the Oolites, and in it be found a Liassic fossil, it cannot be assumed that such a fossil is extraneous, however its appearance may militate against our opinions of the age of the deposit. Should, however, the fossil be found imbedded in a stratum totally dissimilar to the bed which marks the character of its natural habitat, it cannot be received as any other than an extraneous fossil, and ought to be rejected from the list of characteristic fossils. In geology there should be no spirit of partisanship, as the object is not to support the territorial rights of formations, but to arrive at truth. Such, I am sure, is the object of Professor Buckman; and, as he promises hereafter to offer further remarks on the physical conformation of the Oolitic district he has described, we may expect that this question will then be finally settled. In like manner, I am satisfied that Dr. Wright, when convinced that he has, in this particular case, been led into error, will frankly admit it.

A paper by Professor D. T. Ansted on the geology of the Southern part of Andalusia, between Gibraltar and Almeria, brings the Jurassic beds under notice, with some little variations in the physical characters of the rocks with which they are associated. Having described the mica-schists of the Sierra Nevada, he states that in the north-west they are overlaid by a crystalline limestone, on which repose thick beds of tertiary marls. Beds of shale in some places are interpolated between the schists and the limestones; and near Malaga they pass into a conglomerate, and then into triassic and jurassic beds. The old schists and the shales are traversed by serpentine-veins, which, in the absence of fossils, serve as a proof of their general identity. East of Malaga the Professor observed a black fœtid magnesian limestone (distinct from the true dolomites), which underlies shales and sandstones, the upper grit-bed containing Calamites or Equisetites. This limestone he considered the equivalent, as regards position, of the *conglomerates* between the shales and sandstones above mentioned; but as the first-named shales were said to pass into the *conglomerate*, and at the same time were closely connected by the serpentine-veins with the mica-schists, there appears much complexity, as might have been expected, in these partial (or at least locally-studied) deposits.

The limestones of the Sierra de Gador pass towards the west into the light-coloured limestones of Gibraltar, and are considered jurassic, —a red marble at San Anton being probably Cretaceous, and an overlying calcareous breccia the base of the Tertiary series. On this latter rock rests another limestone of oolitic structure, but associated with a Nummulitic rock. All these are followed by a series of Upper Tertiary strata, the lower beds rich in Foraminifera, and the others exhibiting one of those curious alternations of land and freshwater fossils, with beds abounding in the most marked marine fossils. The more recent raised sea-beaches close the geological details of Professor Ansted's paper; but, as his great object in visiting Spain appears to have been the investigation of its mineral treasures, I may observe that irregular deposits of argentiferous copper occur in the mica-schist, that galena is found in the first-mentioned crystalline limestone, that copper-ore is also found in the beds of shale (which is another link between them and the mica-schist), and, finally, that *enormous deposits of galena* are found in fissures which traverse the supposed jurassic limestones,—results which sufficiently prove the importance of geological knowledge to the practical mineralogist.

Our indefatigable member Capt. T. Spratt, R.N., has extended his inquiries into the Eastern part of the Dobrutcha, and has favoured us with some remarks in continuation of his former paper. The flanks of the Northern chain of mountains, in itself composed of highly inclined limestones, shales, and slates, are smoothed down, as it were, by a deposit of arenaceous and variegated marls. These marls are considered of recent date; and though not fossiliferous, Capt. Spratt now considers that this group of superficial marls of the Steppe is distinct from the freshwater marls, or lower freshwater deposits, of Kustenjeh. At the north-east of the Dobrutcha there are older rocks, which Capt. Spratt considers to be in a metamorphic condition from volcanic action, and, in his opinion, to have been either Devonian or Carboniferous; to them he assimilates the thick beds of dark shale which occur at the south-west corner of the Raselm Lagoon, where the Delta of the Danube commences; they resemble the shales and schists on the flanks and base of the Balkan, near Cape Emmeneh. In the coast-cliff a secondary limestone is observed to overlie the shales, whilst it immediately underlies the superficial earthy marls of the Steppe. Capt. Spratt had no opportunity to search for fossils amongst the deep beds of shale, sometimes amounting to 500 or 600 feet in thickness; but the fossils found by him in the limestone appear, from the examination of our Assistant-Secretary, Mr. Rupert Jones, to correspond with those of the secondary section of the white limestone of the Mediterranean: and I use the term "section" because, as I have on a previous occasion observed, the same physical condition is preserved in the limestone from the jurassic into the tertiary epoch as is shown in the Ionian Islands, and more especially in the Island of Paxo, where Nummulites in great abundance occur in connexion with flints, and with the general characteristic appearances of the hardened chalk. Some of thephysical changes which have taken place in this region are highly interesting. The limestones Capt. Spratt supposes to have stood as ridges, rocks, or islets in a freshwater lake, which once covered, in his opinion, the whole area of the Black Sea and Archipelago, and which has left evidence of its existence in several freshwater formations, both of marls and limestones. Following in succession the hard porcelain-like limestone, Capt. Spratt notices a chalk-marl and a limestone of a more truly cretaceous character; but even these would appear not to be clearly determinate in age, were it not that Mr. Jones states that a Ventriculite and Cretaceous Foraminifera occur amongst the fossils. I shall conclude my brief notice of Capt. Spratt's researches by observing that the base of the tertiary system is in several localities observed to be, as at Varna, and at Sevastopol on the opposite shore, a limestone oolitic in structure,—a fact which confirms my observations of the continuance of a prevailing mineral type through a vast range of organic life.

Another brief but very interesting paper, "On the freshwater deposits of the Levant," may be considered supplementary to the preceding, as its object is to trace out the boundaries, and determine the age of a great Oriental lake or chain of lakes which embraced the Dardanelles, Sea of Marmora, and perhaps part of the Mediterranean, as indicated by the detached or fragmentary deposits along the ancient margin. This is a noble speculation; and I will only add that Capt. Spratt, who invites the attention of geologists to the subject, has proved himself a very able pioneer of their researches.

During the late war, the occupation of part of the Crimea by the allied armies brought within the scope of observation the geology of a country, which, although it had been previously examined, still left much open to further investigation. Had the proposition which was made at the commencement of the war, to attach a scientific committee to the army, been carried into effect, there cannot be a doubt that much most valuable information would have been obtained towards the correct correlation of the strata of the Crimea with those of England; but, even as it was, some of our officers found time, amidst all the dangers and privations of that most remarkable campaign and siege, to collect materials for geological investigation. Amongst these intellectual soldiers, Capt. F. Cockburn, Royal Artillery, was one who not only worked hard to collect a series of fossils and rock-specimens illustrative of the geology of the neighbourhood of Sevastopol and Balaclava, but who wisely placed them in the hands of our able member, Mr. W. Baily, for description; and the result is a very copious list of fossils, which have been well illustrated by three lithographed plates. The range of strata extends from the shales of the Woronzoff road (described by M. Dubois de Montpéreux as the oldest fossiliferous deposits, and considered by Mr. Baily to be equivalent to the Lower Lias) through Jurassic and Cretaceous strata, up to the Steppe Limestone, which, though often oolitic in character, is proved to belong to the Newer Tertiaries,—an example which, like those I have before cited from Capt. Spratt's and my own observations, exhibits the long continuance of the same physical conditions, notwithstanding the variation in the imbedded organisms. Specimens of the various intrusive volcanic rocks which have disrupted the strata, and doubtless effected much metamorphic change, were also collected by Capt. Cockburn, who observes that the upper Tertiaries, occurring sometimes shelly, sometimes sandy, and then again as oolitic limestones, are generally marine, but sometimes freshwater, and are occasionally associated with volcanic ashes and tufa. Mr. Baily, in working up the materials placed in his hands by Capt. Cockburn, first does justice to all the preceding authors who have either given descriptions of the geology of the district, or of other districts having an immediate connexion with it—not overlooking Keyserling, De Verneuil, and Sir R. Murchison—and then proceeds to the examination of the fossils, the lowest geological formation noticed in his list being Jurassic. The number of species passed under review was 286, of which 60 are described by Mr. Baily as new. The proportions in the several formations are as follows:—

	Before-described Species.		New Species.		Total.
Jurassic or Lower Secondary....	44	....	16	....	60
Cretaceous or Upper Secondary..	106	....	11	....	117
Older Tertiary	24	....	0	....	24
Newer Tertiary	52	....	33	....	85

It is somewhat remarkable that 0·26, or above $\frac{1}{4}$th of the lower secondary, and ·39, or above $\frac{1}{3}$rd of the newer tertiary, are new fossils, whilst in the upper secondary less than $\frac{1}{10}$th are new, and in the older tertiary no new fossils at all were discovered. I do not draw from this circumstance any other conclusion than that much more must be done before a perfect correlation of the strata can be effected: and I cannot help hoping that all the specimens will be hereafter carefully drawn and published; for it is almost impossible to determine the identity of those which have been compared only with the figures of foreign works, without having carefully-executed plates to examine; and it is to be hoped that hereafter the museum in Jermyn-street will become complete in typical series of specimens with which all foreign specimens may be collated. Several other military names are mentioned as having been contributors of the specimens, such as Lieut.-Col. Munro, Major Anderson, R.A., Major Cooke, R.E., Major Hudson, 39th Regiment, Dr. Sutherland, Dr. McPherson, and Mr. Olver. Many of these names have been given to the new species; and I would have been happy to relinquish the honour conferred in one instance upon me, in favour of some of the others.

The judicious remarks with which Mr. Baily concludes his paper show an alternating approximation to and divergence from the British types. Thus, for example, in the lowest division there is a close approximation to our Lias, whilst there is a considerable divergence from the Oolites. In the Cretaceous group there is again a tolerable resemblance to the several British divisions; and even in the Lower Tertiaries there is some; whereas the Middle or newer Tertiaries, constituting the Steppe Limestone, and forming one of the most important members of the whole series in the Crimea, are very distinct from the British Tertiaries in fossils, and are believed to have formed part of the deposits of the great Aralo-Caspian Sea, which was probably even larger than the present Mediterranean.

Mr. Baily has turned to good account the opportunity afforded him by Capt. Cockburn; and I trust Capt. Spratt, and Dr. Abich, who is also engaged in this interesting research, will bring these observations into comparison with their own, and by their continued labours assist in rendering the whole complete.

Permian and Trias.—Every day's experience has added fresh proof of the difficulty of accurately discriminating between detritic formations when in close contact with each other; and it may be fairly said that it would never have been possible to allot to the Magnesian Limestone of England its true place in geological classification, had not Sir Roderick Murchison discovered in Russia all the elements necessary to constitute a distinct formation, and recognized the Magnesian Limestone of England, the Zechstein of the Continent, and several detritic members as belonging to the new formation he then established under the name Permian. The general correlation of the strata of both the Triassic and Permian formations of the Thüringerwald and Hartz had been before pointed out by Sedgwick, Murchison, King, and Morris; and it is the object of Mr. Edward Hull, in his paper on the Odenwald, to inquire how far a similar parallelism could be traced between the Triassic strata of Germany and of England. In the Odenwald, the Permian strata are very limited, and are identified with the formations of the Thüringerwald and Hartz, or with the trappoid breccias of Worcestershire, almost entirely by lithological characters; but as the Zechstein appears, though sparingly, at Heidelberg, the fact of the existence of Permian deposits may be safely admitted. Mr. Hull had in 1854 pointed out three well-defined subformations in the Bunter sandstone of England; and it was his principal aim to ascertain whether this member of the Trias is similarly subdivided in Germany,—a species of minute correlation attended with much difficulty. The sandstone of the Odenwald has been sometimes classed with the Permian; but after a careful examination, and depending on mineral resemblances, Mr. Hull considers it Triassic, and the representative of the middle one of his three divisions of the English Bunter, viz. the conglomerate-beds of the West of England,—the two other divisions, or the upper and lower variegated sandstones, being here wanting. But though this sandstone exhibits only one form of physical deposit, it attains a thickness equal to that of all the three English subdivisions, and may therefore be their full equivalent. The Muschelkalk, being absent in England, does not admit of a comparison; but Mr. Hull concludes, as the general result of his examination, that the three divisions of the Permian as established by Murchison, and the four divisions which, as regards mineral characteristics, have been noticed in the Keuper, have all their representatives both in England and in Germany. A tabular view is given of this correlation of the deposits; and as Mr. Hull regrets that he was unable to extend the range of his inquiries to the Vosges, we may hope with him that he will at a future day be in a position to obtain more complete data for this class of deduction.

Professor Nicol has brought under our notice some phænomena connected with the New Red Sandstone of Loch Greinord, in Ross-shire. Preceding authors had noticed the occurrence on the shores of this loch, of two small patches of red sandstone, and suggested their apparent relation to the Red Marl, or New Red, of England. Professor Nicol, after making due mention of the labours of Macculloch, Sedgwick, and Murchison, points out the manner in which the newer sandstone overlies the older formation, the stratification being at a low angle. The underlying sandstone, notwithstanding some peculiarities, Professor Nicol identifies with the quartzite of the neighbouring mountains, and he finds the newer sandstone deposited, in a very remarkable manner, among the broken edges of the older strata.

As even the calcareous matter occasionally connected with the sandstones has hitherto produced no fossils, the determination of age must depend on other considerations, such as the position of the beds and the fragments of rocks they contain; and on such evidence Professor Nicol concludes that the upper formation belongs to a *far more recent* period than the underlying sandstones. To connect it, however, with still more recent formations is a matter of difficulty; great numbers of fragments, however, of a compact white limestone are scattered on the shore near Tinafuline, opposite to Island Ewe, and, having been but little worn by transport, appear to be the remnants of a formation now worn away. The fossils they contain show that the formation must have been the same as the Oolite of the North of Skye (which therefore must have once had a very considerable extension), and add to the probability that the red sandstones were all upper members of the Trias, or perhaps of the Lower Lias; and that these small patches are also relics of a much more extensive formation. Professor Nicol offers some interesting observations on the variation in the amount of metamorphic action; and closes his paper by pointing out what he considers to have been glacier-moraines—one ridge of boulders of gneiss and other rocks having been the terminal, and another the lateral moraine of a glacier cradled in the mountain-valley in which Loch Fuir now lies.

Of other papers, less directly falling into the divisions of the subject I have adopted, one by Mr. R. Brough Smyth is of much interest, as it brings under our notice a district in the Colony of Victoria, Australia, remarkable for volcanic products and other evidences of recent igneous action. This district is represented as 250 miles in length, and 90 miles in breadth; and Mr. Smyth enumerates many hills of various heights (some as much as 700 and 1500 feet) in which either craters can be traced, or marked relics of volcanic action discovered. An interesting letter from Mr. Selwyn, the colonial geologist, states that one of them, "Tower Hill, is certainly the most recent volcanic vent he had seen in Victoria," as the ash and scoriæ emitted during its later eruptions rest on beds of shell, sand, and earthy limestone containing numbers of the living littoral species of Mollusca. The crater now forms a lake.

Whilst granite appears to be the basic rock of the Victoria system, Mr. Smyth recognizes two eruptions of basalt—the most ancient having penetrated the Palæozoic and Tertiary strata, and the newer having not only penetrated these, but overflowed the Tertiary (forming, it is presumed, a sheet of submarine lava), being, however, sometimes underlain by an intervening bed of hard quartz rock, and overlain by a quartzose drift, and by the recent volcanic lava. The Tertiary beds are, from their fossils, considered of miocene age; they do not appear to have been disturbed by the eruptions, but continue horizontal. The streams of lava are in some places more than 25 miles in length, and of great thickness; and the occurrence of auriferous deposits around the centres of eruption, and the contiguity of the extinct cones to the great volcanic chain which extends from the Aleutian Isles to New Zealand, give, in Mr. Smith's opinion, a peculiar interest to this exhibition of volcanic forces in action almost up to the historic period. It is, indeed, yet to be determined whether the number of still active volcanos is equal to, in excess of, or in defect of the number of the extinct.

The Rev. Samuel Haughton, Fellow of Trinity College, Dublin, and Professor of Geology in that University, has submitted to us his further researches into the chemical constitution of the granites of Ireland, which I might perhaps have noticed more appropriately in a preceding portion of my address. In his former paper he expressed his opinion that the granites of the neighbourhood of Newry, like those of Leinster, belong to two distinct types, namely, potash- and soda-granites,—those south of a north-east line drawn through Newry and including the Mourne granites belonging to the potash-type, whilst those to the north of the line belong to the soda-type. In the present paper Professor Haughton supports this opinion, first by the chemical analysis of granites selected from five localities south of the line, in which there is a general resemblance in the composition of all, the potash exceeding the soda in amount in the proportion of 4 and 5 to 3, and then by a similar analysis of the soda-granites from four localities, which, however, do not exhibit the same regularity of composition, whilst the proportions are reversed in respect to the soda and potash, the soda being now in excess.

The atomic proportions of Silica, Peroxides, and Protoxides in the two types of granite are as follows:—

Potash-granite.		Soda-granite.	
Silica	1·582	Silica	1·429
Peroxides ..	0·311	Peroxides ..	0·367
Protoxides ..	0·301	Protoxides ..	0·294

And the mineral composition,

Potash-granite.		Soda-granite.	
Quartz	18·36	Quartz	21·24
Felspar	76·66	Felspar	41·45
Green Mica ..	5·00	Mica	36·50
	100·02		99·19

The composition of what Professor Haughton terms a "pink elvan or soda-elvan-dyke," he deduces from his analysis to be,

Soda-elvan.	
Quartz	29·52
Felspar	60·15
Hornblende	8·81
	98·48

—hornblende being in this instance supposed to replace the mica. These pink elvans penetrate the granite. From all his observations, both in Down and in Wicklow (in the examination of which latter county he was assisted by Mr. Jukes), Professor Haughton concludes that the potash-granites are the normal type, and that other granites are formed by the addition of bases. He also points out the great difficulty in deciding on the quantities of the component minerals by the eye alone, and adds that, though the potash-granites of Leinster are more persistent in external character than the Newry granites, the latter are quite as regular in chemical composition.

A section of the gravel-beds at Taunton, in Somersetshire, was contributed by Mr. J. Pring; and the very last paper of our late member, Mr. Joshua Trimmer, was on his favourite subject, the distribution of the superficial detritus which covers up most of the consolidated, and hence, in part, metamorphosed, strata of the earth. In the Gorlstone cliffs of Norfolk, Mr. Trimmer recognized an upper and a lower Boulder Clay; and this very fact proves that the old so-called diluvium was the result, not of an abnormal and instantaneously acting cause, but of a long-continued series of natural causes, marked in this case by the recurrence of glacial phænomena at two successive periods. Mr. Trimmer considered this portion of the earth to have been gradually sinking at the time, and to have been thus subjected to the overflowing of the northern wave, carrying with it fields of boulder-charged ice.

Having thus incidentally referred to the preceding minor papers, I shall close this notice of papers on Descriptive Geology by a brief commentary on the two papers which Sir R. Murchison has read before the Society during the present session. Nothing can be more gratifying to us, or more encouraging to our younger members, than to observe the undiminished energy with which Sir Roderick strives to put the last finishing touch to his labours on the rich subject of Silurian deposits. The first of the two papers was a supplementary comparison of the Silurian rocks and fossils of Norway as described by M. Theodor Kjerulf, with those of the Baltic provinces of Russia as described by Professor Schmidt, and both with their British equivalents. In South Norway there is a vast development of *unfossiliferous* rocks, which, as in our own country, are denominated Cambrian; but we may at least hope that hereafter, even in these unpromising rocks, the same success will attend the searchers for fossils as has already rewarded our British inquirers, and that it will be ascertained without doubt whether any epoch antecedent to that of Siluria was marked by organic life. The recent discovery, by Mr. William Rogers, of the genus *Paradoxides* in the metamorphic rocks (ordinary mica-slate) of the neighbourhood of Boston, United States, is one additional proof that we ought not to despair of making many similar discoveries, some, as in that case, within the Silurian epoch, and others probably far antecedent to it. M. Kjerulf divides the Silurian system of Norway into three groups distinguished by their physical characters, or, in other words, by the conditions under which the several deposits had been formed: and these he names from the localities where they can be best studied, the Oslo, the Oscarskal, and the Malmo or upper group; and then further establishes fourteen subdivisions.

The sandstone and conglomerate at the base of the Oslo group is unfossiliferous; but it is followed by fossiliferous schists and limestones. The Oscarskal group is composed of calcareous and argillaceous rocks, including Encrinital schists. The Malmo group is argillaceous at its base, with calcareous flags and a Pentamerus-limestone, an upper Orthoceratite-limestone, and an upper Graptolite-schist,—repetitions which strongly prove that they are but the natural alternations of mineral deposits, accompanied by a corresponding variation in the organic structures which belong to any one great geological formation. The total thickness of the fossiliferous rocks is above 1900 feet; and Sir Roderick classes the lower and the upper Oslo and the Oscarskal series, or the lower eight subdivisions, with the Lower Silurian as representing the Stiper-stones, the Llandeilo, and the Caradoc series, and the lower and upper Malmo, or the six upper subdivisions, with the Upper Silurian as representing the Llandovery, the Ludlow, and the Wenlock series.

In the comparison of the fossils of the Silurian basin of Christiania with those of Great Britain, Sir Roderick has of course found many specific differences; but the coincidence in the succession of the fossils, considering the distance between the localities, is stated to be truly remarkable, and without doubt it is by this correspondence in the change of organic life in two different and distant regions that their identity as formations must be determined, rather than by an actual identity of species, which ought not to be expected under such circumstances. Occasionally, however, common species step in to decide on the true value of a bed; and thus the alum-slates of Norway, which from its Trilobites had been supposed to belong to a peculiar zone, are by *Orthis calligramma* and *Didymograpsus geminus* brought into direct connexion with unquestionable British Lower Silurian deposits, such as the Stiper-stones and Longmynd rocks. Taking indeed the whole thickness of the Scandinavian beds with all their subdivisions, Sir Roderick maintains that, though so much less extended in development than the British, it constitutes one conformable and natural system, whether viewed physically or zoologically. Where pierced by eruptive rocks, some of the members of the Silurian series have been metamorphosed into crystalline gneiss—a fact which has been confirmed by Mr. David Forbes.

The Silurian deposits of Esthonia and Livonia, as described by M. Schmidt, differ in physical character from those of Norway, as calcareous bands constitute the greater portion of them. M. Schmidt recognizes five stages, each of which is characterized by a peculiar fauna,—very few species traversing two entire stages, some being present in the *two* upper, and some in the *two* lower, whereas only one species, the *Calymene Blumenbachii*, passes through the five lower stages, being, however, in the fifth, the equivalent of the Upper Ludlow, modified into *C. spectabilis* of Angelin. The sharpest separation is between the second and third bands, or between the Lower and Upper Silurian, though there is even there a sufficient transition to show that there has been no "violent break in the development of organic life," or such as could warrant the separation of the lower from the upper Silurian as part of one great natural-history system. I need not follow further the ingenious and successful effort of Sir Roderick to prove that the system of classification which he was the first to originate in England is equally applicable to every country in which the more ancient palæozoic deposits have been noticed; and perhaps in nothing is the truth of the proposition more manifest than in the position of the Pentamerus-zones; for, as Sir Roderick points out, the same species of *Pentamerus*, *Atrypa*, &c. occur in two successive bands in England, thus uniting together the faunæ of the lower and upper Silurian. The Pentamerus-zone in Esthonia is simply the central link of an unbroken Silurian chain—the former being the result of accident or physical disturbance, the latter the normal condition of the deposit. It is, indeed, the object of Sir Roderick to prove that in Scandinavia, as in Russia, Silurian rocks, both lower and upper, copiously charged with characteristic fossils, form a united and unbroken whole, and, viewed both palæontologically and geologically, exhibit a natural-history system quite as complete and more easily understood than their more expanded but much dislocated equivalents in the British Isles. Species may indeed change, or undergo variations so great as to be considered different; but the grouping of the whole will always enable the geologist to determine that he has arrived at a Silurian deposit.

The last paper of the official year was also by Sir Roderick Murchison, and is directed to the elucidation of the succession of rocks in the Northern Highlands. The object of this paper is to rectify both the opinion which had been previously formed, that the mountain-masses of red conglomerate and sandstone of the west coast of Scotland were detached portions of the Old Red Sandstone, and that of Professor Nicol, that the quartzite and limestone occurring in this series might be considered an equivalent of the Carboniferous series of the South of Scotland. It will be observed that this latter opinion was based on certain fossils found in the limestone of Durness by Mr. C. Peach, and that Sir Roderick founds his alteration also upon the fossils, after a determination of their true nature by Mr. Salter. Sir Roderick first describes the fundamental or true gneiss, which is the basis of the whole series, then an accumulation of quartz-rocks, crystalline limestones, chloritic and micaceous schists, and younger gneiss. The fossils from the quartz-rocks consist of small Annelide-tubes, now called *Serpulites Maccullochii*, and traces of fucoids; they have been traced in beds for long distances by Mr. C. Peach. The strong band of limestone between two quartz-rocks contains, however, fossils of a higher degree of organization, namely, a species of the genus *Maclurea* (*M. Peachii*, Salter) and its curious twisted operculum, the genus being one formed by our American friends; again, *Ophileta compacta*, a Canadian fossil, *Oncoceras*, and a smooth species of *Orthoceras* with compressed siphuncle. They all resemble Lower Silurian fossils of North America, which range from the Calciferous rocks up to the Trenton limestone, but especially grouped together in the limestones of the Ottawa River in Canada. Following up the succession of rocks to the eastward, Sir Roderick states his belief that the limestones intercalated with the chloritic and quartzose rocks of Dumbartonshire are unquestionably of Lower Silurian age, and that the overlying masses of mica-schist and quartzose-gneissic flagstones of the Breadalbane district may be some day found to be merely the prolongation of the micaceous flagstones of the North-Western Highlands, described as overlying the quartz-rocks and fossiliferous limestones.

The inquiry was then extended, ably and extensively, into the Devonian system; and, after many judicious observations on the divisions and arrangement of this great formation, Sir Roderick maintains the importance of the Devonian series in the scale of formations, and that the Old Red Conglomerates, ichthyolitic schists, and cornstones, with the overlying sandstones of Scotland and Herefordshire, fully represent, in time, the Devonian rocks of the South of England and the Continent, so full of corals, crinoids, and marine mollusks.

It is impossible, in noticing this paper, not to dwell for a moment on two interesting points connected with it; namely, that the recognition of the Silurian age of the Durness deposit should have been made, not through the intervention of a comparison of its fossils with those of the closely approximate Silurian regions of England, but with the remote Silurian regions of America, and it may be said that the Silurian deposits of Ireland are perhaps richer in American fossils than the English deposits. Supposing these relations true, many curious speculations might be founded upon them worthy of the attention of Mr. Austen. The next is the superposition of completely metamorphosed rocks over others in a comparatively slightly modified condition, passing as it were in a diminishing degree of metamorphism, from the supposed younger gneiss above, through micaceous flags, to the semicrystalline limestone with fossils. This seems to be a matter full of interest, and, assuming that the geological facts are correct, implies that we have yet much to learn respecting the true nature of metamorphism, at least as to the mode in which metamorphic action has been exercised; but I must still refrain from giving a decided opinion on a subject so replete with difficulties, in which two such able observers as Sir Roderick Murchison and Professor Nicol are still at issue.

The papers I have hitherto noticed have been prepared in conformity with the ordinary rules of the Society, and have more or less contributed to our knowledge in some one or other of the leading branches of geological science. The papers I am now about to refer to are, in some respects, less conformable to the rules of the Society, but are by no means devoid of interest and value, as they are intended to facilitate the appreciation of the labours of our Transatlantic brethren, by submitting them to us in a well-arranged and carefully considered form. You are all aware that Dr. Bigsby, the author of these papers, has never lost the enthusiasm which his travels, on a public and important duty, through the most remote and wild regions of North-west America, excited in his mind nearly forty years ago. I well remember him at that time, when his energies were at their maximum; and the bent of his mind was even then well-marked, as he was the first to point out to me the remarkable veins of sulphate of strontian (Celestine) in the island of Lough Erie, now called "Strontian Island;" and I do not forget that he required me to forward to him a correct drawing of a trilobite from Lake Huron, then in my possession. He has lately been most industriously occupied in preparing a general Geological Map of North America, and (whilst engaged in that laborious task) having been doubtless led to observe and estimate the difficulty of wading through so many detached reports drawn up by independent United States geologists, has wished to spare others a similar necessity. His first paper treats of the mineralogical and fossil characters of the Palæozoic strata of New York, and divides itself into the following heads:—"Mineral character," "Mode of transition," "Place," "Position or dip," "Thickness," "Fossils common and typical," "Fossils occurrent in Europe," "Fossils recurrent in New York."

As Dr. Bigsby's principal object is to form a standard of comparison, by which the palæozoic strata of New York may be brought into relation with those of other districts, he has drawn up tables, constructed from the writings of many preceding authors, both American and European; and, though he admits that some revision of the American fossils is still required, it cannot be doubted that his work will be a great aid to those who hereafter may undertake the systematic correlation of the palæozoic formations of the whole earth. Admitting for the present the minute subdivisions of the palæozoic formations by the American geologists to be correct, he proceeds to describe *seriatim* the seventeen subdivisions of the Silurian from the Potsdam Sandstone to the Upper Pentamerus Limestone, and the twelve subdivisions of the Devonian from the Oriskany Limestone to the Old Red Sandstone, under each of the distinctive heads I have enumerated. In this respect it is curious to observe the approximative horizontality even in the lower palæozoic formations, though occasionally and very partially disturbed by local causes. The two terms, occurrent and recurrent fossils, represent, 1st, the correlation in fossils with European strata, and, 2nd, the repetition of the same fossils in successive American strata. In the Potsdam sandstone (the lowest member of the Silurian system), only one fossil is represented as *occurrent* in Europe and none as recurrent in America; but in ascending, the number both of occurrent and recurrent species increases; and the latter occasionally pass up to a much higher level. It cannot be doubted that all these considerations are of the highest interest; and when the fossils of America have been carefully compared with those of Europe, specimen with specimen, not figure with figure, so as to separate varieties from species and enable the geologist to avoid the introduction of old species into the catalogue as new, a correlation effected on the principles adopted by Dr. Bigsby will lead to a more correct knowledge of this great section of the palæozoic formations. In his second paper he discusses the stratigraphy and classification of the whole series of the palæozoic rocks, and agrees almost entirely with M. De Verneuil, the modifications proposed by himself being principally characterized by the formation of natural groups in which are merged several of the sections adopted by the American geologists, and the establishment of a "Middle Silurian" stage, as also a similar Middle Devonian. This tripartite classification would of course assimilate these two great formations to the Permian and Triasic, and thus introduce a certain amount of harmony in the system of classification, even though it might not be an exactly true representation of nature. After a most careful lithological and palæontological description of the strata, he deduces some interesting conclusions, as, for example, that all the strata from the Potsdam sandstone to the summit of the carboniferous were quietly deposited, being subjected only to occasional vertical oscillations and consequent superficial changes; and that the elevation, fracture, and metamorphism of the strata were subsequent to the deposition of the whole, in one prolonged operation, and in a N.E. and S.W. direction along the Appalachians, so well described by the Professors Rogers, whose views Dr. Bigsby fully states, though he does not entirely agree with them.

It is trusted that the preceding review of the works of the last session will prove that our members and contributors have exhibited zeal, energy, and ability in following up the study of every branch of our science; and that our foreign fellow-labourers have been equally zealous and successful: but, to the proof my previous citations have afforded, I may add a reference to the last publications of Von Hauer, Oppel, Jokely, Ludwig, Neumann, and many others, as being sufficient to show that in every quarter the materials are collecting which will hereafter enable the philosophic geologist to describe the history of the earth in all its physical and organic changes, though I cannot presume to trespass further on your attention by dwelling upon the works of these able authors; I must, however, notice very briefly some recent observations of M. Alph. Favre, Professor of Geology at the Academy of Geneva, on that portion of the stratification of Savoy which has so long been a puzzle to the geologist. M. Sismonda and M. Elie de Beaumont appear to have considered the several beds of coal as all belonging to one epoch; and the first of these eminent geologists having found in the bed of coal of Taninge the impressions of true coal-plants above, as he supposed, the jurassic strata, he adopted the bold assumption, that "in the Alps the coal-ferns continued to live on, whilst deposits were taking place in the sea, up to the nummulitic epoch," to which therefore he assigned the coal of Taninge; and M. Elie de Beaumont considered the coal of the Diablerets, Darbon, Taninge, &c. to be so far of the same age as to be all comprised within the nummulitic period. M. Favre, on the contrary, who is well known as one of the most active and successful explorers of Alpine geology, states that in the neighbourhood of Taninge, which he had often visited, he found at a high elevation a fine deposit of hypersthene and serpentine rocks not before noticed; that to the S.W. of Taninge, on the summit called La Vuarde, he collected very characteristic Liassic fossils; and that he traversed in every

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direction the point of Taninge or the Dent de Marcely to the height of 7000 feet.

He then compared the coal of Matringe with the neighbouring bed of Taninge, and found the fossils of the lower Lias in the massive calcareous deposit *over* the Matringe deposit of coal, and determined that this mass is the same as that which *covers* the coal of Taninge. He therefore concludes that both these carbonaceous deposits are covered by deposits which from their fossils ought to be considered Liassic, and cannot therefore be considered in any respect as Nummulitic. M. de Heer has examined the specimens of fossil plants collected by M. Favre; and, though he differs in some respects from M. A. Brongniart and M. Schimper as to the species, he quite agrees with them in considering that they are truly Carboniferous; and, on his part, M. Favre maintains that the stratification is in accordance with that opinion. To the north of Taninge the nummulitic formation does not appear; but to the south it is found at between three and four miles from that town; and M. Favre imagines that its occurrence there has probably led M. Sismonda to class the coal with it, though in reality there is no connexion between the two formations. Without doubt, the obscurity of the stratification of the Alps must always render it very difficult to escape from error: M. Favre considers, however, that he has fully shown that, in the Alps, the more ancient jurassic strata are more highly developed than the nummulitic.

He then corrects the statement of M. Elie de Beaumont, by showing that the coal of Darbon, like that of the Cornettes de Bize, belongs to the upper jurassic, being distinguished from that of Taninge by its fossils; and the observations of M. Delaharpe and M. Studer are in conformity with his own. Again, the coal of the Commune d'Arrache, near the hamlet of Pernaut, described by MM. Sismonda and Elie de Beaumont, really belongs, as stated by those geologists, to the nummulitic formation; and it is therefore no matter of surprise not to find in it coal-ferns. The deposits of the Diablerets and Entrevernes are of the same age; and as M. Favre has noticed eight localities where this carbonaceous deposit is found, and has traced it from Savoy into the centre of Switzerland, it cannot, he observes, be considered a very local deposit. This determination of three distinct carbonaceous deposits in successive epochs is certainly more in harmony with nature than the supposition that the coal-plants had resisted all the physical changes which must have elapsed in so long an interval as that between the Carboniferous and Nummulitic epochs; and we may admit that M. Favre has not broken a lance, to use his own words, in favour of the value of fossil botany as an indication of the age of deposits, in vain.

I may mention, that Signor Cocchi has informed me that he is about to resume his researches on the geology of Tuscany, of which I took notice in my last address, and has promised another visit to England at no distant period to communicate the results of his inquiries into fossil fishes. But what I am particularly desirous to bring before you is the Report on the Geological Survey of Canada, made by Sir W. Logan to the Governor of that colony, Sir Edmund Walker Head. The report embraces the labours of the years 1853, 1854, 1855, and 1856, and must, with its illustrative maps, be considered highly creditable, both to the observers themselves and to the press of Toronto, the former capital of Upper Canada, by which it has been published. In a comparatively new country, it is only natural that economic questions should be considered the primary objects of geological research; but it will doubtless surprise many, that Sir W. Logan should have been required by the Geological Survey Act to ascertain the longitudes and latitudes of important places, or, in fact, to fulfil one of the functions of the Topographical Survey; and for this purpose he has availed himself, wherever possible, of the electric telegraph in order to exchange and compare signals. The Laurentine rocks are described as gneiss interstratified with important masses of crystalline limestone, the gneiss frequently containing crystals of hornblende, and merging into a syenite which is traversed by dykes of a porphyry analogous to the melaphyr of the French; and it is worthy of notice, that the overlying fossiliferous rocks appear to have been sometimes deposited upon worn edges of the porphyry, which must therefore have been erupted before their deposition. Sir W. Logan considers four-fifths of Canada to stand upon the unfossiliferous rocks, and the other one-fifth to have become the seat of colonization from the superiority of the soil, produced by the decomposition of the fossiliferous rocks; he in like manner points out the natural direction given to settlement by a similar result produced by the decomposition of the crystalline limestone bands. Sir W. Logan remarks, indeed, that the lime produced from these bands is fully equal for economic purposes to that obtained from the more earthy limestones; for constructive purposes, I may say better fitted, as is certainly the case in Ireland, where the beds of limestone which alternate with the mica-slate of the north yield a lime much better suited for mortar than the rich (as it is technically called) lime of the chalk.

Sir W. Logan's first report is principally of a mineral or economical character, and he particularly notices the abundant occurrence of lime-felspar, or labradorite, which forms a component of mountain-masses. When it is remembered that this comparatively rare form of felspar was first noticed in the Island of St. Paul, on the coast of Labrador, and since by Dr. Bigsby in an island of Lake Huron, it may be fairly considered a mineral link by which the Laurentine and Huron groups of crystalline rocks may be connected together in one great system. The map which illustrates this report shows that in the district, north of the Ottawa, the Laurentine group is immediately succeeded by the Potsdam sandstone. The inquiry to the westward was conducted by Mr. Alexander Murray, Assistant Provincial Geologist. In describing the district between the Ottawa and the eastern shore of Lake Huron, Mr. Murray points out many interesting physical facts in connexion with the numerous rivers and lakes of this remarkable country, in which the watershed-lines are singularly varied. The level of Lake Huron is quoted from the reports of the Michigan Surveyors as 578 feet; and the bottom of that lake is doubtless, as I formerly observed, in many parts below the surface-level of the ocean, whilst other lakes occur at the level of 1400, 1300, 1200, and all the intervening levels, down to Round Lake, 521, or nearly 60 feet below Lake Huron, and Chats Lake, 233,—the country rising to the north, and falling eastwards to the Ottawa. The Laurentine series of gneiss and crystalline limestone occurs here fully developed, and is overlaid by patches of Lower Silurian shale; and Mr. Murray seems, from the fossils contained in some of the beds, to have recognized some portions of the series of four beds (Calciferous sandstone, Chazy limestone, Birdseye limestone, Trenton limestone) which follow the Potsdam sandstone. In further investigations, when he had the valuable assistance of Professor James Hall of New York, he carried the ancient rocks of Western Canada a little higher up, to the Trenton limestone and Utica slate, or nearly to the upper limit of the Lower Silurian.

Mr. James Richardson, another assistant-geologist, conducted the inquiries more to the east. Here, supposing that the Mingan Islands may be assumed to exhibit the lower or basic member (that is, the Laurentine system), Harbour Island the calciferous sandstone, Large Island the Chazy and part of the Birdseye formations, and the sea-interval to be occupied by a succession of strata about 1700 feet thick (assumed to be equivalent to the upper part of the Birdseye limestone, the Trenton formation, the Utica slates, and the lower portion of the Hudson-River group), the Anticosti rocks are formed into six divisions, of which the lower portion is considered by Mr. Billings to belong to the Hudson-River group, the middle as merging into the Clinton, and being more in conformity stratigraphically with the Oneida conglomerate and Medina sandstones, that is, distinctly transitional or Middle Silurian, Mr. Billings having adopted that term in anticipation of Dr. Bigsby. The upper section passes into the Upper Silurian; so that the whole series is here exhibited in a very moderate space. Mr. Billings has given lists of the fossils found in all these beds; and Dr. Bigsby's paper will be of great use in comparing them with the lists given by the United States geologists. The geological reports are concluded by a description of many new Canadian fossils by Mr. Billings, in which the great number of new species of Crinoids, of Cystideæ, and of Asteriadæ is very remarkable. A new species is added to the genus *Bronteus* or *Brontes* of Goldfuss, as also one to the genus *Triarthrus* of Greene; and I may add, that here, as everywhere, the *Calymene Blumenbachii* appears to link together all the members of the Silurian, and, in my opinion, did it stand alone, would prove their identity as parts of one great natural-history system*. The final reports are chemical and mineralogical, by Mr. Hunt, the Chemist and Mineralogist of the Canadian Geological Survey.

In the United States there has been no cessation of that activity

* As yet no figures of these fossils have been published.

which for many years has distinguished the State and other geologists. The Geological Map of Pennsylvania has been finished in spite of many difficulties and the partial cessation of Government aid, by the two brothers Rogers, and was exhibited by Professor H. D. Rogers at the late Meeting of the British Association in Dublin. The rich fossiliferous deposits of Nebraska, which some years ago excited so much interest, from the numerous mammalian remains collected and afterwards described by Professor Leidy, have been again diligently investigated by Mr. F. B. Meek and Dr. F. V. Hayden. The attention of these able observers was first drawn to this region by Professor Hall, and they have been very successful in their researches. Their great object was to determine a parallelism of the Cretaceous formation of Nebraska with that of other portions of the United States' territory, and also to determine the true position of the Tertiary formations.

By the map which accompanies the account of their labours, it appears that on the S.E. corner of the Nebraska district Carboniferous rocks appear, that they are succeeded by the Cretaceous, and finally by the Tertiary deposits. Many new fossils are described, but as they are not figured, and are to appear in a report to be published by Dr. Warren, I shall merely state the general conclusions at which Dr. Hayden and Mr. Meek have arrived from the affirmative evidence of the fossils present, as well as the negative evidence of the fossils absent.

From the marked typical difference between the organic remains of the principal fossiliferous Cretaceous deposits of the south-west and those of the Upper Cretaceous beds of Nebraska, Alabama, and New Jersey, differences which cannot be wholly explained by local peculiarities, whether zoological or physical, the authors conclude that they belonged to different geological horizons, or, in other words, lived during different epochs.

The formations in New Jersey and Alabama are on a parallel with the *upper* and *lower* members of the Nebraska section, whilst those of Kansas, Arkansas, Texas, and New Mexico are on a parallel with the *middle* and *lower* portions. The Nebraska section, therefore, exhibits the fullest development of the Cretaceous formation in the United States.

In the Tertiary, Mr. Meek and Dr. Hayden come to the conclusion that the mammalian fossils formerly ascribed to the Eocene must be transferred to the Miocene; and there is no evidence of the existence of any Tertiary deposit in Nebraska older than that formation. I regret that I cannot devote more space to the works of these indefatigable observers, who have already made known to us the existence of a Permian deposit, in addition to the present and other works of geological interest.

Referring now to another region of the world, I may observe that I have heard from our fellow-member Mr. Oldham on his voyage back to India, and that he expresses himself with enthusiasm as to his hopes of future success, and his full confidence in the arrangements and the support of the East India Company. I have been favoured by the Directors of that body with the perusal of many of the geological papers published under their auspices; and I can confidently state that a judicious selection from the work performed, which the recent institution of an establishment similar to our Museum of Practical Geology will hereafter secure, was alone wanting: and I cannot but therefore express a hope that, should the changes which are now the subject of public conversation and discussion be carried out, care may be taken that the interests of geological and other sciences will not be overlooked, but that the example of activity and judicious management which the Directors are now exhibiting in that direction may be followed by their successors*.

Many of the reciprocal connections of the several branches of the science are discussed in an able Report on the prize for physical sciences for 1856, by MM. Elie de Beaumont, Fleurens, Is. Geoffrey Saint-Hilaire, Milne-Edwards, and Ad. Brongniart, in which the general views of palæontological science, as now generally entertained, are well explained, as well as the connexion which must exist between the organic and physical changes in order to produce one uniform and harmonious system. For example, "the study of mountainous countries has shown that the presence of fossil bodies on the most elevated points may be explained by the elevation of those mountains, in a more simple manner than by the depression of the waters of the sea; and hence has arisen the theory of the successive lifting up of mountains, which owes to M. Elie de Beaumont its principal development, but which, whilst it determines, with the contained fossils, the successive epochs of formation, does not explain the mode of creation, which still is, and probably must ever remain, a mystery. The treatise presented for the prize was one by the well-known Bronn, who, aided by his long experience, and taking advantage of the published labours of other eminent palæontologists, submitted classified lists of about 30,000 species of animal and vegetable fossils, distributed amongst 25 or 30 distinct epochs of creation. This expression naturally leads to the discussion of the theoretical views connected with it, or those views which are taken of the fact (which cannot be disputed), that at successive epochs lived distinct and successive forms of organized creatures. The mode, however, in which the changes of organic beings have been effected is a subject of fair speculation." Nor can any discussion do harm so long as disputants will remember that they are only dealing with a question of probability, not one of mathematical accuracy. Of the two great modes of accounting for the successive changes in the fauna of the world, advocated by those who maintain the invariability of species, the one advocated by Agassiz is, that all the organic bodies which existed on the earth at any one epoch were simultaneously destroyed, and replaced by a totally different group. The other, advocated by Bronn, is that only a part of the population of the earth, varying in

* These changes have been carried into effect; but geologists will feel at ease when they observe that Sir Proby Cautley has been appointed a member of the New Council of India.

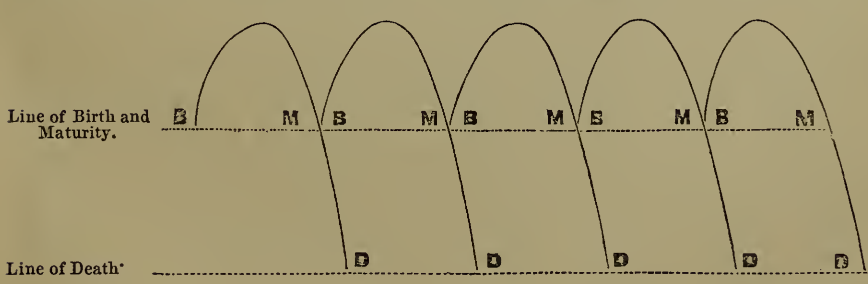
magnitude at different times, was destroyed at any one epoch and replaced by a new group, whilst another portion continued to live on in combination with the newly-created forms. The French Academicians express themselves adherents of this view of the case, as well as of the further opinion, that the number of species destroyed always exceeds the number of those preserved. As a preliminary, the authors of the report reason against the theory of development, admitting, however, that they do not mean to oppose those variations in a species which might be fairly attributed to variations in the physical conditions (such even as man has effected on domestic animals), but those greater changes which were once supposed capable of producing, from one set of genera, others widely distinct in character and magnitude. But this reference to the opinions of Lamarck seems scarcely necessary at the present day, whilst it cannot be admitted by the philosopher, that there is any greater simplicity, as a mode of action, in destroying one set of organized beings and creating another in many respects closely allied to their predecessors, than in endowing all created organisms with a susceptibility of change under the varying influences of the several physical conditions to which they may be exposed. At any rate, let us not argue such a question by appealing to extravagant examples, but let us keep within the bounds of reasonable cause and effect—such, indeed, as our authors have admitted in respect to the variations of existing species. One great truth is admitted by the French academicians, namely, that the history of the ancient world is still incomplete; and well may this be asserted, when it is remembered that three-fourths of the surface of the globe are covered by water, and that, whilst large portions of the sea-bottom and of the marginal sea-zone of ancient epochs have been rendered manifest by fossil remains, the portions of dry land made known to us are comparatively small. Why, then, should we assume that every newly-discovered genus or species is a new creation, and not a colony (according to Barrande's view) from some other region, still submerged and therefore unknown to us? It is manifest that such a question cannot be answered until the whole field of ancient fossil history has been worked out. And, further, who can tell how creation was effected? but if by an act imposing laws upon matter, and calling into existence organisms subject to the controlling and modifying action of physical circumstances, why should not an alteration in these circumstances produce the same change in a created being, as they would work on the creations newly called into existence? Such a result would be more in harmony with the notion of creative intelligence, than that new species or new genera should be created by the same intelligence so nearly alike those destroyed as to require the utmost skill of the naturalist to distinguish one from the other. I cannot, at least, but think that we are very far still from the solution of the mysteries of creation, and that we are too prone to separate portions of the same true organic whole from each other, losing sight of the unity and harmony of creation whilst seeking to use the relics of past ages in geological classification.

Having in my last address endeavoured to give a correct representation of the amount and success of the labours of the many eminent men engaged under Sir Roderick Murchison in the National Geological Survey of Great Britain and Ireland, I shall not now go over the same ground further than to state, that Mr. W. Baily has been attached to the Irish section of the work, and will, under the able superintendence of Mr. Jukes, be soon able to place the palæontology of Ireland on an equal footing with that of Great Britain: I trust he will be appointed palæontologist to Ireland, and have the means afforded him to emulate the bright example, and to secure the well-merited honours, of the English palæontologist, Mr. Salter.

Let me now close my address with a few general remarks, summing up, as it were, the views I have already expressed; maintaining as I do, that in all branches of geological inquiry there are still many important links of evidence deficient. At the same time let me add that I consider we are on the right way now to get over all difficulties, provided we continue to adhere to the true principles of inductive science, and abandon the common custom of rushing wildly to conclusions upon the most vague and insufficient data. The Rev. Baden Powell says, in respect to the bearing of scientific progress on theological reasoning—"The unparalleled advances in physical science which characterize the present age alone suffice to stamp a totally different character on the spirit of all its deductions; and they now are, and will be to a far greater extent, influential on the tone of theology. It is now perceived by all inquiring minds, that the advance of true scientific principles, and the grand inductive conclusions of universal law and order, are at once the basis of all rational theology, and give the death-blow to superstition." And in like manner, that every true advance in science has a direct tendency to make men more scrupulous and careful in drawing deductions from facts observed.

The actual condition of the earth's crust; the order and manner in which the various changes from its primæval condition have been effected; the real nature of metamorphism, the means by which it has been effected, the original and the ultimate condition of the rocks acted upon; the nature of creation, the mode of progression and distribution of organic bodies,—are all subjects which men now think it necessary to examine patiently and systematically, neither jumping rashly at conclusions, nor flippantly sneering at those who see the same objects in a totally different light. We have every reason, indeed, to expect to obtain great results, because we are at last determined to follow after truth, whatever may be the path she takes, or the aspect she assumes.

It is this general recognition of the authority of truth which has enabled men of science to reason fearlessly on many subjects which were considered, not very many years since, proscribed from inquiry, and expected to be received and admitted without hesitation and without question: the mode of creation was one of these, as it was laid down as a rule that the Mosaic account was not only in *spirit* but in *letter* inspired, and that human discoveries were only illusions when apparently in opposition to it. As ably pointed out by Professor Powell, the evil was only increased by those who endeavoured to escape from the difficulty by putting a constructive meaning upon the words, quite opposite to their literal sense, and then to adjust their theories to this new meaning. How different would have been the result, and how much bickering would have been avoided, had men attended only to the subject before them, and studied Geology for itself alone, and not as a supposed corroboration of statements, in what could never be considered a lesson in science! Well indeed may Mr. Powell maintain that proofs of inspiration ought only to be looked for in those manifestations of divine wisdom which are to be found in the precepts set forth for the moral government of men: to expect proofs of inspiration in other topics irrelevant to the main object of prophesying, would result only in fastening upon divine wisdom the ignorance and folly of erring man. I say this preparatory to making a few brief observations on the recent work of Mr. Gosse, entitled "Omphalos, or an attempt to untie the Geological Knot." Now, the geological knot appears to me to be the difficulty of explaining by what causes, and in what order, have been produced the various physical and organic phænomena observed in a study of the earth's crust, not in explaining the Mosaic account of Creation. Mr. Gosse thinks differently, and imagines that he has discovered a new law by which the observed facts of Geology can be put in harmony with the account of creation, or, in other words, that everything connected with the creation of organic life has been the work of the first six days. This is a bold assumption, and it must be admitted that Mr. Gosse has shown considerable ingenuity in the invention of very convenient terms, which serve instead of arguments; for to those who, adopting his theory, are not possessed of his ability, the words prochronism and prochronic must be of immeasurable advantage. But let us inquire into the nature of his argument. First, then, he represents the course of life as circular or cyclical; but, although such a course is real in respect to many motions, such as that of the earth round the sun, the horse moving in a mill, and many others where the motion is necessarily, in accordance with the laws of motion, either in a circular or in some other re-entering curve (unless, indeed, we may suppose the comets sometimes to go beyond the limits of attraction, and be finally lost



in interminable space), in organic life it cannot be said that the true representation is a re-entering circular or other curve, as death cannot be said to be the beginning of life. The true representation of life is rather a succession of open, or, as I may call them, eccentric cometary curves, one springing out of the other, as life begins, not where life ends, but *where it is in highest vigour.*

The plant and the animal, even, continue to live long after the new plant or the new animal has commenced its course of life. This, however, does not affect Mr. Gosse's argument, if we assume that the inquiry is limited to a part only of the curve extending from birth to maturity; for if creation were supposed to commence at old age, it would pass below the curve, and would then cease. The physiologist, then, having observed that there is a certain course of operations, of changes, of modifications, or of additions, called growth, in the passage from a seed to a tree, or from an ovum to a full-grown animal, most of which leave marks of their occurrence behind them,—is able to deduce, in the spirit of inductive reasoning, the age, or rather the epoch of existence from the visible marks of growth he finds upon the plant or animal; boldly therefore he says, This plant, or this animal, was 20 or 30 or more years old. But Mr. Gosse assumes that he has been deceived, because he knew not that this plant or animal had been created only that very morning, and was also ignorant of the great law of prochronic existence, which means (adopting some more tangible explanation than that of ideal existence) that, whilst the Creator was bringing into existence the plant or animal at any point of the supposed cyclical curve, the image of all the stages through which all future animals should pass flitted across His mind, and were incorporated in the new creation as a prophetic indication of what would take place hereafter. It is evident, however, that Mr. Gosse confounds two different things in this idea—namely, the laws which regulated creation, and the laws which regulated the progression and continuance of life. Plants and animals, for example, might have been created, as a statuary forms a statue, not to grow, but to continue permanently in one state of existence; but when the work of creation had ended, the laws of life were imposed; so that it is by no means necessary that the newly-created plant or animal should exhibit the workings of laws only required to bring up future organisms, by gradual steps, to the same condition which had been arrived at *instantaneously* by Divine will. Neither Mr. Gosse, nor any one else, has ever had a glimpse or a *revelation* of the *modus operandi* of creation, except in the one instance of the creation of Man, which affords no support to the prochronic theory, and cannot therefore be justified in assuming that it afforded an anticipation of what would be the product of growth. Indeed, it may be well to remind Mr. Gosse that, whilst he is apparently endeavouring to conform to the literal words of Scripture, he is seriously departing from the account there given of the first formation of man, which represents the created thing as without life, an inanimate thing, until the breath of life had been breathed into his nostrils; so that blood, and everything, whether fluid or solid, connected with organic life, were either created or adapted to the purposes of the new animal—not found existing, partly in perfect condition and partly effete or excremental, as if it had previously existed, though that existence was ideal.

Admitting then the ingenuity of Mr. Gosse's reasoning so far as he restricts himself to animals or plants, the structure, functions, and growth of which are experimentally known, and even admitting that a work which accumulates so many interesting examples may have its value in exciting a taste for natural history, I regret that he should have thought it necessary to assist geologists over a difficulty which to them has no existence. For this purpose he hints (for he cannot affirm) that it is possible that the inorganic world may also be subjected to a cyclical course, and that the "prochronic" law may be recognized even in the earth's strata. The meaning of this must be, that what appears to the geologist, reasoning from the analogy of recent causes and effects, a series of successively deposited beds characterized by the relics of the organic life associated with each, was in fact a single creation, and that the several layers were so created rather than in one simple mass, in order to typify the future formation, by the ordinary processes of nature, of other masses—masses which may therefore be studied hereafter by the relics of other generations of organic beings with accuracy and reason, although all our present studies are mere delusions. The extension of the same reasoning to the fossils, and the supposition that they may typify some future state into which existing animals may be intended to pass as the cycle proceeds, is manifestly in opposition to the very explanation suggested rather than given of Prochronism: for assuredly fossil bones and fossil teeth, or fossil plants, cannot be considered ideal; and although the author repudiates the old notion of *lusus Naturæ*, it is difficult to conceive what better notion could be formed of the numerous organic relics which are every day being discovered, if they are not admitted to have been once living organisms rather than mere idealities. I do not dwell on Mr. Gosse's effort to explain away the astronomical fact of the vast space of time which must have elapsed before the Mosaic record of the creation of man as proved by the long period required for the passage of light, before some of the fixed stars could have become visible to man, namely, that the undulation might have commenced at the eye, and proceeded to the star, rather than at the star, and proceeded to the eye; leaving it to astronomers to notice, should they think it deserving of their attention. I should not have dwelt so long on this work, had I not heard an able geologist and scientific man declare that he thought the argument indisputable; and therefore I presume that he considered the opinions of all living geologists fallacious, founded on their mistaking ideal creations, both organic and inorganic, for real *bona fide* plants, animals, vestiges of marine, lacustrine, and fluviatile organisms, deposits of deep seas, volcanic ashes and lavas of all ages. Let us hope at least that no one will again endeavour to solve the supposed geological knot, but allow geologists to study and understand nature as they find her.

Another matter which has much engaged attention lately, is the degree of antiquity of man, as also the question whether man was created unlike other animals, as one species only, or was created in numerous species adapted to the physical conditions of various localities, such as we now find them. The latter question is intimately connected with the first; for if we once satisfy ourselves that the races of men found in portions of the earth, which during the historic period could have had no possible connexion with the seat of the leading race of men, must have been independent creations, there is no absurdity in considering that they are remains of the organic human inhabitants of some earlier stage in the earth's progressive change. However, independent of any such speculation, M. Agassiz has adduced strong reasons for admitting an original plurality of human species, in his contribution to the work of Nott and Gliddon on "the indigenous races of the earth;" and after advocating the judicious principle, "that in the study of the races of man much light might be derived from a careful comparison of their peculiar characteristics with those of [the lower] animals," he selects the monkeys as being most nearly allied to man, and points out the differences of opinion which have existed amongst the most able naturalists as to the unity or diversity of species in some of the tribe—as, for example, in the orang-outans, those of Borneo, Java, and Sumatra being considered by some eminent naturalists such as Wagner as constituting only one species, whereas others, as Professor Owen and the American naturalist Jeffreys Wyman, consider them as constituting three distinct species.

The singular manner in which particular races are localized within narrow limits, as if specially adapted to them, is compared with the similar adaptation of the races of men to special localities; and it is urged that there is equal reason to consider that man has, like the monkey tribe, been originally created in varieties or in species, fitted for the regions to which they were to be attached. The philological argument for the unity of man is also discussed on the same principle of comparison with animals, in which a similarity of language, as it may be called, may be traced over the whole world amongst animals or birds of the same families.

These are not flattering, but they are philosophical views of the subject; and I dwell upon them, not with the desire of enforcing any opinion against the conviction of conscientious men of any creed or doctrine, but simply for the purpose of claiming for geologists the right of studying the works of nature on scientific principles alone. Even then we must be often obliged to modify our opinions, and to give up our most cherished theories; for it must be recollected that our science is even yet in a course of growth, and that the light of each new day may enable us to discover new facts and to correct old errors, just as the increasing power of the telescope enables the astronomer to penetrate into stellar spaces before veiled from his vision. In truth, the age of blind belief has passed from geology, and everything is now brought to the test of rigid examination: for example, how long have we now admitted as a demonstrated truth, though at first not an undisputed one, that the heat of springs, &c., was due to the communication to them of internal heat, proceeding from the still heated nucleus of the earth! and yet, as I have before stated, our able member and former President, Mr. Hopkins, has, from a comparison of the conductibility for heat of various mineral substances, shown that the heat observed does not vary in proportion to these conductibilities, and hence that we may perhaps have to abandon this favourite theory, and seek for some other explanation of a positive and well-known fact.

Such advances in knowledge ought not, however, to distress us; but on the contrary we ought to feel that, however charming any cherished fancy may be, the discovery of truth is to a rational being far more so. A fairy tale may gratify and amuse the child; but the man can only find instruction and enjoyment in the pages of true history.

Having now completed my allotted duties as your President, I relinquish your chair with a full confidence that you have elected as my successor the very best person who could have been found in any country for filling such an office. I have indeed pointed out how wide the range of geological science has now become; and I know that in Professor Phillips you have obtained a President fully able to master the subject, however extensive and however difficult. I undertook the task myself with doubt and hesitation; but such has been the kindness and support I have experienced from all the members, and from none more than our most able Assistant-Secretary, Mr. Jones, that the office I undertook almost with alarm has been to me a source of unalloyed pleasure, and will be ever remembered with gratification and with pride.

THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

APRIL 22, 1857 (*continued**).

3. *On the* GEOLOGY *of* STRATH, SKYE. By A. GEIKIE, Esq., of the Geological Survey of Great Britain. *With Descriptions of some* FOSSILS *from* SKYE; by T. WRIGHT, M.D., F.R.S.E.

[Communicated by Professor Ramsay, F.G.S.]

[PLATE I.†]

CONTENTS.

Introduction.—The first notice of the district described in the present paper was that published in 1800 by the late Professor Jameson in his 'Mineralogy of the Scottish Isles.' It is exceedingly meagre, having been compiled from the notes of a brief excursion in bad weather, and contains only a list of minerals found in the ascent of Beinn na Cailleaich, with the mention of numerous basalt-veins

* See vol. xiii. pp. 360 *et seq.*

† The Sections figured on this Plate have been selected from the series of sketches communicated by the author as illustrative of the Geology of Strath, and now in the Society's Library. The unfigured Sections will be referred to in the paper.

that traverse the limestone in every direction*. Eighteen years later Dr. Macculloch published his 'Description of the Western Islands,' wherein he pointed out the existence in Skye of secondary strata—the equivalents of the lias and oolite of England, extending in broken and irregular series up to what has since been determined to be the equivalent of the Oxford Clay†. He also described with considerable minuteness some of the more remarkable features in the geology of Strath. Yet of the structure of the district he seems to have had but a vague general idea—not a few of its most important features having escaped his notice, while of some of the facts which he mentions he has failed to perceive the true bearing. I shall even have occasion to show that, notwithstanding the minuteness of his description, he can only have examined a limited portion of the district, and that too but superficially.

Several years later Sir Roderick Murchison examined the eastern coast-line of Skye, and, from a comparison of fossils, ascertained the existence and limits of strata belonging to the lias, and the lower and middle oolite‡; and I am not aware that, since the date of this paper, any further observations have been made upon the south-eastern part of the island.

That portion of Skye of which I offer a description to the Society comprises nearly the whole of the parish of Strath. It may be regarded as an irregular belt from three to six miles in breadth, extending from sea to sea where the island narrows most. Its physical features are those of a wide undulating valley between two elevated ranges—the red sandstone and gneiss hills of Sleat to the south, and the syenitic mountains of Beinn na Cailleaich and Beinn Dhearg to the north. This district—embracing an area of nearly thirty square miles—includes the largest development of the lias in Scotland; and, indeed, as that formation in its lower and middle divisions reaches here a thickness of not less than 1500 feet, it may be regarded as no unfair representative of that of England. The geological structure of Strath—so intricate and confused—gives to these liassic beds an additional and peculiar interest. Along the shores the strata form low reefs and skerries, brown with algæ, and extend in regular sequence throughout their series. Yet no sooner do they strike into the interior than, in many localities, all seems to be involved in hopeless confusion; regularly stratified limestones become crystalline amorphous marbles; shales assume the appearance of metamorphic clay-slate or burnt pottery; great outbursts of syenite cut through the beds, dislocating, contorting, or overspreading them; trap-dykes in countless numbers traverse the glens and the hill-sides; while, by the agency of faults, higher members of the group are thrown down among the lower, and long tracts of red sandstone are brought into the heart of the lias. Before attempting to detail these complicated appearances, I shall describe the character and order of the beds from their base upwards.

* Jameson's 'Mineralogy of the Scottish Isles,' vol. ii. p. 91.
† Forbes, Quart. Journ. Geol. Soc. vol. vii. p. 104.
‡ Trans. Geol. Soc. 2nd series, pp. 293, 353.

I. *Character and sequence of the Liassic beds of Strath.*

It is a somewhat remarkable fact that in Scotland the Lias invariably rests on a palæozoic or metamorphic base—usually Old Red Sandstone. And it is equally striking that the formation is confined to the northern counties, among the hypogene and older palæozoic districts; none being found to the south of the great granitic barrier. These facts are of importance in investigating the physical history of the country. The lias of Skye rests sometimes conformably and often unconformably upon red sandstone or purplish-grey quartz-rock. These underlying beds have never yet yielded any organic remains, so that it is uncertain whether they should be regarded as Old Red, Silurian, or some of the later portions of the gneissic series of central Scotland. They graduate southwards, according to Macculloch, into a series of gneiss- and mica-schists; but considerable doubt rests upon their stratigraphical relations, and it does not seem probable that the difficulty can be cleared away without a careful and somewhat extended examination, not merely of the rocks in Skye, but of their prolongations into the mainland*.

The boundary-line of the lias and red sandstone commences on the north-eastern shore at the village of Lussay, whence it proceeds in a south-westerly direction for three miles to a point about half a mile south of the village of Sculamus, from which it runs nearly due south to the hamlets of Heast on Loch Eishort. See Map, Pl. I. fig. 1. This is a well-marked line; for the observer may not unfrequently stand at the same moment upon lias and red sandstone. The only part on which there hangs a shade of uncertainty is at the turning of the beds near Sculamus, where, owing to the thick covering of peat and the swampy nature of the ground, the two rocks cannot be approximated quite so closely as along other parts of the line. Yet this and similar obscurities could be shown only on a map of a very large scale.

I have been not a little surprised by the manner in which this line is mapped and described by Dr. Macculloch. He commences it at the head of the long narrow creek of Obe Breakish, instead of at the village of Lussay, thus colouring as red sandstone a space of fully two miles in length, which is actually lias. After quitting the shore his line is undefined, the formations being shaded into each other, indicative of a very uncertain boundary. Beyond this a large mass of syenite is introduced, breaking through the line, and for about three miles separating the two rocks. They are represented as meeting again to the south of the syenite, whence they run south-west to the shore of Loch Eishort, near the farm of Borereg—an error of considerably more than a mile. His lines are thus frequently set down at random, great tracts of red sandstone are altogether omitted both in map and memoir, the existence of faults is ignored, long tracts of syenite are inserted where none exist

* Since this paper was written, Professor Nicol's Memoir "On the Red Sandstone, Quartzite, &c. of N.W. Scotland" has appeared in the Quart. Journ. Geol. Soc. vol. xiii. p. 17.

in nature, and false dips are given, by which the very lowest beds are made continuous with the highest parts of the series. It pains one therefore to find such statements as the following:—"Fortunately a rigid topographical detail is but of little moment;" "and there is the less reason therefore to dwell on those minutiæ, though they have been examined in the most scrupulous manner;" "commencing from the lowermost beds, it must be remarked, that it is impossible to trace their common boundary with the red sandstone*." And there are many other passages where, by a similar bold assertion or by a certain vagueness and ambiguity, the author leads his readers to take for granted what he affirms, and to give him credit for having observed a great deal which he has not thought it necessary to narrate.

These remarks are made with much diffidence and reluctance. It is a delicate task to criticise the labours of one of the earliest cultivators of geological science, especially one of his works which has ever ranked among the standard treatises on British geology. And when I reflect that his account of this limited area is one of the fullest and most elaborate parts of his "description," embracing about twenty-five pages of letter-press, I am sensible that my remarks tend to throw a shade of discredit over other portions of his work on the Western Islands. But it was impossible to pass over the subject in silence.

The lowest bed of the lias (Pl. I. fig. 2) is a sandy conglomerate, averaging 2 or 3 feet in thickness, and traceable from near Lussay at intervals along the boundary-line to Heast. It is formed of well-rounded pebbles of red sandstone and white quartz—the waste of the surrounding knolls that formed reefs and skerries when the Scottish lias began to be thrown down. To this succeed, at Lussay, beds of white and greenish chloritic sandstone, varying from 3 or 4 to fully 15 feet in depth. Next follows a seam of dark-blue compact limestone about a foot thick, surmounted by a stratum, irregularly 2 feet deep, of massive *Isastrææ* enveloped in a dark sandy clay. This remarkable bed escaped the notice of Dr. Macculloch: it was first observed by Sir Roderick Murchison; and afterwards examined and described† by one who has scarcely left a district of his country unvisited, or unrecorded by his classic pen—the late lamented Hugh Miller.

I have not succeeded in detecting the coral-bed in the interior of the island; it probably thins out at no great distance from the shore.

Above the corals there are 7 or 8 feet of a calcareous grit, which shades off into a series of dark blue limestones with occasional courses of shale. The calcareous beds are not peculiarly fossiliferous, showing however on the weathered surface mouldering casts of *Ammonites* and *Gryphææ*, and on a fresh fracture the minute joints of *Penta-*

* Description &c. vol. i. pp. 316, 317.

† In a paper read before the Royal Physical Society of Edinburgh, 21st April, 1852. This coral was mentioned at the Cheltenham Meeting of the British Association by the Rev. P. B. Brodie, to whom I sent a specimen. See also Edinb. New Phil. Journ. April 1857, p. 263.

crinites. The shales too, when contrasted with those higher up in the series, are remarkably barren in fossils.

The long narrow peninsula at Obe Breakish consists, on its south-eastern side, of beds of white sandstone, and along its north-western shore of a thick deposit of dark sandy micaceous shale abounding in *Gryphææ*. Above these shales there occurs in the interior a stratum of brecciated conglomerate formed of lias-limestone and red sandstone fragments.

From Breakish to Broadford the shore is occupied by low shelving reefs of dark blue limestone with alternating courses of shale. As the rocks approach Corry, beds of calcareous grit often charged with *Gryphææ* begin to appear. The series described up to this point corresponds in position to the lower lias of England.

Beyond Corry and on the opposite island of Pabba there begins a series of dark micaceous and sandy shales abounding in fossils*, and answering to the lower horizon of the English middle lias. The syenite of Beinn Bhuidhe descends to the shore north of Corry; but the shale can still be traced along it as far as the entrance of the Sound of Scalpa, where the last beds visible are of sandstone, greatly disturbed by syenite and trap-dykes. The series is, however, prolonged on the coast of Scalpa Island near Scalpa House, where a series of calcareous shales rest unconformably on the red sandstone, which has here a south-easterly dip. The organisms of these shales are in a wretched state of keeping, but some of the better-preserved Pectens suggest a comparison with the marlstone of England.

The continuation of the series through the upper lias will doubtless be made out along the eastern coast-line of Skye and Raasay, but my explorations have not hitherto extended further north than Scalpa. The sequence of the beds described will be at once perceived from the subjoined Table.

Table of the Lias of Strath.

Middle Lias.	Dark calcareous shales (with Pectens, &c.)		Scalpa.
	Dark-grey or brown, sandy, micaceous shales (with numerous fossils)		Pabba.
Lower Lias.	Calcareous grits (with *Gryphææ*)		Broadford Bay.
	Limestones and shales in alternate bands		
	Calcareous brecciated conglomerate		(Inland.)
	Dark brownish-grey sandy shale (with *Gryphææ*)		Obe Breakish.
	White sandstone		
	Limestone and occasional seams of shale	(with Ammonites, Gryphites, and Pectens).	Lussay.
	Calcareous grit; 7 to 8 feet		
	Coral-bed; 2 feet (*Isastræa*)		
	Limestone; 1 foot		
	Green and yellow sandstone; 3 to 15 feet		
	Fine conglomerate; 2 to 3 feet		
Red sandstone and quartz-rock.			

The dip of these beds from their base at Lussay to their top at Scalpa House (fig. 2) is pretty uniformly 5°–8° to the north-west;

* For a description of the fossils collected in Strath I am indebted to the kindness of Dr. Wright. See APPENDIX.

and, as the distance is nearly four miles, their entire thickness must be at least fully 1500 feet.

II. *Geological Structure of the Strath Valley.*

Coast-sections.—The previous enumeration of the liassic strata of Strath is in reality a description of the beds seen in section along the north-eastern shore (Pl. I. fig. 2). They follow each other regularly, from the sandstones and coral-bed of Lussay up to the Scalpa shales, with no material disturbance from faults or igneous rocks. The structure of the south-western coast-line is somewhat more complex.

At the head of Loch Slapin (fig. 4), among the roots of Beinn Chro and Beinn Dhearg Mor, there occurs a set of limestones and shales occupying the same horizon as those of Breakish. In the bed of the stream that descends between these two mountains a few yards of altered limestone abut against the syenite of the hills ; this is followed by a series of indurated shales with occasional fragments of *Belemnites*; and further down the water-course, a hard bluish-grey and streaked metamorphic limestone becomes the prevailing rock. The dip of these beds is S. by W. at angles of from 25° to 60°. They are capped on the shore at Torrin by a small patch of shale, seen only at low-water, which may possibly represent the under portion of the Pabba series. Following the eastern shore of Loch Slapin, we find the dip turning round to the north-west, and the same series of altered limestones again presenting itself. The bedded structure of the rock is nearly obliterated ; but, where the angle of dip can be observed, it increases southwards beyond the Torrin promontory, until the shore is covered by a great protrusion of syenite, which stretches eastwards for three miles, forming the long ridge of Beinn an Dubhaich. It extends along the shore for about half a mile, and, at the promontory south of Camus Smalaig, is succeeded by the limestone as before. South of this junction the beds dip S.W. at 15°–25°, where the bedded structure begins to reappear. They gradually lose their metamorphic aspect, till at the mouth of the stream which descends from Glen Kilbride, they pass into a coarse shelly limestone abounding in *Gryphææ*. The grits and limestones, which for a short space succeed, are the equivalents of similar beds between Broadford and Corry ; and, as in that locality, so also here, they are surmounted by a thick set of dark micaceous shales, identical in character and fossils with those of Pabba. They stretch into the interior for upwards of a mile, whence they deflect to the south, and reach the shore of Loch Eishort at Borereg,—thus occupying the tongue of land which separates the two lochs. At Suishnish Point they are covered by a patch of yellow calcareous sandstone, which, at one part, displays a rude grotto with pendent stalactites, like not a few other caves formed by the decomposition of trap-dykes along "Slapin's caverned shore." This lip of sandstone is succeeded by the same series of shales dipping N.W. at 3°–5°. Half a mile from Suishnish they are interrupted by a large mass of augitic greenstone, which has broken through and overflowed them atop. The headland of Carn Nathrach is formed by this protrusion of greenstone surmounted by another of fine-grained syenite. At Borereg the shales strike inland, as already mentioned, and are succeeded by a set of limestones and thin shales —the representatives of the limestones of Broadford and Torrin*. The Sketch No. 1. illustrates this locality.

The occurrence of quartz-beds in the limestones at this locality is interesting, inasmuch as it proves that pure white crystalline quartzite is not necessarily a product of igneous influence. The syenite of Beinn na Charn, it is true, is only a short way distant; that it could not, however, have had any material effect upon the quartzite is abundantly evident from the unaltered character of the interstratified limestones; and if further proof were needed, it would be found in the occurrence of a precisely similar quartzite among the limestones of the interior, on the ridge to the south of Glen Kilbride. There it rests on an elevated belt of red sandstone, and is overlaid by a limestone-breccia, and a series of unaltered limestones. The nearest syenite is that of Beinn an Dubhaich on the other side of the Glen, but a large fault intervenes between them. There is, indeed, a small basalt-dyke traversing the lias-beds at this point, but it is of much too trifling extent to have produced the supposed metamorphism; while I shall take occasion to show that the trap-dykes of the district generally have not exercised any marked influence upon the texture of its rocks. Of the quartz-beds on Loch Eishort, the upper, as exposed on the beach, is much jointed and fractured; and, as far as I could penetrate into its substance, it seemed to be a nearly transparent crystalline quartzite, with an occasional tendency to be dull and subgranular. The under bed is also a good deal fractured, owing, perhaps, at least in part, to the proximity of a fault. It forms a tall cliff, remarkable for its brilliant whiteness, and for the large snowy blocks that cumber the beach around its base. A fresh fracture shows that this peculiar brilliancy is chiefly owing to a thin crust, from $\frac{1}{8}$th to $\frac{1}{12}$th of an inch in thickness, consisting of minute aggregated granules or crystals of quartz. Further from the surface the rock assumes the character of a very fine quartzose grit.

The shore of Loch Eishort is now occupied by a great tract of red sandstone, extending inland as far as the north-eastern corner of Beinn na Charn. Its western boundary is formed by a fault, which throws out fully 400 feet of the lower lias, and brings down the Sculamus and Broadford limestones against the palæozoic beds. The dip of the sandstone is generally westerly, at angles varying from 20° to 50°. Its eastern edge has likewise been produced by a fault that extends from near the north-east corner of Beinn na Charn to the village of Heast. This latter dislocation has thrown out a still larger portion of the lower lias; and the effect of the two movements together has been to cut a rude scalene triangle out of the lias limestones and shales, inserting in their stead a corresponding area of red sandstone. The Heast fault can be well observed in the channel of the stream, where the fractured ends of the limestones, shales, and breccia distinctly abut against those of the older strata. Beyond

* With the above description of this coast-section, for the accuracy of which I can vouch, compare that by Macculloch; Description, vol. i. p. 328.

the cultivated patches of Heast the coast-line is fringed with sombre, lichen-clothed crags of red sandstone and quartz-rock, stretching away to north-east over a bleak moorland region, and swelling southwards into the grey wrinkled mountains that form the long peninsula of Sleat.

Interior.—I have now gone over the coast-sections of the district, whence a good idea may be gained of the general arrangement of the rocks in the interior. To describe that arrangement regularly in detail would be not a little tedious, and, from the want of local references, would be attended with inconvenience and difficulty. I have accordingly drawn several sections through the more remarkable parts of Strath, whereby much is shown at a glance that could not be so well understood even from the clearest description. These sections, with the accompanying map, will, I trust, convey a fair idea of the structure of the district. They show the Liassic region of Strath to be a great synclinal trough bounded on the north-west by syenite, and on the south-east and east by red sandstone, and ridged up along its centre by an anticlinal axis.

Notwithstanding this seemingly simple structure, there is not a little complexity when we descend to details. Thus, we should expect that along the outer edges of the synclinal hollow, the lowest beds would be always those visible, but this is not strictly true. The most northerly of the sections, Pl. I. fig. 2, exhibits no sign of any bending of the beds: these follow each other in regular sequence from the lower conglomerate and coral-bed up to what is probably the marlstone. Section III., MS., and fig. 5 display the full swell of the anticlinal axis, and likewise the effects of denudation in partly baring the sandstone-ridge of its mantle of limestone. The lower beds seen at the eastern end of the line do not rise against the syenite at the western; those visible along the flanks of Beinn na Cailleaich belong to a higher part of the series. The shales and limestones at the foot of Ben Chro are not the bottom beds, nor do these occur at the other edge of the trough on the shore of Loch Eishort, for there, as shown above, the fault cuts off all the strata below the white quartzite. And thus, though the general structure of the district is that of a synclinal hollow, its regularity has been assailed by syenite and faults.

Nor is there greater regularity in the occurrence of the central anticlinal ridge. Eastwards it is produced by a broad undulation of the red sandstone and superincumbent lias without visible igneous rock; westwards it is caused by a long protrusion of syenite, while midway there is a confused coalescing of the two axes. Moreover, throughout nearly the whole extent of this central area, the limestones have been so altered that it is no easy task to ascertain their true dip. They are ploughed up on all sides by trap-dykes; faults have dislocated their connexion; great protrusions of syenite have ridged them up, and long tracts of red sandstone are found running through their centre.

Instead, therefore, of attempting to describe this confused district, I must refer to the map and sections alluded to for the general disposition and relations of the rock-masses, and content myself with describing under three or four subdivisions those appearances that seem most worthy of consideration in the geology of Strath. The first subject to which I shall advert is the long sandstone-ridge and its accompanying breccia.

Limestone-breccia.—In detailing the sequence of beds along the north-eastern shore, reference has been made to a bed of limestone-breccia which, though not visible on the coast, can be seen at many places in the interior. This rock and its attendant circumstances appear to have escaped the notice of Macculloch *; yet it is a point of not a little interest, and throws some important light upon the physical history of the district. Its horizon lies a short way above the thick shale that occurs in the lower portion of the series at Breakish; and this position it probably always retains. It varies in thickness from 3 or 4 feet to 10 or 12, and is made up of rounded and subangular fragments of quartz-rock, red sandstone, and lias-limestone.

Its line is accurately defined by the eastern edge of a long belt of red sandstone (similar to that whereon the lowest lias-beds repose), around which it seems moulded. This narrow strip of sandstone is bounded on the west by a fault that runs through the valleys of Glen Kilbride, Loch Lonachan, and Glen Shuardail, and is well exposed in the channel of the Shuardail Water, where it gradually dies out before reaching Sculamus. The other edge of the sandstone-belt is fringed by the breccia. Except at one spot on the southern ridge of Glen Kilbride, where, for a short way, there intervenes the lenticular mass of white quartz-rock already noticed, and also on the western slope of Beinn Shuardail, where the breccia is overlapped by limestone, the sandstone is always found to have a capping of breccia; and, I make no doubt, were the anticlinal ridge of Beinn Shuardail stripped of the limestone by which it is enveloped, the sandstone below would be found girdled by a zone of breccia. The only locality where I have detected the latter rock away from the sandstone is in the bed of the stream that descends from the Black Lochs to Heast. The following sections will explain the structure of that part of Strath.

The Section through the northern end of Beinn Shuardail (fig. 5) crosses the anticlinal of red sandstone with the flanking breccia and limestones. The breccia probably thins out over the older limestone and shales as here delineated. Had it been continuous, we should have found it at *b′* above the Breakish-shales. These lower beds must abut against the bottom of the breccia in the manner shown in the section; for that they cannot pass above the breccia, is proved by the position which it occupies at Heast, and by the limestone-fragments with which it abounds. Assuredly it cannot be on the same horizon with the lower conglomerate found resting on the red sandstone from Lussay to Heast (fig. 4).

The Section between Beinn na Charn and Hill of Harripool (fig. 6) passes south of the gap in the syenite-range of Beinn na Charn and

* He does, indeed, mention a calcareous conglomerate next the syenite, but adds that "its connexions cannot be traced."—Description, vol. i. p. 325.

Hill of Harripool. It differs from the preceding in so far as it shows the effect of the fault along the eastern side of Beinn Shuardail, and the reappearance of the breccia in the Heast stream at *b′*. In Section IV. MS. a small knob of red sandstone is seen projecting through the limestone on the west side of Beinn Shuardail. I think it highly probable that this and another similar patch half a mile north are prominences of the underlying rock from which the overlying limestone has been torn away, so that the breccia, though invisible, may flank their base, as shown in the section. As corroborative of this conjecture, I may remark that at Sithean, where the sandstone, divested of its calcareous covering, descends almost to the level of the road, the breccia is found resting above it; but where the limestones begin to creep up the hill-side to the south, the breccia gets covered over, together with the sandstone below.

I am thus particular in the details of this sandstone-ridge and its casing of breccia, because the appearances described appear to me indisputably to prove that the period of the Lower Lias of Skye was marked by movements of upheaval and depression. Whilst limestones and shales were alternately accumulating at the bottom of the old liassic sea, a long low reef was thrown up, raising with it the calcareous and muddy deposits that had formed the ocean-bed. Exposed to the beating of the surf, these strata were broken up, their fragments dispersed along the slopes of the reef, and the red sandstone once more laid bare. At length the ridge began to suffer a downward movement, and, as it slowly sank, fresh accumulations of limestone gathered around and over it, in a sea swarming with *Ammonites*, *Pinnæ*, and *Pectines*.

There is another point of interest in this sandstone-ridge which I am unwilling to omit. The remarkable parallelism of the mountain-ranges and glens of Scotland long ago drew the attention of geologists, and the progress of investigation has shown that what is so marked in the north can be no less distinctly traced in the general structure of the British Islands. The great faults traced on the maps of the Geological Survey have generally a parallel strike from south-west to north-east, corresponding with the direction of the Highland glens and straths. With regard to the relative ages of these upheavals and depressions mere parallelism can prove nothing, for there is strong reason to believe that at least most of the great disturbing movements which have taken place within the area of the British Islands, from the earliest eras whereof we have any cognizance, have been along a north-east strike. Now, the sandstone-ridge of Strath preserves the same direction, and, though invaded by the syenite of Beinn an Dubhaich and shattered by the fault of Glen Kilchrist and Glen Shuardail, it is still tolerably perfect for nearly five miles. Of its age there can be no doubt; it was formed towards the close of the lower horizon of the Lower Lias, and had begun to sink when the limestones of the upper horizon of that division were deposited. Many a long year had rolled away, and its site was well nigh effaced, when the Pabba-shales, belonging to the lower and middle horizons of the Middle series, were thrown down, enveloping the remains of *Ammonites Jamesoni*, *A. brevispina*, and *A. Davœi*. The circumstance is interesting, therefore, in a twofold point of view: 1st, because it proves that the disturbing agencies which afterwards played such an important part in Hebridean geology had already begun to show themselves as early as the time of the Lower Lias; and, 2ndly, because it clearly indicates that in the same ancient period the forces which produced the parallelism of the Scottish glens and mountain-chains acted in the prevailing north-easterly direction.

Igneous Rocks.—The igneous rocks of Strath belong to two great classes, and assume three distinct modes of occurrence. There are, first, the various hills and mountain-chains of syenite—huge amorphous masses breaking through and overlying the liassic beds; and, secondly, the innumerable dykes of augitic trap that cut the strata at every angle, and not unfrequently spread out between them in a bedded form.

The northern limit of the liassic region was described as formed by a bold eruption of syenite rising into an elevated chain of mountains (see Map, Pl. I. fig. 1). The summits of these hills, bleak and bare, rise out of a thick mantle of shattered blocks and broken debris, which, together with the scantiness of the vegetation, give them an air of ruin and desolation. Beinn na Cailleaich, the highest of the range, attains an elevation of over 2000 feet. In addition to this great syenitic tract, there are numerous minor isolated portions scattered throughout the district. Of these the largest is Beinn an Dubhaich, which stretches eastward from the shore of Loch Slapin for about three miles, with an average breadth of about a quarter of a mile. Another syenitic hill of considerable size is Beinn na Charn, rising abruptly above the hamlets and cultivated patches of Borereg. It is of an irregular form, thickest towards the west, and tapering to a point in the opposite direction. The Hill of Harripool may be regarded as a continuation of Beinn na Charn. It runs as a long sloping ridge in the direction of the village from which it derives its name. The rocky headland named Carn Nathrach, that forms the point of Suishnish, is likewise a syenitic protrusion, having an irregularly oval form, and bulging out a little towards the west, like the other detached eminences. There is but one other portion of considerable size in the district,—the rounded hill, called Ben Bhuidhe, that rises over the western arm of Broadford Bay.

In addition to these, however, there occur numerous smaller eruptive masses in various parts of Strath. One juts over the rugged path along the cliffs of Loch Slapin, between Glen Kilbride and Glen Suishnish; another projects into the breccia between Loch Lonachan and Beinn na Charn. I have observed several more, and it is probable that others may have escaped my notice. Indeed, after a somewhat lengthened examination of the district, the conviction forced itself upon me that there might be large masses of syenite hidden at no great depth beneath the surface, especially in the more highly metamorphic regions, where the syenite at present exposed would seem inadequate to explain the amount of alteration which the lias-limestones have undergone.

The syenite of Strath assumes two distinct and easily recognizable forms;—one overlying the liassic strata without markedly disrupting them; the other violently disrupting, but not overlying them. In the former case the junction of the two rocks is horizontal, or rather parallel with the plane of stratification, and the igneous rock consequently conforms to the dip and strike of the limestones and shales on which it rests. In the latter case the junction is vertical or nearly so, and the igneous rock breaks through the beds without reference either to their inclination or direction. The one class of phenomena recalls the circumstances attendant on the eruptions of the trap-family, the other reminds one of the appearances that characterize the protrusions of the granites.

To the latter class belongs that great expanse of syenite of which Beinn na Cailleaich, Beinn Dhearg, and Beinn na'a Cro are the terminal heights on the south, and which, stretching north for eight or ten miles, occupies a large area in the centre of Skye. The only part of this extended district that I have examined is the southern edge abutting against the lias from the head of Loch Slapin to the Sound of Scalpa; hence among the glens and hill-sides there may be isolated patches of the liassic limestones and shales, although the whole area is coloured and described by Macculloch as syenite.

The rock of which Beinn na Cailleaich and Beinn Dhearg are composed is a granular admixture of brownish felspar and grey quartz with a little hornblende. Occasionally a few scales of mica are observable, so that the rock is fully entitled to rank among the granites. The felspar readily crumbles away, giving rise to long tracks of debris—whence the brownish tint and rounded outline of the hills.

The line of junction of the lias-beds and syenite can be accurately traced for some distance along the western flanks of Beinn Dhearg. In the bed of the stream which flows down the glen between that hill and Beinn na'a Cro, there occur the limestones and shales already described, dipping away from the hills at angles (decreasing as they retire) of from 50° and 60° to 20°. They cannot be seen in contact with the syenite, but that rock can be traced down to a few yards from them, well displayed in the channel of the stream. From this spot the line of demarcation strikes up the slope of Beinn Dhearg, and, though the exact point of junction always eluded me, the two rocks, judging from the contour of the ground and from the section cut by a stream between Beinn Dhearg Mor and Beinn Dhearg Beag, must have a very nearly vertical line of separation. If there be any inclination, it is probably that of the lias-beds dipping away from and resting against the syenite, which along some parts of the line courses the hill-sides like a ruined wall, its base thickly strewn with prostrate blocks that obscure the line of contact. Occasionally, as on the flanks of Beinn na Cailleaich above the milestone on the Sligachan Road, there are large masses of limestone caught up by and resting on the syenite. They do not usually appear imbedded in the igneous rock, but rather look as if lying upon it or sunk into it. The syenite can be seen at different points protruding among these detached masses of limestone, but in no instance did I observe it enveloping and overlying them. It is, moreover, equally void of all fragments of altered limestone or shale, such as one sees caught up in many greenstones, especially along the sides of dykes; nor, save in one or two doubtful instances, did I detect it sending out veins into the adjacent rock. I may remark, in passing, that these isolated masses of limestone, as well as the great body of that rock for some distance from the syenite, are highly altered, assuming, in fact, the aspect of a crystalline marble. To this remarkable metamorphism I shall refer more at large after the igneous rocks have been described.

The class of disrupting syenites includes, in addition to the hills above described, the long irregular ridge of Beinn an Dubhaich. This eminence exhibits along its northern boundary the same abrupt vertical junction with the limestone that is shown on the sides of the opposite hills. Its southern edge is more irregular, containing many isolated masses of limestone, like those referred to on Beinn na Cailleaich, while the contiguous limestone in turn contains not a few protruding knobs of syenite. In short, it is a repetition on a smaller scale of the great syenitic zone that girdles in the Strath Valley to the north. But as its western extremity has been much wasted by the waves of Loch Slapin that come surging in from the Atlantic, a section has been cut across its breadth, and its contact with the limestone is accordingly well displayed on both sides. The following cliff-sections convey an idea of the appearances here presented.

The South junction of Syenite and Marble on Loch Slapin (Sketch No. 4, MS.).—Here the marble has a vertical dip, and a few yards southwards it inclines to the south-west. The syenite is a coarse granular rock, meeting the marble vertically below and bending a little over above. A syenite-vein is seen extending into the marble horizontally for 2 or 3 feet from the main mass of syenite. It looks as if it had been squeezed into an open fissure.

The North junction of Syenite and Marble on Loch Slapin (Pl. I. fig. 7) represents the junction at Camus Smalaig. The marble here is a pure white, almost saccharoid rock. It seems to have a rude dip to the north-west, but this may be deceptive. The syenite assumes a somewhat finer texture along the line of contact, and at the lower part of the visible junction is charged with green serpentine, which likewise discolours the contiguous marble. Neither in this junction, nor in the corresponding one, half a mile south, does the syenite overlie the limestone. At the southern locality it falls over atop, as above stated, but the appearance is probably caused by a sudden change in the strike of the line of demarcation, whereby, in place of its edge, its plane is presented to view.

The remaining masses of syenite belong, for the most part, to the second or overlying class, of which Beinn Bhuidhe may be taken as an illustrative example. This hill forms the elevated promontory between Broadford Bay and the Sound of Scalpa, and occupies an area of not much less than a square mile. The coast-line is fringed with low flat reefs of black shale, identical with that of Pabba; and as the waves have in many places cut a steep cliff that topples over the beach, the connexion of the igneous rock with the lias-beds can be accurately studied. Nothing could present a greater contrast to the junction of the syenite and marble along the flanks of Beinn Dhearg or Beinn an Dubhaich, than the junction of syenite and shale along this sea-margin of Beinn Bhuidhe. Here we see no great tilting of the beds, no wide-spread metamorphism, no wall-like contact of the two rocks. On the contrary, the shales dip gently under the sea, showing in many places no evidence of their proximity to a large mass of igneous rock. They are unaltered except within a foot or thereabouts from the syenite, and at the contact show a flinty porcelain-like texture. The syenite has manifestly rolled over them, catching up fragments in its progress, insinuating itself, after the manner of the traps, into cracks and fissures, and conforming exactly to all the inequalities of the stratification. Fig. 8 shows the manner in which this junction is displayed along the cliff-section.

The Junction of Syenite and Shale at Beinn Bhuidhe (fig. 8).—Here the syenite is a lighter-coloured, more felspathic, and finer-grained rock than that already described. At the point of contact it is very homogeneous and compact, and hand-specimens may easily be obtained showing the two rocks fused together—an appearance nowhere observable among the disruptive syenites.

The headland of Carn Nathrach must be referred to the same overlying class with Beinn Bhuidhe. Its structure is represented in fig. 4.

The overlying nature of Beinn na Charn is well displayed along its eastern boundary, where the limestones and shales dip under it, unaltered save near the point of contact; and there, it may be remarked, they are not by any means so much changed as near the disruptive masses; nor is the limestone in any instance altered into a white crystalline marble, as it is along the northern hills.

The Hill of Harripool is more complex in its structure, and not less manifestly a superjacent, intrusive mass (see fig. 3). At its northern extremity it subdivides, shales and limestones being found between the separated portions. In truth, it is identical in its mode of occurrence with an ordinary greenstone, which it further resembles in the limited amount of its attendant metamorphism.

Such, then, being the marked differences between these two forms of syenite, I think the inference may be legitimately drawn, even were there no other evidence, that they are not probably the products of contemporaneous eruptions. At Beinn Bhuidhe they approach within a few hundred yards of each other, and it is inconceivable how at the one spot the rock should have tilted up, pierced, and greatly metamorphosed the strata, after the manner of the granite of Arran; while at the other it in no way disturbed either their dip or their texture, save along the immediate line of contact, but insinuated itself between their planes, and conformed to every inequality of the floor over which it rolled. There is usually, moreover, a marked difference between the mineralogical texture and even the composition of the two rocks. The disrupting class are coarse-grained, and of a brownish-yellow tint; the overlying and intrusive are of a finer texture and lighter shade, and generally considerably more felspathic. There are indeed exceptions to this rule, as in Beinn na Charn, where the rock approaches more closely to the texture of the northern hills; but the distinction is in most cases sufficiently obvious. It seems impossible, therefore, to avoid the conclusion that the one series of outbursts must be older than the other.

But there is another source of evidence, of a somewhat negative kind, which not only corroborates this inference, but indicates, as far as merely negative evidence can do, to which of the two classes the higher antiquity should be assigned. For, as in no observed instance do they intersect each other, it is obvious that they do not of themselves furnish material for a determination of their relative ages. Yet I believe an answer to the question may be gathered from a survey of the other igneous rocks of the district; and to these I shall now refer.

Trap-dykes.—Certainly one of the most remarkable features in the geology of Strath is the almost incredible number and variety of its trap-dykes. From their greater permanence they are visible at a considerable distance, now coursing up the hill-sides like ruined walls, now plunging deep amid the heather of the glens, now damming up the channel of some mountain-torrent that pours over them its white cascades. They preserve a general north-westerly strike, but frequently intersect each other or unite, being seldom continuous for long distances. These features are well displayed along the eastern shore of Loch Slapin, where for upwards of two miles the waves have cut a vertical line of cliff. Along this cliff, and on the beach below, the dykes may be seen running parallel, uniting, again bifurcating, interlacing in labyrinthine confusion, now thickening, now thinning, terminating abruptly and commencing again, entangling masses of limestone, and sending out minor veins; at one time rolling in an undulating course, wholly irrespective of the dip or strike of the beds, at another running along the line of the natural joints; now seeming to conform to the planes of bedding, now cutting through them like walls of masonry, and at length ending off in a point sometimes well nigh as fine as that of a pen. In truth there are few localities where the nature of trap-dykes could be better studied than along this coast-line, for there is both an admirable ground-plan of them along the beach, and, for a considerable part of the shore, they are exposed in section along the cliffs. (Pl. I. fig. 9, and MS. Sketches Nos. 8 and 9, illustrate the trap-dykes on the shore of Loch Slapin.)

The eastern margin of the island also exhibits the trap-dykes in abundance; but they are there more regular, and generally keep parallel to each other in a north-west direction.

On Pabba Island they are also numerous, running along the line of the natural joints, with the usual north-westerly strike. Here they show very unequal degrees of permanence, in some cases crumbling away as rapidly, or even more so, than the surrounding shale; in others jutting up like walls. Of the latter kind one very noticeable example occurs on the northern shore of the island. A dyke, from 3 to 4 feet thick, and, next the cliff-line, about 30 feet high, crosses the beach and runs out to sea (MS. Sketch No. 11). The shale has been washed away on all sides of it, and it blocks up the walk along the beach like a wall of smoothly built masonry. These Pabba dykes are of interest in so far as they enable us to estimate the extent to which trap-rocks have altered the strata of the district; for in Strath there is so much metamorphism and so many protrusions of syenite, that one is apt to miscalculate the amount of influence of the different igneous eruptions. Pabba, however, is nearly two miles distant from the nearest point of syenite, so that this rock could not have had any effect upon the shales of the island. There is thus no conflicting agency to mar or heighten that of the trap-dykes; and, as in Pabba they fully equal in number those in the most metamorphic regions of Strath, it follows that, if, either wholly or in part, they have produced the metamorphism of Strath, they must have caused a corresponding amount of alteration in Pabba; but in that island there is no metamorphism beyond the mere hardening of the shales in immediate contact with the trap. At the distance of 2 feet they are generally as soft and fissile as when furthest removed from dykes. It is evident therefore that the remarkable metamorphism I have yet to describe cannot have been produced by the trap-dykes, startling as their number may seem. Their effect is limited to a few inches from their edges, and even this slight alteration becomes undiscernible in the interior, where it is lost in a far more extended and complete metamorphism.

The trap-dykes, like the syenites, are divisible into two well-marked classes, differing from each other in mineralogical texture and in age. The one group comprises nearly all the dykes of the district, and is formed of a dark-grey or bluish-black basalt*, not columnar, but much jointed. The rock is exceedingly hard, and weathers with a greenish-brown crust. The dykes of the other class are not numerous, and consist of a dark crystalline augitic greenstone*, which sometimes approaches the basalt in texture.

The annexed ground-plan (fig. 10) of the neighbourhood of the old Manse at Kilchrist shows the relation of these two classes to

* These terms are here used, as they have, I think, always been in Scottish mineralogy, to signify two rocks differing from each other, not in composition, but in texture; *basalt* being a compact black mixture of augite and felspar without visible crystals, *greenstone* a lighter-coloured mixture of the same minerals, the crystals being easily recognizable. When hornblende replaces the augite, it is called a hornblendic greenstone. In Scotland, where so large a proportion of the traps are augitic, this distinction is a very useful one.

each other. The greenstone-dyke extends from the road at Loch Kilchrist in a south-easterly direction for fully half-a-mile, cutting through marble and syenite. Along both edges of the syenite-belt there are numerous smaller basalt-veins cut off abruptly, together with the marble which they intersect. Similar appearances are visible on the south front of Beinn na Cailleaich, where all the basalt-dykes of the Sithean valley are truncated by the syenite, while a large one of greenstone, traversing perpendicularly the bare slope of the mountain, forms a prominent dark scar. These facts seem to me to show that the trap-dykes are of two ages; those of basalt being older than the disruptive syenites, those of greenstone later. The intrusive syenites are not traversed by basalt-veins, but they are intimately connected with the greenstones; and this relation, when examined, throws important light upon the respective ages of the different igneous rocks of the district.

Reference has been already made to the headland of Carn Nathrach, that divides Lochs Slapin and Eishort (fig. 4). It is formed by a great sheet of augitic greenstone, surmounted by an irregular bed of fine-grained felspathic syenite. The greenstone, which resembles in texture and mode of occurrence the other rocks of the same kind in the district, forms a bed of considerable regularity, and is connected at its southern edge with a thick dyke that cuts vertically the nearly horizontal shales of Suishnish. The syenite, owing to its liability to decay, has a somewhat irregular surface; but it undoubtedly forms a bed, and is everywhere found resting on the greenstone. At the large loch on the top of the headland it has carried up a considerable fragment of the calcareous sandstone of Suishnish Point, and there can be no question that both greenstone and syenite are alike intrusive.

Along the eastern base of Beinn na Charn there are also at several points indications of a substratum of greenstone. The same fact is observable in the Hill of Harripool: that eminence forms a long ridge extending southwards from the village of Harripool and merging into the northern projection of Beinn na Charn. At its seaward end it consists of limestones and shales belonging to the Breakish-series; and, about two miles south from the sea, beds of syenite, probably ramifications of the main mass east of the Black Lochs, are found intercalated with the liassic strata: at several points the syenite has a distinct capping of greenstone, perhaps the result of a difference in cooling, but more probably the product of a different eruption.

The connexion of these intrusive syenites with the greenstones is such as to leave no doubt that they are both later than the disruptive masses; that in truth they must be regarded as the latest of the igneous products of Strath. Thus the greenstones, whether regarded as merely the result of a difference in cooling, or as the products of distinct eruptions, confirm the conclusion that the syenites are of two ages, and indicate with tolerable distinctness to which class the higher antiquity should be assigned.

It may be well, ere passing on, briefly to sum up the evidence here collected as to the dates of the igneous eruptions of Strath. 1st, they are all posterior to the Middle Lias, being intrusive and not contemporaneous; 2ndly, the first period of igneous action gave rise to a great profusion of trap-dykes, which intersected every part of the district; they did not, however, produce any marked alteration of the general stratification and texture of the rocks, but rather conformed themselves to the natural joints of the beds, and hence acquired a prevailing strike to north-west; 3rdly, subsequently vast tracts of syenite tilted up the liassic strata, in a manner analogous to that of the Arran granites, and produced in them an extensive and complete metamorphism; 4thly, the last period of igneous action was characterized by the outburst of great hills of fine-grained syenite, that intruded itself among the beds without either tilting them or producing any considerable amount of alteration upon them; at the same period sheets of greenstone were occasionally thrust among the syenites and limestones, or broke through them as massive dykes*.

Metamorphism.—The general arrangement and effects of the igneous rocks having been pointed out, I shall proceed to describe the metamorphism so often alluded to. The metamorphic district, as may be conjectured, lies among the disruptive syenites. Its north-western limit is formed by the great syenitic chain of Beinn Dhearg and Beinn na Cailleaich; the hillward slope of Beinn Shuardail and the hollow of Glen Kilbride bound it on the south-east; the shore of Loch Slapin, from Beinn na'a Cro to the mouth of Glen Kilbride, forms its south-western termination; while to the north-east it approaches Beinn Bhuidhe and Broadford. Within this area the bedded limestones of Broadford Bay are altered into a crystalline mass; stratification is usually obliterated, along with all trace of fossils, and what was before a dull blue limestone assumes all the sparkle and varied tints of a primary marble, mottled sometimes like that of Balahulish, or pure like that of Carrara.

The action of atmospheric agents upon this rock has caused it to weather in a very singular manner. The eminences which it forms, in not a few instances, look as if a shower of oblong grey blocks had been shot into their soft peaty surfaces. In some places the marble assumes a finely cavernous exterior, pitted all over, like a sandy beach after rain. At other times the blocks are smooth as tombstones, and stand out in bold relief from the heath and furze that surround their base. No moss or lichen can cling to them, nor does the vegetation of the soil cluster up their sides, as it never fails to do round the mouldering dykes, so that the marble-hillocks arrest the eye at once, and can be distinguished at a considerable distance. This manner of weathering is not, however, peculiar to the marble. It may be seen, though in a much less marked manner, along the outcrop of unaltered limestone south of Sculamus. But the most

* The geological era of these events has still to be fixed. Professor Edward Forbes was of opinion that the trap-hills of the north-east of the island were of Middle Oolite age, but admitted that the district would require a more extended investigation before the point could be made out with certainty. See Quart. Journ. Geol. Soc. vol. vii. p. 109.

remarkable example of weathering is probably that on the beach south of Camus Smalaig, where, to the action of the atmosphere, there has been added that of the waves. The rock is there of a leaden-blue colour, and its surface bristles thickly with sharp rough irregular fragments, having a greenish hue and adhering to the marble often by the merest point. These small roughnesses are so angular as to wound the hand when it is passed even gently across them, and they render walking dangerous alike to boots and skin. I can compare them to nothing but what we might conceive would be the appearance presented by a shower of moist tea-leaves that had been thrown athwart a freezing pond and become hard and fixed in the ice.

The texture and colour of the marble vary in different parts of the district. The whitest varieties are to be seen at the Kilchrist quarries, and in the vicinity of Kilbride. In each of these localities there is a large mass of syenite close at hand. Various shades of grey occur, in some instances (as on the shore south of Camus Smalaig), in contact with the syenite,—the marble assuming a crystalline or saccharoid texture. Green streaks of serpentine mottle the rock where it is intersected by trap-dykes, and also, at Camus Smalaig, where it is cut through by syenite. Specimens may also be obtained prettily veined with blue and purple (rarely with red) even in the immediate vicinity of the purest crystalline varieties, as at the Kilchrist quarries. As the marble recedes from the syenite it darkens in colour, loses its metamorphic aspect, and gradually passes into an ordinary limestone.

On the exposed marble-cliffs that fringe Loch Slapin, a little way north of Glen Kilbride, I have found what appears to be the fragment of a Pentacrinite. With this exception I have not succeeded in detecting in the altered limestone any trace of organic remains. There are, however, a number of rough nodular accretions of cherty carbonate of lime, of great hardness, that protrude, sometimes in considerable numbers, from the smooth surface of the marble. These may represent some of the organisms seen along the eastern shores, and I have sometimes fancied that my eye could detect what bore a remote resemblance to a Gryphite. If such irregular nodules do actually represent *Ammonites*, *Gryphææ*, &c., these organisms must have undergone no little distortion and obliteration—Pentacrinite, Ammonite, and Pecten being jumbled together into rugged lumps of cherty limestone.

The passage of the metamorphic into the unaltered limestone is a point of considerable interest, and may be studied to advantage on the shore of Loch Slapin at the mouth of Glen Kilbride (MS. Sketch No. 13). There the altered limestone is seen abutting against the syenite of Beinn an Dubhaich. As it approaches the sea it becomes dark, compact, and dull in grain, with streaks of white, but devoid of fossils. Then occur seams of lighter-coloured limestone and hard shale with *Gryphææ*, succeeded by a dark blue close-grained limestone with *Ammonites*, &c. These beds are followed southwards by calcareous grits, sandstones, and limestones similar to those above

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the Broadford-limestone; while, as the strata pass towards Suishnish, the Pabba-shales supervene. I know of no other locality where a similar section can be seen. Macculloch indeed describes one on the shores of Loch Eishort near Borereg*. But he has mistaken the quartz-beds there for altered sandstones, and consequently has been deceived as to the true character of the interstratified limestones. They are assuredly not metamorphic, for they contain *Ammonites*, *Gryphææ*, and comminuted fragments of shells, and are identical in position and texture with the beds along the Broadford shore†.

The amount of alteration is not uniform throughout the metamorphic area. It is greatest in the immediate vicinity of syenite, and slightest where that rock is at a distance. Perhaps the most thorough degree of alteration has taken place in that limestone-patch enclosed in the syenite of Beinn an Dubhaich, whence Lord Macdonald has quarried some large blocks of snowy whiteness. It is exceedingly hard, and probably could not be worked without considerable labour and cost. It has moreover the defect of losing its brilliant purity on exposure: a fragment that was polished about twenty years ago has a dirty yellow surface, while a piece of Carrara marble that was prepared at the same time is still as bright as at first.

A less amount of metamorphism is discernible among the knolls round Torrin, where the marble possesses in some places an easily discernible stratification, and dips north-west at from 20° to 37°. The texture of the rock at these points is usually crystalline, sometimes dull and compact, having a bluish-grey shade that merges on the one hand into white, and on the other into a dark leaden-blue. The faintest trace of alteration can be observed at the spot on Loch Slapin, where the metamorphic shades off into the unaltered rock. In these instances, as in the district generally, the amount of metamorphism is regulated, on the whole, according to the proximity of the igneous rock. But, as stated above, the alteration in parts of the district removed some way from any syenite is still so great as to suggest that it may have been produced by igneous masses which,

* Description, vol. i. p. 327.

† The section given by Macculloch (Description, pl. xiv. fig. 2) of the northern coast-line of Loch Eishort bears at best but a remote resemblance to nature. The long ridges of marble, which he there inserts, have no existence; and the vast tract of syenite, represented as stretching away eastward across the red sandstone, is equally imaginary.

Another section (*ibid.* pl. xviii. fig. 3), explanatory of the occurrence of the marble, cannot be passed over without comment. It is entitled a "Sketch of the relative position of the marble and shelly limestone at Kilbride." Now it so happens that at Kilbride there is no shelly limestone. The whole district is one of crystalline marble, except at the roots of Beinn Dhearg, where the shales already described occur. Nor is there, that I am aware, either at Kilbride or anywhere else in Strath, such a thing as a mass of marble intercalated with shelly limestone in the way shown in this section. He observes that "these circumstances are all much more obvious in nature than in the sketch." Yet I have very carefully gone over the whole of that locality without discovering where the sketch was taken, or what appearances it was intended to represent. The only passage of marble into shelly limestone is that noticed above; but the repeated intercalation of the one rock with the other, so very obvious in the sketch, is not observable in nature.

having never reached the surface, may be the underground prolongations of the hills now visible. The minor protrusions of syenite seen in various parts of the metamorphic region seem to favour this supposition *.

I should leave my notice of the metamorphism of Strath incomplete were I to omit mention of the fact that, as the basalt-dykes were erupted previous to the syenite, they must have suffered from the general baking of the rocks. The dykes of the altered area are perhaps harder and closer-grained than those among the unaltered strata. But I confess that the great variety in the texture of the basalt-dykes, as a whole, renders it difficult, if not impossible, to establish any distinction among them.

Faults.—The faults of the district are not very numerous, nor do they merit special remark. Their general strike is northerly, varying a few degrees east or west; the details of several have been given above, and for the others I must be permitted to refer to the accompanying map and sections (Pl. I.).

Conclusion.—I have thus gone over what seemed most worthy of notice in the geology of Strath, and, in conclusion, will now briefly sum up these scattered facts, that the general bearings of this paper upon Hebridean geology may be distinctly seen.

The old basement-rock upon which the various changes described took place, is the Red Sandstone of Sleat. As it has never yielded any fossils, its age is still matter of doubt. It can scarcely be Old Red Sandstone; possibly it is Silurian, or one of the later deposits of the gneissic series, for it graduates southwards into the schists of the Sleat hills. The geological history of Strath accordingly opens among the records of a venerable antiquity. But here a great gap occurs in its chronology. The district contains no memorials of palæozoic life; and thus, while other parts of Scotland had successively their land and sea of the Old Red Sandstone, Carboniferous, and Permian periods, the old grey hills of Skye seem to have remained unchanged.

After the lapse of long centuries, the Red Sandstone, shattered and broken, slowly sank beneath an ocean in which *Ammonites*, *Belemnites*, and *Gryphææ* began to appear. The margin of the foundering land was first fringed with a band of conglomerate as the waves broke against the cliffs, while greenish sand accumulated farther from the shore. In deeper and stiller water the peculiar organisms of the Lias began to abound; seams of limestone were slowly aggregated, and, at least at one spot, a reef of massive *Isastrææ* gleamed white beneath the waves. The growth of these corals was suddenly arrested by the inroad of a large amount of muddy sediment, which silted up around them, and insinuated itself into their minutest crevice. By degrees the waters became clear, organisms began once more to swarm, but the *Isastræa* had perished for ever. Beds of limestone, occasionally checked by irruptions of argillaceous matter brought by the shifting currents, were gradually elaborated; and when they had attained a

* I find that Macculloch throws out a similar conjecture (Description, vol. i. p. 333).

thickness of fully 150 feet, the series was suddenly brought to a close by a protracted accumulation of sandy mud, abounding in *Gryphææ*, which now forms the shale-reefs of Obe Breakish. This muddy sediment had ceased to darken the water, and the abundance of animal life had spread a limy floor below the sea, when, like a premonitory symptom of the changes of after-times, the long ridge of Beinn Shuardail was upheaved. Its summit, exposed to the dash of the waves, was ere long bared of the capping of lias-beds under which it rose, and fragments of limestone, red sandstone, and quartz-rock, some well-rounded, others sharp and angular, rolled down the sides to form the limestone-breccia already described. The reef, wasted by the surf, began at length to sink together with the surrounding ocean-bottom. Limestones formed over its site, many of them richly charged with the characteristic organisms of the Lias, and often seamed with thin courses of shale. And when they had attained a depth of not less than 200 feet, a change in the direction of the currents, or some other modifying cause, brought the calcareous series to an end. Dark sandy mud settled down on the floor of the sea, entombing in rich profusion the remains of *Ammonites, Belemnites, Pectines, Gryphææ, Pinnæ, Pentacrinites*, and many others. The thickness attained by these argillaceous deposits fully doubled that of all the preceding beds, and my excursions have not yet carried me further than the shales of Scalpa, which are not probably the close of the series. These latter strata seem to be the equivalents of the Marlstone of England. It remains as the labour of future years to carry on this history through the Upper Lias and Lower and Middle Oolites that fringe the eastern shores of Skye, as far as its most northern promontory—the pillared cliffs of Duntulm.

The next point in the geology of Strath to which the evidence conducts us, is the eruption of the igneous rocks. I have said that there is nothing in the district itself to indicate how long after the deposition of the Scalpa-shales the first of these eruptions took place. That is a question which a careful examination of the northern part of the island may do much to solve. Meanwhile we are in possession of some important facts in the history of the igneous eruptions of the Hebrides. The district of Strath affords convincing evidence that at a period posterior to the Middle Lias, there was an extensive outburst of basalt, which, in the form of dykes, penetrated the liassic strata throughout their entire area, without, however, effecting any marked alteration of them ; that at a subsequent time a tract of syenite fully forty square miles in extent, along with several minor masses, broke through the beds, tilting them on end, and producing in them a widely diffused and complete metamorphism ; and that at a still later period a series of syenitic and greenstone eruptions forced their way among the limestones and shales, not, however, tilting them, nor giving rise to any extraordinary amount of alteration.

Future labours in other parts of Skye, and among other islands of the Hebrides, will probably throw much light on the history and age of these volcanic rocks. The Western Islands, unquestionably, must have been the seat of powerful igneous action during the

Fig. 1.

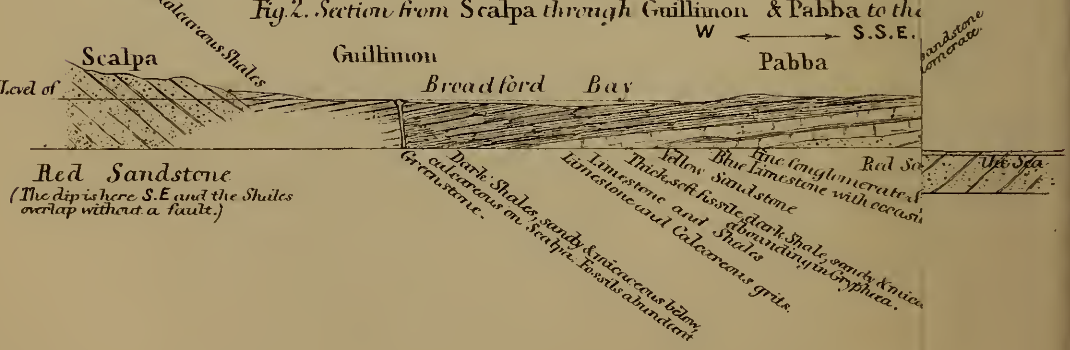
GEOLOGICAL MAP

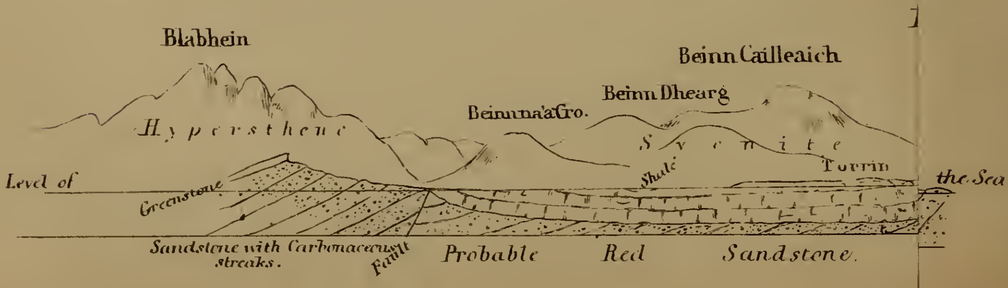
of the

LIASSIC DISTRICT OF STRATH,

ISLE OF SKYE.

Fig. 2. Section from Scalpa *through* Guillimon & Pabba *to the*





later secondary or earlier tertiary epochs; and I am much inclined to think that some of the later felspathic ashes and basalts which dot the mainland, together perhaps with not a few of the great parallel faults and dykes, may belong to this volcanic era. A thorough examination of these islands cannot fail, therefore, to elicit much truth as to some obscure points in the physical history of Scotland.

Of the geology of Strath, however, there is one branch that seems to be complete in itself, whereon we can expect little light to be thrown from other districts. I allude to what is certainly its most characteristic feature—the metamorphism of the lias-limestone. Strath may be surpassed by other localities among the Western Islands in the preservation and number of its organic remains; but I despair of meeting with a more striking example of metamorphism. The igneous rocks of this parish, with their varieties of kind and form, and their effects on the surrounding strata, impart to it an interest all its own.

Notes to the Map and Sections: Plate I.

The accompanying Map has been taken partly from that of Dr. Macculloch, partly from the Charts of the Admiralty Survey, of which a tracing was kindly sent me by Captain Wood, R.N., Kyle, and partly from bearings with the azimuth-compass. It is far from being accurate; yet the errors are not probably so material as to affect to any considerable extent the general bearings of the geological lines.

With regard to the geological part of the Map, there is but one remark needed here. The irregular bulging hill of Creag an fithick, south of Beinn Dhearg, is coloured (in the original) like the syenite, but of a fainter tint. The rock has puzzled me not a little. Sometimes it seemed like an earthy greenstone, sometimes like a felspathic porphyry; at some points it assumed many of the characteristics of an ash or tufa, with fragments of altered shale; at others it approached in texture and general appearance the syenite of the contiguous hills. It is likely that there may be several kinds of igneous rock in the series of lumpy knolls from Kilbride north-eastward, but I was unable to separate them out, and I have coloured the whole as one mass. It is by no means easy to ascertain to what age these rocks belong; they seem to have come up in the rent formed by the disruptive syenite of Beinn Dhearg, and to have flowed over atop. But it would be rash at present to hazard any conjecture regarding them.

[The lines of sections, with roman numerals, on the Map, fig. 1, refer to the MS. Sections.]

The Sections are drawn on the scale of 1 inch to the mile, except with regard to the height above the sea-level, which in most cases has had to be exaggerated. [In fig. 8 the syenite has been lessened in height.] The upper horizontal line in each of the Sections marks the sea-level, and the space between that line and the lower one represents a thousand feet of vertical depth.

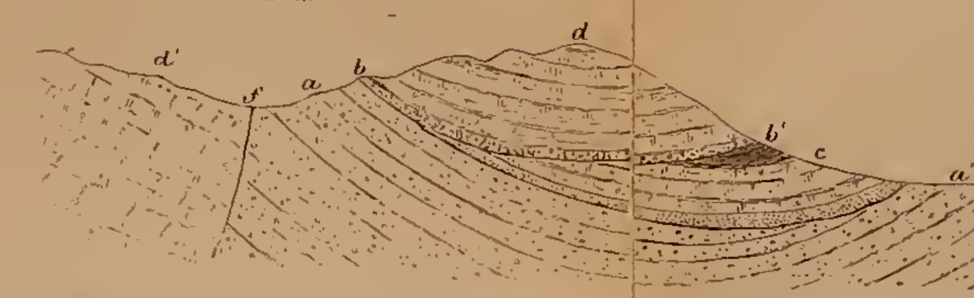
Fig. 1.

GEOLOGICAL MAP of the LIASSIC DISTRICT OF STRATH, ISLE OF SKYE.

Fig. 5. Section through northern end of Beinn Shuardail.

a. Red sandstone. b. Breccia. c. Shales & Limestones exposed along the shore from Breakish to Lussay. d. Limestones of Suardale. b'. The point where the breccia would have appeared had it been continuous.

Fig. 6. Section between Beinn na Charn and Hill of Harripool.



a.a'. Red Sandstone. b. Breccia. c. Limestones & Shales as in Fig. 5. d. Limestones & Shales: d'. Limestone of Beinn Shuardil approaching the metamorphic region. f. Fault.

Fig 7. North junction of Syenite & Marble, Beinn an Dubhaich.

a. Syenite. b. Marble with a rude dip to N. W.

Fig. 8. Junction of Syenite & Shale, Beinn Bhuidhe.

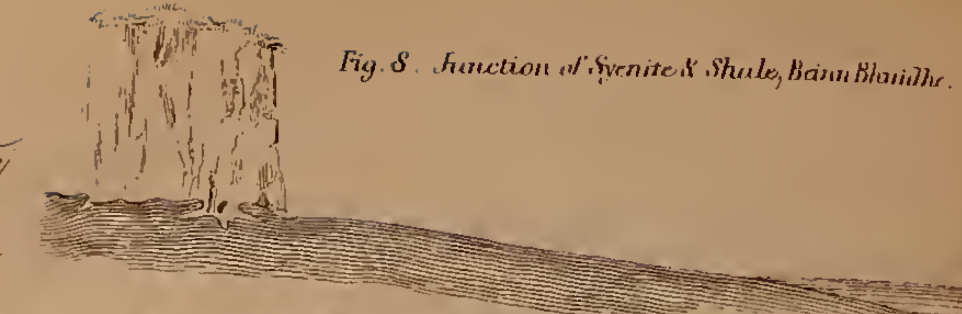
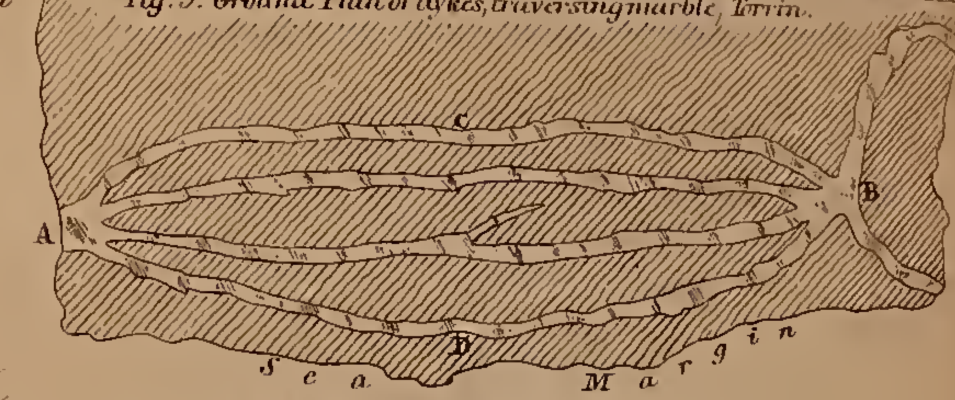


Fig. 9. Ground Plan of dykes, traversing marble, Torrin.



From A to B. 132 feet; from C to D 36 feet.

Fig. 10 Ground plan of neighbourhood of Kilchrist Manse.

a. Crystalline marble. b. Syenite of Beinn an Dubhaich. c. Greenstone dyke. d.d. Basalt dykes.

Fig. 2. Section from Scalpa through Guillimon & Pabba to the Road between Breakish & Lussay.

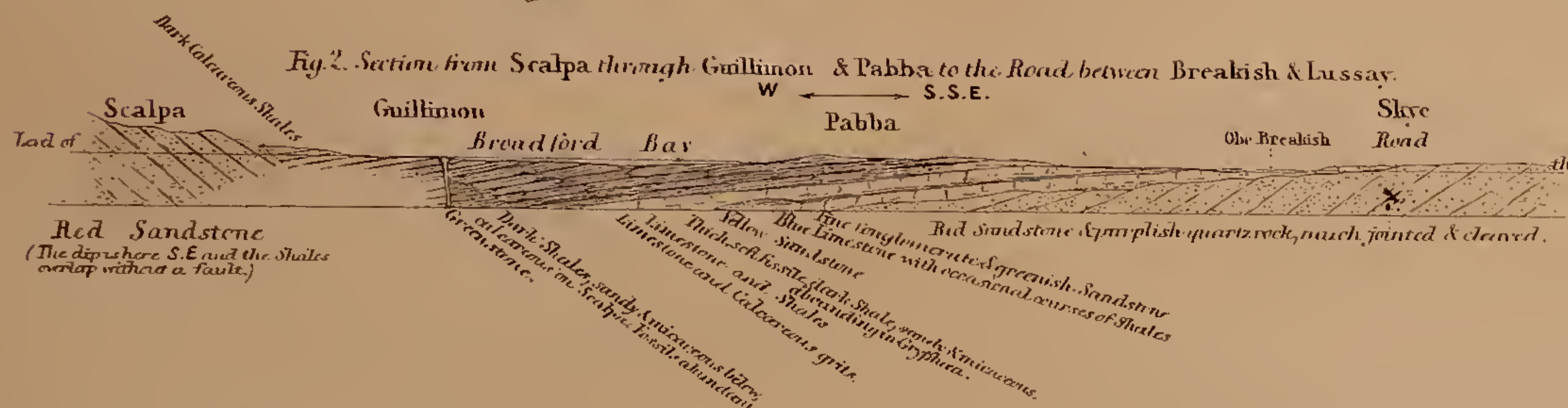


Fig. 3. Section from Beinn na Cailleaich through Beinn Shuardail and Hill of Harripool.

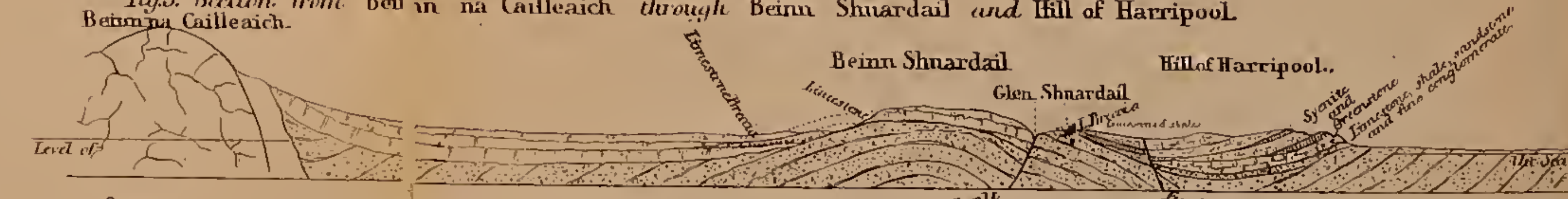
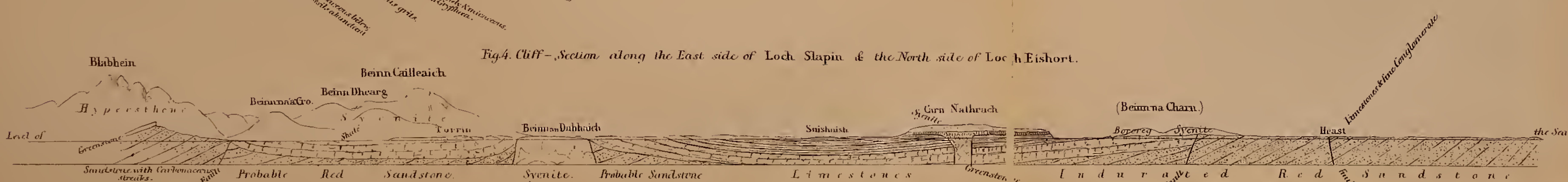


Fig. 4. Cliff-Section along the East side of Loch Slapin & the North side of Loch Eishort.



Notes on the Fossils *collected by* Mr. Geikie *from the* Lias *of the* Isles *of* Pabba, Scalpa, *and* Skye. By Thomas Wright, M.D., F.R.S.E.

At the request of my friend Professor Ramsay I made an examination of the fossils collected last summer by Mr. Geikie from the Lias of Pabba, Scalpa, and Strath; first, for the purpose of determining the species to which they belonged; and, secondly, to assign the subdivisions of the formation which they characterized.

Previous to laying before the Geological Society my notes on the different species contained in this interesting collection, it is necessary that I should premise a few remarks on the classification of the Lias, in order that I may rigorously define the portion of the formation I include in the term *middle*; so that the true stratigraphical position of the beds which yielded these organisms may be fixed with certainty.

English authors in general divide the Lias into *Upper Lias, Marlstone,* and *Lower Lias*; but these subdivisions require additions and modifications in order to place our liassic beds in correlation with those of French and German authors. For on the Upper Lias clays are superimposed beds, which, previously to the publication of my memoir on the "Upper Lias Sands"*, were grouped with the Inferior Oolite; and with the Lower Lias are placed several beds which, with the Marlstone, constitute the Middle Lias of the Continental authors.

Taking the Lias-beds as they occur in Gloucestershire, in descending order, and naming each bed by the species of Ammonite which characterizes it, we find the series tabulated at p. 25, which is nearly the equivalent of the Lias-beds of Germany so well described by Dr. Oppel in his valuable work now passing through the press, "Die Jura-Formation, &c." In the following Table (p. 25) a comparative view is exhibited of the subdivisions of the Lias, according to Prof. Quenstedt, Dr. Oppel, the late A. d'Orbigny, and Sir Roderick Murchison.

The following list contains the most characteristic species of Mollusca and Radiata of the Middle Lias of Gloucestershire, and is given for the purpose of indicating the age of the Pabba-shales, by a comparison of the respective fossils.

Belemnites paxillosus, *Schloth.*
—— elongatus, *Miller.*
—— clavatus, *Schloth.*
—— compressus, *Stahl.*
—— longissimus, *Miller.*
—— breviformis, *Ziet.*
Nautilus intermedius, *Sow.*
Ammonites spinatus, *Brug.*
—— margaritatus, *Montf.*
—— Normanianus, *d'Orb.*
—— heterophyllus (amaltheus), *Quenst.*
—— fimbriatus, *Sow.*
Ammonites Henleyi, *Sow.*
—— ibex, *Quenst.* (Boblayei, *d'Orb.*)
—— bipunctatus, *Roem.* (Valdani, *d'O.*)
—— Loscombi, *Sow.*
—— capricornus, *Schloth.* (maculatus, *Y. & B.*)
—— Jamesoni, *Sow.*
—— Davœi, *Sow.*
—— Maugenesti, *d'Orb.*
—— Taylori, *Sow.*
—— Centaurus, *d'Orb.*
Chemnitzia undulata, *d'Orb.*

[Continued at p. 26.]

* Quarterly Journal of the Geological Society, vol. xii. p. 292.

A Table showing the Correlation of the Lias Beds in France, Germany, Gloucestershire, and Skye.

SWABIA. *Quenstedt.*	WÜRTTEMBERG. *Oppel.*	FRANCE. *D'Orbigny.*	GLOUCESTERSHIRE. *Wright.*	GLOUCESTERSHIRE. *Murchison.*	SKYE.
Lias ζ. *Jurensismergel*........	Jurensis-bett	*Toarcien.*	Jurensis-bed	Base of Inferior Oolite.	
Lias ε. *Posidonienschiefer* ...	Posidonomyen-bett...........	UPPER LIAS.	Communis-bed	Upper Lias.	
Lias δ. *Amaltheenthone* ... {	Spinatus-bett		Spinatus-bed	} Marlstone	Scalpa.
	Margaritatus-bett		Margaritatus-bed		
Lias γ. *Numismalismergel* {	Davœi-bett	*Liasien.*	Davœi-bed		
	Ibex-bett	MIDDLE LIAS.	Ibex-bed	}	Pabba.
	Jamesoni-bett		Jamesoni-bed		
Lias β. *Turnerithone* ...... {	Raricostatus-bett		Raricostatus-bed..............	Lower Lias Shales and Limestone.	
	Oxynotus-bett..................		Oxynotus-bed		
	Obtusus-bett		Obtusus-bed		
Lias α. *Sand u. Thonkalke* {	Tuberculatus-bett	*Sinémurien.*	Tuberculatus-bed		
	Bucklandi-bett	LOWER LIAS.	Bucklandi-bed.................		
	Angulatus-bett		Planorbis-bed	....	Lussay.
	Planorbis-bett.................		Insect-bed		
Vorläufer des Lias	Bone-bed.......................	....	Bone-bed.......................	Bone-bed.	

[Continued from p. 24.]

Trochus imbricatus, *Sow.*
Pleurotomaria expansa, *Sow.*
—— concava, *Wright*, n. sp.
—— Anglica, *Sow.*
Rotella compressa, *Sow.*
—— polita, *Bronn.*
Dentalium giganteum, *Phil.*
Gryphæa cymbium, *Lamk.*
—— gigantea, *Sow.*
Pholadomya ambigua, *Sow.*
—— decorata, *Hartm.*
Pleuromya unioides, *Roemer.*
Panopæa elongata, *Roemer.*
Mytilus (Cypricardia?) hippocampus, *Young & Bird.*
—— cuneatus, *Sow.*
Cypricardia cucullata, *Goldf.*
Cardinia attenuata, *Stutchb.*
Cardium acutangulum, *Phil.*
—— truncatum, *Sow.*
Unicardium cardioides, *Phil.* (Ianthe, *d'Orb.*)
Arca Buckmanni, *Richard.*
—— truncata, *Buckm.*
Pinna folium, *Young & Bird.*
Lima Hermanni, *Ziet.*
Limea acuticosta, *Goldf.*
Avicula cygnipes, *Young & Bird.*
—— inæquivalvis, *Sow.*
—— longiaxis, *Buckm.*
Inoceramus ventricosus, *Sow.*
Pecten æquivalvis, *Sow.*
—— sublævis, *Phil.*
Pecten corneus, *Goldf.* (non *Sow.*)
—— velatus, *Goldf.*
Plicatula spinosa, *Sow.*
Gervillia lævis, *Buckm.*
Goniomya, 2 sp.
Homomya, sp.
Gresslya, 3 sp.
Astarte, 2 sp.
Leda complanata, *Goldf.*
——, n. sp. allied to L. lachryma, *Qu.*
Terebratula cornuta, *Sow.*
—— Edwardsi, *Davids.*
—— resupinata, *Sow.*
—— punctata, *Sow.*
—— subpunctata, *Davids.*
—— numismalis, *Lamk.*
—— subovoides, *Roemer.*
Spirifer rostratus, *Schloth.*
Rhynchonella variabilis, *Schloth.*
—— rimosa, *V. Buch.*
—— tetrahedra, *Sow.*
—— acuta, *Sow.*
Cidaris Edwardsii, *Wright.*
Hemipedina Bowerbankii, *Wright.*
Acrosalenia crinifera, *Quenst.*
Ophioderma Gaveyi, *Wright.*
Tropidaster pectinatus, *Forbes.*
Uraster Gaveyi, *Forbes.*
Pentacrinus robustus, *Wright.*
—— basaltiformis, *Miller.*
—— punctiferus, *Quenst.*
—— gracilis, *Charlesw.*

In the above list I have only enumerated the most characteristic species, as there are many undescribed forms of *Gasteropoda* and *Conchifera* in the Middle Lias of Gloucestershire which cannot be cited in this paper.

List of the Liassic Fossils collected by Mr. Geikie in Skye.

Belemnites elongatus. Pabba.
—— paxillosus. Pabba.
—— breviformis. Pabba.
Ammonites Jamesoni. Pabba.
—— brevispina. Pabba.
—— Davœi. Pabba.
Trochus imbricatus. Pabba.
Pholadomya ambigua. Pabba.
Pleuromya Scottica, n. s. Pabba.
—— unioides. Pabba.
Cardinia concinna. Lussay.
Avicula, sp. Scalpa.
Unicardium cardioides. Pabba.
Pinna folium. Pabba.
Mytilus cuneatus. Pabba.
Lima gigantea. Pabba.
Lima Hermanni. Pabba.
Limea acuticosta. Pabba.
Inoceramus ventricosus. Pabba.
Pecten æquivalvis. Pabba and Scalpa.
——, sp.
Plicatula spinosa. Pabba.
Gervillia Maccullochii, n. s. Pabba.
Gryphæa cymbium. Pabba.
—— obliquata. Pabba.
Ostræa arietis. Lussay.
——, sp. Lussay.
Rhynchonella tetrahedra. Pabba.
Pentacrinus robustus, n. s. Pabba.
—— gracilis. Pabba.
Isastræa Murchisoni, n. s. Lussay.

Belemnites elongatus, Miller, 1823.

Belemnites elongatus, Miller, Trans. Geol. Soc. 2nd Series, vol. ii. t. 7. f. 6–8 ; Sowerby, Mineral Conchology, t. 590. f. 1 ; De Blainville, Mémoire sur les Bélemnites, pl. 4. f. 6.

Belemnites paxillosus, numismalis, Quenstedt, 1848, Cephalopoda, t. 23. f. 21, 22.

This species is found in the Middle Lias at Charmouth from the bed with *Ammonites Jamesoni*, Sow., to that with *Ammonites Davœi*, Sow. It was collected in Crick Tunnel, near Daventry, and is also found in the lower beds of the Middle Lias, with *Terebratula numismalis*, Lamk., at Cheltenham. Two specimens have been collected from the Pabba shales; although only 6 inches in length, they are good type-forms of this species. In France it is found in the Middle Lias in twelve different Departments, and in Wurtemberg it forms a characteristic fossil of the Lias γ. of Quenstedt, and "der mittlere Lias" of Dr. Oppel.

Belemnites paxillosus, Schlotheim, 1820.

Belemnites paxillosus, Schlotheim, die Petrefactenkunde, p. 46.

—— *Bruguierianus*, d'Orbigny, Pal. Franç. Terrains Jurassiques, pl. 7. f. 1–5.

—— *paxillosus amalthei*, Quenstedt, Cephalopoda, t. 24. f. 4.

Three specimens of this species were collected from the Middle Lias shales of Pabba, but the distinct horizon in which they occur has not been noted. In Gloucestershire it is found in the Marlstone with *Ammonites margaritatus*, Montf., and in the same rock at South Petherton with that Ammonite. In France it has been collected from the same horizon; and in Southern Germany, Dr. Oppel says it is one of the most widely distributed species of the Margaritatus-bed.

Belemnites breviformis, Zieten, 1831.

Belemnites breviformis, Zieten, die Versteinerungen Württembergs, t. 21. f. 7.

—— *breviformis amalthei*, Quenstedt, Cephalopoda, t. 24. f. 21–23, 1848.

There is only one specimen of this Belemnite in the collection. This species is found in the Marlstone of Gloucestershire, and in the Lias δ. of Quenstedt, with *Ammonites spinatus*, Brug.

Ammonites Jamesoni, Sow., 1827.

Ammonites Jamesoni, Sowerby, Mineral Conchology, pl. 555. f. 1.

—— *Bronni*, Römer, die Versteinerungen des Norddeutschen Ooliten-Gebirges, t. 12. f. 8, 1836.

—— *Regnardi*, d'Orbigny, Paléont. Française, Ter. Juras. t. 72.

—— *Jamesoni, angustus*, Quenstedt, Cephalopoda, t. 4. f. 8, 1845.

—— *Jamesoni, latus*, Quenstedt, Cephalopoda, t. 4. f. 1.

—— *Jamesoni*, Quenstedt, der Jura, t. 15. f. 1–5 ; Oppel, Mittl. Lias Schwabens, p. 38 ; die Juraformation, p. 159.

The original type of this species was collected by Sir Roderick Murchison in the Isle of Mull. There are several fragments in the collection, one showing the inner and larger whorls, *in situ*, from which we learn that up to the third whorl the ribs are fine and numerous, about 56 in a whorl; in the fourth whorl they are further apart; in the fifth whorl they become more prominent, are directed obliquely forwards, and as they pass over the dorsal surface they form an arch, the convexity of which is towards the mouth of the shell.

This appears to be the most abundant species in the Pabba-shales, as there are several specimens of different ages in the collection; the largest specimen measures 6 inches in diameter. Compared with Sowerby's figure (Min. Conch. pl. 555. f. 1), the lateral ribs in the specimens from Pabba are less flexed, the second whorl is disproportionately small, and the ribs are closer together.

Ammonites Jamesoni, Sow., is found in the Middle Lias near Charmouth, and in the grey shaly clays of the same zone at Robin Hood's Bay, Yorkshire coast; I have obtained only three specimens in the lower beds of the Middle Lias near Cheltenham.

This Ammonite is found in the lower part of the Middle Lias of Swabia, in many localities, as at Pliensbach by Boll, at Sondelfingen, Hechingen, Balingen, &c. The German specimens are mostly fragments. In France it is found in the same region of the Middle Lias at Saint Amand (Cher) and Évrecy (Calvados). As the ribbing of the shell varies at different periods of its growth, such varieties have been supposed to constitute distinct species. The *Ammonites Regnardi*, d'Orb., and the *Ammonites Bronni*, Roemer, are but different states of this very characteristic Ammonite from the lower region of the Middle Lias.

Ammonites brevispina, Sowerby, 1827.

Ammonites brevispina, Sowerby, Mineral Conchology, t. 556. f. 2.
—— *natrix*, Zieten, die Verstein. Württemb. t. 4. f. 5, 1830.
—— *natrix, rotundatus*, Quenstedt, Cephalopoda, t. 4. f. 17, 1845.

Sowerby's text and the numbers of pl. 556 do not agree; this mistake will mislead the reader, unless he is acquainted with the two Ammonites figured in that plate. Figure 1 represents *Amm. brevispina*, Sow., and Figure 2, *Amm. laticostatus*, Sow., as stated in the description. On comparing the fragment of this species from the Pabba-shales with *A. natrix*, Zieten, from the Middle Lias of Balingen (Swabia), I find them to be identical; the spines near the inner edge of the whorl are nearly obsolete, those towards the back are short well-developed processes, and are well characterized by the specific name *brevispina*. The type-specimen of this Ammonite was collected at Pabba by Sir Roderick Murchison, with which the fragment before me entirely agrees. It is found likewise in the lower shales (Middle Lias) of Robin Hood's Bay with *Amm. Jamesoni*, Sow.

Ammonites Davœi, Sowerby, 1822.

Ammonites Davœi, Sowerby, Mineral Conchology, t. 350 ; d'Orb. Paléontol. Française, Terr. Jurassiques, t. 81, 1844 ; Quenstedt, Cephalopoda, t. 5. f. 6.

The only specimen of this Ammonite contained in the collection has the shell tolerably well preserved ; the fine irregular layers of growth which impart a wrinkled appearance to the whorls, with the few distinct tubercles, from ten to twelve in a whorl, placed on its outer border, serve to distinguish this species from *Amm. armatus,* Sow., and *Amm. subarmatus,* Sow., with which it might be confounded.

Ammonites Davœi, Sow., is found at Charmouth in the upper region of the Middle Lias; in Gloucestershire I have a specimen collected from a bank of clay above the zone of *Ammonites ibex,* Quenst. (*A. Boblayei,* d'Orb.) and *Amm. bipunctatus,* Roem. (*A. Valdani,* d'Orb.). In Swabia Dr. Oppel found it in this horizon near Boll, at Füzen and at Randen. D'Orbigny gives many localities for this species in France, where it is proper to the Middle Lias, "bien au-dessous de la *Gryphæa cymbium.*"

Trochus imbricatus, Sowerby, 1819.

Trochus imbricatus, Sow. Mineral Conchology, t. 272. f. 3, 4.

The only examples of this species are two interior moulds, from which the shell is entirely denuded ; the whorls are rather more convex than the type-forms of this fossil from the Middle Lias Clays near Cheltenham, from whence Sowerby's specimens were obtained.

Pholadomya ambigua, Sowerby, 1819.

Pholadomya ambigua, Sowerby, Mineral Conchology, t. 227.

The two specimens of this shell are small, about 2 inches in length ; but they agree in the form of the mould, the number of the ribs, and the style of the lines of growth, with true forms of this species of the same size found in the Middle Lias, near Cheltenham, in company with *Ammonites Henleyi,* Sow., *Pleurotomaria expansa,* Sow., *Pecten æquivalvis,* Sow., and *Modiola scalprum,* Sow.

Pleuromya Scottica, Wright, nov. sp.

Shell oval, umbos large, prominent, and forming conspicuous recurved projections, the points of which extend to the anterior border; sides much inflated below the umbos, and marked with numerous longitudinal elevations and depressions; the moulds are so much distorted that neither their number nor the true form of the shell can be ascertained.

This species resembles *Pl. unioides,* Roem., in the longitudinal elevations on the shell, but differs from it in having the curvature of the umbos level with the anterior border, instead of at the anterior third, as in *Pl. unioides.* The forward position of the umbos likewise distinguishes it from *Pl. rostrata,* Agass.

Pleuromya unioides, Roemer, 1836.

Venus unioides, Roemer, Norddeutschen Oolit. t. 8. f. 6. p. 109.

Pleuromya unioides, Agassiz, Études Critiques, Pleuromya, p. 236. t. 27. f. 9–13.

The single specimen before me from the Pabba-shales so closely resembles the same species from the Capricornus-bed of the Middle Lias, and likewise from the Margaritatus-bed of the Marlstone, that there can be no doubt of their identity; it appears to be rare at Pabba.

Avicula, sp.

In a fragment from Scalpa, with a portion of *Pecten æquivalvis*, there is the interior of one valve of an *Avicula*; but the species is indeterminable.

Cardinia concinna, Sowerby, 1819.

Unio concinnus, Sowerby, Mineral Conchology, t. 223.

Cardinia concinna, Agassiz, Études Critiques, Myes, t. 12. f. 21, 22.

Six valves of this shell lie on a thin slab of greenish sandstone, which came from beneath the coral-bed at Lussay; the *Cardiniæ* are mostly in the form of moulds, and on the under side of the slab are similar impressions of the same shells.

The specimens from Lussay agree much better with Agassiz's than with Sowerby's figure. In Germany this species characterizes the lower beds of the Lower Lias, in Wurtemberg. In France it is found in the same strata in the Departments of Moselle and Côte d'Or.

Unicardium cardioides, Phillips, 1839.

Corbula cardioides, Phillips, Geology of Yorkshire, t. 14. f. 12.

The single valve of this species from the Pabba-shales agrees with the type-forms of this shell found in such abundance in the shales of the Middle Lias, beneath the Marlstone in Gloucestershire, and in the same horizon in Robin Hood's Bay, Yorkshire.

Pinna folium, Young and Bird, 1822.

Pinna folium, Young and Bird, Geological Survey of the Yorkshire Coast, t. 10. f. 6.

Pinna inflata, Chapuis et Dewalque, Fossiles Ter. Second. Luxembourg, t. 30. f. 1.

Several specimens of this species, from the Pabba-shales, are in the collection, which entirely agree with the Gloucestershire examples of the same shell, and with those from Robin Hood's Bay, Yorkshire.

Mytilus cuneatus, Sowerby, 1821.

Modiola cuneata, Sowerby, Mineral Conchology, t. 248. f. 2.

Modiola scalprum, Phillips, Geology of Yorkshire, t. 14. f. 2.

The three specimens of this Mussel are from the Pabba-shales; they are small imperfect examples of the species, but identical with the Gloucestershire forms of the same size found in the shales of the Middle Lias, and in the Marlstone of that county.

LIMA GIGANTEA, Sowerby, 1814.

Plagiostoma giganteum, Sow. Mineral Conchology, t. 77; Zieten, die Versteinerungen Württembergs, t. 51. f. 1, 1830.

Lima gigantea, Goldfuss, Petrefact. Germaniæ, t. 101. f. 1, 1834.

The specimen from Pabba agrees so well with the small smooth forms of this species found in the Lower Lias of Gloucestershire and Lyme Regis, that I have referred it to *L. gigantea*. As I believe that *L. gigantea* does not occur in the Middle Lias, I think it probable that this specimen was obtained from some of the lower beds.

LIMA HERMANNI, Zieten, 1838.

Lima Hermanni, Zieten, die Verstein. Württemb. t. 51. f. 2.

The specimen is a fragment, but the large ear, the flattened shell, the waved ribs with wide interspaces, and the distinct concentric layers of growth are sufficient to distinguish this fragment from its congeners. It was collected from the Pabba-shales.

LIMEA ACUTICOSTA, Goldfuss, 1836.

Limea acuticosta, Goldfuss, Petrefact. Germaniæ, t. 107. f. 8.

Plagiostoma acuticosta, Quenstedt, der Jura, t. 18. f. 22–25.

This species is catalogued in Murchison's Geology of Cheltenham as *Plagiostoma duplicatum*; it is found in the Marlstone and Middle Lias shales of Gloucestershire. It is collected likewise in the same zone at Robin Hood's Bay, Yorkshire. In France it is found at Fontaine-Etoup-four, Calvados, in the Middle Lias. It is abundant in the Middle Lias of Swabia. The two characteristic specimens of this shell before me, contained in fossiliferous nodules, were collected from the Pabba-shales.

INOCERAMUS VENTRICOSUS, Sowerby, 1823.

Crenatula ventricosa, Sowerby, Mineral Conchology, t. 443.

Inoceramus nobilis, Münster in Goldfuss, Petr. Germaniæ, t. 109. f. 4.

This species is very abundant in the Middle Lias near Cheltenham; a solitary specimen from the Pabba-shales agrees entirely with our shells; the regular undulations on the sides, and the general contour of the mould, are identical with fossils of the same size from Hewlett's Road near that town, where it occurs with *Ammonites Henleyi*, Sow. At Charmouth, Dorset, Dr. Oppel collected it with *Ammonites Davœi*, Sow.

PECTEN ÆQUIVALVIS, Sowerby, 1818.

Pecten æquivalvis, Sowerby, Mineral Conchology, t. 136. f. 1.

The specimens of this species from the Pabba-shales are small and mostly in the state of moulds. There is one large compressed shell from Scalpa identical in size with the same species found in the Marlstone of Gloucestershire. The beds at Scalpa have been supposed to be Inferior Oolite; but the presence of *Pecten æquivalvis*, of large size, in them is against that opinion. The fewness of the specimens collected at Scalpa, added to the bad state of preservation of those found, make it a desideratum that these beds should be worked with the view of clearing away the doubt. Looking at Mr. Geikie's sections, and comparing them with the section which accompanies Sir Roderick Murchison's paper on the Oolitic Rocks of Sutherland, Ross, and the Hebrides*, I am disposed to think that the geologist would be rewarded by the discovery of both Marlstone, Upper Lias, and Inferior Oolite in the Island of Scalpa.

Pecten, nov. sp.

This specimen is distinct from all the other Middle Lias *Pectines*; but, as it is only an imperfect mould, it is impossible to give a diagnosis of the species.

Plicatula spinosa, Sowerby.

Plicatula spinosa, Sowerby, Mineral Conchology, t. 245. f. 1–4; Goldfuss, Petrefacta Germaniæ, t. 107. f. 1.

This species is a very common shell in the Middle Lias of England, France, and Germany, and is found in the Pabba-shales. The specimens from Pabba measure $\frac{9}{10}$ths of an inch in height.

Gervillia MacculLochii, Wright, nov. sp.

Shell large, oblong, equivalved; moderately thick anteriorly, and thin posteriorly; umbos acute, extending to the extreme limit of the anterior border; hinge-margin straight, about 3 inches long; anterior auricle absent; posterior long, wing-like, but imperfectly preserved; folds of growth irregular, and strongly marked on the mould; a prominent carina passes in an oblique direction, from the middle of the left valve towards the posterior border; inferior border very convex, which gives an unusual height to the shell; anterior border oblique, but nearly straight.

Dimensions. — Length $5\frac{1}{4}$ inches; height $2\frac{3}{4}$ inches; thickness $1\frac{1}{2}$ inch.

This fine specimen, which is unfortunately broken, was collected from the Pabba-shales (Middle Lias). A portion of the posterior wing and of the convex lower border are absent, so that my measurements are only approximately true. The diagnosis, however, will enable palæontologists to distinguish this *Gervillia*, which is the largest species yet found in the Lias; the height of the shell, the flatness of the valves, the straightness of the anterior border, the acuteness of the umbos, and the convexity of the inferior border distinguish it from *G. lata*, Phil. The size of the shell, the straightness of the hinge-margin, and the irregular marking of the lines of growth distinguish it from *G. lævis*, Buckm., which is found in the

* Trans. Geol. Soc. 2nd series, vol. ii. p. 353.

Middle Lias near Cheltenham; with *G. crassa*, Buckm., from the Lower Lias, it has no affinities whatever.

I dedicate this fine species to the memory of Dr. Macculloch, to whom we are indebted for much valuable information on the geology of the Western Islands of Scotland. I am the more desirous of connecting that eminent geologist's name with the Pabba-beds, seeing that the *Gryphæa* dedicated to him proves to be a previously-described species.

Gryphæa cymbium, Lamarck, 1816.

Gryphæa cymbium, Lamarck, Animaux sans Vertèbres, vol. vi. p. 198; Goldfuss, Petrefacta Germaniæ, t. 84. f. 5; t. 85.

Gryphæa Maccullochii, Sowerby, Mineral Conchology, t. 547. f. 1, 2, 3.

This species has long been misunderstood by English palæontologists, as it is not an abundant shell in England; I have collected it, with *Ammonites Henleyi*, Sow., at Charlton near Cheltenham, and I have received specimens from near South Petherton. The shells collected by Mr. Geikie from the Pabba-shales enable me to clear up a doubt which has long existed relative to *Gryphæa Maccullochii*, Sow., being a variety of *Gryphæa obliquata*, Sow.; for these specimens, collected, like the types of Sowerby's species, from the Lias at Pabba, enable me to state that *Gryphæa Maccullochii*, Sow., from Pabba is the true *Gryphæa cymbium*, Lamk.

One of the Pabba specimens represents Goldfuss' var. γ, *dilatata*; it is $3\frac{1}{2}$ inches in height by 3 inches in breadth; other examples nearly agree with Sowerby's figures 2 and 3. t. 547. In Gloucestershire this *Gryphæa* is found in general in the Middle Lias Clay; but in Yorkshire it occurs in the Marlstone.

In France it attains a very large size, and is collected in several Departments from the upper region of the Middle Lias with *Ammonites margaritatus*, Montfort.

Gryphæa obliquata, Sowerby, 1818.

Gryphæa obliquata, Sowerby, Mineral Conchology, t. 112. f. 3.
—— *obliqua*, Goldfuss, Petrefacta Germaniæ, t. 85. f. 2.

Although this shell is sometimes mistaken for *Gryphæa arcuata*, Lamk., and sometimes for *Gryphæa Maccullochii*, Sow., it is nevertheless distinct from both. In Gloucestershire it is found in the Obtusus-bed of the Lower Lias, and ranges upwards to the base of the Middle Lias. It has a similar distribution at Lyme Regis, Dorsetshire, and at Robin Hood's Bay, Yorkshire; and is found in the lower beds at Pabba.

In Gloucestershire *Gryphæa arcuata*, Lamk., is found in the lower beds of the Lower Lias; *Gryphæa obliquata*, Sow., in the upper beds of the Lower Lias; *Gryphæa cymbium*, Lamk., in the Middle Lias; and *Gryphæa gigantea*, Sow., in the Marlstone.

OSTRÆA ARIETIS, Quenstedt, 1856.

Ostræa arietis, Quenst. der Jura, t. 10. f. 10.

On two slabs of sandstone from Lussay, obtained from the Lower Lias beneath the coral-bed, there are a number of small plaited Oysters which resemble Quenstedt's *Ostræa arietis*; they are not identical with the figure in his "Jura," but they resemble it more closely than any other described species I am acquainted with.

PENTACRINUS ROBUSTUS, Wright.

Pentacrinus Goldfussii, Wright, 1854, Annals and Mag. of Nat. Hist. 2nd series, vol. xiii. p. 380, pl. 13. f. 3.

This Pentacrinite is a very characteristic Crinoid of the Middle Lias of Gloucestershire, where it has been collected with *Ammonites capricornus,* Schlotheim (*A. maculatus,* Young & Bird), at Chipping Campden, and at Hewletts near Cheltenham, in the same zone.

The plates of the column are thin; each fourth or fifth plate is broader, and projects beyond the plate below and above it.

The pelvis and primary and secondary arms are very robust, hence the specific name; I originally figured and described this species as *Pentacrinus Goldfussii,* Wr., before I was aware that Professor M'Coy had previously given the same name to another species; it will therefore be figured in my monograph on the Oolitic Echinodermata as *Pentacrinus robustus.*

Mr. Geikie collected five fragments of the column of this species from the micaceous shales at Pabba.

PENTACRINUS GRACILIS, Charlesworth, 1847.

Pentacrinus gracilis, Charlesworth, London Geol. Journal, t. 9.

The specimen is not in good preservation; it consists of a portion of the calyx, with its primary and secondary arms; the bifurcation of the primaries, almost as soon as they branch from the calyx, and the long, simple, cylindrical, secondary arms, without pinnules, sufficiently distinguish this species from its congeners. It is contained in a highly micaceous fossiliferous slab of the Pabba-shales; nearly the same horizon in the Lias as that from whence the original specimen from Staithes, Yorkshire, in the York Museum, was collected.

ISASTRÆA MURCHISONI, Wright, nov. sp.

Corallum large, and very massive; surface convex, and covered with numerous concave cells. *Calices* unequal in size and form; the larger ones occupy the upper surface, and the smaller ones are situated on the sides of the corallum. The calices are polygonal, deep, and concave; their sides are of unequal length, and are terminated by a very thin mural edge; an ordinary-sized calyx contains thirty-six septa: in some of the smaller ones there are thirty, and in some of the larger ones forty or more septa. The septal systems appear to vary considerably; but, as the calices are much covered with a fine muddy matrix, it is difficult to count the numbers accurately. The septa are of unequal length, and they are thin, waved, and granulated on their upper surface; the columella is absent or rudimentary, and the point of convergence at the bottom of the calyx is always excentral.

Dimensions.—Longest diameter of calyx $\frac{4}{10}$ths of an inch; transverse diameter $\frac{3}{10}$ths of an inch; depth of the calyx $\frac{3}{20}$ths of an inch.

These corals were noticed by Sir Roderick Murchison* as Polypifers of the genus *Astræa,* and compared to the coralline bodies found in the Lias at Ledbury near Bridgewater. The coral-bed was found by Mr. Geikie at Lussay underlying calcareous grit and sandstone of the Lower Lias; it was irregularly about 3 feet thick, and the corals are enveloped in a fine dark mudstone: the coral-bed rests on a thin band of hard blue limestone, beneath which is a stratum of greenish micaceous nodular sandstone containing *Cardinia concinna,* Agassiz.

Isastræa Murchisoni closely resembles another species of the same genus found in the Lower Lias near Evesham, Warwickshire, *Is. Haimeii,* Wright; but it is distinguished from that species by having the calices larger, the mural edge narrower, the septa thinner and more waved; the columella more excentral. The two corals require a careful comparison to detect their diagnostic characters. I dedicate this species to Sir Roderick Murchison, to whose researches we are indebted for much valuable information on the geology of the Hebrides.

Having thus critically examined each of the species contained in this collection of Lias fossils from the Isle of Skye, the following conclusions may be inferred from their study:—

1st. That the Lower Lias is represented at Lussay by greenish micaceous sandstone, overlaid by hard blue limestone, on which rests a bed of corals (*Isastræa Murchisoni,* Wr.) wrapped in a dark mudstone, the coral very closely resembling a species found in the Lower Lias of Warwickshire; the coral-bed, 3 feet in thickness, is overlaid by calcareous sandstone and compact blue limestones. Unfortunately no Ammonite has been found in these beds, so that their precise age cannot be determined; still, however, the presence of *Cardinia concinna,* Zieten, is, *per se,* good evidence that the greenish micaceous sandstones with *Cardiniæ* belong to the Lower Lias; for that shell is found only in the lower beds in France and Germany, its true position in Wurtemberg having been ascertained to be below the Bucklandi-bed, where it is associated with *Ammonites angulatus,* Schloth.

2nd. The "Pabba-shales" belong unquestionably to the Middle Lias, as defined in the beginning of this paper; they appertain to their lower division, which includes the *Jamesoni*-bed, the *Ibex*-bed, and *Davœi*-bed; a comparison of the species collected by Mr. Geikie with the list of the Middle Lias species inserted at pages 24 & 26 is conclusive as to the age of the Pabba-shales. The number of leading

* Trans. of the Geol. Soc. 2nd series, vol. ii. p. 368.

species collected by our author, during his short visit to Pabba, makes it highly probable that, were the shales worked diligently, nearly all the species of the Middle Lias of England would be found therein.

3rd. The shells from the Lias of Scalpa are very meagre and in bad preservation; they consist of *Pecten æquivalvis*, Sow., *Gervillia inæquivalvis*?, Sow., and a *Pleuromya*. The position of the beds which yielded these shells, as shown by the section (Pl. I. fig. 2) from Scalpa, through Guillimon and Pabba, to the road between Breakish and Lussay, indicates that they may be the equivalent of the Marlstone, and represent the Margaritatus-bed and Spinatus-bed of the table at page 25; the size and form of the large *Pecten* likewise favours this opinion.

Much good work might be done if these beds and those immediately above them were carefully examined, as the species enumerated are not sufficient to prove that the beds are "Marlstone," inasmuch as *Pecten æquivalvis*, Sow., is common to the clays below the Marlstone, as well as to that rock itself.

It is probable that the Upper Lias and Inferior Oolite will also be found in the neighbourhood, for it has been already proved that the lower division of the Inferior Oolite, characterized by *Ammonites Murchisonæ*, Sow., exists in Skye, as the type-example of that most important fossil was found by Lady Murchison, in a nodule of micaceous sandstone, at the base of a cliff east of Holme near Portree; so that doubtless the intermediate strata exist between Holme (Skye) and Scalpa.

May 6, 1857.

Arthur R. Abbott, Esq., Hitchin, Herts, Lieut.-Gen. John Briggs, Clayton, Sussex, and Capt. G. Harker Saxton, of the 38th Regt. M.N.I., were elected Fellows. Dr. H. R. Goeppert, Professor of Botany &c. in the University at Breslau, was elected a Foreign Member.

The following communication was read:—

The Silurian Rocks *and* Fossils *of* Norway, *as described by* M. Theodor Kjerulf, *those of the* Baltic Provinces of Russia, *by* Professor Schmidt, *and both compared with their* British Equivalents. By Sir R. I. Murchison, V.P.G.S., F.R.S., D.C.L., Pres. R. Geogr. S., &c.

Introduction.—My former brief sketches of the Silurian rocks of Norway* have recently been much improved and enriched by the labours of M. Theodor Kjerulf, who has published an excellent memoir, entitled "The Silurian Basin of Christiania†." He has also addressed

* Proc. Geol. Soc. vol. iv. p. 601; Quart. Journ. Geol. Soc. vol. i. p. 467; *ibid.* vol. iii. p. 1; *ibid.* vol. xii. p. 161; 'Geol. Russia in Europe,' &c.; 'Siluria,' p. 319, &c.

† Das Christiania-Silurbecken, chemisch-geognostisch untersucht. 4to, 1855.

to me descriptive letters, with illustrative diagrams, exactly defining the relations and dimensions of the different rock-masses, as well as the organic remains of each stratum; the most characteristic specimens of the latter having been transmitted to England for comparison*.

The same zealous author has published a work in which he classifies the two great sedimentary deposits of South Norway, the one exhibiting a vast development of unfossiliferous rocks, to which he applies the name of Cambrian,—the other being the overlying Silurian rocks, of which he describes each stratum with its respective fossils from the Alum Shales upwards.

My able coadjutor in the work on Russia and the Ural Mountains, Count A. von Keyserling, had previously translated and sent to me a memoir, by Prof. Schmidt, on the succession of the Silurian rocks of the Russian province of Esthonia, and the adjacent isles, which portrays the distinctions of the various members composing the Silurian system with much greater precision and clearness than had ever before been applied to that region.

I now lay an outline of these documents before my associates, in order to show them how independent observers in other tracts have come to the conclusion, that the Silurian system, as defined by them, as well as by myself, forms a natural-history group, whether we look to its geological relations, or its zoological contents. In the sequel I will revert to my own comparison, and point out how the Silurian rocks of Scandinavia and Russia agree with those of our own country, from the lowest to the highest beds inclusive.

Norway.—To begin with Norway, M. Kjerulf divides the whole Silurian series of his country into three physical groups, which he severally names in ascending order from the tract where it is best exhibited; viz. Oslo, Oscarskal, and Malmö, and in these he recognizes fourteen subdivisions.

A. The Oslo group consists of a base of sandstone and conglomerate, which, though not exposed near Christiania, occur at Langö, Mjosen, and other places. This bottom rock (1), which is unfossiliferous, is followed by alum-schists and bituminous limestone (2); Lower graptolite-schists (3); Orthoceratite-limestone (4); and Upper graptolite-schist (5).

B. The second or Oscarskal group is composed of calcareous and argillaceous flags (6 & 7); with intermediate orthoceratite-limestone with encrinite-schists and calcareous sandstone (8).

C. The Malmö or upper group exhibits at its base argillaceous schists (9^a) with calcareous flags (9^b), and Pentamerus-limestone (9^c); Coral-limestone, often concretionary (10); Encrinite-shale (11); Upper orthoceratite-limestone (12); Upper graptolite-schist (13); Upper Malmö limestone and schist (14).

The following Table and the annexed general section, fig. 1, explain this order.

* These are now placed in the Museum of Practical Geology.

Fig. 1.—*General Section of the Silurian Rocks in Norway.*

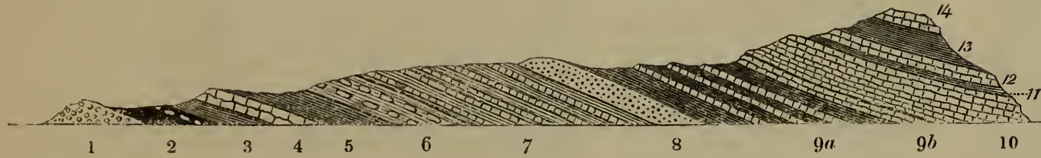


Fig. 2.—*Section of a part of Ladegaards-ö.*

N.N.W.
Beston Kilen.

S.S.E.

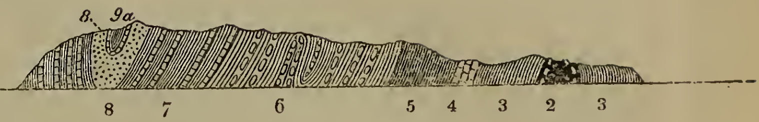


Fig. 3.—*Section from the Lower Silurian (Caradoc) Rocks of Ormö to the Ludlow Rocks of Malmö.*

W. Ormö. Malmö (130–150 feet). E.

14. Upper Malmö limestone.
13. Upper Graptolite-schists.
12. Lower Malmö- or Upper Orthoceratite-limestone.
11. Upper Encrinal schists.
10. Coral-limestone.
9b. Pentamerus-limestone.
9a. Lower argillaceous schists.
8. Calcareous sandstone.
7. Calcareous and argillaceous flagstones.
6. Orthoceratite-limestone and Lower Encrinal schists.
5. Upper Graptolite-schists.
4. Lower Orthoceratite-limestone.
3. Lower Graptolite-schists.
2. Alum-schists.
1. Quartzite.

Thickness in feet.	*Local Subdivisions.*	*Local Groups.*	British equivalents.
180	14. Upper Malmö limestone . .	Upper Malmö	*Upper Silurian.* (Woolhope, Wenlock, & Ludlow Rocks.)
	13. Graptolite-schists		
	12. Orthoceratite-limestone . .		
280	11. Upper encrinal schists . .	Lower Malmö .	*Llandovery Rocks.*
	10. Coralline and encrinal lime-stone		
370	9. *b.* Pentamerus-limestone .		
	9. *a.* Argillaceous schists . .		
700	8. Calcareous sandstone . . .	Oscarskal .	*Lower Silurian.* . Caradoc.
	7. 6. Calcareous and argillaceous flags (Orthoceratites and Encrinal schists) . . .		
160	5. Graptolite-schists	Upper Oslo	. Llandeilo.
30 to 40	4. Orthoceratite-limestone . .		
50	3. Graptolite-schists	Lower Oslo .	. Stiper Stones.
150 to 160	2. Alum-schists		
Total 1930	1. Quartzite and unfossiliferous rocks.		

In referring to the section, fig. 1, we see, that the alum-schists (2) with bituminous limestone rest upon unfossiliferous and siliceous grauwacke (1), evidently the equivalents of a part of the Longmynd (Cambrian) of Britain. In No. 2, the lowest zone in which intelligible fossils have been detected in Scandinavia, or the "Regiones A, B," of Angelin, there are found small Graptolites, *Graptopora flabelliformis*, several species of *Lingula*, including one like *L. Davisii*, a horny shell nearly allied to *Obolus Apollinis*, *Agnostus pisiformis*, *Olenus scarabæoides*, Boeck, *Olenus* (*Trilobites*) *latus*, Boeck (*Eurycare latum*, Angelin), (*Trilobites alatus*, Boeck), *Sphærophthalmus alatus*, Angelin, *Trilobites pusillus*, Sars, *Olenus* (Dalm.) *gibbosus*, Wahl., and *Asaphus grandis*, Sars.

This zone (2), being unquestionably the same as the Regiones A, B, of Angelin in Sweden*, is manifestly the northern equivalent of the "primordial zone" of Barrande in the Silurian Basin of Bohemia, and of the Stiper Stones and Lingula-schists of Britain; and, though only 150 feet thick, contains *Graptopora*† *flabelliformis* (*Gorgonia* of Eichwald), mixed with *Lingula* as in our country, and with them the *Agnostus pisiformis* and the Graptolite *Didymograpsus geminus*, as well as the Silurian Brachiopod *Orthis calligramma*, the last three of which occur also in the true Llandeilo zone of the Silurian region of Britain. In other words, we thus see clearly how, in extending our survey, it is impracticable in general classification to separate the Lingula-flags, or "Zone Primordiale," from the Lower Silurian rocks.

The next mass of schists (3, 4, 5), with an intermediate limestone, bears a close analogy to its congener in Britain, by ushering in with it a profusion of brachiopods, and clearly represents the Llandeilo formation. Thus, amongst its fossils are the Graptolites, *Diplograpsus pristis*, *D. folium*, *D. teretiusculus*, *Graptolithus sagittarius*, and the shells, *Orthis calligramma*, *O. elegantula* (*O. parva*, de Vern.),

* See M. Barrande's lucid memoir, "*Parallèle entre les Dépôts de Bohéme et de Scandinavie*," 1856.

† The generic name proposed by Mr. Salter in 1857 for this curious form, which is evidently one of the Fenestellidæ, and connects that group with the Graptolites. Report American Assoc. for 1857, Montreal.

O. flabellulum (?), *Bellerophon bilobatus, B. acutus, Orthoceras duplex, O. annulatum, Lituites cornu-arietis, Phacops conophthalmus* (*Powisii*, Sil. Syst.); with many Trilobites of species peculiar to Sweden, but all belonging to the Lower Silurian genera, *Asaphus, Ogygia, Trinucleus, Olenus*, &c.

The group (6, 7) consisting of calcareous and argillaceous flags, intermediate orthoceratite-limestone, and lower encrinal schists, though intimately connected by many forms with the underlying divisions, is yet characterized by many other fossils, which enable us to refer it to the true Caradoc or Bala formation, as now defined, and as will be more completely explained in a new edition of 'Siluria.' These fossils are, *Orthis calligramma, O. testudinaria, O. Pecten, Leptæna sericea, Lingula attenuata, Bellerophon bilobatus, B. acutus, Conularia quadrisulcata*, and probably *C. Sowerbyi*, with other species. *Orthoceras duplex, O. gigas, O. dimidiatum, O. distans*, and *O. annulatum*; the last three being Upper Silurian forms in Britain. The other fossils of Lower Silurian age are: *Lituites cornu-arietis, Trocholites anguiformis, Euomphalus*, and *Turbo*; several species, including *Euomphalus alatus*, Hisinger, with *Echinosphærites aurantium, Tentaculites anglicus* (*annulatus*, Sil. Syst.), with the well-known Trilobites *Asaphus expansus, Trinucleus concentricus* (*Caractaci*, Sil. Syst. var.), *T. seticornis, Ampyx nasutus, Ogygia, Calymene Blumenbachii* (var. *pulchella*), and the *Phacops macroura*, Sjogren, which closely resembles the *P. truncato-caudatus* of the British Caradoc formation. The Corals are *Stenopora fibrosa* and its variety *Lycoperdon*, with species of *Turbinolopsis*, &c.

The calcareous sandstone (No. 8, sections) would seem, from its organic remains, to constitute the commencement of a transition from the Lower to the Upper Silurian rocks, such as is seen in the Lower Llandovery rocks of South Wales. Thus, with the *Orthis testudinaria* and *O. zonata*, Dalm., and *Patella antiquissima*, His., occurs a characteristic Lower Llandovery species, *Rhynchonella angustifrons*, M'Coy, and many large smooth *Pentameri* of species not yet named. Here are some associated fossils which are also commonly found in the Upper Silurian rocks of Britain. These are: *Strophomena depressa, Euomphalus sculptus, Phragmoceras*? (*Cyrtoceras*) *ventricosum, Encrinurus punctatus, Actinocrinus moniliformis, Favosites alveolaris, Heliolites megastoma, Halysites catenularius, Cyathophyllum turbinatum*, &c.

In speaking of the characters of the fossils of this zone, it is to be observed, that the characteristic Lower Silurian trilobites have already disappeared*.

The argillaceous schists with calcareous flags (No. 9*a*) obviously represent also a part of that intermediate group connecting the Lower and Upper Silurian, to which I have now assigned the name of "Llandovery rocks." For, in these beds certain species of *Pentameri* are first met with, whilst the overlying limestone (9*b*) is, as in

* Several of these corals and shells in Britain range from the Llandeilo formation to the base of the Ludlow rocks.

Britain, charged with the *Pentamerus oblongus,* and forms in both countries a clear horizon.

The fossils are: *Fenestella assimilis, Alveolites* (*Millepora*) *repens, Cœnites intertextus, Ptilodictya* (*Eschara*) *scalpellum, Halysites catenularius, Orthis calligramma, O. elegantula, O. testudinaria, O. Pecten, O. zonata,* Dalm., *O. lamellosa, Strophomena depressa, Leptæna transversalis, Orthis* (*Spirifer*) *insularis, O. biforata* (*Sp. Lynx, Sp. dentatus, Atrypa crassicostis,* Dalm., &c.), *O. biloba* (*Sp. sinuatus,* V. Buch), *Cyrtia trapezoidalis, Trigonotreta compressa, Pentamerus* (*Atrypa*) *galeatus, Atrypa prunum, A. tumida, Pentamerus Lens, P. lævis, Atrypa reticularis, A. aspera,* Dalm., *Euomphalus funatus, E. sculptus, Acroculia Haliotis, Calymene Blumenbachii, Encrinurus punctatus, Ampyx, Acidaspis,* and the *Trilobites elliptifrons* (*Proetus?*) of Esmark, *Tril. elegans,* Sars, &c.

The band with *Pentamerus oblongus* is at once followed by another limestone (No. 10) highly charged with corals and crinoids, and which evidently characterizes the mass of the Wenlock limestone. It is, however, important to remark that, with many corals, the *Euomphalus sculptus, E. carinatus,* and even the *Orthoceras annulatum* and *O. Ibex,* Sil. Syst., we again meet with the *Pentamerus oblongus* and *P. lævis* of the subjacent band, thus linking together, still better than in England, these beds with the inferior strata, and showing a higher vertical range of the above species of *Pentameri* than is known in England, where they never rise into the Wenlock formation. The list of fossils includes *Ptilodictya lanceolata, P.* (*Eschara*) *scalpellum,* and the corals, *Cyathophyllum turbinatum,* Goldf., *Ptychophyllum patellatum,* several species of *Heliolites,* and several forms noticed in the underlying strata, with *Sarcinula organum,* a species of Lower Silurian age in Britain. The prevailing Encrinite is *Actinocrinus moniliformis,* Goldf., whilst the *Cornulites serpularius,* Sil. Syst., is accompanied by the following shells, *Rhynchonella borealis* (*Ter. plicatella,* Dalm.), *Euomphalus carinatus, E. sculptus,* and other spiral forms, *Orthoceras Ibex, O. annulatum,* with the *Pentamerus conchidium* and the other species above noted. The encrinal schists (11) and Upper Orthoceratite-limestone (12), the Upper Graptolite-marls (13) and the Upper Malmö limestone (14), with the schists and marls of Overland, Opsahl, Noes, Krogsand, &c., represent other members of the Upper Silurian, as far as the lower and middle members of the Ludlow rocks inclusive—the Upper Ludlow rock not being well represented by fossils.

Whilst the ordinary Wenlock Corals seem to pervade all the last-named rocks, their lower members or the encrinal schists and Orthoceras-limestone, characterized by large Orthoceratites with centrals iphuncles, may be supposed to represent the Lower Ludlow, the more so, as it contains *Gomphoceras pyriforme,* Sil. Syst. In the overlying shales *Graptolites* (*Ludensis*) *priodon* abounds; but it is to be noted that this zoophyte is associated with the *Retiolites Geinitzianus,* Barr., and *Cyathocrinus rugosus,* both of Wenlock age in Britain the former even pointing to the very base of the formation.

Even the upper limestones, schists, and shales, as seen at Malmö and the places above cited, are still charged with some corals and crinoids, known in England only in the Wenlock formation, including among the latter, *Eucalyptocrinus decorus* and *Crotalocrinus* (*Cyathocrinus*) *rugosus*. On the other hand, here are also found some of the typical species of the Ludlow rocks, viz. *Chonetes* (*Leptæna*) *lata*, *Rhynchonella Wilsoni*, *R. navicula*, *Turbo corallii*, *Pterinea retroflexa*, *Orthoceras Ibex*, &c.

In my own rapid survey of the environs of Christiania, as formerly explained to this Society, I could not, any more than M. Kjerulf, detect fossils indicative of the uppermost Ludlow rock, though I first pointed out the conformable passage upwards from the grey Silurian rocks into an overlying red sandstone. In some parts of Sweden, however, and on another occasion, my coadjutor M. de Verneuil and myself detected organic remains in strata which must, we thought, represent the Upper Ludlow, and even a transition into the Devonian. Thus, in Scania we found true Upper Ludlow fossils in red flaggy sandstones which Forchhammer had classed as Old Red Sandstone *.

Again, in proceeding from the northern and central parts of Gothland, which are occupied by the Wenlock limestone, we at length reached beds of a sandy and marly character, in which some of the species above mentioned, including the *Pterinea retroflexa*, *Chonetes lata*, and *Turbo corallii*, were collocated with the *Rhynchonella* (*Terebratula*) *nucula*, *Orthonota retusa*, *Murchisonia articulata*, and *Beyrichia tuberculata*, all fossils of the Upper Ludlow rock. As these forms are, in the ascending order, associated with fossils which occur in the Eifel and other Devonian tracts, including the *Calceola sandalina*, it was presumed, that the southern promontories of Gothland offer a passage from the Silurian into the Devonian rocks.

In the meantime we learn by these evidences, how, with the varying conditions of the seas during these epochs, the same species have had a longer existence in one region than in another.

M. Kjerulf has verified, *in situ*, all the organic remains he enumerates, and has followed each band of rock throughout all its undulations or breaks in the Bay of Christiania. From his numerous sections I have extracted three, which are annexed (p. 38). The first of these is the general diagram, fig. 1, the second (fig. 2) represents the ascending order near Beston Kilen, from the lowest fossiliferous beds, No. 2 (alum-slates, or "primordial zone"), through the lowest graptolite-schists (3), the Orthoceratite-limestone (4), and the Upper Graptolite-schists (5),—the three beds representing the Llandeilo flags, to the calcareous and argillaceous flags, 6 & 7, containing Caradoc fossils: all these beds and fossils are Lower Silurian, and are seen to be overlaid by the basement-beds of the Upper Silurian, Nos. 8 & 9.

The third diagram is a section from Ormö, across the whole island of Malmö, and exhibits at the base Nos. 6 & 7 of the Lower Silu-

* Quart. Journ. Geol. Soc. vol. iii. p. 34.

rian, followed by 8 & 9, or the equivalents of the Llandovery rocks, which connect the inferior and superior divisions. These masses are overlaid conformably by, and pass up into the Upper Silurian series, 10 to 14 inclusive, the whole of which are chiefly characterized by fossils of Wenlock and Ludlow species.

These detailed sections of the strata in the environs of Christiania are most valuable: first, in demonstrating, by comparison, that the Silurian rocks of Norway are, from their base upwards, the true equivalents of those of Britain; secondly, in pointing out in the very lowest fossiliferous zone the presence of those zoophytes (Graptolites) which prevail throughout the series. In the same beds occurs a *Lingula,* associated with *Orthis callactis* and other forms which, in Britain, have as yet been found only in the lower part of the Llandeilo formation; and with these is found the *Graptopora flabelliformis,* a fossil of the Lingula-schists of Wales: thus showing that, like them, the alum-schists form the natural-history base of the Silurian System. The sections also demonstrate that from this base to the uppermost beds, these zones (in all occupying less than 2000 feet in vertical dimensions) represent the whole of the vastly expanded British series, and constitute one conformable and natural system, whether viewed physically or zoologically*.

In addition to the clear order of superposition of the various Silurian rocks and their identification by fossils, M. Kjerulf has further shown, how different members of the series have been here and there metamorphosed into crystalline gneiss. The numerous points at which the sedimentary formations have been pierced by eruptive rocks long ago offered to Professor Forchhammer and myself sufficient explanation of such conversions†.

This subject has, indeed, been since worked out in some detail by Mr. David Forbes, whose residence at Christiania has enabled him to contribute satisfactory information, which clearly demonstrates the conversion of sedimentary Silurian strata into crystalline rocks replete with simple minerals‡.

Results of an examination of the Silurian Rocks of Esthonia, Northern Livonia, and the Isle of Oesel, made in the years 1853 *to* 1856. By Professor Fried. Schmidt, of Dörpat.

The Silurian rocks of Esthonia, Northern Livonia, and the Isle of Oesel, represented in a map which was transmitted to the Society, consist essentially of a series of strata which follow each other in ascending order at slight angles of inclination, and constitute zones trending generally from east to west. These strata have the following descending order:—

* Judging from a collection recently transmitted by M. Kjerulf, and which has been examined by Mr. Salter, the specific identification with the British forms may be for the most part depended upon.

† Quart. Journ. Geol. Soc. vol. i. p. 470, &c., and Russia in Europe, vol. i. p. 14, *note.*

‡ Quart. Journ. Geol. Soc. vol. xii. p. 166, &c.

Grey limestone with shales. Fishes. (No. 5.)
Limestone and dolomite. (No. 4.)
Pentamerus-limestone. Corals. (No. 3.)
Limestone with marly beds. Corals. (No. 2.)
Brandschiefer.
Calcareous flagstones or "Pleta." (No. 1.)
Green sand-beds and chloritic limestone.
Argillaceous schist.
Ungulite grit.
Blue clay and sands.

The most ancient beds of the system are seen to subside under No. 1 of Schmidt's Map (and the above list), or summit of the cliffs of the north of Esthonia on the Gulf of Bothnia, known under the name of "Glint;" and, although occupying no considerable portion of the country, those rocks alone have been hitherto chiefly studied. With the exception of the lowest argillaceous and sandy beds, which are well known (as extending from St. Petersburg into the base of these cliffs), the Silurian series of Esthonia is almost entirely composed of calcareous bands more or less pure, which, in the upper strata, often pass into dolomites. The latter varieties, however, occupy no special stratigraphical position, and are not distinguishable through their organic remains from the ordinary limestone with which they are associated. On the contrary, the limestone and the dolomite of the same zone or stage contain precisely the same fossils.

Each of the five stages indicated in the map prepared by M. Schmidt possesses a peculiar fauna, which is constant throughout the whole of the horizontal extension of the zone. Very few species traverse two entire stages without undergoing what are termed by that author "modifications." Thus, several species belong in common to the two lower bands,—others to the two upper; but, according to him, one species only, the *Calymene Blumenbachii*, passes through all the stages, from the first to the fifth inclusive, though in the last of these (the equivalent of the Upper Ludlow rocks) it is modified into the *C. spectabilis* of Angelin.

The sharpest separation in the fossiliferous contents of this series occurs between the second and third bands; thus dividing the "terrain" into Lower and Upper Silurian. These two divisions seem to contain few species common to them, or, to use M. Schmidt's language, no form which has not been modified. At the junction of these inferior and superior masses there are, however, transitions, which testify that there has been no violent break in the development of animal life, and induce the author to believe, that in this country the Silurian formation is a whole, whose members constitute a compact series of calcareous strata shading into each other, but not conducting by similar points of approximation to the overlying Devonian rocks of Livonia, which occur, he says, as an entirely separate system.

This sharp distinction is indeed explained by the physical relations of the rocks; for, whilst the uppermost Ludlow rocks are clearly represented, they are overlaid transgressively by those Devonian masses which, as formerly shown by my colleagues and myself, contain the Devonian shells of Devonshire and the Rhine, united in the same beds with the fishes of the Old Red Sandstone of Scotland.

However small may be the number of species common to two of the Silurian zones, examples are not wanting to show that, when a change occurs, each typical fossil is replaced in the next succeeding band by an analogous form, which, in its turn, is constant throughout the entire extent of its stratum. Now, as this continuity of forms stops at the uppermost limit of the Silurian rocks, the phænomenon, as M. Schmidt observes, seems to operate as much in favour of the distinction of the various bands or stages, as it clearly does for their union in one system of life.

The researches of M. Schmidt have furnished him with nothing new respecting the inferior portion of the Silurian strata, which, passing from the Government of St. Petersburg, underlies the cliffs of Esthonia called Glint. That lower series consists in an ascending order of sands and clay, Ungulite-grit, argillaceous schists, and a chloritic grit and limestone, as described in 'Russia and the Ural Mountains.' The summit of the cliffs is composed of grey, flag-like limestone, the "Pleta" of the Government of St. Petersburg, and marked No. 1 in M. Schmidt's map. This limestone ranges a little southwards into the continent, disappearing at a very gentle angle under the superior formations. The blue clay, cropping out to the east of Reval only, sinks on the west beneath the sea-level. The "Ungulite-grit" contains its usual fossils, *Obolus Apollinis*, *Orbicula Buchii**, and *O. reversa*; whilst the schists present us with the *Graptopora* (*Gorgonia*) *flabelliformis*, Eichw. (the *Phyllograpsus* of Angelin), which, in Sweden, is characteristic of the lowest fossil-beds or alum-slates.

In the green sand† or chloritic rock of Esthonia, no one has positively discovered the existence of the microscopic tooth-like bodies that M. Pander has collected from the same bed in the Government of St. Petersburg, and described as fish-teeth. Along with the *Obolus*, however, M. Schmidt has detected a *Lingula* and the *Orthis calligramma*. The chloritic limestone is specially developed at the foot of the cliffs of the Isle of Odinsholm. Grains of chlorite are there strikingly disseminated in a greyish-white limestone. This rock constitutes a marked feature, and is equally visible at Baltisch Port and Reval. In point of organic remains, it contains numerous fragments of *Asaphi*, and notably of a species resembling *A. Tyrannus*, Murch. (the *A. heros* of Dalman). This chloritic limestone passes into the Government of St. Petersburg without containing a peculiar fauna.

The calcareous flagstone called Pleta, No. 1, is exhibited in great

* The names of all the fossils in this part of the memoir are those given by Prof. Schmidt. The species have not been yet compared, like those of Norway, with their British analogues.—R. I. M.

† Prof. Ehrenberg's researches (Berlin Transact. 1855) tend to prove that a portion at least of the green grains in this sand has been derived from the minute stony casts of the shells of Polythalamia.

constancy of character from the Isle of Odinsholm and the cliffs of Baltisch Port to Narva and the hills south of St. Petersburg, where it is part of the Lower Silurian of M. Kutorga*. The most important fossils of this rock are its Orthoceratites, *Orthoceras duplex*, *O. vaginatum*, *O. undulatum*, Schlotheim and Quenstedt, and the *O. acutum*, Eichw. These are accompanied by *Asaphus expansus*, *A. raniceps*, *Illænus crassicauda*, *Lichas Hubneri*, *L. verrucosus*, *Cheirurus exsul*, Beyr., *Lituites convolvans*, *L. falcatus*, *L. Odini*, Eichw., *Bellerophon locator*, Eichw., *B. megalostoma*, Eichw., *Porambonites æquirostris*, *Rhynchonella nucula*, *Orthis calligramma*, *O. inflexa*, *O. extensa*, *O. obtusa*, *Orthisina adscendens*, *Siphonotreta unguiculata*, *S. verrucosa*, *Sphæronites aurantium*, *Echinosphærites Balticus*, *Hemicosmites pyriformis*, *Receptaculites orbis*, Eichw., &c.

Towards the upper limit of this stage, and in the eastern part of Esthonia, there is found a bituminous shale, known as "brandschiefer" or inflammable schist, formerly described by Colonel Helmersen†. Occurring at Tolks and Pungern, it is very rich in well-preserved fossils, which seem to connect the underlying calcareous stage with the next overlying limestone, many of the species being peculiar to the deposits. Trilobites abound, but have not yet been all identified, though among them are *Asaphus acuminatus*, Boeck, *Cheirurus aculeatus*, Eichw., *Ampyx*, *Trinucleus*, and *Phacops*, with *Beyrichia* and *Leperditia*, *Leptæna sericea*, *L. Humboldtii*, and other fossils.

The second limestone is a fine-grained, yellowish, and bluish rock, occasionally having almost the aspect of lithographic stone, and passing often into marly beds particularly rich in fossils. This stage forms the northern half of the Isle of Dagden, and thence passes eastwards in a broad zone across Esthonia to the south of Narva and into the Government of St. Petersburg, where it has been called Upper Silurian by M. Kutorga.

In reality, however, says M. Schmidt, this limestone is only the superior member of the unquestionable Lower Silurian rocks of Russia.

Among its prevailing fossils may be cited *Lichas angusta*, Beyr., *L. Dalecarlica*, Ang., *Calymene brevicapitata*, Portl., *Encrinurus multisegmentatus*, Portl., *Phacops*, several species of *Lituites antiquissimus*, Eichw., *Murchisonia bilineata*, Hall, *Subulites elongatus*, Conr., *Strophomena Asmusii*, *S. rugosa* (distinct from *S. depressa*), *Leptæna deltoidea*, *L. sericea* (very abundant), *Orthis Actoniæ*, *O. testudinaria*, *Orthisina anomala*, *O. Verneuilii*, *Streptoplasma corniculum*, *Heliolites megastoma*, *H. favosa*, *Ptilodictya acuta*, *P. pulchella*, Hall, *Coccinium proevum*, Eichw., *Cyclocrinites Spaskii*, Eichw., and *Calamopora patellaria*, Kutorga‡.

The two preceding stages contain the following fossils in com-

* See the Map of the Government of St. Petersburg, by M. Kutorga.

† Annuaire du Journal des Mines de Russie, 1838, p. 97.

‡ The so-called *Pentamerus ventricosus*, Kutorga, of this stage seems to be a *Porambonites* of Pander.

mon: *Phacops Odini*, Eichw., *Orthis lynx*, Eichw., *Leptæna imbrex*, *Lingula quadrata*, and *Chætetes Petropolitanus*.

The upper limit of these Lower Silurian strata is characterized by a profusion of Corals, such as *Catenipora*, *Heliolites*, *Caninia*, *Sarcinula organon*, &c. Accompanying these, there are other fossils peculiar to the band, viz. *Proetus brevifrons*, Ang., *Lichas*, n. s., *Pleurorhynchus*, n. s., *Strophomena alternata*, *Atrypa* (*Spirigerina*) *marginalis*, and *Orbicula*, n. s. These two latter, however, are associated with most of the previously mentioned fossils of the second stage; so that the whole form one natural division.

This coralline limestone is surmounted by the most ancient stratum of the group classed as the Upper Silurian of Esthonia; being characterized chiefly by the presence of its smooth *Pentameri*.

A marly limestone forms the basement-layer of No. 3, and contains *Leperditia marginata*, *Pentamerus linguifer*, *Strophomena Pecten*, *Orthis Davidsoni*, *Rhynchonella aprinis*, Vern., and *Calamopora aspera*, D'Orb. This stratum is covered, throughout the whole length of the zone, by the shelly band with *Pentamerus borealis*, which occupies the highest ground of the mainland of Esthonia, and forms the watershed of all the tract. The bottom beds, with *Leperditia*, observed at a very few spots to the north of the Pentamerus-zone, reappear to the east, west, and south, in a more developed form. In the last-mentioned direction, they serve as the support of a band containing another species of *Pentamerus*, the *P. Esthonus*, Eichw., probably identical with the *P. oblongus* (see Sil. Syst.); but, unlike the *P. borealis**, this species does not occupy all the rock.

The associated characteristic fossils are, *Bronteus signatus*, Phill., *Orthoceras canaliculatum*, Sow., and *Catenipora escharoides*. Other fossils, the chief habitat of which is in the next overlying stage, now appear, and these are *Encrinurus punctatus*, *Calymene Blumenbachii*, and *Atrypa* (*Spirigerina*) *reticularis*.

This stage, as already stated, offers points of connexion with the subjacent No. 2, along its line of junction, but the Corals (*Catenipora*) of the two bands are specifically separable.

The stage No. 4, which is developed partly on the continent and partly in the north-eastern portion of the Isle of Oesel, consists of two different rocks, the one a bluish-grey marly limestone, the other a dolomite or magnesian limestone. Its chief fossils are, *Proetus concinnus*, *Lichas Gothlandicus*, Ang., *L. ornatus*, Ang., *Bumastus Lindsteineri*, Ang., *Orthoceras annulatum*, Sil. Syst., *Rhynchonella Wilsoni* (Russian variety: see 'Russia in Europe,' vol. ii. p. 88), *Athyris tumida*, *Orthis osiliensis*, Schrenck, *O. elegantula*, Dalm., *Leptæna transversalis*, *Streptoplasma calicula*, &c. This zone also

* In reference to these detailed views, my friend Count Keyserling is of opinion that the band containing the *Pentamerus borealis* is virtually included in the zone beneath it; fallacious appearances in this flat and obscure country having led Prof. Schmidt to believe in the superposition of the one to the other. Count Keyserling also thinks that, in consequence of its fossils, more importance should be attached to the brand-schiefer or inflammable schist, which might be considered a distinct subformation.

contains some remains described as fishes by Eichwald under the name of *Sphagodus obliquus*.

The fifth division forms the summit of the Silurian system of Esthonia, and is composed chiefly of a crystalline limestone, rarely dolomitic, alternating with beds of marl or shale. The remains of fishes now begin to appear frequently, and Pander has recognized in the materials sent to him twenty species, all of which, however, are affirmed by him to be specifically distinct from any Devonian or Old Red forms.

The finest of these Upper Silurian species is the *Cephalaspis verrucosus*, Pand. (*Thyestes*, Eichw.), and with it is found the *Onchus Murchisoni*, Ag., of the Ludlow rock; sufficient fragments of the former having been detected to complete the restoration of an almost entire fish. These remains, including numerous scales and also portions of jaws, are now described by M. Pander*.

One of the most remarkable fossils of this band is the *Eurypterus remipes*, Dekay, which is abundant in some of the marly beds, and in so admirable a state of preservation as to permit the delineation of all its minutest parts, which Dr. Schrenck will elucidate.

The most important of the other fossils of this, the highest Silurian zone in Russia, are: *Beyrichia tuberculata*, Klöd., *B. Wilckensiana*, Jones, *Leperditia Baltica*, His., *L. phaseolus*, Klöd., *Orthoceras imbricatum*, *O. bullatum*, Sow., *Murchisonia cingulata*, *Trochus helicites*, *Pterinea reticulata*, *Grammysia cingulata*, His., *Lucina* (*Tellina*) *prisca*, *Chonetes striatella*, Dalm., *Spirigerina prunum*, Dalm., *S. didyma*, *Rhynchonella Wilsoni*, Sow. (Sil. Syst.), *Orthis orbicularis*, Sow. (Sil. Syst.), *Tentaculites annulatus*, His. (?), *Cyathocrinus rugosus*, Mill., *Cyathophyllum articulatum*, &c.

These grey beds (so manifestly identical through many of the species of their organic remains with those of the Upper Ludlow rocks) present no ascending passage, as in England, into the superjacent red or Devonian strata. The latter are not seen in the Isle of Oesel, but appear on the continent, where their junction with the Upper Silurian is evidently transgressive. At Tannekill, to the north of Tellin, for example, the Devonian rocks, consisting of a yellowish-grey coarse-grained grit and bluish marls, are seen to overlie at once the formations Nos. 3, 4 of the preceding Silurian succession, with their characteristic Corals. At Dörpat, Randan, Tellin, and Tongal,

* The work of my distinguished friend, M. Pander, has been seen for the first time by me as these pages are printing off.

Professor Huxley, who has been so obliging as to examine this work, informs me that the *Cephalaspis verrucosus* (*Thyestes*, Eichwald) presents a tuberculated ornamentation on the head- and body-scales, which is, as it were, a more regular development of the ornamentation described by Sir P. Egerton as occurring in *Cephalaspis ornatus* of the uppermost Ludlow rocks (see Quart. Journ. Geol. Soc. vol. xiii. p. 285). These remarkable ichthyolites, of which many genera and species are described, will be alluded to in the new edition of 'Siluria,' when the nature of the singular minute and enigmatical remains, from the Lower Silurian rocks, called "Conodonts" by M. Pander (*op. cit.* pls. 1, 2, 3, 4) will be discussed. With the highest respect for the author, and the great ability he displays in his works on ichthyolites, I am not yet convinced that these microscopic bodies are portions of the teeth of fishes.—(Oct. 10.—R. I. M.)

which lie at a considerable distance from the junction with the Silurian rocks, the strata are charged with many well-known Devonian fossils.

Conclusion.

In the opening pages of this Memoir a running comparison was instituted between the different subformations which constitute the Silurian basin of Christiania in Norway and their British equivalents; and, considering the distance of the Norwegian tract from our own country, the coincidence in the succession of fossils is truly remarkable.

The point, however, of the labours of M. Kjerulf to which I now particularly recall attention, is that in the very lowest fossiliferous zone (the alum-slates of Norway) the types of Trilobites which were supposed by some authors to be confined to that zone are united with the *Orthis calligramma* and the *Didymograpsus geminus*, species known as occurring in unquestionable Lower Silurian British rocks. Any one of the published sections across the western parts of Shropshire, *i.e.* from the Longmynd over the Stiper Stones, shows what the parallel order is in Britain*.

Having for the last twenty-four years considered and described the Stiper Stones as the true physical base of the Silurian series of strata, it has been satisfactory to me to detect recently, in the black schists associated with the siliceous flagstones of that ridge, additional fossils which so intimately connect them with the Llandeilo formation, that the additional evidence in the new edition of 'Siluria' will, I believe, be conclusive as to the natural base of the British Silurian rocks. For neither in Shropshire nor in Norway can we draw a line of physical or zoological demarcation between these basement-strata, whether termed Lingula Flags, Stiper Stones, or Alum Slates, and those overlying schists into which they graduate, and of which they form an integral part.

This union is indeed particularly well marked in Scandinavia, where the alum-slates are simply a mass of black schist, which is no more capable of separation from the overlying beds of similar characters than one bed of the Lower Lias or any other secondary shaly subformation is from another.

Seeing the dissimilarity of forms which prevails throughout the Silurian series of Bohemia, as described by M. Barrande, when we look to the distinction between the fossils of each of the subdivisions, and especially when we compare such subdivisions with their acknowledged equivalents in the northern Silurian zone now under consideration, it seems to me to be impossible to establish a new classification of the Lower Palæozoic rocks by eliminating the "Zone Primordiale" of that distinguished author from the natural-history system in which he has himself placed it. In Bohemia the "Zone Primordiale" is as integral a part of the Silurian basin so called, as the Stiper Stones were in my original classification. If I am not

* See the 'Silurian System,' pl. 32. fig. 1, &c., and 'Siluria,' diagram, p. 29.

justified in referring to my sections and memoirs of the years 1833, 1834, when I classed the Stiper Stones with the overlying deposits, I am at all events entitled to adhere to that view, now that M. Barrande also unites his "Zone Primordiale" with the overlying strata; and since, fully aware of the distinction between its fossils and those which succeeded it in Bohemia, this eminent geologist continues to classify it with the Silurian System.

We all know how in those secondary and tertiary rocks which have been most examined there is often a marked discrepancy in the fossils of each succeeding stratum, *so long as we examine a limited area only*, and how such sharp separation and isolation of the former inhabitants of the seas vanishes when the same strata are followed over great distances. So is it when, quitting our insular area and extending our researches to Norway, we find strata of black schist, mineralogically resembling the Lingula-flags or the schists of the Stiper Stones, and occupying the same place in the geological series, to be charged with some of the organic remains which in Britain are peculiar to that band, mixed up with species which are known in our own Llandeilo rocks. Again we observe that, as in the Stiper Stones of Shropshire, there is in Norway a vast underlying series of slates and quartzose rocks like those of the Longmynd; so also are the beds into which the alum-schists pass *upwards* laden with many species of fossils which are with us in the Lower Silurian rocks of Llandeilo age.

The attempt to separate the alum-schists of Scandinavia from the overlying beds with which they are united in numerous natural escarpments is indeed forbidden on stratigraphical, lithological, and zoological grounds; and as Linnæus and every subsequent explorer of Scandinavia have connected them, so I confide in the belief that they constitute, by their organic remains, the best base we have been able to trace of that which I call Silurian life.

In comparing the Silurian rocks of Scandinavia and Russia with those of Britain, there is no feature by which the whole system is seen to be better characterized in those countries than by containing in its central part a formation distinguished from the rocks above and below it by certain species of *Pentameri*, of which the *Pentamerus oblongus* and the *P. lens* are the prevailing types.

Having satisfied myself, in my own country, that the lower portion of this formation is (as I always maintained) related by its organic remains to the Caradoc formation, and that the upper part of it is charged with a number of shells of the Wenlock age (though still intermixed with the peculiar *Pentameri* and a few Lower Silurian fossils), I have deemed it right to assign to the deposit a separate and intermediate place in the table of Silurian strata.

I have named this formation "Llandovery rocks," reverting to that tract of South Wales which was originally described in detail, and where both the lower and upper members of the group, and their relations to the underlying and superjacent rocks, are clearly exhibited.

It is the upper member only of these Pentamerus-rocks which is exhibited at May Hill, on the west flank of the Malverns, and also in the typical Silurian tracts of Shropshire, Herefordshire, and Radnorshire. This upper band only is the May Hill Sandstone*.

In parts of South Wales, where both members of the Llandovery rocks exist, there is usually, indeed (but in my opinion not always), a transgression between them, as traced by Professor Ramsay and Mr. Aveline, the lower member constituting over large areas the regular capping of the Caradoc or Bala formation, the upper or May Hill rock appearing to be usually the symmetrical base (as in Siluria proper) of the Upper Silurian group. As, however, the same species of *Pentamerus*, *Atrypa*, and *Petraia*, &c., occur in both these divisions, I am induced by this community of type, and by the opinion of Mr. Salter, to consider the two bands as forming one natural-history province which connects the fauna of the Lower and Upper Silurian groups.

Now, if we refer to certain other regions, the truthfulness of this view is strikingly confirmed; since in them we can detect no such transgression or hiatus as occurs in Wales and the border-counties of England.

Even in the neighbourhood of Girvan, in Scotland, fossiliferous Lower Silurian rocks of the Caradoc age seem to graduate upwards conformably into the Pentamerus-zone in question, containing not only the *P. oblongus* in profusion, but also the *Atrypa hemisphærica*, with the *Phacops Stokesii* of the Wenlock limestone; and thus leaving no doubt that we have there reached, as I formerly showed, the base of the Upper Silurian rocks†.

In Norway, however, where the area under consideration is much larger, and where all the Silurian strata are clearly exposed in numerous convolutions in the different islets of the Bay of Christiania, there is, independently of all breaks caused by the intrusion of igneous rocks, a perfectly conformable succession from the Lower to the Upper Silurian‡. There, as in Esthonia, the Pentamerus-zone is simply the central link of an unbroken Silurian chain; so local is the physical disturbance in the Welsh region seen to be, when the whole surface of Northern Europe is explored.

Whilst the Norwegian and Swedish sections are so valuable in showing the base of the System, the Esthonian order of the fossiliferous strata is highly instructive in demonstrating the accordance of the Upper Silurian rocks with our own. The observations of M. Schmidt are, indeed, most valuable in placing before us, for the first time, a complete exposition of all the natural subdivisions of the Silurian series of so large a part of European Russia. In Esthonia, the approximation to the British succession, from the Llandeilo formation to the summit of the Upper Silurian, is very remarkable.

Just as in Norway, England, and America, so in Esthonia the

* See Proc. Geol. Soc. vol. ii. p. 13; Sil. Syst. p. 442, pl. 36. f. 13; Sedgwick and M'Coy, Quart. Journ. Geol. Soc. vol. ix. p. 215; and Phil. Mag. 4th Ser. vol. viii. p. 301, &c.

† Quart. Journ. Geol. Soc. vol. vii. p. 149.

‡ See the diagram-section across the Territory of Christiania, Quart. Journ. Geol. Soc. vol. viii. p. 182.

transition-zone from the Lower to the Upper Silurian is the deposit laden with *Pentameri*, to which the name of Llandovery Rocks has been assigned, because it was long ago described by me at and around the town of Llandovery in South Wales. Whilst the Wenlock fauna is quite recognizable in Esthonia, as in Norway, the fossils of the highest zone of the former country, including many large Crustaceans (*Eurypteridæ*), with *Lingula cornea* and *Trochus helicites*, are strikingly characteristic of the Ludlow rocks.

Such agreement between those remote foreign rocks and our strata of the same age is the more remarkable, when we consider the difference in thickness and the simplicity of lithological characters of the deposits in these northern countries, as compared with the vastly extended British types. The thousands of feet of diversified British Silurian rocks, whether slates, schists, shales, conglomerates, sandstones, quartz-rocks, limestones, mudstones, with vast sheets of interstratified igneous rocks, are represented in the Baltic provinces of Russia by little more than one lithological character only. There, they are all closely united calcareous masses, any one of which has so great a resemblance to another, that, without the aid of Palæontology, they could never be separated or distinguished. The united Lower and Upper Silurian constitute, in fact, to use the language of Count Keyserling, "but a single volume of limestone of small capacity and thickness, capable of division into leaves by that person only who is acquainted with their included fossils;" the whole series not exceeding 2000 feet, and all the strata graduating into each other by conformity of deposition.

The interest, however, which attaches to the full illustration of these Northern European types of the oldest known fossiliferous rocks, does not terminate with the precise comparison between them and the British contemporary formations*.

The same species, even, are found to prevail far to the westward in northern latitudes. Small as are the deposits, in vertical dimensions, both of Scandinavia and Russia, the very same succession of life which they offer is found to be persistent from those countries across the British Isles to the heart of North America. The vastly extended Lower Silurian rocks of the United States and Canada, and the enormously spread Upper Silurian of the Arctic Regions, are, like those of our own country, the absolute historical equivalents in time of the thin and simple series described on this occasion, and exhibit a vast number of forms specifically identical with those I have enumerated.

Other species, however, of Silurian typical genera prevail throughout the southern region of Europe†. Already we know that the Silurian rocks of France and Spain, as illustrated and compared by

* It is true, that in Russia there are fewer British species than in Sweden and Norway, but this is just what we might expect from the relative distances of those lands from our own country.

† With additional researches, may not this Silurian type of Southern Europe and Siberia be found to have its equivalents in the central and southern parts of America?

my distinguished associate, De Verneuil, have, however, many specific equivalents in the Lower Silurian rocks of that Bohemian basin which has been rendered classic through the works of M. Barrande.

Count Keyserling further recalls my attention to the fact, that the Ural Mountains and Siberia fall into the same category. This comparison, which was to some extent shadowed forth in the work 'Russia and the Ural Mountains,' published in 1845, has been strikingly confirmed by the researches of M. Grünewaldt into the characters of the fossils of the eastern flank of the Ural Mountains near Bogoslofsk (lat. 61°). Again, M. Hofmann concludes his Siberian work in terms which show, that the parallel was suggested eleven years ago by Keyserling, as a result of his researches and comparisons in the Northern Ural. In short, my coadjutor long ago directed notice to the fact, that, both in palæontological contents and lithological characters, the Silurian rocks on the eastern side of the Ural Mountains were dissimilar to those of European Russia and Scandinavia. Metamorphism alone, he always contended, could not explain this essential difference. The conditions of life, he added, had been one thing in the seas that occupied the Siberian area, and another in the waters which covered the low countries of western and southern Europe during the Silurian epoch.

Since that time, this distinction of the varying faunas in contemporaneously formed basins, separated from each other during the older palæozoic period, has been abundantly developed by M. Barrande, who has well shown the specific distinctions between the animals which inhabited respectively the regions of Bohemia and Scandinavia during the Silurian era.

It is to the similarity, on the contrary, of the organic remains in the *northern zone of Silurian rocks*, which extends over so vast a space, that attention has been mainly directed on this occasion.

Finally, let me state, that another chief object I have had, in bringing together the observations of Count Keyserling, Professor Schmidt, and M. Kjerulf, with comparisons of my own, is to demonstrate that in Scandinavia, as in Russia in Europe, Silurian rocks, both Lower and Upper, and copiously charged with characteristic organic remains, form a united and unbroken whole; and that, whether viewed palæontologically or geologically, they exhibit throughout those northern European regions, and in a very small compass, a natural-history system quite as complete, and more easily understood, than their much more expanded, highly varied, and dislocated equivalents in the British Isles.

May 20, 1857.

Lieut. H. Thurburn, of the 42nd Regiment M.I., and James Salter, M.B., F.L.S., 6 Montagu Street, were elected Fellows. Dr. H. B. Geinitz, Professor of Geology and Mineralogy in the University at Dresden, was elected a Foreign Member.

The following communications were read :—

1. *Description of a small* Lophiodont Mammal (Pliolophus vulpiceps, *Owen*), *from the* London Clay, *near* Harwich. By Prof. Owen, F.R.S., F.G.S., &c.

[Plates II., III., IV.]

Contents.

Introduction.—The remains of Mammalia from Eocene beds below the Binstead, Gypseous, and Headon or Hordwell series have hitherto been very scanty, and for the most part fragmentary; whether from the clays of London and Bracklesham, or from the equivalent sands, conglomerates, or "calcaires grossiers" of the Continent. The best evidence of *Pachynolophus*—a Lophiodont genus represented by species of small size, characteristic of the conglomerate of Mont Bernon (*Pachynolophus Vismæi*, Pomel) and of the "calcaire grossier" of Nanterre, Passy, and Vaugirard (*Pachynolophus Duvalii*, Pomel),—consists of portions of upper and lower jaws, with teeth. The *Dichobune suillum*, Gervais, from the "calcaire grossier" of Passy, if it be a true *Dichobune*, rests upon a fragment of mandible with three teeth, and on a few detached teeth, with an astragalus. The genus *Propalæotherium*, Gervais (*Palæotherium isselanum* and *Pal. aurelianum*, Cuv.), is represented by similar fragmentary evidences of jaws and teeth from the lacustrine calcareous deposits at Buchsweiler, on the Lower Rhine, at Issel in the department of Aude, and at Argenton. The fossil eocene Monkey (*Macacus* [*Eopithecus*] *eocænus*) is known only by a small fragment of the under jaw with two teeth, and by a detached mandibular molar from the lower eocene sand of Suffolk. The best and most instructive mammalian fossil hitherto obtained from the London clay has been the portion of cranium with the molar series of teeth on which the genus *Hyracotherium** was founded. But the subject of the present communication is an entire skull with the complete dentition of both upper and lower jaws (Plates II. and III.) and a portion of the skeleton of

* Trans. Geol. Soc. 2nd series, vol. vi. p. 203, pl. 24.

the same individual, including the right humerus, Pl. IV. figs. 1–4, the right femur, *ib.* figs. 5 and 6, a great part of the left femur, the left tibia, Pl. IV. figs. 10–13, and three metatarsal bones, *ib.* fig. 14, apparently of the same hind foot. There have, also, been extracted recognizable portions of the pelvis, and some fragments of ribs; other fragments of ribs, vertebræ, and small bones are left in the matrix. The osseous tissue is silicified and partly impregnated with pyritic matter.

This, therefore, is the most complete and instructive mammalian fossil of the age of the London Clay which has hitherto been discovered, and its study is replete with peculiar interest.

In the course of last winter Mr. Colchester, the able and successful explorer and collector of organic remains of the eocene sands at Kyson, Suffolk, brought to the British Museum for my inspection one of the nodules of the Roman-cement bed of the London clay, near Harwich, from which nodule a portion had been chipped off, exposing on the fractured surface the faint outline of a skull, in size and shape like that of a fox.

This appearance had arrested the further progress of the breaking-up of the nodule by the workmen, and the specimen came into the possession of the Rev. Richard Bull, M.A., Vicar of Harwich, by whom it was intrusted to Mr. Colchester for my opinion respecting the nature of the fossil, and by whose liberal permission the subsequent operations were carried out, by which I am enabled to communicate to the Society the following description of a new genus and species of perissodactyle pachyderm, for which I propose the name of *Pliolophus vulpiceps**, or Fox-headed Plioloph.

The nodule presented the common subspherical form, and was about a foot in diameter. On closely inspecting the fractured surface, indications of other bones, besides the skull, were detected, and as the work of exploration proceeded, it plainly appeared that the carcase, or great part of the carcase, of a quadruped, about the size of a fox, had formed the nucleus round which the clay, modified by the chemical constituents of the dissolving and decomposing flesh, had become aggregated and consolidated.

I have rarely broken up any septarian nodule of the London clay, which, thus altered, forms the chief material of the 'Roman cement,' without detecting some organic relic which seemed to stand in the relation of a nucleus to such compact spheroid mass.

The hardness and compactness of the matrix are extreme; but, by the aid of the lapidary's saw and the skilful and careful use of the chisel, Mr. Dew, by whom most of the Sewalik fossils in the British Museum were brought to their present instructive state, succeeded

* Accomplished Palæontologists of France having included one of the elements of the term *Lophiodon* (λοφίον a small crest, ὀδοὺς a tooth) in the names of sub-genera of the Lophiodont family, as, *e. g.*, in *Pachynolophus*, the same principle has guided to the choice of the term *Pliolophus* for the present accession to the family. By it I simply mean that it is more near to the Lophiodont type than its close ally the *Hyracotherium.* But the sooner a term becomes an arbitrary sign the better.

in extricating entire the skull, and in relieving it from the surrounding closely adherent matrix, and subsequently in working out the other bones above specified.

Description of the Skull: Plate II.—The skull is moderately long, slender, tapering gradually from the zygomatic region to the muzzle, Pl. II. fig. 2, with an unusually straight upper outline, from the occipital crest to the end of the nasal bones, Pl. II. figs. 3 and 4. The bony rim of the orbit, fig. 3, *or*, is incomplete behind for an extent of about one-fifth of its circumference.

The occipital region is triangular, bounded by a strong occipital crest, 3, which is continued on each side into the upper border of the zygomatic arch, Pl. II. fig. 3, 27, and, by the middle of its upper part, with a parietal crest, 7. This latter, rising clearly above the calvarian surface, Pl. II. fig. 4, to an extent of from one to two lines, advances forward one inch nine lines, and bifurcates, subsiding to the level of the frontal surface, 11, each division diverging and curving outward, with the convexity forward, to the post-frontal process, 12, which projects backward and a little downward, terminating freely about 8 lines above the zygoma, 26, 27. The interorbital part of the frontal region, *ib.* 11, is nearly flat at its middle, and bends gently down on each side to the superorbital border. The long nasals, 15, form the rest of the upper surface of the skull, which is at first moderately convex transversely, and is then grooved along the mid-line to the free ends of the nasals. These bones are 13 lines across their base, and gradually contract to a breadth of 7 lines, which they retain for the terminal inch of their extent.

The zygomatic arch, springing outward and a little forward from its hinder root or pier, Pl. II. fig. 3, 27, describes a slight sigmoid flexure, first convex then concave upward, where it forms, 26, the lower border of the orbit; this border extends some 4 or 5 lines further outward than the upper border. There seems not to have been a zygomatic process rising toward the postfrontal, 12, but a mere convexity of the upper border of the zygoma behind the orbit. The extreme vertical diameter of the zygoma is 4 lines. The cerebral part of the cranium forming the inner wall of the temporal fossa shows the greatest expansion of the brain at about the middle of that fossa, behind which, on both sides, the concavity exhibits several irregular indentations and some vascular perforations. There is no superorbital foramen; a very feeble indent of the base of the postorbital process is the sole indication of the place of issue of the superorbital nerve. The antorbital foramen, Pl. II. figs. 3 and 4, *a*, about $1\frac{1}{2}$ line in diameter, is situated 9 lines in advance of the orbit, and between 2 and 3 lines above the alveolus of the second premolar.

The vertical outer plate of the maxillary, 21, slightly expands where it forms the sockets of the small canine, *c*. The sides of the bony nostril are almost straight, extending from a distance of 5 lines from the free ends of the nasal, *o*, obliquely downward and forward, and being formed by the premaxillary bones, Pl. II. fig. 4, 22: the vertical extent of the aperture is about 10 lines.

The mandible, 29, 30, had been dislocated, about 4 lines in advance of its place of articulation, prior to the consolidation of the surrounding matrix, by which it is now fixed with the lower teeth to the same degree in advance of their correspondents above, as in Pl. II. fig. 3. This dislocation enables the flattened surface of the major part of the glenoid cavity to be brought into view, at *g*, fig. 3. In figure 4 the mandible is figured as in its proper position.

The ascending ramus of the mandible developes a short recurved coronoid process, Pl. II. fig. 4, *r*; below this and the condyle *d*, it expands, gradually extending backward as it descends from the condyle, describing an irregular convex curve as it passes into the under border, and forming a broad angular plate, 29, for the implantation of the pterygoid and masseter muscles. The fossa indicating the insertion of the temporal muscle, fig. 3, *t*, is limited to the upper half of the ascending ramus, where it is bounded by a curved line or bank continued downward and forward from the outer part of the condyle: the anterior border of the depression subsides upon the part of the jaw which extends outward from the alveolus of the last molar. The outer side of the horizontal ramus of the mandible is lightly convex: the lower border, continued from the broad rounded angle, is at first gently concave, then as slightly convex. The ramus very gradually decreases in depth to the first premolar, below which the symphysis begins, Pl. II. fig. 1, *s*, *i*. Here the mandible is a little compressed and again expands slightly to form the alveoli of the canines, *c*, and incisors, *i*, 1, 2, 3. The line of the symphysis rises very gradually to the incisive border, *s i*, figs. 1 and 2, Pl. II.

The following traces of sutures are unmistakeable: the squamous, Pl. II. fig. 3, *q*, continued forward from the irregular depressions on the side of the cranium, at first straight, then with a downward curve; the straight part is 9 lines below the sagittal crest, 7: the interfrontal suture, Pl. II. fig. 2, 11, continued into the internasal one, *ib.* 15, along the midline of the facial part of the skull: the fronto-nasal suture, *ib. f*, describes a slight sigmoid curve, as it extends transversely outward and downward to the lacrymal, 73, fig. 3, Pl. II. The suture connecting this bone, 73, to the maxillary, 21, and malar, 26, shows that its facial plate is about 4 lines in vertical, and 3 in fore-and-aft, diameter. The malar, 26, forms the lower half of the fore part of the orbit; the anterior end of its almost horizontal suture with the squamosal, 27, begins just below the postorbital process. The naso-maxillary suture, Pl. II. figs. 3 and 4, *m*, is nearly straight, 1 inch in length; its continuation by the naso-premaxillary suture *n* is about 6 lines in extent; but this part of the lower border of the nasal, 12, is slightly convex downwards, with a corresponding curve of the suture. The maxillo-premaxillary suture, *p*, is almost a straight line, parallel with the lateral border of the nasal aperture.

The following are admeasurements of the skull of the *Pliolophus*, with some comparative admeasurements of that of the *Hyracotherium*:—

	Pliolophus vulpiceps.		*Hyracotherium leporinum.*	
	in.	lines.	in.	lines.
Length of skull	5	0		
Extreme breadth of skull, at the zygomata	2	2		
Extreme breadth of cerebral part of cranium	1	3		
Breadth across postfrontal processes	1	$6\frac{1}{2}$	1	7
Breadth of upper jaw opposite first premolars	0	9	0	11
Vertical diameter of skull opposite first true molar	1	4	1	$6\frac{1}{2}$
Vertical diameter of orbit	0	9	1	0
From occipital crest to fore part of orbit	2	9		
From occipital crest to fore part of temporal fossa	2	2		
From the fore part of the orbit to the end of nasals	2	3		
Length of mandible	4	4		
Length of symphysis mandibulæ	1	0		
Breadth of ascending ramus	1	6		
Height of ascending ramus at the condyle	1	6		
Height of ramus below first true molar	0	7		
Extent of molar series, upper jaw	1	11	2	0
Extent of molar series, lower jaw	2	0		
Extent of three true molars, upper jaw	0	$11\frac{1}{2}$	1	1
Extent of the four premolars, upper jaw	0	$11\frac{1}{2}$	0	11
Extent of three true molars, lower jaw	1	0		
Extent of the four premolars, lower jaw	1	0		

Comparison of the Skull.—The extent and well-defined boundary of the temporal fossæ by the occipital, parietal, and post-frontal ridges, and their free communication with the orbits, give almost a carnivorous character to this part of the cranium of *Pliolophus*: but, as in the Hog, Hyrax, and Palæothere, the greatest cerebral expansion is at the middle and toward the fore part of the fossæ, with a contraction toward the occiput; the brain-case not continuing to enlarge backward to beyond the origin of the zygomata, as in the Fox.

The zygomatic arches have a less outward span, especially at their hinder pier, 27, than in the *Carnivora*. In this part of the cranial structure *Pliolophus* resembles *Palæotherium* more than it does any existing mammal; but the post-frontal processes are longer and more inclined backward.

The incompleteness of the orbit occurs in both *Anoplotherium* and *Palæotherium*, as in *Rhinoceros*, *Tapirus*, and the Hog-tribe; but, in the extent of the deficient rim, *Pliolophus* is intermediate between *Palæotherium* and *Tapirus*. The orbit, Pl. II. fig. 3, *or*, is not so low placed as in *Palæotherium*, *Tapirus*, and *Rhinoceros*, nor so high as in *Hyrax* or *Sus*. The straight upper contour of the skull is like that in the Horse-tribe and Hyrax, and differs from the convex contour of the same part in the Anoplothere and Palæothere. The size of the antorbital foramen, Pl. II. figs. 3 and 4, *a*, indicates no unusual development of the muzzle or upper lip. In the conformation of the nasal aperture by four bones (two nasals, 15, and two premaxillaries, 22), *Pliolophus* resembles the Horse, Hyrax, Hog-tribe, and Anoplothere, and differs from the Rhinoceros, Tapir, and Palæothere, which have the maxillaries, as well as the nasals and premaxillaries, entering into the formation of the external bony nostril.

The ungulate and herbivorous character of *Pliolophus* is most distinctly marked by the modifications of the lower jaw, especially by the relative dimensions of the parts of the ascending ramus which give the extent of attachment of the biting (temporal, *t*) and grinding (masseteric and pterygoid, 29) muscles respectively. In the shape of the mandible *Pliolophus* most resembles *Tapirus* among existing mammals, and the *Palæotherium* among the extinct ones in which that shape is known. Unfortunately no mandible of a true Lophiodon has yet been found so entire.

As far as the portion of the skull of the *Hyracotherium leporinum* permits the comparison to be made, there is a close general resemblance between it and *Pliolophus*; but the skull of the Hyracothere is broader, at the orbital region, in proportion to the length of the antorbital or facial part*. The orbits are both absolutely and relatively larger; they are also rounder and have a lower position. The straight upper contour of so much of the skull of the Hyracothere as has been preserved, the size and position of the antorbital foramen, the course of the maxillo-premaxillary suture, and the formation of the bony nostril by the nasals and premaxillaries exclusively, are further indications of the affinity of *Hyracotherium* to *Pliolophus*.

This affinity is decisively shown by the more important characters derived from the dentition.

Description of the teeth of Pliolophus: Plate III.—As in the *Hyracotherium*, and, indeed, as in almost every species of Eocene quadruped yet discovered, the *Pliolophus* presents the type-dentition of the placental Diphyodont series, viz.:—

$$i\,\frac{3-3}{3-3},\ c\,\frac{1-1}{1-1},\ p\,\frac{4-4}{4-4},\ m\,\frac{3-3}{3-3} = 44.$$

The incisors, Pl. II., *i* 1, 2, 3, are preserved in the lower jaw with marks of attrition on their crowns demonstrating corresponding teeth of the same number, 6, and of similar size, in the upper jaw, from which the alveolar part of the premaxillaries had been broken away.

The lower incisors, Pl. II. fig. 1, *i* 1, 2, 3, form a semicircle terminating the slender sloping symphysis mandibulæ, *s*, and projecting parallel with it, so as to be almost procumbent, Pl. II. figs. 3 and 4, *i*. Their crowns present the common wedge-shaped form, with the trenchant border obliquely beveled off, and the more so from the first, *i* 1, to the third, *i* 3: they slightly decrease in size, or at least in length of crown in the same course; but the outer incisor, *i* 3, is not so small relatively as in the Tapir. The degree of attrition to which they have been subject produces a certain breadth of the trenchant border.

The canines, *ib. c*, are small in both jaws: only the crown of the right lower one, Pl. II. fig. 3, *c*, is entire: it is about 4 lines long, in the form of a slender cone, inclined a little forwards, with the front border convex, the hind one more nearly straight. The lower canine is separated by an interval equal to its own basal breadth, viz. about 2 lines, from the outer incisor, and by an interval of 5 lines

* *Op. cit.* pl. 21. fig. 2.

from the first premolar. In the upper jaw the canine is separated by a rather wider space than in the lower jaw from the incisors, and by a rather narrower space from the premolars. In thickness of base and, apparently, in length and shape of crown, the upper canines resembled the lower ones. The premolars, *p*, and molars, *m*, form a continuous series on each side of both jaws; except that a space of about a line intervenes between the first and second premolars in the lower jaw.

The premolars increase in size and complexity to the fourth, which nearly equals that of the true molars. The last of these, *m* 3, in the lower jaw, presents a third lobe. In Pl. II. fig. 3, the premolars of the upper jaw are marked 1, 2, 3, 4: the true molars of the lower jaw are marked 1, 2, 3: the dislocation of the jaw carries these one tooth in advance. In the upper jaw, the first premolar, Pl. II. fig. 3, *p* 1, presents the common subcompressed conical shape, with the base of the crown swelling out below the fangs, and the protuberant part continued along the outside of the middle part to the apex of the cone; on each side of this prominence the crown presents a depression; and the surface, though polished, is broken by a few irregular longitudinal indentations, which give the enamel a slightly wrinkled character.

The second premolar, *p* 2, resembles the first; but is somewhat larger, especially thicker, and with the front and back parts of the base more produced; an outer longitudinal groove near the summit of the cone indents it deeply.

The third premolar, *p* 3, has two cones on the outer side, and an anterior basal talon; from this a slight ridge is continued upon the outer part of the anterior cone: the whole outer base of the posterior cone is girt by a similar low cingulum, continued into a rudimental talon behind. The crown expands posteriorly, and its working surface is increased by an internal ridge, and the valley dividing it from the two outer cones.

In the fourth premolar, the crown, Pl. III. figs. 1 & 2, *p* 4, with an increase of thickness, presents greater complexity: the cingulum is uninterrupted along the outer side from its anterior well-developed talon, *c'*, to the back part where the ridge, *t*, represents the talon. The two outer cones resemble those of the true molars; but there is only one inner cone, and the crown of *p* 4 differs accordingly from that of *m* 1, in being triangular rather than square. A ridge, *r*, is continued from the interspace between the anterior talon, *c'*, and the outer anterior lobe obliquely inward and backward to the inner lobe, swelling into a small tubercle at the middle of its course; a lower rising, hardly to be called a tubercle, intervenes between the inner cone and the outer posterior cone. The cingulum forms a well-marked ridge, *t*, along the back part of the crown, and is continued more feebly round the base of the inner lobe, with a brief interruption at its most prominent middle parts: beyond this the cingulum is continued into the anterior basal ridge, which expands into the small antero-external basal tubercle, *c'*. The fourth upper premolar is implanted by two external and one internal roots.

The first molar, Pl. III. fig. 2, *m* 1, shows, as usual, a greater amount of attrition than the preceding premolar : its grinding surface presents four low thick cones, two internal as well as two external : each external cone is connected with its opposite internal one by a low ridge extending from the fore part of the external to the middle of the internal one, and swelling into a tubercle, *r* and *s*, at the middle of its oblique course. The cingulum, *c c*, seems to be continued uninterruptedly round the crown of this tooth, thickest at the fore and back part, and at the interspace of the inner lobes ; and developing the small accessory antero-external tubercle, *c'*. The outer lobes are connected together by a low plate, internal to the cingulum.

The degree of attrition to which this tooth has been subject has exposed the dentine, which is surrounded by a belt of thick enamel upon the summits of the four principal lobes and of the intervening tubercles. This molar is implanted by two external roots and by a broad internal one, longitudinally indented at the middle, and which may divide where it lies deeper in the jaw.

The second molar, *m* 2, is similar to, but rather larger than, the first ; and the tubercle on the oblique ridge connecting the two hinder lobes is less developed. The cingulum, *c*, is obliterated on the inner side of the posterior lobe. The implantation of the tooth is like that of *m* 1.

The last molar is rather narrower behind than *m* 2 ; the tubercle, *r*, on the anterior of the oblique connecting ridge is smaller: that on the posterior ridge is almost obsolete. The hinder of the two inner cones is relatively less and lower than in *m* 1 and *m* 2, and is scarcely defined from the oblique ridge *s* ; the cingulum is interrupted at its inner base : the talon, *t*, formed by the back part of the cingulum is better marked than in the other molars. In all these teeth the enamel is wrinkled by longitudinal wavy impressions.

Of the mandibular teeth, Pl. IV. figs. 4, 5 & 6, only the molar series remain to be described.

The first premolar, Pl. II. figs. 3 & 4, *p* 1, is small, simple, subcompressed, conical, like the one above ; but it stands apart, an interval of about half its breadth dividing it from the second premolar.

This tooth, *ib. p* 1, of rather larger size, has a similar form, but with a better-marked hinder talon.

In the third premolar, Pl. III. fig. 6, *p* 3, the talon, *c*, is developed into a second lobe, which is lower than the first. The first or front cone, *a*, shows a small anterior or antero-internal talon, and the apex of the cone is cleft ; a ridge from the inner division, *b*, being continued obliquely down to the inner angle of the base of the low hinder cone, *c*.

In the fourth premolar, fig. 6, *p* 4, the division and development of the anterior lobe has proceeded to establish a pair of cones, one external, *a*, the other internal, *b*, connected anteriorly by a basal ridge, in front of which is the fore part of the cingulum. The low posterior lobe, *c*, shows the rudiment of a second internal cone, *d*. The cingulum is developed at the fore part, and feebly between the two outer cones. The posterior one, *c*, is connected by a ridge, which advances inward and forward, to the interspace between the anterior pair of cones.

The first molar, *m* 1, with an increase of size over the last premolar, also shows an equal development of both fore and hind pair of lobes; the summits of the two outer lobes are more abraded than those of the two inner ones, and the dentine is exposed in each. The same oblique ridge is continued from the fore part of the postero-external lobe to the interspace between the anterior pair: the cingulum is not developed upon the internal part of the tooth, but it is upon the external part, and especially upon the anterior lobe: posteriorly it forms a kind of low talon wedged into the interspace of the hinder pair of lobes.

The second molar, *m* 2, shows an increase of size; but its chief and most interesting modification is the development of a tubercle, *e*, between the two anterior lobes, making three cones on the same transverse line, and thus repeating the character of the molar tooth above. The oblique ridge from the outer and hinder lobe, *c*, abuts against the intermediate anterior tubercle, *e*. The inner surface or plane of the inner and hinder cone, *d*, inclines as it extends forward toward the middle of the crown: the fore parts or prolongations of the hinder cones thus converge as they pass forward toward the middle of the crown. The cingulum extends from the back part of the crown along the outer side to the fore part. Both this and the preceding molar are implanted by four roots.

The third molar, *m* 3, is distinguished by its greater fore-and-aft extent, due to its additional or third lobe. The ordinary two pairs of cones resemble those of the preceding molar, but the intermediate tubercle between the anterior pair is reduced to a short connecting bar. The hind lobe appears to have been divided into two small cones, but this part of the tooth was fractured in the attempt to remove the very hard and adherent matrix.

I beg to express my obligations to the accomplished artist, Mr. Ford, for the pains which he has bestowed in attaining the utmost accuracy in the figures above referred to.

Affinities of the Pliolophus vulpiceps *as shown by the skull and teeth.*—Before proceeding with the description of the other parts of the little quadruped which have been extricated from the septarian nodule, it may be convenient to record here the deductions as to the nature and affinity of the *Pliolophus vulpiceps* which may be drawn from the skull and teeth.

The form of the articular surface for the lower jaw, and above all that of the mandible itself, demonstrate the ungulate and more or less herbivorous nature of *Pliolophus*. Amongst recent non-ruminant Ungulates, *Tapirus* offers the nearest resemblance in the disposition and form of the zygomatic arch, and in the general form of the lower jaw: amongst the extinct Ungulates, *Palæotherium* most resembles *Pliolophus* in the same parts of the skull, with a nearer approach than the Tapir makes, in the production of the nasal bones; but in this character, and in the important one of the more simple formation of the nostril, *Anoplotherium* offers a closer resemblance to *Pliolophus*. In the almost straight upper contour of the skull, the Horse and the *Hyrax*, amongst existing Ungulates, resemble *Pliolophus*, and both these Perissodactyles add the corresponding character of the juncture of the premaxillaries with the nasals, which *Pliolophus* presents in common with the Anoplotherioids. But the orbit is circumscribed by bone in the above-cited existing Perissodactyles, whilst it opens behind into the temporal fossa in both *Anoplotherium* and *Palæotherium*, as in *Pliolophus*. *Microtherium* resembles the small Musk-deer in the entire bony frame of the orbit.

The form of the skull in *Lophiodon* proper has not yet been ascertained; but the comparative simplicity of the premolars in *Pliolophus*, and the configuration of the surface of the upper true molars, especially the last, Pl. III. fig. 2, *m* 3, demonstrate that the present small Eocene quadruped has the nearest affinity to the Lophiodont family, amongst the known extinct and recent members of the class. To a Lophiodont mammal, indeed, of the same size from the marls of the 'Calcaire grossier' in the vicinity of Paris (*Lophiodon leptognathum*, Gervais *, *Hyracotherium de Passy*, De Blainville †), on which M. Pomel subsequently founded his subgenus *Pachynolophus*, I felt most inclined, at first, to refer the *Pliolophus*; and it was in the prosecution of this comparison that I determined to sacrifice the entireness of one side of the fossil skull, in order to obtain a more complete and satisfactory view of the grinding surface of both upper and lower molars than could otherwise be got.

For the comprehension of the following comparison, Pl. II. figs. 3 & 4, and Pl. III. fig. 2, of the present memoir should be examined by the side of the views of the upper molar teeth and of the right mandible and teeth of the *Pachynolophus* (*Lophiodon*) *Duvalii*, Pomel, which M. Gervais has given in his excellent 'Zoologie et Paléontologie Française,' 4to, pl. 17. f. 1, 1 *a* & 2. Unfortunately the grinding surface of the upper molars only of *Pachynolophus* has been figured, and with these I proceed to compare the same teeth of *Pliolophus vulpiceps*.

I may premise that the generic or family character of the upper molars in *Lophiodon* is the development of the outer wall of the true molars and last premolar into two cones, and by the continuation, therefrom, in the true molars, of two oblique ridges which thicken and rise into rather smaller and lower cones on the inner side of the crown. In the last premolar the oblique ridge is continued only from the anterior of the two outer cones, and expands into a single large cone forming the inner half of the crown.

In *Pachynolophus* as in *Pliolophus* the oblique ridges are lower at their commencement, in comparison with their inner terminal cones, than in *Lophiodon*, and accordingly a degree of attrition

* Comptes Rendus de l'Acad. des Sciences, Paris, vol. xxviii. p. 547.
† Ostéographie, Lophiodonts, p. 190. pl. 2.

which affects the enamelled summit of the whole ridge in *Lophiodon*, abrades only the summits of the inner cones in *Pachynolophus* and *Pliolophus*; moreover the oblique ridges in *Pachynolophus* appear from M. Gervais's figure to dilate a little in breadth at their beginning, but this swelling is not so marked and circumscribed as in *Pliolophus*, and consequently an intermediate island of enamel, as at *r* and *s*, Pl. III., between an outer and inner cone, is not presented in any of the molars of *Pachynolophus*, although the first of these, *m* 1, in the specimen figured by M. Gervais, has been as much worn down as in the corresponding molar of *Pliolophus*. In this respect *Pliolophus* presents the next transitional step in the passage from the type-dentition of *Lophiodon* to that of *Hyracotherium*, in regard to the modification of the working surfaces of the molar teeth.

The hinder half of the last molar, *m* 3, presents a minor area, as in *Pachynolophus*, and a more simple configuration; the ridge from the postero-internal cone being simple, not expanding into an accessory tubercle.

M. Gervais calls attention to the seeming quadrilobate character of the outer side of the crown in the true molars of *Pachynolophus*, produced by the development of the cingulum into a tubercle at the fore and back part of that side of the tooth. *Pliolophus* resembles *Pachynolophus* in the tubercle at the fore part of the outer wall, but the cingulum is not so expanded at the back part as to give the appearance of a fourth cone. In this respect *Pliolophus* resembles *Lophiodon* proper.

In regard to the lower jaw, the lower contour of the symphysis is in the same line with that of the lower border of the ramus in *Pachynolophus*, and the symphysis with the incisor teeth are more procumbent even than in *Pliolophus*: the diastema between the premolars and canine is twice as long, and the consequent modification of the mandible led M. Gervais to propose the specific name *leptognathum* for the small Lophiodont of the 'Calcaire grossier,' which M. Pomel had previously dedicated to his friend M. Duval. But a distinction of more decided generic importance between *Pachynolophus* and *Pliolophus* is presented by the absence of *p* 1 in the former, which reduction of the number of the molar series to six, M. Gervais regards as normal, and assigns as the chief generic distinction from *Lophiodon*; adopting in this respect the conclusions of M. Pomel. The demonstration, which the rare perfection of the skull and teeth of the *Pliolophus vulpiceps* from the London Clay affords, of the retention of *p* 1 in the lower jaw, and consequently of the typical dental formula, justifies the same generic distinction of *Pliolophus*, as of *Lophiodon* proper, from the small Lophiodont called *Pachynolophus* by Pomel. The generic distinction of *Pliolophus* from all previously known Lophiodonts is more decisively established by the singular modifications of the grinding surface of the lower molar teeth.

This surface, in *Pachynolophus*, seems not to have been figured: M. Gervais describes it, in the penultimate molar (*m* 2), as presenting "two transverse eminences connected by a diagonal crest* ;" and such is described as the type of the lower true molar teeth in *Lophiotherium* † and *Tapirulus* ‡. This is, in fact, the structure of the lower molar teeth in *Lophiodon* proper, and that by which it so nearly resembles the existing Tapirs.

Pliolophus differs from all previously known Lophiodonts by the division of the part of the tooth answering to the "colline transverse" into two distinct cones, Pl. III. fig. 6, *a*, *b* and *c*, *d*; and the penultimate molar, m_2, more especially differs from that tooth in all hitherto known eocene or later forms of hoofed Mammals, in having a third cone, *e*, interposed between the two anterior cones, and thus exhibiting three cones on the same transverse line, as in the upper molars ;—a structure which we have hitherto seen only in the small mammal of the Lower Oolite described under the name of *Stereognathus ooliticus* §. I expressed my regret, at that period, when I could only cite the upper molars of *Hyracotherium* and of a few other eocene Ungulates as manifesting the three transverse cones, that the structure of the lower molars in *Hyracotherium* was then unknown. As the *Pliolophus*, though in some respects intermediate between the *Lophiodon* and *Hyracotherium*, has a closer affinity to the latter, we may, with some confidence, regard the modifications of its lower molars as significant of those that the same teeth of *Hyracotherium* will present when found. And the unlooked-for confirmation of my expectation of some further illustration of the affinities of *Stereognathus* by the lower molars of *Hyracotherium*, through the now acquired knowledge of the structure of those in the nearly allied *Pliolophus*, adds, in the same degree, probability to the inference which was founded upon the resemblance between the lower molars of *Stereognathus* and the upper ones of *Hyracotherium*. In offering this remark, however, I am quite sensible how uncertain any inference from a single lower molar is shown to be by the degree of resemblance in the structure of the lower molar teeth which exists in *Tapirus*, *Macropus*, *Lophiodon*, *Dinotherium*, and *Manatus*, and, again, in those of *Hippopotamus* and *Halitherium*. The reference by Cuvier of detached teeth of the *Halitherium* to the genus *Hippopotamus*, and of detached teeth of *Dinotherium* to the genus *Tapirus*, just and exact as were these references, viewed as expressions of the correspondence detected by a comparison of the fossil with the recent teeth, ought to warn us against placing too much confidence in dental characters, exclusively, as proofs of the closer degrees of determination which Cuvier has shown must depend upon an empirical study of coincidences, rather than on the rational deductions from correlations.

The same caution I now feel to be instructively reiterated by my reference of the *Hyracotherium*, on the ground of similarity of modi-

* "A deux collines transverses reliées par une crête en diagonale." Paléontologie Française, descr. of pl. 17.

† Ibid. pl. 11. f. 10–12.

‡ Ibid. pl. 24.

§ Quart. Journ. Geol. Soc. vol. xiii. Part I. February 1857, pp. 1, &c. pl. 1.

fication in the grinding surface of its upper molars, to the same secondary group of *Ungulata* as includes the *Chœropotamus*.

Most comparative anatomists who have studied the unique evidences of that old eocene genus, since my description of them, have arrived at and have recorded the same conclusions *. The only dissentient from them was Mr. H. N. Turner, jun., a most promising and acute naturalist and anatomist, who died too soon for the interests of science. In a very able and characteristic paper "On the Evidences of Affinity afforded by the Skull in the Ungulate Mammalia †," Mr. Turner points out the basal expansion of the nasal bones, the absence of the superorbital foramen and groove, and the slightly marked depression for the origin of the obliquus inferior oculi, within the orbit, as indications of the perissodactyle affinities of the *Hyracotherium*: he, also, most acutely discerned in the rudimentary oblique ridges upon which the small intermediate tubercles were developed in the molar teeth rudimental homologues "of the bent transverse ridges in the *Rhinoceros, Tapirus, Palæotherium*, and other allied genera;" but the degree of resemblance of the molars to those of the *Anthracotheria* and *Chœropotami* was such as led Mr. Turner, in regard to the question of the artiodactyle or perissodactyle affinities of the *Hyracotherium*, to admit, "to whichever group, then, this little animal be referred, the teeth will present marked exceptional characters, and, therefore, it becomes more necessary to seek for further evidence ‡."

This evidence I believe to be now afforded by *Pliolophus*, on the ground of the following illustrations of its close affinity to *Hyracotherium*.

Like that genus, its upper true molars exhibit the modification of the Lophiodont type of dentition in the more circumscribed and better-developed enlargement of the middle of the connecting oblique ridges: it also shows the more simple structure of the last premolar by the same non-development of the postero-internal cone. *Hyracotherium* differs from *Pliolophus* in the more distinct development of the intermediate tubercles, especially of the second or posterior one in $p\ 4$: the cingulum girts the crown uninterruptedly in the true molars and last two premolars. *Hyracotherium* differs, also, in the wider interval between the first and second premolar.

It may be questioned whether these differences are of generic importance, or whether, with those before pointed out in the configuration of the skull, they may not merely indicate another species of this genus which seems to be peculiar to our London Clay. In resolving this question I have been influenced by comparing the

* De Blainville, Ostéographie des Anthracotheriums et Chœropotames, fasc. xxi. p. 194. *Hyracotherium* described and figured " d'après un plâtre assez bon, envoyé à la collection du Muséum, par M. R. Owen."

Gervais, Summary of *Ungulata* observed in France:—

11. Chœropotamina. *Entelodon, Chœropotamus, Hyracotherium.* Pal. Franç. descr. of pl. 36. p. 6.

† Ann. and Mag. Nat. Hist. Dec. 1850, 2nd ser. vol. vi. p. 397.

‡ *Loc. cit.* p. 408.

degree of difference in their dental characters with that which has influenced MM. Pomel and Gervais in subgenerically separating *Pachynolophus* from *Lophiodon*; and by the fact of the mandibular teeth of the *Hyracotherium leporinum* being yet unknown.

Lophiodon, Pachynolophus, Pliolophus, and *Hyracotherium* seem thus to form so many subgeneric modifications of the same natural family of Perissodactyle Ungulates; and in the modifications of their dentition, especially in the comparative simplicity of their premolars as compared with those of the subsequently introduced *Palæotheria*, and in the progressive approach to the molar type of the Chœropotamoids made by *Pliolophus* and *Hyracotherium*, they exemplify the tendency to a closer adherence to the general ungulate type. The third trochanter on the femur of the *Pliolophus*, Pl. IV. fig. 5, *t*, and the association of three metatarsals, in one portion of the matrix, fig. 14, which appear to belong to the same hind-foot, confirm, however, the essentially perissodactyle affinities of that genus, and, therefore, of its close ally the *Hyracotherium.*

In stating that these modified Lophiodonts are the most artiodactyloid of the Perissodactyles, no particular hypothesis is advocated: there can be but one inference from this and the numerous analogous facts that have already been made known. So, likewise, in regard to the typical character of dentition, as manifested by the number and kind of teeth, we find in this last eocene mammal which has come to light a repetition of that remarkable adherence to a more general mammalian character. The older Oolitic Mammals exemplify a tendency to a type of dentition of a still higher generality than the Mammalian class, as, for example:—

Mammalia of which the dentition resembles the general vertebrate type by the back teeth exceeding 7 in number:—

Genera.	Formations.	
Thylacotherium	Lower Oolite.	
Spalacotherium	Upper Oolite	Purbeck.
Triconodon	Upper Oolite	Purbeck.

Mammalia resembling the Mammalian diphyodont type in the dental formula of

$$i\,\frac{3-3}{3-3},\ c\,\frac{1-1}{1-1},\ p\,\frac{4-4}{4-4},\ m\,\frac{3-3}{3-3};\ \text{or}\ p\,\frac{3-3}{3-3}\ \text{and}\ m\,\frac{4-4}{4-4}=44.$$

Genera.	Formations.
Palæocyon	Sables de Bracheux (or somewhat older).
Coryphodon	Plastic clay.
Pachynolophus	Calcaire grossier moyen.
Lophiotherium	Marnes lacustres d'Alais (Gard).
Pliolophus	London clay.
Hyracotherium	London clay.
Palæotherium	Paris gyps.
Anoplotherium	Paris gyps.
Anchitherium	Lignites de la Débruge, près Apt.
Dichobune	Binstead.

Genera.	Formations.
Xiphodon	Lignites de la Débruge.
Dichodon	Hordwell.
Microtherium	Marnes calcaires lacustres, Puy du Dôme.
Amphitragulus	Marnes lacustres en Velay.
Amphimeryx	Lignites de Débruge.
Dorcatherium	Miocène d'Eppelsheim.
Chalicotherium	Miocène d'Eppelsheim.
Aphelotherium	Marnes calcaires de Barthélemy.
Anthracotherium	Marnes miocènes de Moissac.
Hyopotamus	Binstead and Hordwell.
Anchilophus	Calcaire grossier de Batignolles.
Bothriodon	Miocène de Moissac.
Palæochœrus	Calcaire lacustre de Cournon.
Chœropotamus	Paris gypsum, and Binstead.
Chœromorus	Calcaire lacustre, Sansan.
Poëbrotherium	Eocene (upper?), N. America.
Hippohyus	Miocene, Sewalik Hills.
Hippotherium	Miocène d'Eppelsheim.
Hipparion	Marnes fluviatiles de Cucuron.
Heterohyus	Miocene, Sewalik Hills.
Entelodon	Lignites de Soissonnais.
Hyænodon	Eocène supérieure du Gard; Hordwell.
Pterodon	Lignites de Débruge.
Arctocyon	Eocène inférieure à la Vère.
Galethylax	Paris gyps.
Amphicyon	Miocène de Sansan.
Chœrotherium	Miocène du Bourbonnais.
Rhagatherium	Eocene of Mauremont, Switzerland.

All general rules in organic nature have their exceptions, and differ in that respect from inorganic phænomena, in regard to some of the general laws of which no exceptions have been as yet discovered.

I shall, on a future occasion, discuss the value of the exception to the inference from the body of facts above cited which has been adduced from the *Plagiaulax* *, and conclude the present paper with some remarks on the bones of the limbs of *Pliolophus*.

Description of some of the Bones of the Extremities. Humerus. Pl. IV. figs. 1 to 4.—The humerus, from the right fore limb, measures 4 inches in length. The convex articular surface of the head of the bone, Pl. IV. fig. 3, is subtriangular in shape, rather flattened above towards the outer side. The great tuberosity is of equal breadth with, but rises above, the articular head. It is slightly grooved obliquely near its outer part, but is not so widely or deeply notched there, as in the Tapir or Hyrax: it terminates by a single convexity. The small tuberosity is not quite so large relatively as in the Tapir and Hyrax, but it is situated, as in them,

* Quart. Journ. Geol. Soc. vol. xiii. p. 276.

at the fore and inner part of the articular head, and not so low down as in the humerus from the "terres noires du Laonnais," ascribed to *Lophiodon* by Cuvier *.

The deltoid surface is short: a smooth oblique tract separates it from a second low oblique (pectoral) ridge; the shaft of the bone rapidly contracts below the head, where it is not so compressed or so broad from before backwards, as in *Palæotherium*; it is thicker transversely than in *Hyracotherium*.

The supinator ridge begins at about the lower third of the bone, is moderately sharp for about 9 lines, and then subsides into a rather rough flattened surface above the inner condyle; it is very slightly produced. The bone is perforated above the lower articular surface; this surface has one depression and two prominences, as in the Perissodactyles. The general shape and proportions of the bone are like those of the humerus of the Hyrax.

Femur: Pl. IV. figs. 5 to 9.—The femur is rather more than 5 inches in length: its most important character, as indicative of the affinities of the *Pliolophus* in the ungulate series, is the continuation of the outer ridge of the great trochanter vertically down the outer border of the shaft and its development into a third trochanter, *t* †, which subsides before it reaches the mid-length of the bone. The great trochanter rises in an obtusely pointed form 5 lines above the articular head; and it developes a tuberosity at the fore part of its base. The neck sinks behind the head before it rises into the trochanter. The small trochanter is a longer ridge than in the Hyrax: the shaft below the trochanter becomes less flattened than in the Palæotheres or Lophiodons: the transverse section gives a kind of semi-ellipse with the flatter side slightly convex: it shows a compact wall of bone of about a line or a line and a half thick, and a medullary cavity of from 3 lines to 4 lines in diameter. At about 2 inches from the distal end the shaft begins to expand and become three-sided, the hind- and the out-sides being less convex and broader than the inner side; then an anterior surface is established by the beginning of the rotular groove, about an inch and a half from the lower end: the inner border of the groove is produced and sharp; the outer border was broken off in the extraction of the bone: the condyles are produced backward, but not so much forward as in *Palæotherium*: the inner surface of the expanded condyloid end of the bone, Pl. IV. fig. 8, is flat, with a much less prominent part for the internal lateral ligaments than in *Tapirus*, *Hyrax*, or *Palæotherium*. The popliteal depression is very slightly concave transversely: it is divided from the intercondyloid fossa by a ridge continued inward from the back of the outer condyle.

Tibia: Pl. IV. figs. 10–13.—The tibia, which was extracted

* Ossemens Fossiles, ed. 8vo, tom. iii. p. 411. pl. 79. f. 6 & 7.

† "Les pachydermes qui offrent cette particularité sont les rhinoceros, les tapirs, les chevaux et jusqu'à un certain point les damans, c'est-à-dire les genres que j'ai désignés comme formant une petite famille distincte, et à système de doigts impairs au pied de derrière; et c'est précisément à cette famille qu'appartiennent les Palæothériums, par tous les autres rapports."—Cuvier, Ossemens Fossiles, ed. 1835, 8vo, tom. v. p. 287.

almost entire from the septarian nodule, was of the left leg; its length is 4 inches 9 lines. The proximal articular surface, Pl. IV. fig. 11, is more equally triangular than in *Palæotherium*. The outer facet is slightly convex; the inner one slightly concave transversely. The back part of the proximal end of the bone, fig. 10, shows a broad and deep concavity, bordered by sharp margins; the outer part is somewhat less concave; the inner part is slightly convex; the rotular ridge was not extracted entire, but was evidently well developed, and extended an inch and a half down the bone. The most characteristic feature of the tibia is the articular surface at the distal end, fig. 13, of which sufficient is preserved to show the obliquity of its course across that end, corresponding with the obliquity of the articular trochlea of the astragalus which is common to the odd-toed hoofed quadrupeds. From these the even-toed group are distinguished by the rectangular disposition of the ankle-joint.

Metatarse: Pl. IV. fig. 14.—The portion of matrix containing the part of the calcaneum, *c*, and three metatarsals, shows the latter dislocated, and with only one articular end entire—the lower one—in one of them. This is, however, as characteristic as any of the distinctive features of the before-described bones, by the unsymmetrical form of the distal trochlea, due to the position of the ridge near one of the borders of the bone. Both this configuration and the position of the metatarsal show it to have been the outermost of the three: the proximal end is broken off: the length of the bone preserved is 1 inch 5 lines. Of the mid-metatarsal only a small part is exposed, from which the articular end is broken away. Of the innermost metatarsal 1 inch 8 lines is exposed, but both articular ends are wanting. The difference in the diameter of the three metatarsals is less than in the *Palæotherium*, the middle one being only very little thicker than the other two. In the Tapir the middle metatarsal is less expanded than in the *Palæotherium*. In the *Hyrax* the three metatarsals are of equal thickness; and the *Pliolophus*, and probably other Lophiodonts, thus resemble the *Hyrax* and *Tapir*, more than the *Palæotheria* did.

Remarks on the Bones of the Extremities.—On a retrospect of the characteristics of the limb-bones above described, it will be seen that the humerus testifies to the ungulate character, and the bones of the hind-leg to the perissodactyle modification, of *Pliolophus*, with a demonstration that the odd number of hind-toes was "three" instead of "one" or "five."

The great size, position, and altitude of the proximal tuberosities of the humerus, with the shape of the sessile head of the bone, indicate the limited extent and direction of motion of the humerus, and that it belonged to a limb not capable of being rotated or bent outward, as in the action for seizing, striking, climbing, or burrowing. The comparatively small size of the distal end, and the little-developed supinator ridge equally indicate the want of size in the supinator or pronator muscles in a limb where the rotation of the wrist or the fore-arm is abrogated. The third trochanter on the femur, the oblique

Fig. 1.

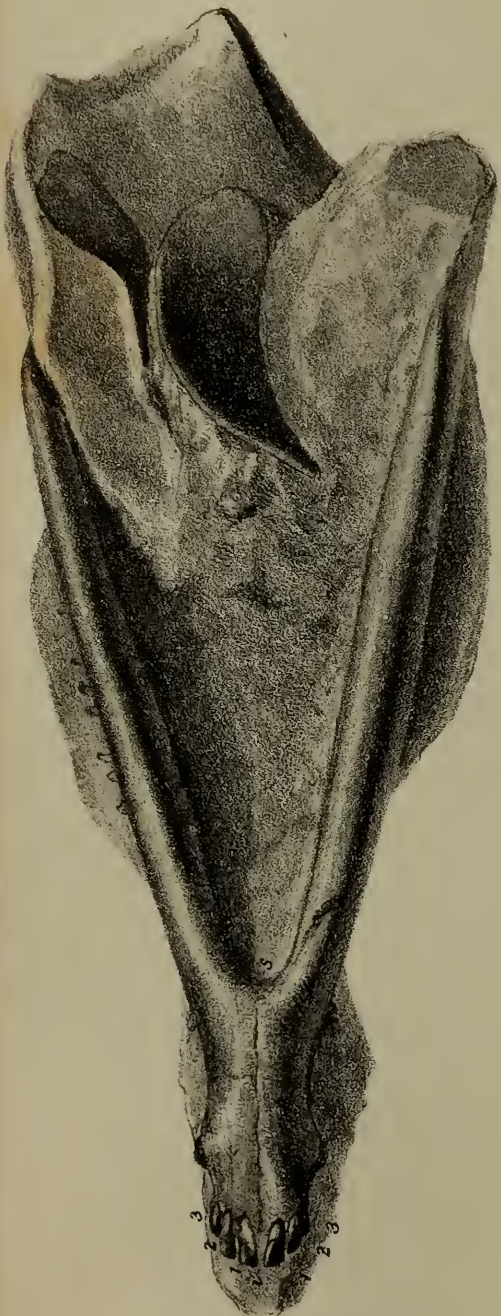


Fig. 2.

PLIOLOPHUS

G. H. Ford

Fig. 3.

Fig. 4.

S. VULPICEPS.

W. West imp.

Fig 1

Fig 2

Fig 3

Fig 4

PLIOLOPHUS VULPICEPS

W West imp

Fig 2

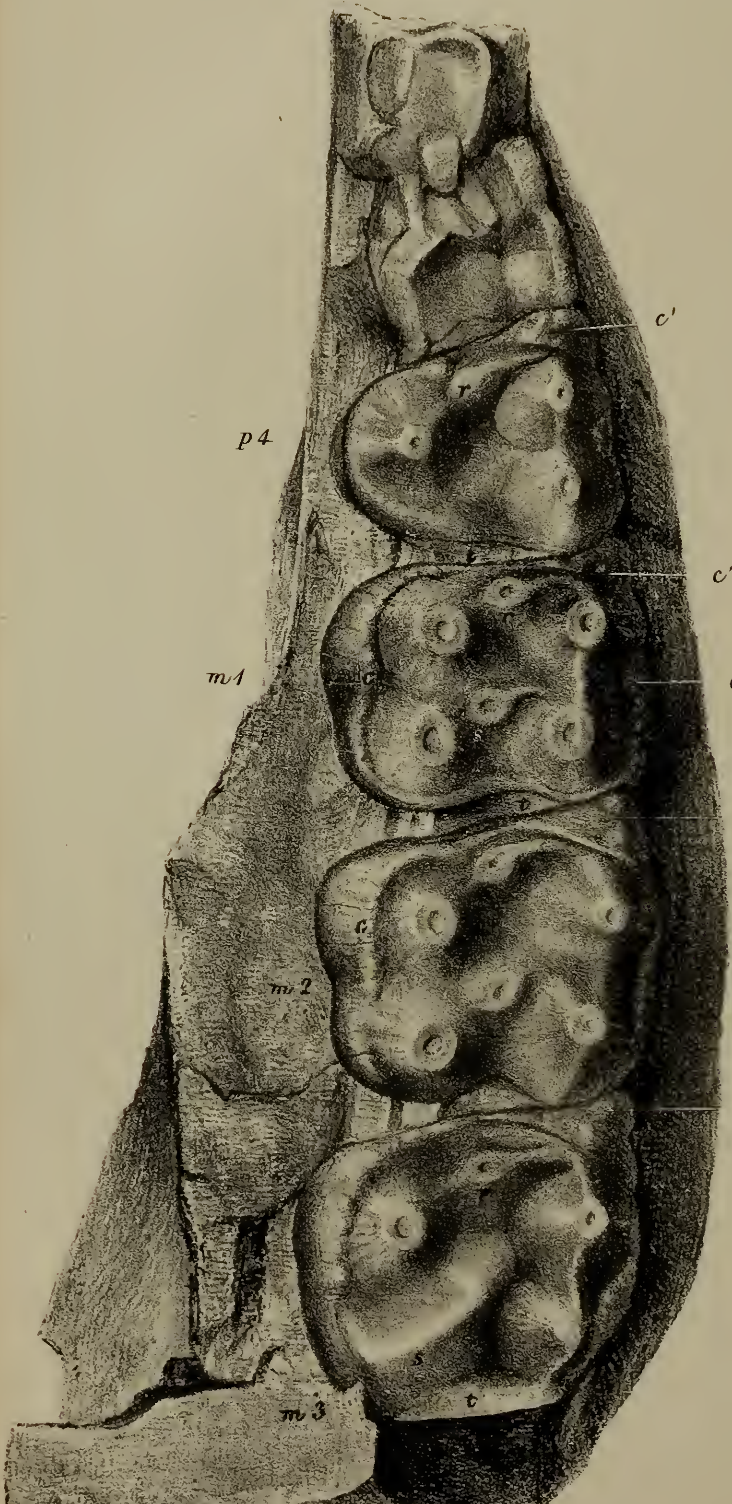


Fig 1

Fig 3.

G.H.Ford

PLIOLOPHUS

Fig 6.

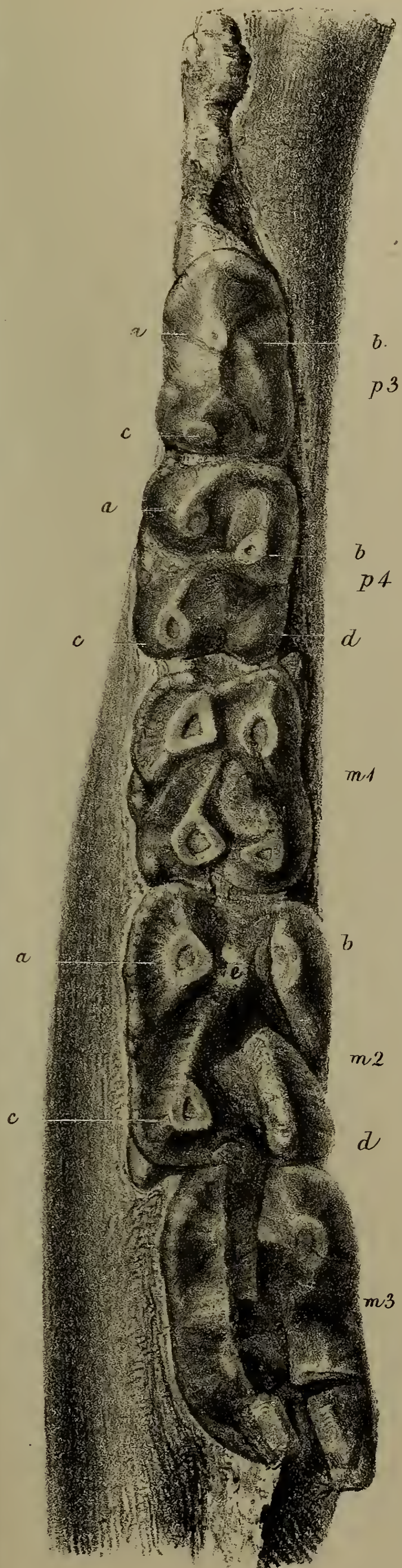
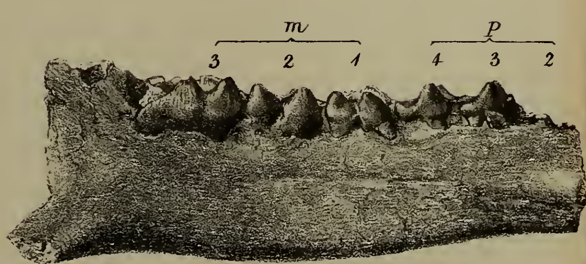


Fig. 5.

Fig. 4.



S. VULPICEPS.

W. West. Imp.

Fig. 2

Fig. 1

Fig. 3.

Fig. 6

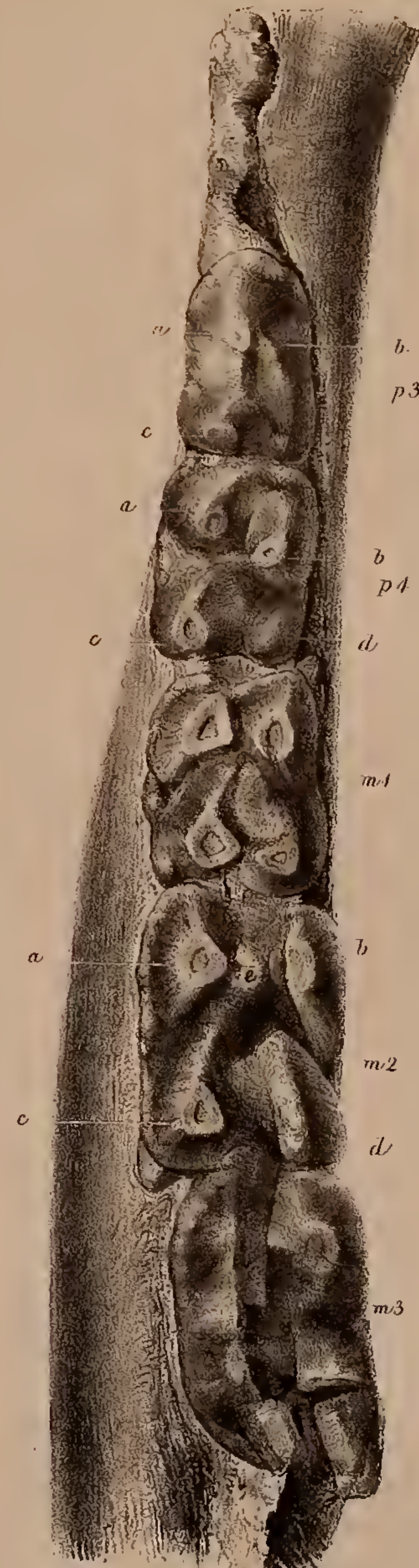


Fig. 5

Fig. 4

G.H.Ford.

PLIOLOPHUS VULPICEPS.

W. West lith.

Fig 3

Fig 4

Fig 6

Fig. 5

Fig 1

Fig 2

PLIOLOPHU

G.H. Ford

Fig. 7.

Fig. 11.

Fig. 12.

Fig. 14.

Fig. 10.

Fig. 8.

Fig. 9.

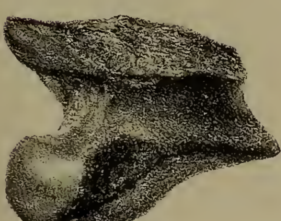
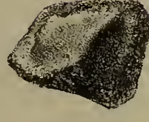


Fig. 13.



VULPICEPS

W. West Imp.

articular fossa for the astragalus on the tibia, and the three metatarsals of the left hind-foot, all concur with the indications afforded by the skull and teeth in the determination of the true position and affinities of *Pliolophus* and, most probably therefore, of *Hyracotherium* in the ungulate series.

DESCRIPTION OF PLATES II., III., & IV.,

Illustrative of the *Pliolophus vulpiceps*, Owen.

Plate II.

Fig. 1. Under view of the lower jaw and incisor teeth.
2. Upper view of the cranium.
3. Right-side view of the cranium and lower jaw, as attached together in the matrix.
4. Left-side view of the cranium, with the lower jaw and teeth brought back to their proper place.

Plate III.

Fig. 1. Grinding surface of the molars and last premolar, upper jaw.
2. The same, magnified 4 diameters.
3. The first and second molar, upper jaw of an older individual. From the London clay, Valley of the Thames.
4. Inside view of the molars and last two premolars, lower jaw.
5. Grinding surface of the molars and last two premolars, lower jaw.
6. The same, magnified 4 diameters.

Plate IV.

Fig. 1. Outer-side view of humerus.
2. Front view of humerus.
3. Proximal articular end of humerus.
4. Inner-side view of proximal end of humerus.
5. Front view of right femur.
6. Upper articular end of right femur.
7. Back view of right femur.
8. Inner-side view of lower end of right femur.
9. Lower articular end of femur.
10. Back view of tibia.
11. Upper articular end of tibia.
12. Outer-side view of upper end of tibia.
13. Part of lower articular surface of tibia.
14. Portion of matrix, with the calcaneum and three metatarsals of the left hind-foot.

[All the figures are of the natural size, except where otherwise expressed: the letters and figures are explained in the text.]

2. *On some Remains of* Terrestrial Plants *in the* Old Red Sandstone *of* Caithness. By J. W. Salter, Esq., F.G.S., of the Geol. Survey of Great Britain, &c.

[Plate V.]

Numerous fragments of plants have for several years past been discovered in the Old Red Sandstone of the North of Scotland; but as yet a few only have been figured. The specimens have now been gathered together by the Director of the Geological Survey for the purpose of illustration.

As no experienced botanist has yet been willing to take up such obscure relics, I have thought that some general notes on this old flora might be useful, if only to lead the way to a more critical examination of the specimens. Some of them will be figured also in the second edition of "Siluria."

The best that I have seen are in the collection of Mr. John Miller, of Thurso, who has for some time directed his attention to these Devonian plants, and at the request of Sir Roderick Murchison, who long ago observed them, has most kindly entrusted to us the whole of his collection. Mr. R. Dick, of the same place, has also aided largely in these discoveries. Mr. C. W. Peach has more lately found similar plants at Wick, and Dr. Hamilton in Orkney. I have examined all these collections, and many of the specimens are now placed in the Museum of Practical Geology.

The fossils are preserved in hard, grey, sandy flagstones, which are in many cases abundantly marked with impressions of Annelide-burrows in pairs (Pl. V. fig. 6); and these probably indicate that there was no great depth of water where these beds were deposited. The late Hugh Miller has even suggested that these strata may have been accumulated on an extremely level muddy shore*.

The most striking of the fossils are large stem-like fragments, of every size up to 3 feet in length, either straight and finely fluted, *stems* (Pl. V. fig. 1); or curved and occasionally branched, *roots*? (Pl. V. fig. 2). These are all highly bituminized, and divided by oblique lines, which are evidently only due to mineral structure. Indeed the most striking feature about all these specimens is the mode in which they are mineralized. The carbonaceous substance is cleaved throughout in a series of oblique planes, which in the long root-like specimens (fig. 2) are set quite close (2 or 3 in the space of $\frac{1}{10}$th of an inch), and cleave the substance in lines perfectly parallel, whatever may be the position or curvature of the specimen. In the stems (fig. 1), these cleavage-lines are generally far wider apart, often $\frac{1}{4}$ of an inch; and they form fissures, often filled up by siliceous matter. Owing to the further compression of the wood, the silex stands out in relief, and forms impressed lines upon the matrix, which may readily be mistaken for the marks of structure. Similar diagonal lines have been noticed by Dr. Hooker†, and attri-

* Testimony of the Rocks, p. 437.

† Quart. Journ. Geol. Soc. vol. ix. p. 50.

buted to "pressure during silicification," in specimens of very similar plants (*Calamites*, without articulations). The plants he described, from near Lerwick, Shetland, were in the upper division of the Old Red Sandstone, according to Sir Roderick Murchison*.

Coniferous Wood. Pl. V. figs. 1 & 2.

The above-noticed stems are 4 inches wide, and the fragments measure more than 3 feet in length, without any tendency to taper away. See fig. 1.

The surface is fluted pretty regularly by delicate longitudinal ridges; the intervening hollows being gently concave, not abruptly grooved; these ridges are tolerably regular and equidistant, without being absolutely continuous; seldom as much as a line apart, but occasionally more. They are not interrupted by any transverse joints as in *Calamites*; and, from this circumstance, as well as from the more solid texture of the stem, they might have been judged to belong to the *Stereocalameæ* of Unger, some of the genera of which, *Calamopitys* or *Calymma*, would, from Unger's description, present a very similar appearance.

With these there are long, curved and flattened linear specimens (fig. 2), sometimes more than 4 feet long, and from an inch to 1½ inch broad, very slowly tapering, and forked near the end.

Both the straight and the curved stems are even-edged, as if originally cylindrical; and there are evident traces, in some portions, of a central pith (probably not a woody axis, as the space in the centre is now filled by the matrix), while the enveloping thick sheath is all carbonized. This structure, a thick woody envelope, surrounding a central pith, may be that of a Conifer allied to the *Dadoxylon*† of the Coal-measures; and this is confirmed by the microscopic sections (fig. 1*c*) which have been kindly examined for me by Prof. Quekett, who finds the ordinary coniferous structure—wood-fibres dotted with disks; and these appear to have been in alternating double rows, as in the modern Araucarians, and as in the fragments of Coniferous wood, described by Hugh Miller, from beds of Devonian age near Cromarty‡. This dotted structure will, of course, effectually distinguish these large stems from the woody structures (*Aporoxylon*), without disks to the wood-cells, which Prof. Unger has lately§ described; otherwise the external appearance, and even the mode of fossilization, are so similar in both, that I should have provisionally referred our specimens to the same genus, had there been no means of ascertaining the minute structure.

Besides these large stems and roots, there are tapering branches, an inch broad and often more than a foot in length, less regularly striated than the stems, but still distinctly fluted all the way up;

* *Loc. cit.*

† In *Dadoxylon* the wood-fibre has more numerous rows of disks than in the Caithness fossils.

‡ Testimony of the Rocks, p. 435.

§ Denkschrift. Kais. Akad. Wissensch., Math.-Nat. Classe, vol. xi. 1856: Beitrag zur Paläontologie des Thüringer Waldes, von R. Richter und F. Unger: p. 181, pl. 13. figs. 3–11.

and these bear branchlets at short intervals, in whorls of threes or fours, which diverge at nearly right angles from the branch, something like those of an *Araucaria*.

It is not improbable that these striate branches may belong to the same plants as the stems (and roots?) above mentioned.

Rootlets (Pl. V. figs. 3–7).—Other and very numerous specimens, lying flat in the stone, and presenting simply a linear rachis with alternate (fig. 4) or dichotomous (fig. 3) smooth branchlets, appear to me to be far more likely referable to the smaller roots than to anything else. They occur about 6 or 8 inches long, and seldom so much as a quarter of an inch broad; they taper slowly, and are flexuous or zigzag at the origin of the branches, which are themselves again branched.

In a few instances irregular granulations occur on the roots: in others (fig. 7) lateral buds or tubercles take the place of the terminal branchlets or rootlets, and become crowded towards the tips. They put one in mind of the tubercular roots of some of the Leguminous plants, or may be still better compared with the tubercles or exostoses found on the roots of many Coniferous plants, *Araucaria, Thuja, Podocarpus*, and others*. These tubercles seem to me to give great colour to the idea that the linear fragments to which they are attached are roots; and, as these are in most respects similar to the other specimens, with dichotomous or alternating branches (figs. 3–6), there is a strong presumption that the latter are roots too. Whether any of them may be referable to the woody plants above described, rather than to the Lycopodiaceous plants next to be noted, it is scarcely possible to decide; but the former is certainly probable. I am more inclined to regard all these as roots, since they bear the greatest resemblance to similar fragments abundant in the Upper Devonian beds of the South of Ireland, and which, from their mode of occurrence in a sort of hardened underclay beneath the beds of sandstone, I have always thought to be roots†.

Similar fragments are figured in Mr. Hugh Miller's last work‡, and in these the dichotomous character is clearly seen.

I do not think their structure or mode of branching at all like that of marine plants. Nor have they any distinct trace of a midrib, as if they were cleft or divided leaflets, or of parallel veins, as in the seawrack (*Zostera*). Nor, indeed, do they show anything but a linear riband (probably once a soft cylindric root) which branched repeatedly.

A few more perfect plants deserve to receive specific notice; and, in naming the remarkable Lycopodiaceous plant (fig. 8), I have had in view both the kindness of Mr. John Miller, of Thurso, and the memory of the lamented author of "The Testimony of the Rocks."

* See Dr. Hooker's paper on these root-tubercles, Proc. Linn. Soc. 1845, No. 58. p. 355*. I have the satisfaction of Dr. Hooker's concurrence in this view of the nature of the fossils.

† Proc. Dublin Geol. Society, vol. vii. p. 63.

‡ Testimony of the Rocks, p. 429.

A fossil fern found in Orkney and described in Hugh Miller's work (p. 25) has not occurred among the specimens under our notice.

Lycopodites Milleri, sp. nov. Pl. V. figs. 8*a*, 8*b*.

L. ramis flagelliformibus, 2 *pedes et ultra longis; ramulis remotis, foliis secundis* 2–3 *lineas longis, lanceolatis* [*obtusis?*].

This fine specimen is worthy of a name on account of the rarity of such remains in rocks of this age; but not much can be said as to its structure. The stem (only a fragment 2 feet long is preserved) is flexuous, about $\frac{3}{8}$ths of an inch thick, and was probably of prostrate growth as indicated by the secund arrangements of the foliage, and the length and slenderness of the stem itself. In this length of 2 feet are only two short branches, about an inch long, and about 7 inches apart, and set on at a very oblique angle, as often seen in recent Club-mosses. The foliage is much larger than in the *Lepidodendron* next described. The leaves are very indistinct, but are about $\frac{1}{3}$rd of an inch long, lanceolate (obtuse?), and much curved upwards to one side (the upper side probably). There is some indication of their being set on in spiral lines, instead of quincuncially.

Locality. Near Thurso. (Mr. John Miller's collection.)

Lepidodendron nothum, Unger (?). Pl. V. figs. 9*a*, 9*b*, & 9*c*.

Richter & Unger, Beitrag Paläont. Thüringer Waldes, Vienna Acad. Transact. 1856, pl. 10. fig. 4.

Lycopodites, Hugh Miller, Testimony of the Rocks, figs. 12 & 120, pp. 24 & 432 &c.

Stems about a foot long, or even longer, and nearly $\frac{1}{2}$ an inch broad, tapering but very little from end to end; the branches short, set on at an acute angle, and blunt at their terminations. Leaves in 7 to 10 rows, very short, not a line long, and scale-like, of an ovate, acuminated form, and rather spreading than closely imbricate. Their acuminate tips are about as long as their broader bases (fig. 9*c*).

Our specimens do not agree exactly with that figured by Unger, having the scales or leaves rather longer. But his figure appears to show only the cicatrices, not the leaves themselves; and the size, diameter of the branches, and close small leaf-scars in both agree, and are different from any species that I have seen figured from the Coal-formation.

Loc. From Stromness, Mr. Peach; Thurso, Mr. John Miller. Abundant.

The late Mr. Hugh Miller figured* a fine and much-branched specimen of this species. We have others, in which the main stem (a little flexuous) gives off short and narrower branchlets, which are again branched, as in his figure. The tips of the shoots often scarcely show the scales.

* *Op. cit.* p. 432.

The above species all occur (with the exception of the *Lycopodites Milleri*, which is only yet known at Thurso) as well in the Orkneys as at Caithness. Both the *Lepidodendron* and the linear root-like branches are found in Dale and Viewan quarries at Stromness, Miram Blaw, and near Frith, Orkney. The large stem-like bodies and curved roots are also found with them. These were sent by Dr. Hamilton and Mr. Peach. The best examples, however, were found in the flag-quarries at Thurso, and are in Mr. Miller's collection, and most of our figures are from his specimens.

Mr. C. W. Peach has for some years been diligently searching for these plants, and has sent up some 70 specimens from Kilminster, near Wick, which comprise only the smaller species.

We have here therefore the fragments of a flora, which may at least be compared with that discovered in the Thüringer Wald by M. Richter, and which has been so beautifully illustrated by Prof. Unger in the work above quoted. Though not so numerous in species, yet the Scotch collections contain some forms of larger size, indicating a vegetation of considerable importance at an era so far back as that of the Middle Devonian. Prof. Unger's plants, which he has spoken of as being of a totally new type, and in some respects a prototype of succeeding floras*, are from the Cypridina-schist, or Upper Devonian of Germany, strata which are believed to be of younger age than those described by Mr. Hugh Miller, and plants from which are here figured.

The discovery† by Mr. Strickland and Dr. Hooker of spores of a Lycopodiaceous plant in the passage-beds between the Old Red Sandstone and Ludlow Rock (to which I lately added, during a visit to Ludlow, branched fragments of the stems‡) is a sufficient indication that we have to make out the characters of a still more antique vegetation, of which, to judge from the fragmentary evidence yet obtained, the characters were not altogether unlike those of later palæozoic times.

The strata from which the fossils above enumerated were obtained have been long ago described, and their relative age determined by the labours of Prof. Sedgwick and Sir R. Murchison‖. They are regarded by these authors as part of the Middle Devonian rocks, while in Hugh Miller's classification they stand as part of his Lower Division. *Dipterus* and *Diplopterus* are the prevailing genera of fish that accompany the plants.

Note on the Plant-bearing Devonian Beds *of* Caithness. By John Miller, Esq., of Thurso.

The fossiliferous beds of the Old Red Sandstone of Caithness form by far the larger part of the area of that county. Along the whole

* 'Siluria,' 1st ed., p. 358.

† Quart. Journ. Geol. Soc. vol. ix. p. 10 &c.

‡ It is to be regretted that these small branched specimens, which were ⅓rd of an inch thick, were lost before they could be fully examined in London.

‖ Geol. Trans. 2nd Ser., vol. iii. p. 125 &c.

FOSSIL PLANTS FROM CAITHNESS AND ORKNEY.

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W. West imp

of the boundary-line between Sutherland and Caithness, the gneissose rocks of the Highlands extend into Caithness to the distance of from three to eight miles, and are succeeded by the Old Red Sandstone, which stretches in one unbroken deposit eastward to the German Ocean and northward to the Northern Ocean. Along the whole of the line of junction of the two deposits, the rocks are so covered with moss and heath that it is extremely difficult to get at the base of the Old Red Sandstone; at the Ord of Caithness, however, in the sea-cliffs immediately under the celebrated mountain-pass of that name, very fine sections may be seen of the great fossiliferous conglomeratic base of the Devonian or Old Red. From the Ord of Caithness northwards to Duncansbay Head, and from Duncansbay Head westwards to Sandside Head, the seaboard of the county is composed of a range of mural precipices, from 40 to nearly 400 feet in height; and the whole of the Devonian portion of the county northwards of the Morven and Scarabin Hills is an elevated plateau, rising abruptly out of the sea, but seldom attaining a greater height than 500 feet above the sea-level in any part of the interior. The strata are inclined at low angles, generally dipping towards the north-west, and sometimes almost horizontal; and throughout the greater portion, wherever a quarry has been opened, at the foot of the cliffs, on the sea-shore, or on the tops of the hills, the practised eye can detect fragments of plants mixed with the bones and scales of fish. The most entire and largest specimens, however, of plants have been hitherto found in the neighbourhood of Thurso, in the flagstone-quarries, which are numerous in that locality.

DESCRIPTION OF PLATE V.,

Illustrative of Fossil Plants from Caithness and Orkney.

Fig. 1*a*. Fragment of a large, straight, compressed, finely fluted, bituminized, stem-like body; from a quarry three miles west of Thurso. One-fourth of the natural size. (Mr. J. Miller's collection.)

Fig. 1*b*. Portion of the finely fluted surface; magnified.

Fig. 1*c*. Traces of woody structure, showing the remains of pitted fibre, with a double row of pits or disks. Highly magnified.

Fig. 2. Fragment of a large, curved, compressed, bituminized root-like (?) body; from a quarry four miles east of Thurso. One-fourth natural size. (Mr. J. Miller's collection.)

Fig. 3. Dichotomous rootlet; from Kilminster, Wick. Natural size. (Geological Survey collection.)

Fig. 4. Dichotomous root; from Kilminster, Wick. Natural size. (Geological Survey collection.) The oval mark in the specimen is the outline of an Annelide-burrow.

Fig. 5. Branched root, marked with fine tubercles, which have somewhat of a spiral arrangement. Natural size. From Dale Quarry, Stromness. (Geological Survey collection.)

Fig. 6. Branched rootlet lying on a flagstone which presents traces of Annelide-burrows (*Arenicolites*), frequently in pairs. Kilminster, Wick. Natural size. (Geological Survey collection.)

Fig. 7*a*. Terminal rootlet with lateral tubercles.

Fig. 7*b*. The terminal tubercles, magnified.

Fig. 8*a*. *Lycopodites Milleri*. From a quarry four miles east of Thurso. One-fourth of the natural size. (Mr. J. Miller's cabinet.)

Fig. 8*b*. The same; a small portion, magnified.

Fig. 9*a*. *Lepidodendron nothum*, (Unger)?, portion of stem; natural size. From Harland, Wick. (Geological Survey collection.)

Fig. 9*b*. Magnified portion of the cast of another specimen, showing the arrangement of the bracts. Magnified three times. From Stromness, Orkney. (Geological Survey collection.)

Fig. 9*c*. Portion of fig. 9*a*, magnified.

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Notices of Scientific Meetings, &c.

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Bengal Asiatic Society, Journal. New Series, Vol. xxvi. No. 84. 1857. No. 1.

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Berlin. Zeitschrift der Deutschen geologischen Gesellschaft. Vol. viii. part 4. 1856.

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

June 3, 1857.

William Reed, Esq., M.R.C.S., York, was elected a Fellow.

The following communication was read:—

On the species of Mastodon *and* Elephant *occurring in the fossil state in* England.—Part II. Elephas. By H. Falconer, M.D., F.R.S., F.G.S.

[The publication of this paper is unavoidably postponed.]

[Abstract.]

In the introductory portion of Part I. of this Memoir*, the author alluded to the ambiguity that has existed relative to the mammalian faunæ of the Miocene and Pliocene periods, in consequence of palæontologists confounding several distinct forms of *Mastodon*, of different geological ages, under one name (*M. angustidens*); and on this occasion Dr. Falconer stated, that, in the application of the name *Elephas primigenius* (Mammoth) to a multitude of elephantine remains from various superficial and deep deposits, over a vast extent of territory, and of different ages, a similar, if not a greater, amount of error and confusion had arisen.

In fact, at least half the habitable globe has been assigned to the

* Quart. Journ. Geol. Soc. vol. xiii. p. 308.

Mammoth as his pasture-ground, if we were to accept the determinations of all those who have written on the remains of *Elephas primigenius*. The duration, too, of this nominal species in time is equally remarkable, so considered; since, as it has been quoted from the lower and the upper pliocene beds, as well as from the post-pliocene glacial gravels, it ought to have existed before the European area received its present geographical form, and indeed before the Alps, Apennines, and Pyrenees reached their present elevation.

After noticing the difficulty met with by the geologist in the classification of the newer Tertiaries, on account of this supposed ubiquitous presence of the Mammoth, the author proceeded to show that several species, belonging to two distinct subgenera, have been generally confounded under the name of *Elephas primigenius*; and that each had its limited range in geographical area and geological time.

The present condition of the nomenclature of the subject, and the history of the established species of European fossil Elephants *, namely *E.* (*Loxod.*) *meridionalis*, *E.* (*Loxod.*) *priscus*, *E.* (*Eueleph.*) *antiquus*, and *E.* (*Eueleph.*) *primigenius*, preceded an explanation of the principles on which the species are determined, and a description of the dental characters by which the Elephants are divisible into subgenera,—a succinct account of which was given in the former part of the Memoir (vol. xiii. p. 462). The "intermediate molars" in Elephants have never less than six divisions of the crown, and sometimes as many as eighteen. These molars have not all an equal number of ridges: some Elephants have an augmentation of only one ridge to the crown of the penultimate of these molars; these are "hypisomerous," namely *Stegodon* and *Loxodon*; others, in which the number of the ridges progressively increases, are "anisomerous," and form a third natural group, namely the *Euelephas* or *Elephas* proper. The *Stegodon* has four species, fossil in India; and approaches the *Mastodon* in the form of the molars. The *Loxodon* includes the existing African Elephant and three fossil species, and is characterized by its distinct rhomboidal discs of wear on the grinders. *Euelephas* has thin-plated molars; but in some species there are intermediate stages, as regards the angular mesial expansion of the plates, between it and *Loxodon*.

Dr. Falconer next proceeded to review some well-ascertained mammalian faunæ localized in certain parts of Europe, where the conditions of deposit are most simple, and to apply the results to the more complex instances, where the remains of more than one distinct fauna are intermingled, or so closely deposited as to be too readily confused by collectors. With this view, the author instanced the Subapennine or pliocene deposits of the Astesan, and elsewhere in Piedmont and Lombardy, where *M.* (*Trilophodon*) *Borsoni*, *M.* (*Tetralophodon*) *arvernensis*, *E.* (*Loxodon*) *meridionalis*, *E.* (*Loxod.*) *priscus*, and *E.* (*Euelephas*) *antiquus*, with *Rhinoceros leptorhinus*, *Hippopotamus major*, &c., are found associated together. In the Subapennine beds of the Val d'Arno, in Tuscany, *M.* (*Tetralophodon*) *arvernensis* and *E.* (*Loxodon*) *meridionalis* occur with the same *Hip-*

* See the Tabular Synopsis, Quart. Journ. Geol. Soc. vol. xiii. p. 319.

popotamus and *Rhinoceros.* Near Chartres, in France, *E.* (*Loxodon*) *meridionalis* accompanies *H. major* and *Rhinoceros leptorhinus.* The above-mentioned are necessarily the leading mammalian forms of the older Pliocene period. North of the Alps pliocene deposits similar to those of Italy occur in some parts of Switzerland, but they are soon overlaid towards the north by a distinct mass of erratic drift of a different age and with different mammalian remains. In the fluviatile "Loess" or "Lehm" of the valley of the Rhine, and in the Glacial Drift of the plains of Northern Germany, these post-pliocene deposits contain remains of the true Mammoth, with the tichorhine Rhinoceros, the Musk-buffalo, &c., which thus constitute the leading types of the post-pliocene mammalian fauna.

On the eastern coast of England, the Crag-deposits (the Red and Norwich Crags) yield the pliocene *M.* (*Tetralophodon*) *arvernensis, E.* (*Loxodon*) *meridionalis,* and *E.* (*Euelephas*) *antiquus*; and the so-called Elephant-beds at Cromer, Mundesley, and Hasborough furnish *E.* (*Lox.*) *meridionalis* and *E.* (*Euel.*) *antiquus,* with *Rhin. leptorhinus* and *Hip. major.* These characteristically pliocene fossils, however, are occasionally intermingled with the remains of the post-pliocene *E.* (*Euelephas*) *primigenius,* the latter fossils having been derived from the overlying and later drift-beds, which have thus proved a fertile source of the confusion and ambiguity already referred to. To some extent, similar conditions exist at Bracklesham Bay and Pagham Harbour, where molars of *E. primigenius* are found in the upper gravels, whilst remains of *E. antiquus* abound in the older mud-deposit, lately described in the Society's Journal by Mr. Godwin-Austen.

Dr. Falconer then considered the fluviatile deposits of the Valley of the Thames, in relation to their Elephantine remains; especially at Grays Thurrock and Brentford. At the former place the author recognizes the true pliocene assemblage of *E.* (*Loxodon*) *priscus, E.* (*Euelephas*) *antiquus, Hippopotamus major,* and *Rhinoceros leptorhinus*; but the group of mammals found at Brentford, according to the published determinations, indicate the close proximity of both the pliocene and post-pliocene faunæ at different levels of the same section. The Grays Thurrock deposits, and the lower beds at Brentford were inferred to be of an earlier age than any part of the Boulder-Clay or Till.

The grouping of the *E. primigenius, Rhinoceros tichorhinus, Bubalus moschatus,* &c., in the newer gravels of England and elsewhere was next dwelt upon, as affording an additional clue to the tracing of the several characteristic mammalian faunas over the European area.

To the possible objection of there being too many large Proboscideans grouped in one fauna, the author replied that the bones of Elephantine animals of three distinct species actually occur together in one stratum in Italy, and that six species are found in deposits of one age in the Sivalik hills.

Dr. Falconer concludes that the same mammalian fauna existed throughout the period during which both the Crag and the fluviatile beds of the Thames Valley were being deposited; and that a chronological division of the newer Tertiaries into older Pliocene, newer Pliocene or Pleistocene, and Post-pliocene is untenable; too much stress having been laid by authors upon the shell-evidence on this point. At the same time, it is not meant to be implied that all the species of the fauna ranged everywhere throughout the area: some in all probability were peculiar to the south, and others to the north.

The presence of *Hippopotamus major* in the pliocene deposits was pointed out as being of great importance in indicating the character of the pliocene land, which, extending between England and the Continent, must have afforded a great system of rivers and lakes, and probably had a comparatively warm temperature, as late as the deposition of the Grays beds, where also (as is well known) occur some southern freshwater shells, now extinct in England.

After some remarks on the negative evidence afforded by this mammalian fauna with regard to the supposed refrigeration of the land during the Pliocene period, Dr. Falconer reviewed the opinions of some English geologists on the physical conditions and faunæ of this region during the newer Tertiary epoch, especially the views of Mr. S. Wood, Mr. Prestwich, and Mr. Trimmer; and concluded with a few remarks on the occurrence of *E. antiquus* in the Cefn and Kirkdale Caves, and of *E. primigenius* in Kent's Hole, and on the non-existence of *E. primigenius* south of the Alps, and its restriction in the United States of America to the Northern and Central States. In the Southern States and in Mexico a distinct fossil species, *E.* (*Euelephas*) *Columbi*, hitherto undescribed, occurs along with remains of *Mastodon*, *Mylodon*, *Megatherium*, Horse, &c.

June 17, 1857.

Charles Preston Molony, Esq., Capt. Madras Army, Holles Street, Dublin, and George Robbins, Esq., Grosvenor Place, Bath, were elected Fellows.

The following communications were read :—

1. *On some* Comparative Sections *in the* Oolitic *and* Ironstone Series *of* Yorkshire. By John Phillips, M.A., LL.D., F.R.S., F.G.S., Reader in Geology in the University of Oxford.

[Plate VI.]

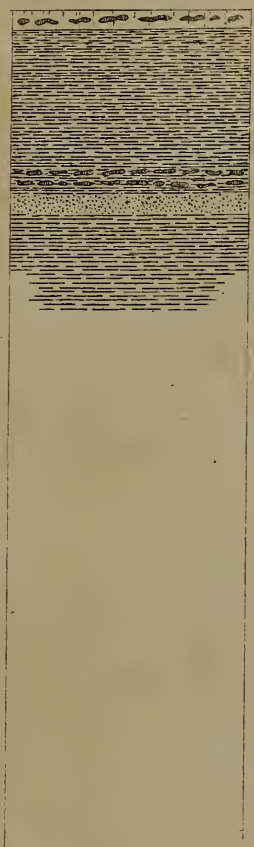
Introduction.—A geologist well versed in the Oolitic groups of the South of England or the North-west of France finds himself perplexed by the first aspect of the coeval strata in the north of Yorkshire, which are so rich in bands of ironstone, layers of coal, and hundreds of beds of gritstone and shale, as to resemble a tract of old carboniferous, rather than a terrace of oolitic rocks. Nor are the features and physical geography more similar in the two districts—broad mountainous moor-lands in one, rich corn-laden hills in the other. On further research, the strong contrasts which thus appear between the series of the north and south of England are found to

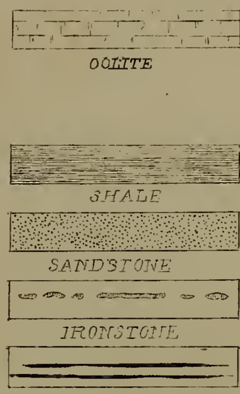
...A OF OOLITE & LIAS.

Fig. 1

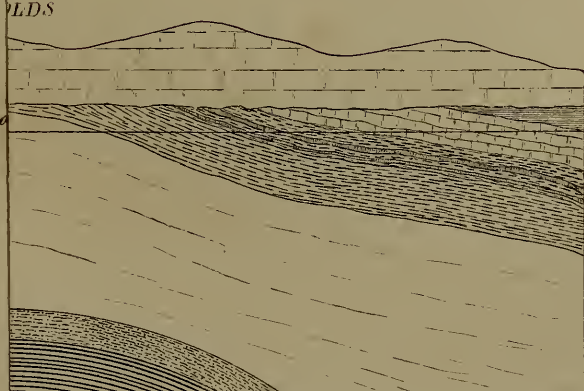
Fig. 5

LIAS AT THIRSK.





...N. TO S.



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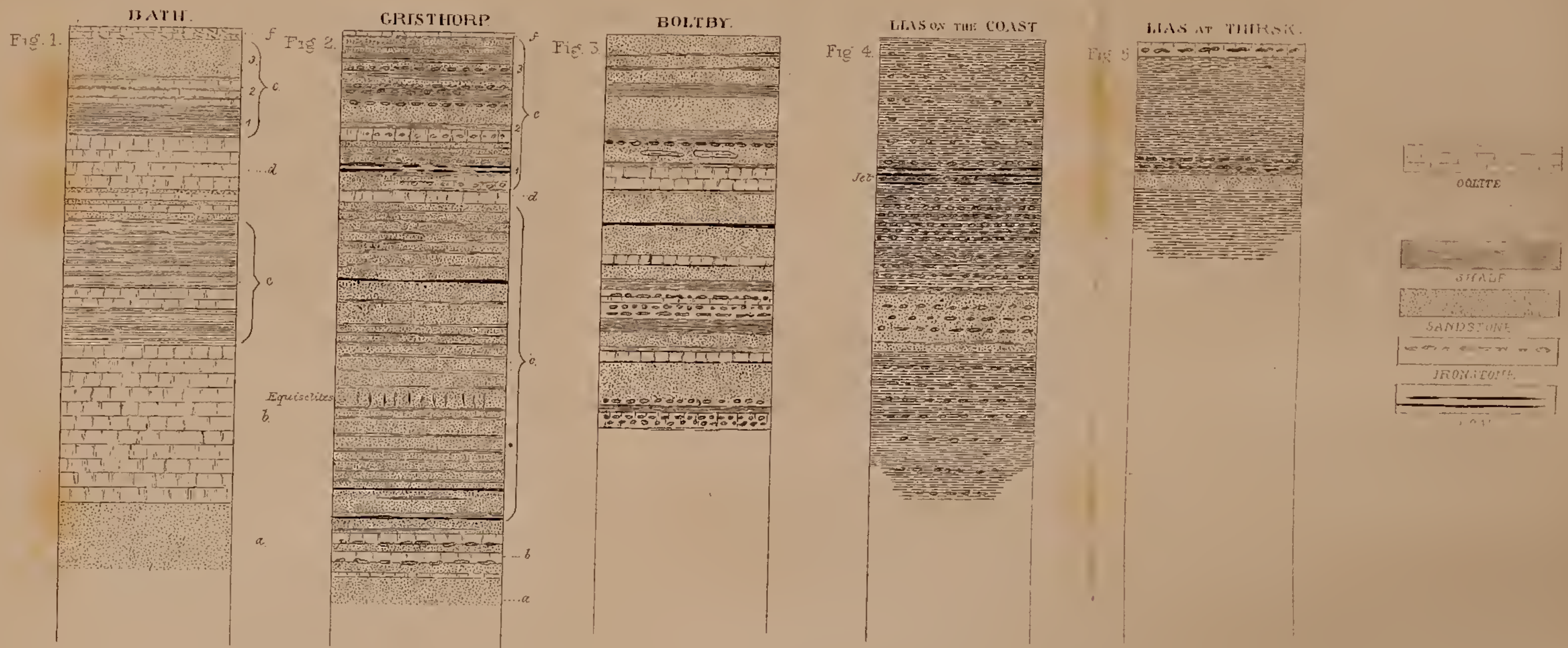
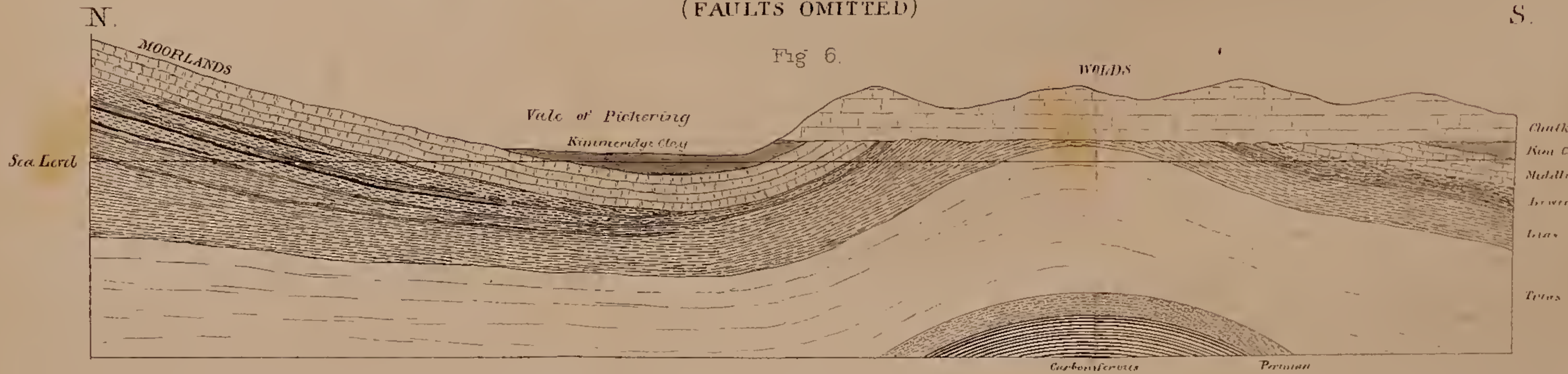
COMPARATIVE VERTICAL SECTIONS OF THE STRATA OF OOLITE & LIAS.



SECTION IN THE OOLITIC DISTRICT OF YORKSHIRE FROM N. TO S.

(FAULTS OMITTED)



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be most remarkable in the group of the Bath or Lower Oolite, though some peculiarities worthy of notice occur in almost every part of the section between the Chalk and the Triassic formations, and even extend to the Chalk itself. The author proposes, on a future occasion, to present a memoir on the Lower Cretaceous and Upper Oolitic deposits, including the Speeton Clay; but his remarks are now limited upwards by the Coralline Oolite and downwards by the Lias, both included. And they relate to the deposition and succession of strata, with some references to the distribution of organic life.

It is now above thirty years since, following the steps of William Smith, I began to draw the parallels of geological time from the south of England into the north-eastern district of Yorkshire. Separated as these districts are by the nonconformity under the Yorkshire Wolds, and still more alienated by modifications affecting more or less all the strata, it was necessary to use great caution in selecting the principal lines of contemporaneity. Guided by the evidence of organic remains and the succession of strata, we traced in the first place the continuous area of the Lias, and marked the place and value of the Marlstone, which Smith, first of all observers, had characterized near Bath. We then defined the Kimmeridge Clay, Coralline Oolite, Calcareous Grit, and Oxford Clay, and beheld with surprise a rock 60 or even 90 feet thick replacing the weak sands of Christian Malford, and holding in abundance the peculiar fossils of Kelloway Bridge. Even this was not achieved without some difficulty; for the Coralline Oolite of Malton contains several fossils identical with, and others not easily separated from, frequent residents in the Inferior Oolite.

Beyond this every fresh step was difficult at that time, and requires wary movements at the present moment.

In my work on the Yorkshire Coast, published in 1829, the section of the cliffs was taken as a type, and the results then affirmed, after three complete surveys of the whole coast, have met with general acceptance. In one important point they have, indeed, been employed by some of my friends with quite as high a trust in their contents as I ever felt,—for I have always regarded as a bold decision my reference of the grey limestone series of White Nab to the Forest Marble and Great Oolite of Bath; and the shelly sandstones of Blue Wick to the Inferior Oolite of Somersetshire (see edition 1, 1829).

On another point, the fixing of the Brandsby slate on a parallel above the assumed Great Oolite, though no doubt has been publicly expressed, my friends can hardly have avoided feeling it; for this rock is analogous to the Stonesfield slate, and that lies under the Oolite of Bath. By three separate investigations I have assured myself of the accuracy of my first determination; and thus, if the place of the Great Oolite be rightly given in the sections of Yorkshire, the Brandsby stone is an equivalent of Hinton Sandstone or Forest Marble.

It is not, therefore, for the purpose of a formal correction, or of an implied amendment of my published sections, that I offer this paper; but for the purpose of recording variations in the deposits, within the limited area chosen, which may throw light on the history of this peculiar type of the Oolites. This history has now acquired other points of interest than those long known to belong to it. The bands of ironstone which were noticed in several parts of my sections, and which, gathered in fragments on the beach, yielded a few hundred tons of iron in a year, when transported to Newcastle, are now so much explored in many of the interior hills and vales, as to feed long ranges of blast-furnaces on the Tees, and send half a million of tons of ore in a year to the great iron-works in the west of Durham, by railways which bring back in return 100,000 tons of iron. In a few years this vast "yield" will be doubled or trebled, for the iron-ore is inexhaustible, and what is now worked is much surpassed in richness by some as yet only beginning to be known.

It must not be supposed that in every part of the district the Lower Oolites of Yorkshire fit themselves to any one section assumed as a type of their development in the north-east of the county: on the contrary, there occur great variations. Neither can the Bath type of the Oolites be adapted to the Midland districts of England, without some important changes. I propose to show, in the first place, what are the principal differences in Yorkshire, and, by comparing these with the sections in North Lincolnshire and Oxfordshire, to show how real is the connexion and how great is the variation of the several parts of this large Oolitic field.

The Yorkshire coast furnishes one complete section of this series, measurable in every part, which has again and again been measured and remeasured by myself, both before and since the year 1829, the year of the publication of the 'Illustrations of the Geology of Yorkshire.' I have no material change to make in this section; but in regard of the beds at Gristhorpe, which correspond to the Bath Oolite and the strata between it and Cornbrash, some details will be useful which were not needed in that æra of geology. Prof. W. C. Williamson * and Prof. J. Morris † have already contributed some observations on this remarkable section, but they do not render it undesirable for me to give measures in detail.

Coast Sections near Scarborough.—A vertical section of the beds on the Yorkshire Coast from the base of the Kimmeridge Clay to the top of the Lias, taken by measure from the face of the cliffs, with only the addition of the Upper Calcareous Grit in Silpho Brow, which is near the coast, is about 1120 feet in thickness, of which 420 feet belong to the Middle Oolitic formation in the subjoined proportions:—

		feet.
Middle Oolite formation.	Upper Calcareous Grit (not seen on the coast, but observed at Silpho, Pickering, Sinnington, &c.)	60+−
	Coralline Oolite	60
	Lower Calcareous Grit	80
	Oxford Clay	150
	Kelloway Rock (It is thicker in other places.)	50 to 70

* Trans. Geol. Soc. 2 ser. vol. v. p. 223; and vol. vi. p. 143; Proc. vol. ii. p. 429.
† Quart. Journ. Geol. Soc. vol. ix. p. 317.

On comparing this with the corresponding section of the south of England, it may be remarked, that only near Weymouth is the Upper Calcareous Grit well exhibited, and that it is there associated with Kimmeridge clay, and contains, like it, *Ostrea deltoïdea*. I have seen this once in the Vale of Pickering in Yorkshire. Again we remark the extraordinary development of Kelloway rock in Yorkshire, to ten times its dimensions in Wiltshire; while, on the other hand, the Oxford clay is reduced to one-fourth of the thickness which it has in the Midland Counties, and is a much more sandy and much less fossiliferous deposit. We now proceed to consider the Lower Oolitic formations. (See Sections 1 and 2, Pl. VI.)

Section No. 1 is the well-known general section of the Lower Oolitic series near Bath, as it was understood and named by Smith. Section No. 2 is the corresponding series in Yorkshire.

	No. 1.		No. 2.
f.	Cornbrash.	*f.*	Cornbrash.
e.	3. Hinton Sandstone.	*e.*	3. Shales, sandstones, ironstones; plants.
	2. Forest Marble.		2. Shelly oolitic beds, ironstone; &c.
	1. Bradford Clay.		1. Shales, sandstones, ironstones; plants, coal, freshwater shells.
d.	Great Oolite.	*d.*	Oolite of Gristhorp.
c.	Upper Fuller's-earth clays.	*c.*	Shales, sandstones, ironstones.
	Fuller's-earth rock.		Beds of coal, plants sometimes erect.
	Lower Fuller's-earth clays.		
b.	Inferior Oolite.	*b.*	Dogger and oolitic ironstone.
a.	Sands over the Lias.	*a.*	Sands of Blue Wick.

The two sections being drawn to occupy the same vertical space, the enormous extension of the sandy and the great contraction of the calcareous portions in Yorkshire, corresponding to the more littoral character of that region, is very apparent. There is also very little "clay," as the term is used in the south of England, in this section in Yorkshire; it is usually more shaly, often more sandy or even streaked with sandstone laminæ, so as to resemble what is called "lin and woon" in Lancashire. The following observations supply a few details regarding the several groups *f* to *a*.

f. Cornbrash.—This is often not above 2 feet 6 inches thick, and in this small thickness is a parting. The top is ferruginous, and mostly very shelly; the lower part is shelly, and often contains root-like bodies at the bottom. Pale blue clay 4 or 5 feet below.

In the strata (*e* 3) immediately below Cornbrash, clays and shales predominate over sandstones for about 80 or 100 feet; then we have for the base of this series about 20 or 30 feet of sandstone, resting on pale clays, full of oblique lamination, often containing fragments of wood. The following is a summary of the beds as they appear in Gristhorp Bay,*, south of the island, the thicknesses being sometimes measured, sometimes estimated. Total 121 feet 10 inches.

* In one of my later examinations of the Gristhorp Section, I received no small help from Mr. Peter Cullen.

		ft.	in.
f.	Cornbrash above.		
Sandy and slaty beds below Cornbrash: about 121 feet 10 inches. *e* 3.	Pale clay, with some root-like masses resting on dark shaly clay	5	0
	Thin skerry sandstone	0	4
	Pale clays ... 3 ft. to	6	6
	Skerry sandstone and shale, changing to solid sandstone ... 1 ft. to	6	0
	Shale, darkens at the bottom	14	0
	White sandstone—"pipy"—with two thin partings	5	6
	Shale, growing *dark* at the bottom	6	0
	Pale blue shale and laminated white sandstone (in one place ironstone)	8	0
	Alternations of pale bluish and purplish shaly clay	9	0
	Thin sandstone; Series of pale bluish and purplish shaly clays, with bands of nodules of *granular iron-ore*	29	6
	Variable grits and shales	8	0
	Variable sandstones, with layers of wood, the top very irony; it is *unconformed* on the beds below ... 12 ft. to	20	0
	Pale clays, with a band of jet and some lumps of ironstone at the bottom	4	0

The thicknesses are all variable in a short distance, and the beds of sandstone vary in quality in a few yards.

On the north side of the island, the lower part of this series, below the granular iron-ore bands, appears as under :—

	ft.	in.
Sandstone	4	0
Shale	5	0
Sandstones, with shale partings	5	0
Sandstones and shales, in wedge-like alternations; the lowest shale very dark ... 16 ft. to	21	0
Irregular sandstone, with partings of shale and layers of wood, in the state of jet or coal	12	0

This rests unconformedly on the subjacent series, *e* 2.

In the whole of this series, no special plant-bed has been recognized in the Gristhorp section, nor have any shells been seen there. North of Scarborough, Cycadaceous leaflets occur in a brown ironstone about 40 feet below Cornbrash, and at Scalby Beck is a layer of the leaves which I called *Sphænopteris latifolia* (Geol. of Yorkshire, ed. 1. p. 148, pl. 7. fig. 18).

e 2.—The beds thus designated are only seen in a complete state on the south side of the island at Gristhorp; on the north side of the island the top was removed by denudation before the lowest beds of *e* 3 were deposited.

Section of the series of subcalcareous and ferruginous beds (*e* 2), some of them yielding marine shells, in Gristhorp Bay, south of the island :—

		ft.	in.
Fossiliferous Beds. *e* 2.	Hard sandy bed, irony at top, with decomposing bisulphuret of iron and some jet	1	3
	Grey streaky sandstone, with some decomposing bisulphuret	2	0
	Brown laminated, partly ferruginous, bed	2	0
	Grey sandy shales, sulphureous	2	6
	Ironstone-balls in a band (*Avicula Braamburiensis*)	1	0
	Subcalcareous, partly shelly, bed	2	0
	Ironstone-balls in a band	0	6

		ft	in.
Fossiliferous Beds. e 2.	Calcareous bed, with *Belemnites Aalensis* at the top, *Ostrea Marshii*, &c.	2	4
	Sulphureous laminated shale, with nodular ferruginous top	1	8

On the north side of the island, as already observed, the upper part is wanting—the uppermost bed seen is the band of ironstone-balls with *Avicula*.

The next series of beds, marked *e* 1, is found nearly alike on both sides of the island in the upper members, but very unlike in the lower members.

Commencing in the south, we have, mostly of freshwater or estuary origin,—

		ft.	in.
	Hard sharp laminated sandstone, with thin lines of shale and distinct vertical joints	5	0
	Shale, dark and "coaly" at top and bottom, the middle occasionally resembles "seat earth"	5	0
	"Pipy" white sandstone, passing downward to "seat earth," and still lower to shale with ironstone pins	5	0
	Lumpy sandstone, partly dotted with ironstone, jet, and wood. Forms resembling *Lutraria*, *Modiola*, but not known for certain to be organic ... 2 ft. 6 in. to	4	0
Coal Series.	Dark laminated curled Coal shale, with many *plants*, and especially *Equisetites columnaris*. Here is a "sulphur* line"	1	8
	Sandy grey laminated shales, or sandstone, a little pipy	2	0
	Shales, with a thin sandstone layer and dark Coal bands, many plants ... 8 ft. to	9	0
	Sandstone laminated with shale lines and lumps—thin coaly layers, *Equisetites*, and other plants	4	0
	Sandstone with thin partings, bands, and lumps of iron-ore, and plants,—very variable in thickness and composition.	20	0

Below is the Oolite with *Cricoporæ*, marked *d*.

In the cliffs on the north side of the island we have, wholly or mostly of freshwater or estuary origin,—

			ft.	in.
	Brown sharp laminated sandstone, with fine shale		5	0
	Pale shale	4 ft.	6	0
	Dark shale	2 ft.		
	Soft pipy sandstone	2 ft. 6 in.	4	3
	Pale pipy shale	1 ft. 6 in.		
	Dark shale	1 ft. 3 in.		
	White pipy sandstone		3	3
Coal Series.	Dark shale and Coal in waved laminæ (*Equisetites*)	6 in.	1	10
	Pipy pale sandstone	10 in.		
	Coaly shale	6 in.		
	Laminated shaly sandstone or sandy shale		1	10
	Pale laminated sandstone and shale	1 ft. 6 in.	8	5
	Dark laminated shale	1 ft. 3 in.		
	Lumpy white sandstone	1 ft. 9 in.		
	Pale shale, with very fine and numerous plants and ironstone pins,—Anodon	1 ft. 8 in.		
	Shale with Coal streaks (pyritous layer at top)	1 ft. 3 in.		
	Coal bed, crossed by "cleat," and of marine or mostly marine origin	1 ft.		

* Such yellow lines are marked by efflorescent sulphate of iron and some free sulphur, derived from decomposed bisulphuret of iron.

		ft.	in.
	Sandstone with partings of shale, the top "pipy," the bottom laminated;—*Tancredia*, *Modiola*, &c.	4	6
	Soft clay ... 6 in. Pale shale with *Brachyphylla* and other plants. 1 ft.	1	6
	Ironstone in shale, with *Trigonia*, *Cardinia*, &c., *in situ*	1	0
Sandy bed, 5 ft., including	Ironstone top, containing *Trigonia*, *Pinna*, *Gervillia*, and *Pecten*	1	0
	Sandstone with ironstone pins and small shells	2	6
	Grey sandy part	1	6
	Nodular ironstone in laminated shale, with *Modiola*, &c. Here sulphuret of zinc occurs in nodules and in shells	5	0
	Sandy bed, with ironstones and many shells of *Pholadomya acuticosta*, *Lima gibbosa*, &c.	1	0
	Shale with *Pholadomya*, *Ostrea*, *Avicula*, *Natica*, &c.	1	3
	Skerry sandstones and shale with scattered plants;—*Pholadomya*	4	0
	Shales with some ironstone in the lower part, scattered traces of plants;—*Pentacrinus*	12	0

Below is the Oolite *d*.

d.—The oolite with its upper laminæ of *Cricopora* has been estimated at 15 feet. It seems not necessary to enter into details regarding it at present. It may be recognized at the point north of Cayton Bay and at Cloughton, though the superincumbent strata are widely different at these two points. Either this or the beds marked *e* 2 appear in all the region to the north as far as Whitby, to the north-west as far as Ingleby, and to the west as far as Thirsk, from whence it can be traced to the southward.

c.—The series below these oolitic beds has been sufficiently detailed in the 'Illustrations of the Geology of Yorkshire.' It consists, from Cloughton northward, in the upper part, of a thick series of sandstones and shales; the sandstones are regular, solid, partially laminated, some containing jet, some waved, some containing branching forms like fucoids. The series changes below to the more usual aspect of shales and sandstones which accompany coal, several rich plant-layers occur, and at about 100 feet deep in it coal is observed.

Thick sandstones succeed, 60 feet.

A series of sandstones and shales, 200 feet. Vertical *Equisetites* in places. COAL.

Grit rocks and thin shales, with ironstone bands and *Cycadaceæ*, 60 feet.

b.—Inferior oolite.

This is represented on the coast by about 70 feet of sandstone—of which

30 feet are fine-grained yellow, micaceous, irony sandstones, in large blocks variously bedded and jointed, containing several layers of pebbles and shells; the top is very irony, but without fossils. *Nerinæa*, *Actæon*, *Trigonia*, *Astarte*, and many other shells.

20 feet are fine-grained yellow micaceous sandstone, with nests or irony masses of *Serpulæ*, *Lingulæ*, &c. (*Lingula Beanii*).

20 feet are grey and micaceous, soft and argillaceous sandstone, mostly laminated and fissile, gradually passing into the Lias shale below. Irony nests of *Serpulæ*, *Belemnites*, *Aviculæ*, *Pinnæ*, &c. (*Facies liassic.*)

Lias shales below.

Inland Section, Hambleton Hills.—We may now refer to a corresponding section within the same geological limits, taken from the ancient sea-cliff—now a bold inland escarpment—of Hambleton, within a small distance of Thirsk. The total thickness of the oolitic series above the Lias is 859 feet.* The Middle Oolite formation consists of

	feet.
Upper Calcareous Grit, as in Wass Bank	60
Coralline Oolite	60
Lower Calcareous Grit	100
Oxford Clay	30
Kelloway Rock, including argillaceous beds at bottom	100 or 120

Section No. 3, Pl. VI. represents the Lower Oolite formation in this district. The Cornbrash is not seen here; its place is assumed, with great probability, at about 120 feet below the top of the Kelloway rock.

		ft.	in.
	f. (Cornbrash, place of.)		
Sandstone and Shales, 182 feet.	Purplish and grey shales, yielding springs; Yellowish sandstone; Grey shales and white sandstone	80	0
	Fire-clay. Plants	2	0
	Shales and sandstone. Plants	20	0
	Sandstone, white, yellow, fine-grained	35	0
	Grey shales	15	0
	Brown iron-ore (rich)		
	Ferruginous sandstone, including towards the base lenticular aggregations of shells (*Avicula*)	30	0
Calcareous group, 37 ft. 6 in.	Sandy laminated shale, with shells at bottom	6	0
	Rough nodular shales, with *Ostrea Marshii* at bottom	4	0
	Shales	2	0
	Solid gritty calcareous beds ("glance")	8	0
	Irony argillaceous purple bed	0	9
	Brown laminated sands	0	3
	Blue solid calcareous bed	4	0
	Shale and layers of *Ostrea crassa*	3	0
	Shale	6	0
	Shale and laminated sandstone	3	0
Grit, Shale, and Coal Series, 122 ft.	White soft sandstone	32	0
	Light-coloured thin sandy laminæ	3	0
	Carbonaceous shale or fire-clay (elsewhere Coal in this stage)	4	0
	White gritstone	40	0
	Yellow sandstone	25	0
	Rough nodular calcareous bed ("glance"), with *Avicula*	2	0
	Rubbly sandstone. (*Nucleolites*)	18	0

* I have had the advantage of being accompanied in my late surveys of this tract by the Rev. C. Johnstone, Dr. Verity, and Mr. C. Strickland.

		ft.	in.
Ironstone Series, 147 feet.	Grey shale	10	0
	Shale and small pale ironstone pins, with one thin layer of *shelly* sandstone	12	0
	Cement-stone — pale-coloured limestone in cuboidal blocks. (*Glyphia*)	3	0
	Dark shale, with ironstone balls. (*Pecten*)	12	0
	Iron-rock or compacted balls	3	0
	Shale, yellowish-grey and dark	20	0
	Sandstone (Pearson's quarry)	12	0
	Shales	20	0
	Cement-stone nodules	1	0
	Pale clay	1	0
	{ Sandstone, brown, yellow, &c.	40	0
	{ The lower part sometimes very ferruginous	3	0
	Shale and ironstone balls	3	0
	Ferruginous and shelly oolite, resting on upper lias	7	0

The total thickness of the Lower Oolitic Series is thus found to be 489 ft. in this combination.

If we now compare these sections measured on the actual coast and against the ancient sea-cliffs, we find in regard to the Middle Oolite formation only differences of thickness; the Oxford Clay being remarkably thinner near Thirsk, but the Kelloway rock thicker. But in all the strata below the Cornbrash the differences between the two sections are very great.

The Cornbrash, as seen on the Yorkshire coast, is never above 5 feet thick. It contains several distinguishable parts—a thin part at the top rather laminated, and a part at the bottom, argillaceous, or actual clay; while in the middle is one thick mass, or two beds, of shelly and somewhat ferruginous limestone, hardly oolitic. It contains *Nucleolites orbicularis, Myacites securiformis, Ammonites Herveyi*, and many other shells, but hardly a trace of *Belemnites*. Near Thirsk, and for a great breadth of the moorlands eastward of Hambleton, I have not clearly seen it. It is, however, conspicuous in Newton Dale, and thicker than on the coast.

The series of sandstones and shales between the Cornbrash or Kelloway rocks and the calcareous beds which first succeed below, yields on the coast two bands of ironstone, and contains *Cycadaceæ*; and one band (rich brown iron-ore) appears near Thirsk.

The calcareous shelly beds below, which occur on the coast, and seem to lie in the place of the Forest Marble group of the south of England, appear under Hambleton at the base of the carbonaceous sandstone, and may perhaps be regarded as including the shelly nests in the lower part of the sandstone. A bed of *Ostrea Marshii* occurs in both situations, near the middle part of the shelly series; a bed of *Ostrea crassa* lies towards the lower part at Hambleton; but *Belemnites* and *Terebratulæ* have not been seen there, as at Gristhorp and Cloughton.

Below this point there is great difficulty in tracing lines of contemporaneity across the district from the coast to the inland cliff. If we suppose, in conformity with many observations, the Gristhorp plant-bearing series to be merely a local deposit, not seen at any point north of Haiburn Wyke, nor in Staintondale Cliff, the grit, shale, and coal of Hambleton, 164 feet thick, will be below the whole of the Bath Oolite, and correspond to the Haiburn coal series.

What in this case is the rough nodular "glance" oolite (2 feet) with *Avicula*, resting on rubbly sandstone, with *Nucleolites*, 18 feet? Is it of the date of Stonesfield slate?

The Cricopora-beds of Gristhorp, below the coal series there, lose their distinctness in going northward and westward, so that they become untraceable; on the other hand, we find the Belemnitic beds to fail entirely toward the southward and westward. On a line which runs north and south between the coast and the Hambleton Cliff, and which thus partakes of both these negative geographical influences, neither of them is yet certainly known, though we may expect to find the upper set of beds; nor have we on that line any trace of the Gristhorp plants. The rough nodular "glance" bed is recognized, as I think, on the line of the Whitby railway, about 100 feet below the shelly beds of the Bath Oolite.

Still less obvious are the lines of contemporaneity lower down in the thick series above the Inferior Oolite, when compared on the two parallels from north to south. On the coast are sandstones and shales, with zones of plants, but no calcareous bands, and no remarkable ironstone; under Hambleton, with a smaller thickness of arenaceous and argillaceous sediments, we have one or even two groups of white cement-nodules (compact argillaceous limestone), one containing *Glyphiæ*, a group of valuable ironstone-nodules, and even a 3-foot band of ironstone. These deposits are only seen in the western range of the Oolites.

The lowest part of the Bath Oolite formation on the Yorkshire coast consists of the ferruginous "dogger," with two bands of shells at the Peak; under it is a group of grey, micaceous, soft, sandy rocks, apparently the "Gold Cap Sandstone" of Lyme Regis, "Sand of the Inferior Oolite" of Bath, and of the Cliff-hill of Lincolnshire. Under Hambleton these are represented by ferruginous oolites, containing *Ammonites*, *Hyboclypeus*, *Trigonia*, &c.; but this character of the rock, by which it approximates to the lower part of the sections of Inferior Oolite in Gloucestershire, ceases as we proceed northward, and is modified as we proceed southward.

On a line drawn from north to south between the coast and the Hambleton, we find the oolitic band at the top of the Lias very rich in iron. In a part of Rosedale, especially, it is an *oolitic iron-rock*, the central part of a great mass on one side of the valley being very attractable by the magnet, and yields, at a maximum, about 50 per cent. of iron.

Other Inland Sections.—We may now proceed to trace briefly the variations which take place in proceeding southward from the country of Thirsk toward the Humber and Lincolnshire, where something nearer the normal type of the Bath Oolites is recognized.

Kilburn.—In the vicinity of Hood Grange, Hoodhill, and Kilburn, the oolitic limestone (*d*) is frequently quarried; and below it, especially on the southern slope of Rowlston Scar, coal has been obtained within the memory of man only a few feet below the oolite.

About Carlton, Coxwold, Newborough Park, and Owlton, the limestone is frequently exposed and dug in quarries; and here also coal has been found below it. At Newborough Park it was about 50 feet below the oolite, which is dug and burnt to lime.

Brandsby.—Proceeding southward from the country of Thirsk to the parallel of Easingwold, in the Howardian Hills, about Brandsby and Gilling, we find the remains of old coal-works, ranges of limestone, and quarries of roadstone, presenting on the whole the following section:—

	ft.	in.
Sandy series, yellowish Roadstone, 2 or 3, or 4 or 5 feet; laminated sandy glance-limestone, often full of shells, often in broad flat nodules, lying in soft yellowish sand Springy sandy clay below	50	0
Sandy series Soft shelly sandstone (at Brandsby) Sandy series	30	0
Hard laminated sandy glance-limestone	4	6
Pale clay	1	3
Ironstone	0	2
Pale clay	3	0
Solid limestone beds, 2 ft. 6 in. each Springs and clay below	9 ft. or less.	
Shale and carbonaceous grits. Signs of COAL	50	0

On Gilling Moor a section is reported by Mr. Winch, 'Geological Transactions,' First Series, vol. v. p. 545, &c., to the depth of 179 ft. 6 in., commencing with—

	ft.	in.
Limestone	9	0
Grits and plates	27	0
Hard blue "Calliard"	2	0
Coal (a trace).		
Plate and soft grit	30	0
Blue limestone	4	0
Grits and plates	99	0
Coal	0	6
Shale	2	0

At no point further to the south-eastward has the coal-seam been found worthy of opening,—it has indeed scarcely been traced; but the oolitic limestone, a few yards or fathoms below which it lies, continues distinct, and is quarried almost in a connected line, by Colton, Dawby, and Terrington, to Bulmer and Crambe. The roadstone is found above it distinctly only a short distance, and can scarcely be identified beyond Terrington and Wiganthorpe. At Welburn, Bulmer, and Crambe, white cement-stones occur below the Oolite, as near Thirsk; and below these are oolitic ironstone and ferruginous sands, corresponding to the Dogger-series of Thirsk and the coast; but the strong white gritstones and most of the shales which lie between the Oolite and the Lias about Brandsby, Kilburn, and Boltby are almost absent from the banks of the Derwent.

Crossing the Derwent, we trace in like manner the Oolite by

Westow to its disappearance (through unconformity) below the chalk at Kirby-under-dale. The rock emerges again from its cretaceous covering at Sancton, near Market Wrighton, and is traced to Brough-on-Humber, where it is quarried above grey partly micaceous sand and sandstone, and is evidently equivalent to the Oolite of Lincolnshire, which appears on the opposite shore of the Humber, and rests on sands, grey, red, brown or white, as these do on the Upper Lias.

The only example which I propose now to present of the Lincolnshire sections is that of Harpswell Hill, north of Lincoln, which was traced by myself in 1821, from the actual road-cutting*. The series begins with—

Bath Oolite Series.	White oolitic limestone	30 feet.
	Pale clay and sand	12
	White sand	3
	Sandy with iron-balls	10
	White micaceous sand	3
	Brown sand	4
	Clay parting	
	Brown sandstones and shells	40
	Blue Lias clays, succeeded by marlstone and lower lias ... exposed	20

Above the white oolite are clays and thin stony beds of the Forest Marble series and Cornbrash. These have been fully illustrated in South Lincolnshire by Prof. Morris†, and are found again with similar characters at many localities in Oxfordshire. This white oolite is perhaps generally admitted to be the Great Oolite of Bath,—a point on which I reserve my opinion; it is certainly represented in Yorkshire by that of Cave, Westow, and Crambe.

The Lias Formation.—The Lias varies not so much as the Oolites in a given geographical area, because for the most part its materials were accumulated from long and widely suspended fine argillaceous sediment. The main differences observable in Yorkshire relate to the upper part of this great series, and may be sufficiently illustrated by three actual sections, representing the succession of beds seen in the cliffs about Whitby,—measured in the works at Eston Nab,—and explored in a boring at Feliskirk, near Thirsk.

The Lias of the Yorkshire coast is exhibited in a complete and magnificent section through all the upper and middle parts of the lower groups for above 500 feet in thickness; about 300 feet of beds still lower being imperfectly traced in the interior. In general terms the series‡ stands thus (see Section No. 4, Pl. VI.):—

Upper Lias Shales, 200 feet.	Alum-shale (80+feet), including cement-nodules and ironstone-nodules. In the upper parts, gradually diminishing downwards, are *Discina reflexa*, *Nucula ovum*, *Ammonites bifrons*, *A. heterophyllus*, and *Belemnites tubularis*. Abundance of Enaliosaurians.

* See Memoirs of W. Smith, p. 97.

† Quart. Journ. Geol. Soc. vol. ix. p. 317.

‡ See Illustr. of Geol. of Yorkshire. Also a section of the Upper Lias and Marlstone, communicated to the Geological Society, by Mr. L. Hutton, 25th May, 1836; Geol. Proc vol. ii. p. 41. This is an elaborate series of the Lias in Rockcliff.

		feet.
Upper Lias Shales, 200 feet.	Shale with nodules .... 60 to	80
	Jet-rock—shale with jet and pyrites	20
	Hard sandy shale .... 20 to	40
Ironstone and Marlstone Series, 150 feet.	Ironstone-band, or ironstone-rock, with irregular partings of shale. (*Avicula cygnipes, Pecten æquivalvis*) .... 15 to	25
	Shales and ironstone-bands........................ 50 to	70
	Sandstone and shale, with *Ophiuridæ, Cardium truncatum*, and many other fossils	40
	Sandstone and shale	30

Lower Lias Shale below.

The details of the great ironstone-bands above the marlstone appear in the following section, measured from the workings at Eston Nab*, and communicated to me by Mr. John Murley, C.E. These beds yield about 50,000 tons to the acre.

	ft. in.	ft. in.	ft. in.
Ironstone: top block left as roof	0 11		
(parting)			
Ironstone: second block..........................	2 3		
(parting)		17 0	
Ironstone: main block	12 0		
(parting)			
Ironstone: bottom block (variable)	1 10		32 6
Shale...	7 0		
Ironstone-band..................................	1 8	15 6	
Shale...	6 0		
Ironstone-band..................................	0 10		

At Grosmont, near Whitby, the same series stands in this altered and divided state, with about 8 feet of ironstone, yielding about 20,000 tons to the acre.

	ft. in.
Shale	
Ironstone, "*Pecten*-seam" in two bands, separated by 1 ft. 6 in. of shale	4 0
Shale	4 0
Ironstone: good	1 0
Shale	7 0
Ironstone: good	1 6
Shale	18 0
Ironstone: "*Avicula*-seam"............................	4 0
	38 6

At Feliskirk, in the vicinity of Thirsk, a trial-bore was made, by my advice, through the upper lias, to the ironstone and marlstone, with the following result. The upper bed mentioned is the Inferior Oolite capping the Lias, as at Thirsk, here very ferruginous (see Section No. 5, Pl. VI.):—

	ft. in.
The oolitic iron-rock of Mount St. John .... 6 to	7 0
Shale, in the upper part cement stones	116 0

* An analysis of the Cleveland iron-ore from Eston is given in Mr. Dick's paper, Quart. Journ. Geol. Soc. vol. xii. p. 357. See also Mr. Crowder's papers, Edinb. New Phil. Journ. New Ser. vol. iii. p. 286, and vol. iv. p. 49.

	ft.	in.
Upper nodular band of ironstone	0	7
Shale	3	0
Lower nodular band of ironstone	0	6
Shale	7	6
Marlstone	1	9
Sandy shale	20	0

Farther to the south this poor representation of the great Ironstone and Marlstone series of the Yorkshire coast is traceable; until in Lincolnshire, Rutland, and Northamptonshire it resumes much of its thickness and importance, though not as yet its commercial value.

Conclusion.—On reviewing the facts here selected to illustrate and exemplify the variations of the middle and lower Oolites, and upper and middle portions of the Lias of Yorkshire, we find sufficient grounds to mark out approximately the geographical ranges of some remarkable mineral conditions—and accumulations of organic remains,—indicative of peculiarities in the depth and currents of the sea, the direction and proximity of land, and other great characteristics of the mesozoic period in this part of the earth's surface.

Reserving for another communication the development of this subject, which cannot be properly examined without additional details, I desire to call attention in the mean time to a few prominent data. (See Section No. 6, Pl. VI.)

The whole series of strata from the Cornbrash to the Marlstone, inclusive, grows thinner towards the south, and in a less degree towards the west; so that from the sea-coast near Whitby to the hills near Thirsk the thickness decreases from 1000 to 590 feet. This appears in each of the main groups. Near Whitby and Guisborough the marlstone and ironstone occupy 150 feet of the cliffs; but near Thirsk only a few feet. The Upper Lias measures 200 feet near Whitby, but near Thirsk less than 120 feet; and in this general diminution each part partakes,—though perhaps the upper part, which is the favourite seat of *Nucula ovum* and *Ammonites bifrons*, has been most severely truncated.

The great series of sandstones, shales, coal-plants, and ironstones, lying above the Lias and below the Oolite of Gristhorp, 500 feet thick in the Peak and the grand range of cliffs at Staintondale, is only 270 feet thick near Thirsk, and is further reduced near Brandsby, until on the banks of the Derwent it is scarcely traceable. The upper carbonaceous series of the coast is of nearly the same thickness at Thirsk, on a line from east to west; but the Oxford Clay diminishes from above 100 to less than 30 feet.

Lines may be drawn in directions not deviating much from E.N.E. to W.S.W. which shall coincide with bands of equal deposition, or equal disappearance, of particular mineral sediments, and particular distributions of organic life. For these lines—as defining equality of earthy sediments,—and thus sometimes marking out similarity of sea-depth and current-action—the author proposes the term "isochthonal," and is of opinion that the tracing of them will hereafter tend much to increase our knowledge of the physical conditions of definite epochs in geology. In the present case the normal to these lines, directed to the N.N.W., appears to the author to indicate the existence of land in that quarter during the whole of the period now under consideration,—land at no great distance, because of the proportion of many of the plants,—the occurrence of *Anodon* and other inhabitants of fresh or brackish water,—and the occasional vertical position of *Equisetites*. These latter facts, indeed, may require the admission of the presence of low marshy land within the area in question; but the author is more impressed by the probability of high and extensive land, which might yield to rivers, of some magnitude, the enormous mass of quartz-sand and mixed ferruginous sediments which abound between the truly marine limestones and subcalcareous shelly bands. It seems necessary to suppose some old palæozoic land towards the north, not eminently granitic, but rather of the argillaceous, arenaceous, and quartzose type, with intermixed trap-rocks, such as the Lammermuir Range, which is now so abruptly truncated on its eastern side.

If an isochthonal line be drawn from near Thirsk to Robin Hood's Bay, it will be found that on the north-western side the ironstone band at the base of the Upper Lias is valuable for working—its value growing greater to the north-west.

Nearly on this line the Inferior Oolite receives its maximum dose of iron, growing more and more sandy to the north-west, and losing its thickness and character to the south-east.

If a line be drawn from near Coxwold to Scarborough, parallel to the preceding, it will nearly coincide with the north-western limit of really oolitic character in the calcareous beds of Westow and Gristhorp, and with the south-eastern limit of the coal and freshwater deposits of the district. For a limited breadth north-west of this line, *Belemnites Aalensis* is found in the upper calcareous beds of the Gristhorp series—a position much above what is usual for this shell,—and it is associated at White Nab with *Ammonites Blagdeni*, equally a species more common in the Inferior Oolite of the South of England.

The further development of this subject, the physical condition and depth of the sea-bed, the alternate influence of sea- and freshwater in the same basin, and the relation of these rocks to those in Lincolnshire and Oxfordshire, must be left for another communication.

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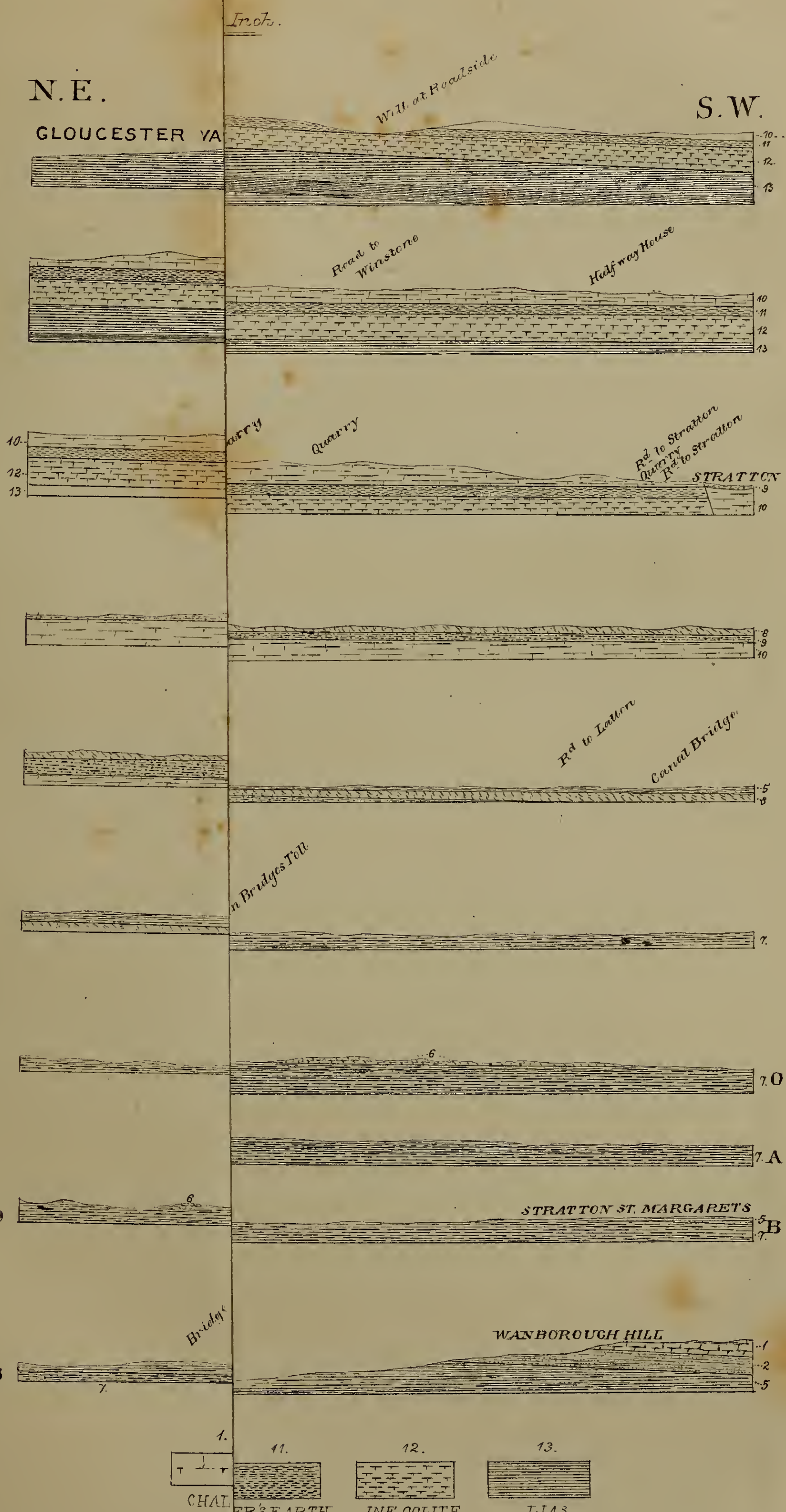
2. *On the* Oolite Rocks *of* Gloucestershire *and* North Wilts. By James Buckman, F.G.S., F.L.S., F.S.A., Professor of Natural History, Royal Agricultural College, Cirencester.

[Plate VII.]

Prefatory Remarks. — The object of the present paper is to point out the general geological characteristics of the different members of the Oolite rocks, as they occur in the Cotteswold Hills,

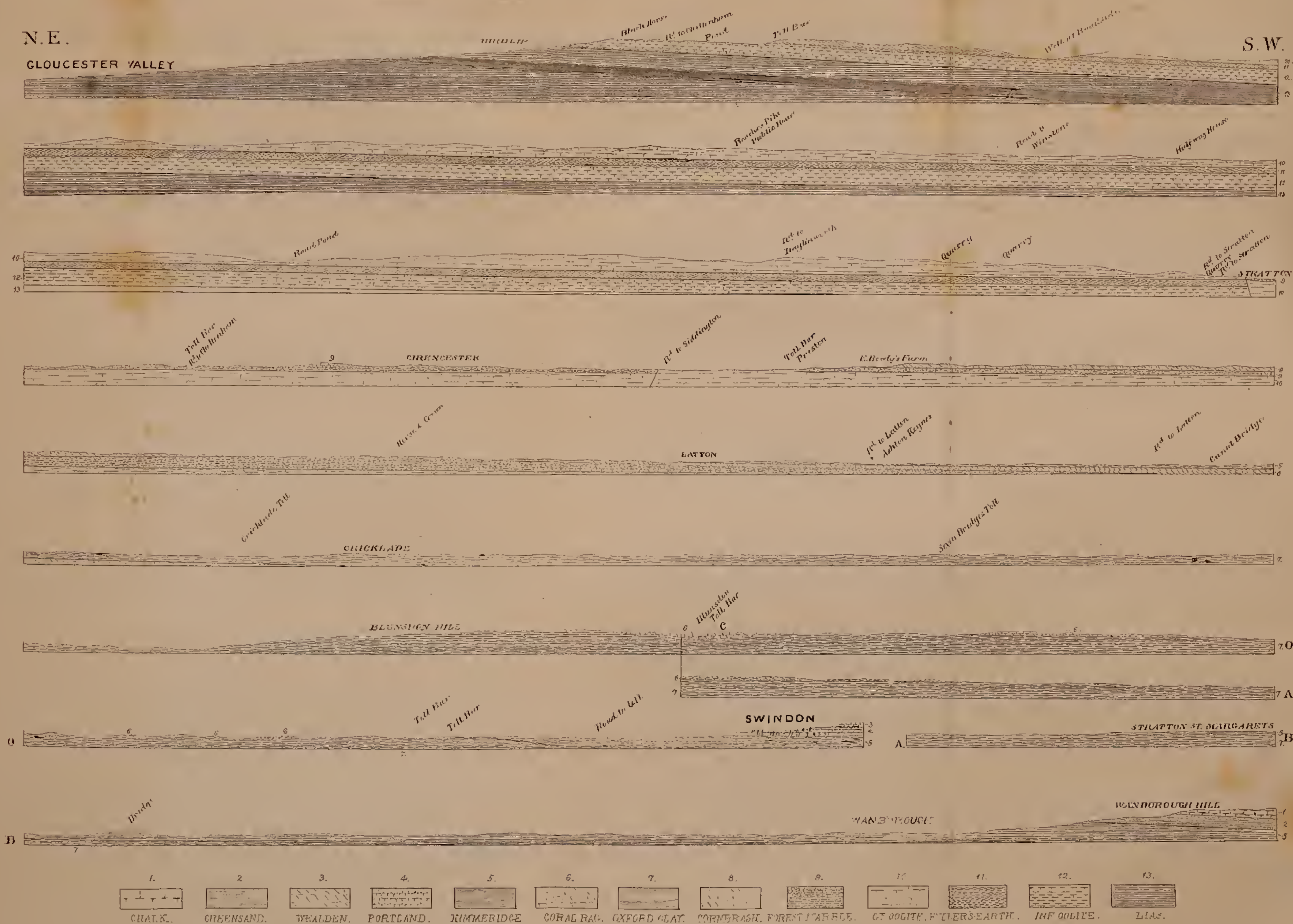


J. Buckman del.

Reynolds & Co. lith.

SECTION FROM BIRDLIP TO SWINDON.

Horizontal Scale 75 Chains to 1 Inch. *Vertical Scale 1600 Feet to 1 Inch.*



J. Buckman del. Reynolds & Co. lith.

and as regards the extension of the higher beds into parts of North Wilts.

This will be done mainly with the assistance of two *surveyed sections* which were made purposely for this paper ; one extending from the Vale of Gloucester through the bold Cotteswold scarp at Birdlip to the Chalk Hills in Wiltshire, in nearly a straight line from the N.E. to the S.W., to which is added a deviation to Swindon (Pl. VII.) ; the other from Cirencester, over the Oolitic wolds, and on through the Vale of Moreton to Shipton-on-Stour, in a direction nearly north and south.

These lines have been taken along the two principal Roman roads which run through Cirencester ; their general straight direction, and the many quarries and openings in and about their fossæ, rendering them very suitable for the purpose.

It may here not be out of place to state how these sections have been taken, as they are the result of much interesting labour, cheerfully joined in by a numerous party. The engineering portion was accomplished by Professor Armstrong, C.E., of the Royal Agricultural College, assisted by several of his pupils. By this staff of engineers the levels were surveyed, and wells, ponds,—whether natural or artificial,—quarries, and other physical features, were carefully noted in their progress, so as to assist in the subsequent plotting, and to guide in determining geological lines.

The geology of these sections has been laid down in journeys taken along the two lines, in company with a large party of my own class, for whom, and for all engaged, it has formed a labour of love, which has rendered Easter and other holidays periods of recreation, notwithstanding the amount of work therein accomplished.

The minor illustrative details I have collected during a period of many years' residence and constant work among my native hills. For the occasional theoretical deductions I throw myself on the indulgent consideration of the Society.

Before commencing with the more immediate subject of this paper, it may be proper to say a few words of the many workers in this district, as their names will show the interest which geologists have for a long time taken in that central chain of hills known as the Cotteswolds.

To Smith and Lonsdale we are indebted for the first stratigraphical details of the different members of the Oolites ; and the paper of the latter in the Society's Transactions * may be considered as a model of industry and accuracy, as the lines therein laid down have been but little interfered with by subsequent explorers.

The 'Geology of Cheltenham,' by Sir R. Murchison, contributed largely to the elucidation of the Liassic and Oolitic rocks of the Cotteswolds ; whilst the publication of Morris and Lycett's 'Monograph of the Fossils of the Great Oolite,' by the Palæontographical Society, has made us acquainted with a most interesting fauna, which has been largely added to by several members of the

* Second Series, vol. iii. p. 341 ; see also Proc. Geol. Soc. vol. i. pp. 98, 111.

Cotteswold Naturalists' Club*, foremost amongst which the papers of Strickland, Brodie, and Woodward may be mentioned.

Even while the notes for this paper were being collected, Mr. Hull, of the Geological Survey, has read a paper before our Society, has completed the map of a great part of the Cotteswolds, and published a 'Memoir of the Geology of the Country around Cheltenham, illustrating sheet 44 of the Geological Survey': all these reflect the highest credit on their author.

Thus, these rocks especially, up to the Great Oolite inclusive, may be considered as having had no small share of attention bestowed upon them by different observers: not so, however, the beds above the Great Oolite; as the details of these, in so far as the counties of Gloucester and North Wilts are concerned, have been but very partially worked out; and, indeed, the existence of the Oxford Clay in the Cirencester district was a matter not understood until lately. Here, then, it will not be out of place, if these Upper Oolite members should receive a large share of attention.

The Oolitic rocks which we shall have to review may be thus tabulated in descending order:—

13.	Portland Oolite	Portlandian	Pervious to water.
12.	Kimmeridge Clay	Oxfordian.	Impervious.
11.	Coral Rag		Pervious.
10.	Oxford Clay		Impervious.
9.	Kelloway Rock		Impervious partially.
8.	Cornbrash	Bathonian.	Pervious.
7.	Forest Marble		Impervious.
6.	Bradford Clay		Impervious partially.
5.	Great Oolite		Pervious.
4.	Stonesfield Slate		Pervious.
3.	Fuller's Earth		Impervious.
2.	Inferior Oolite		Pervious.
1.	Lias		Impervious.

These rocks are all conformable, have a general dip from the N.W. to the S.E., and have a very general evenness of stratification. This, however, is not a little interfered with by a series of downcast faults: these, and the alternations of pervious and impervious strata, have given rise to a very undulating country, the long axes of the valleys being for the most part in the line of dip, whilst a traverse in the line of strike offers a constant succession of hill and vale.

At the North Cotteswolds the elevation of the hills is more than 1000 feet; and here they offer bold scarps, overlooking the Vale of Gloucester; the scarps, headlands, and gorges in the hill-sides having been formed by the water-action of the old Severn sea. As these facts, however, relate to the physical geology of the district, I propose, in the first place, to give a description of the different deposits of the Oolites, and then, in a future paper, to attempt a description of the subsequent physical changes,—concluding with a detailed and comparative list of the fossil contents of the different strata.

* See Proceedings of the Cotteswold Nat. Club, 1848–53.

2. Inferior Oolite.

Basement-bed.—The line of separation of the Lias and the Oolites along the whole of the Cotteswolds has always appeared so well marked, both from structure and fossils, that until lately no practical geologist has had the least difficulty in the matter; recently, however, from some papers by Dr. Wright, we notice an attempt to disturb the classification of the Upper Lias and Lower Oolitic beds, respectively, as laid down by previous observers; this writer contending that the so-called Oolitic Sands and a few feet of compact stone, very oolitic in structure, should be placed with the Upper Lias. Here, then, at the very outset of a description of the Oolitic rocks I find myself obliged to do battle for an important portion of territory, which is attempted to be added to the Lias upon grounds which, if admitted, I conceive can only end in merging the whole of the Oolites into a Liassic series.

Without following Dr. Wright through his elaborate paper*—which I cannot help considering as a clever example of special pleading,—I shall endeavour shortly to review the case as it stands.

When, in 1834, Sir R. Murchison penned his 'Outlines of the Geology of the Neighbourhood of Cheltenham,' he for the first time divided our inferior Oolitic rocks into distinct beds; and in the second edition of that work, which I had the pleasure of editing, this classification was only altered by way of a still greater division of the beds.

It now, however, becomes evident that the descriptions adopted in this work, taken, as they were, from the immediate neighbourhood of Cheltenham, such as Cleeve and Leckhampton Hills, are only locally correct, and more particularly as regards the basement-bed of the Inferior Oolite.

In the work mentioned we find the following remarks:—"The lowest member of the Inferior Oolite has a remarkable mineral aspect; it is of a rusty brown colour, and is in great part made up of small flat concretions from a quarter to half an inch in diameter. It is called 'pea-grit' by the country people." And further on:—"Coralline bodies are spread over the iron-shot faces of the beds below Cleeve Clouds." Now this description of the basement-bed of the Inferior Oolite defines it with tolerable accuracy for the district referred to, as at Leckhampton the ferruginous more or less pisolitic beds rest immediately on the stiff blue micaceous bands of the Upper Lias. The following is the section:—

	ft.	in.
5. Shelly Freestone (Brodie) .... } 4. True Pisolite .... }	10	0
3. Coarse-grained Oolite, more or less pisolitic	13	0
2. Foxy-coloured ferruginous Oolite, seldom pisolitic	20	0
1. Upper Lias shale.		

The late Hugh Strickland, in the 'Geological Journal,' vol. vi. p. 242, gives a complete section of the Inferior Oolite of Leckhamp-

* Quart. Journ. Geol. Soc. vol. xii. p. 292, &c.

ton, which he most carefully measured; and in this he describes "Pisolite (Pea-grit) and Ferruginous Oolite (Belemnite-bed) and sand" (just including 2, 3, and 4 of the above section) as 42 feet in thickness; and upon this he offers the following remarks:—It consists of a "coarse oolite in the upper part, and of the very peculiar large-grained Oolite or *Pisolite* (*Pea-grit*) in the lower. A few miles to the south the pisolite disappears, and is replaced near Painswick and at Haresfield Hill by strata containing oolitic grains in a brown paste. This is the precise equivalent of the well-known oolite of Dundry, near Bristol, which may be recognized as far off as Bridport, on the Dorset coast. At Leckhampton the pisolite rests on a few feet of ferruginous oolite and sand. The total thickness of this portion of the series is 42 feet*." These views are also stated in a paper by my friend the Rev. P. B. Brodie, to which, indeed, Mr. Strickland's section was an appendix.

Recently, more extended observations in the South Cotteswolds, as in the Stroud district, have shown that between the tenacious Upper Lias Shales and the beds of true Oolitic structure, we have a variable thickness of from 50 to 70 feet of an incoherent sandy rock, with occasional bands and nodules of a bastard freestone intersecting it; and this bed has by the Government Surveyors been distinctly mapped as "Oolite Sands." Lately, however, Dr. Wright proposes to add not only these sand-beds, but a true oolitic, and occasionally pisolitic, rock above this, to the Upper Lias; a view which he attempts to substantiate mainly by appealing to certain species of *Cephalopoda* occurring in the bed above the sand at Frocester Hill, which, as some of them are undoubtedly Liassic, he would designate as witnesses of character†, and would tell us that the evidence derivable from the presence of a multitude of Oolitic mollusca with which the Ammonites are mixed—in a rock, too, of oolitic structure—is of no value whatsoever. I here give an analysis of the fossils obtained from Frocester Hill, founded upon a list for which I am indebted to the kindness of my friend Mr. John Lycett; many of these fossils have also been found by myself and others; and the results are confirmed by my own observation of this newly-named *Cephalopoda-bed* of the so-called Upper Lias:—

Analysis of the fauna from the Basement Oolite of Frocester Hill:

	Species.		Common to the Lias.
1. Ammonitidæ	15	..	5
2. Belemnitidæ	3	..	3
3. Gasteropoda	1	..	0
4. Lamellibranchiata ‡	21	..	0
5. Brachiopoda ‡..........	3	..	3
Total......	43	..	11

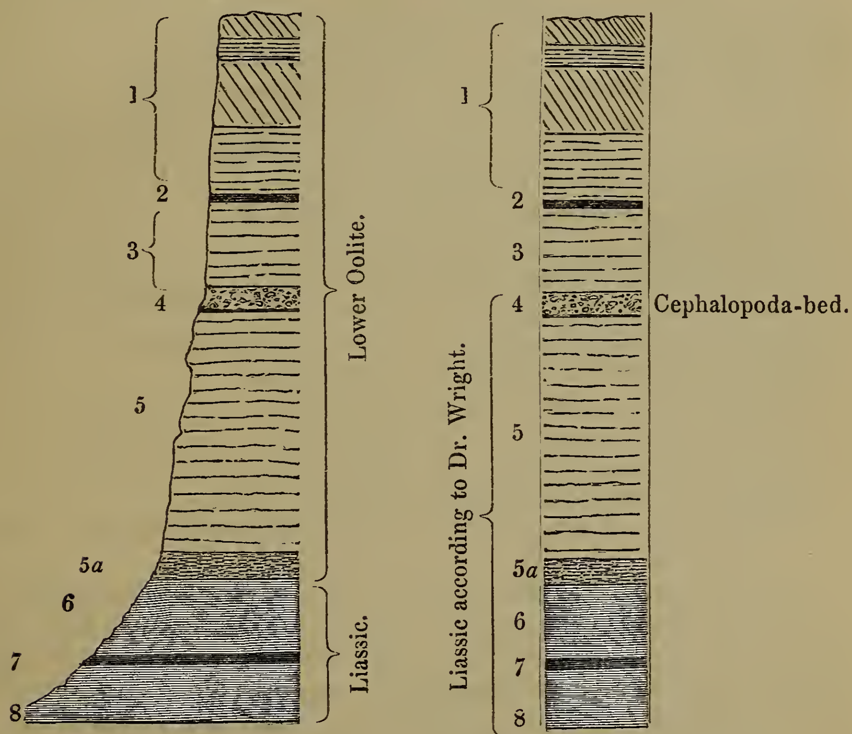
* Quart. Journ. Geol. Soc. vol. vi. pp. 250, 251.

† I would here suggest that the Cephalopoda, being inhabitants of deep seas, and possessed of such wonderful powers of locomotion, are much weaker as witnesses than the non-nomadic Lamellibranchiata.

‡ Many of these extend high up in the Oolites: probably a few go throughout the Oolite-beds.

Here, then, we have a total of 43 species, only 11 of which are truly liassic. It should here be remarked that this list does not include the *Ammonites bifrons* or the *A. fimbriatus*, upon the former of which Dr. Wright, and, after him, Mr. Hull have laid such stress; the truth being, that both Dr. Wright's specimens of these *Ammonites* (for his matrix was traced) and my own were obtained from as much as 20 feet below the oolite-sands, in the true micaceous beds of the Upper Lias Shales, the position of which will be made plain by the accompanying section of beds at Frocester Hill:—

Fig. 1.—*Section at Frocester Hill.*



	ft. in.		ft. in.
1. Oolite-freestone, with two bands of obliquely-laminated beds ......——. ....——....	40 0	5*a*. Position of Inferior Oolite Shells at Nailsworth.	
2. A sandy Oolite, with *Pholadomya*	0 6	6. Upper Lias Shales—very micaceous	20 0
3. Ragstone	20 0	7. Band of indurated White Lias, with *Am. bifrons* and *A. fimbriatus*	1 0
4. "Cephalopoda-bed"...........	4 0	8. Upper Lias Shales, blue.	
5. Oolite-sands	60 0		

Now, if I am right in my interpretation of this matter, Dr. Wright has gone into the Lias Shales for his proofs that the Cephalopoda-bed, 80 feet higher, is Lias; nor is it difficult to understand how he may have been led into this error, inasmuch as the upper part of the Lias Shales has become oxidized from atmospheric exposure; and besides, on this slope the Inferior Oolite Sands have fallen over them, so that their true nature is concealed. At the same time, if these Ammonites are thus to be brought as witnesses for the new Liassic theory, what is to prevent the whole of the Upper Lias fossils from being added to the same category?

But whatever tale may be told by the *Ammonites*, the following shells, taken from Dr. Wright's own list, are those which I should consider as characteristic of the Oolite; yet many of these are from the bottom of the sands; and, while none of them are Liassic, many of them range through the Great Oolite into the Cornbrash.

List of Conchifera: (F) Frocester Hill; (N) Nailsworth*.

Lima bellula, *Lycett*. F., N., also Great Oolite.
Pholadomya fidicula, *Sow*. F., N., Inferior Oolite.
Gervillia Hartmanni, *Münst*. F., N., Inferior Oolite.
Modiola plicata, *Sow*. F., N., ranges as high as Cornbrash.
Trigonia striata, *Sow*. F., N., Inferior Oolite.
Perna rugosa, *Gold*. N., Inferior Oolite.
Hinnites abjectus, *Phil*. F., N., Great Oolite.
Pecten articulatus, *Gold*. F., Coral Rag.
Gresslya adducta, *Phil*. F., N., } both in Cornbrash.
Gresslya conformis, *Agass*. F., N., }
Myacites tenuistriatus, *Agass*. F., N., Inferior Oolite.
Goniomya angulifera, *Sow*. F., Great Oolite.
Astarte excavata, *Sow*. F., N., Great Oolite.
Myoconcha crassa, *Sow*. N., Great Oolite.
Astarte modiolaris, *Desh*. N., Inferior Oolite.
Cypricardia cordiformis, *Desh*. F., Great Oolite.
Cardium Hullii, *Wright* (C. Buckmani, *Lycett*). F., N., Great Oolite.

Now as regards this list, it is not a little curious that so many of the species should take so wide a range above, but not one below the disputed ground; and yet it is on this very account that Dr. Wright prefers, in his metaphorical language, to consider them as "*witnesses of no character*." At the same time we see how inconvenient it was to have so decidedly a Great Oolite fossil as the *Cardium Buckmani*, Lycett, founded on Minchinhampton specimens, in the new Lias list; and so it is made a new species.†

Again, on referring to my Cornbrash fossils, I find that out of 71 species, 45 are common to the Inferior Oolite, and amongst them no less than five forms of Ammonites, as follow:—

Ammonites Herveyi, *Sow*. . . . . Fairford and Siddington.
,, Brochii, *Sow*. . . . . Fairford and Dry Lease.
,, subradiatus, *Sow*. . . . . Fairford.

* This section of Nailsworth and its fossils were unknown to Dr. Wright when his paper was read before our Society, but they are incorporated in his general list at p. 305, and thus their particular bearing is, as it were, stifled. They were commented upon at the Meeting of the British Association; after which the list referred to appears to have been altered.

† In the above list this shell is quoted just as in Dr. Wright's list *loc. cit.*

Ammonites *Humphresianus, *Sow.* (?). Fairford.
,, *Jurensis (?) *Zieten* . . . . . . Dry Lease.

With even this list of *Ammonites* before us, we should hesitate in stating that the bed they came from must be Inferior Oolite; whilst it would be just as unreasonable to demand that the Cornbrash, with its intermediate member the Great Oolite, should henceforth be added to the Inferior Oolite.

Again, we must not always conclude a difference of horizon on account merely of a *change* in species, especially if we reflect how loose is the definition of a species, and how unsettled are opinions concerning their identification; but we must take a more enlarged view of the subject, and not pin our faith too much upon the labels of either Cephalopoda or Brachiopoda, or Mollusca generally: we are bound to take into consideration all the circumstances of lithological structure, stratigraphical position, and every family of included fossils.

As the section of Nailsworth has been referred to, it may be well to state that here, at the *base of the sands*, is a bed of sandy Oolite, which, though small, as is the opening by the road-side, has yet furnished a good list of fossils, which is constantly being added to; the following, however, will afford an analysis of their groups, as worked out by the assistance of Mr. Lycett during my last visit: —

	Species.		Common to Lias.
Ammonitidæ	2	. .	0
Belemnitidæ	1	. .	1
Gasteropoda	4	. .	0
,, new forms	1	. .	0
Lamellibranchiata	15	. .	3
,, new forms	5	. .	0
Brachiopoda	2	. .	1
Total.	30	. .	5

Here, then, as we proceed downwards in these sands, the proportion of Liassic to Oolitic forms decreases; but, once pass the sand boundary-line, and all the species are Liassic; and I still contend that Dr. Wright's *most respectable witnesses to his new theory have been taken from the undisputed Lias.*

In this state of the evidence, then, I cannot subscribe to the new views; but, on the contrary, rather incline to the belief that even the sands belong to the true Oolitic horizon. They mark, where they occur, a great change in physical conditions, and, as a consequence, have induced a corresponding impression upon the included fauna, both as regards general appearance and specific details, — two points to be kept distinct, as the same fossil species from different mineral matrices will have very different aspects; and again, as far as species are concerned, the list from the Cephalopoda-bed has

* These two species are stated with some doubt, as the specimens are very imperfect. The list of Ammonites is being added to constantly, and will be found more in detail in its place in the Cornbrash.

undergone many modifications since the liassic view has been taken of it. Hence, in the Oolitic sands, and the *equivalent beds*, we may mark an oscillation, the effect of which was the continuance of several species identical with those in the Lias which the sands immediately superimpose, though the *general style* of the fossils decidedly points to an Oolitic fauna,—and this the more so, the more the oolitic structure of the rock prevails.

What, then, is here meant by the *equivalents of the sand?* My present opinion is, that the sands of Frocester are identical in time with the mixed pisolitic beds of the Cheltenham district, and that the iron-shot sands of the Dundry Hill and Somerset sections are also of the same period: the pisolitic conditions prevailed in one part of the Oolite sea, and sandy ones in another; and hence the difference of the fauna.

At Haresfield Beacon is found a large *Terebratula*, at first named *T. lata*, but now getting the name of a Lias shell, namely, *T. punctata*, Sow. At Crickley Hill we have a variety of the same shell; but here the pisolitic stratum, as it occurs at Leckhampton, is somewhat changed, since we have as much as 60 feet of a sandy oolite in blocks of hard stone, irregularly interpolated in beds of pisolitic character. The most truly marked pisolite is near the top of this eminently oolitic section, and it is here that the *Ter. simplex* and *Ter. plicata* (Buck.) are in such abundance, together with large forms of *Ter. perovalis*, which, however heterodox the notion may now seem, I feel convinced will be ultimately considered specifically the same as the Haresfield Hill form, and connected by the large specimens thence obtained.*

The following section of Crickley Hill may be compared with that of Leckhampton:—

	ft.	in.
5. Pisolite, with but a small admixture of oolitic ragstone	5	0
4. Freestone, including pisolite	9	0
3. Hard blocks of oolite, consisting in part of very indurated pisolite	35	0
2. Sandy oolite, occasionally pisolitic	25	0
1. Lias.		

Now here the sands are absent, but their thickness is made up by siliceous and indurated oolites; and where the true loose sandy conditions prevailed, the difference is well marked by the fauna; as ever shifting sands and the want of calcareous matters were as inimical to animals in the old as in the modern seas; hence the paucity of fossils in the true sandy deposits: but where muddy conditions occasionally intervened for a while—as even in these sands,

* This notion is not new, as Bronn ('Index Palæontologicus') considers *T. perovalis* as a synonym of *T. lata*, which, again, is the true *T. ovoides* (*T. lata*, Sow.). D'Orbigny considers *T. simplex* to be a synonym of the same ('Prodrome'). Indeed, these are among several forms of *Terebratula* from the same horizon, and yet presenting as much difference as groups of our modern Mussel-shells.

at their base at Nailsworth* and other places—animal remains are abundant.

Hence I am compelled to adopt the following conclusion:—

To class the sands with the Oolites; as they evidently mark, to say the least, an oscillation in the previous or true liassic conditions; and, though a few, and only a few of the Cephalopoda common to the Lias still maintained their ground, yet at the base of the sands we are not without a shelly deposit so thoroughly Oolitic that a glance is sufficient to decide the question.

In adopting the line contended for by Dr. Wright, we do so entirely upon the evidence of fossils which are yet mostly peculiar to isolated positions; and, whilst many of them range high in the Oolites, few, if any, are found in the real Lias,—of course, those got from the Lias itself not being properly classed as proofs of the position of the sands, much less of the Cephalopoda-bed.

We give up also a well-defined line,—namely, that of a blue micaceous clay, overlaid by calcareous sands, the latter being the precursors of the more perfect calcareous condition, which, indeed, did sometimes prevail in the same horizon,—only to form a boundary-line between even courses of beds of true oolitic structure: this, to my view, appears very unreasonable.

Having so far disposed of the question of the basement-bed, it may be well here to give a Table of the different members of the Inferior Oolite rock as they appear in Gloucestershire; they are as follow, in descending order:

B. 6.	Clypeus-brash	Clypeus sinuatus.
,, 5.	Trigonia-grit; Gryphite-grit	Trigonia costata. Gryphæa Buckmanni. Ammonites.
,, 4.	Oolite-marlstone	Terebratula fimbria.
,, 3.	Freestone	Small broken shells.
,, 2.	Flaggy Oolite = "Shelly Freestone" of Brodie	Small shells much like those of Great Oolite.
,, 1.	Ferruginous Oolite; Oolite-sands. } occasionally pisolitic	Urchins in pisolitic beds. Ammonites and bivalve shells.

These beds in their extension from the north to the south Cotteswolds observe many modifications; for, although each member here laid down may be traced either in a typical or representative form, yet each differs widely not only in aspect, but in thickness, at different stations. This is especially the case with the Freestone beds, which at Leckhampton and Dodwell quarries are as much as 80 feet thick; these thin off in the Frocester section to 40 feet, whilst north of Leckhampton, as at Stanway Hill, and along the Stow-on-the-Wold line of section they are nearly absent; but the thickness is made up by an augmentation of the Ferruginous Oolite, which here forms a

* My friend Mr. C. Moore informs me that he found other calcareous bands in the sand section at Nailsworth charged with fossils; and he further informs me that the conditions there marked are precisely the same as at the "Half-way House" near Yeovil, but that there the Ammonite-bed is *in the centre* of the lower blocks of Inferior Oolite.

fine ochre-tinted freestone peculiar to the district, its rich colour giving a character to Toddington Abbey, which is built of it.

B. 6. One of the most persistent of the Inferior Oolite beds is the one named *Clypeus-brash,* from the enormous quantity of *Clypeus,* now *Nucleolites sinuatus,* it contains. The platform upon which the houses at Birdlip stand, rests on this bed, which is well exposed by the denudation of the Fuller's earth. (See Section, Pl. VII.) Here the plough on the Stone-brash turns up this Urchin in large quantities; the same is the case in the Stow district, where we have frequently seen it gathered in heaps for removal from the barley-field, and have not always succeeded in convincing onr bucolic friends that it was not an *annual production*; for this their conclusion, its constant and apparently undiminished appearance in the different crop-rotations may partially excuse them.

B. 5. The *Grits,* which at Leckhampton and Lineover Hills, near Cheltenham, are separated into two thick beds by a thin band of marl, are at other parts of the district so intermixed as to be inseparable. The Lineover section is as under, in descending order:

	ft.	in.
3. *Trigonia-grit,* a bed of hard ragstone, highly charged with *Trigonia costata, T. clavellata,* and other species of this genus, as erected by Mr. J. Lycett	4	0
2. Band of marl full of shells, among which the *Perna mytiloides,* Bronn, L. G. t. 19, fig. 12, is the most conspicuous	0	8
1. *Gryphite-grit,* locally named from the great abundance of *Gryphæa Buckmanni,* Lycett (Proceedings Cotteswold Club, vol. i. p. 236) ..	10	0

These grits occur more or less distinct at the Cleeve Cloud, and on the Stow road, and indeed are universal in this district as part of the Inferior Oolite deposit.

B. 4. *The Oolite-marl* is also a most persistent bed both in character and thickness; it will however be found more or less indurated at different places, even at no great distance apart; thus, at the west end of Leckhampton Hill it is a hard white limestone, highly charged with *Terebratula fimbria,* whilst in the scarps facing the north it is a soft yellowish marl, especially towards the base; and here the former *Terebratula* is less common, its numbers being replaced by the *Ter. maxillata* (*submaxillata,* Davidson), a shell which becomes exceedingly common upwards in marly beds of a like character, occasionally formed in the Great Oolite,—a fact showing how the same circumstances recurring after a lapse of time result in the re-introduction of an older fauna. This same marl-bed was shown me in a section near the Brimscomb station, from which I not only obtained fine specimens of *T. maxillata* and also *T. carinata,* Lam., both abundant at the Leckhampton station, but also of a diminutive form of *Ter. simplex,* Buckman, as pointed out to me by my friend John Lycett: this latter fact affords a remarkable instance of how a species may become altered by a difference of time and surrounding media. In addition to the species just quoted, the bed is remarkable for containing other shells, as *Lima læviuscula, Mytilus obtusus,* Geol. Cheltenham, t. 7, f. 2; *Natica Leckhamptoniensis,* Lycett, with occasional masses of a single species of coral, probably belonging to the genus *Microsolena* of Milne-Edwards.

B. 3. *Freestone.*—This, which is the thickest bed of the Inferior Oolite, often partakes of the character of Bath Freestone; and, when quarried from underground workings, as at Dodswell quarries, near Cheltenham, it is scarcely inferior in quality; in some districts too, as at Frocester Hill, it presents the phenomena of oblique cleavage. The great mass of this rock is remarkably free from fossils, especially any perfect specimens; beds of stone, however, are not unfrequent which appear to have been entirely composed of shell-sand. This rock appears to have attained its greatest thickness at Leckhampton Hill, where it cannot be less than 100 feet thick: at Frocester it thins off to 40 feet. A similar thinning of this bed may be remarked in the north Cotteswolds, though in its general aspect it is wonderfully persistent.

B. 2. *Flaggy Oolite*—"Roestone," 'Geol. Cheltenham,' "Shelly Freestone," Brodie. This is a coarse kind of Freestone, full of shells, and extensively quarried at Leckhampton Hill for rough kinds of stone-work; its chief geological interest consists in the fact, that in this bed of the Inferior Oolite we meet with a large development of that peculiarity of life which so greatly prevailed in the Great Oolite beds; a fact which I first noticed in the 2nd edition of the 'Geology of Cheltenham,' and which has since been worked out in great detail by Messrs. Lycett, Brodie, and Gomonde. To the former gentleman we are indebted for a very elaborate paper, bearing on the distribution of fossil forms in the Oolites, which will be found in the 1st vol. of the 'Proceedings of the Cotteswold Naturalists' Club,' and from which I copy the following general results (pp. 62, &c.):—

	Species.
From the middle division of the Inferior Oolite were obtained	255
Of these, from the Leckhampton beds were..	181
——————— the Minchinhampton beds ..	145
Common to the two localities	73
Common to the Great Oolite and the Flaggy Oolite	64=28 per cent.

The fauna, though differing in species from that of the beds of a like structure in the Great Oolite, is yet of the same character; and hence, though the Upper Rags of the Inferior Oolite throughout our whole district may be characterized by *Cephalopoda* and *Brachiopoda*, species of these families are exceedingly rare in the shelly freestone; but *Gasteropoda* and *Lamellibranchiata* abound, and the following list sufficiently points out the similar fossil conditions of the Freestones of the Inferior and Great Oolite rocks:—

List of Shells common to the Great and Inferior Oolite Freestones.
(From Lycett's Table.)

Patella rugosa, *M. C.*
—— inornata, *Lycett.*
Emarginula scalaris, *M. C.*
—— alta, *Lycett.*
Monodonta sulcosa (Nerita), *Archiac.*
—— Lycllii, *Archiac.*
—— heliciformis, *Lycett.*
—— lævigata, *M. C.*
Turbo capitaneus, *Goldfuss.*
Natica canaliculata, *Lycett.*
Rissoa lævis, *M. C.*
Rissoina obliquata, *M. C.*
Lima, 8 species.
Mytilus, 4 species.
Gervillia, 2 species.
Cypricardia cordiformis, *Deshayes.*
—— siliqua, *Lycett.*
Venus trapeziformis, *Roemer.*
—— Suevica, *Goldfuss.*
Nucula variabilis, *M. C.*
Arca pulchra, *M'C.*; and others.

Here then we see that in this bed we have a fauna similar in character, and to a great extent specifically, as that in the Great Oolite, some 200 feet above; and this is accompanied by the same kind of structure of stone, it being quite impossible to distinguish hand-specimens of this portion of the lower series from the fossiliferous beds of the superior strata.

B. 1. The Ferruginous Oolite, having been dwelt upon in the earlier part of this paper, will require no further explanation here; it may not, however, be out of place to remark, that this bed in its variable character shows clearly, what we might expect, that the first commencement of oolitic deposits was much more irregular, both as to the materials left at different parts of the Oolitic sea-bottom, and the remains of animals which are intermixed in the rock at different places; and in this way may we not readily account for—

a. Sandy deposits at Frocester, where the Pea-grit is absent altogether;

b. Siliceous freestones in blocks, with occasional beds of Pea-grit at Crickley Hill;

c. Sandy deposits with occasional limestone-bands, as at Nailsworth?

As far as fossils are concerned, we may reasonably expect that they differed with various depths; and neither at the bottom of the Oolitic sea, nor of any other formation do we find an evenly laid floor, with an everlasting repetition of the same pattern, like the carpets of those drawing-room geologists who substitute theory for field-exploration.

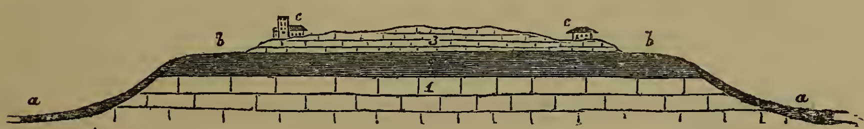
3. Fuller's Earth.

This deposit rests upon the Inferior Oolite, and may be seen in tracing up the Cotteswold scarps along the Section, Pl. VII., about half a mile to the east of Birdlip, where it forms a sloping ridge of blue clay, much exposed in the road-cutting, and at once recognized by wells and springs which supply some cottages with water. This water-bearing bed has been denuded from the Birdlip platform; and hence the bar to the increase of dwellings in that picturesque locality, as the depth to the next water-bed—the Upper Lias, about 200 feet, is much too great for ordinary wells; the dip too of the Fuller's Earth is from the place, and besides it is cut off by a deep ravine in

Nettlecomb Bottom; so that it offers too slight a drainage-area to render reservoirs for the water-supply of the place practicable. Passing along our line of section, dwellings only occur where the surface is a few feet above the Fuller's Earth; and the hill along which runs the old Roman road from Gloucester to Cirencester, and the parallel Cotteswold heights, have the farm-houses and cottages near the junction of the Great Oolite and Fuller's Earth, water being so important an element in domestic use. This bed too is of great importance in an agricultural point of view, as on the hill-slopes meadows with their ponds can be maintained in the "skeins of clay," as the farmer terms the Fuller's Earth band with which the otherwise brashy land is divided; so that, although the Great Oolite has a thin soil, the Inferior Oolite is not only watered from the Fuller's Earth above it, but is covered up with a more or less deep soil, partly made up of the latter,—facts easily understood from the following section:—

Fig. 2.—*Section of the Fuller's Earth.*

Elkstone.



1. Inferior Oolite. 2. Fuller's Earth. 3. Great Oolite.
a. Debris of Fuller's Earth, making meadow-land.
b. Position of Ponds. *c.* Position of Houses.

So regular is the course of the Fuller's Earth bed, except when cut off by faults, that, on ascertaining the depths of wells at different points, a surface-section can be made out almost as accurate as with the theodolite; and hence our sections for the most part enable us to determine along their whole lines the depths to water-bearing beds.

The fossil contents of this bed in the Cotteswold district offers but a comparatively small list, but this is made up by the enormous masses in which most of the species occur; the following are among the common examples:—

Ostrea acuminata, *M. C.*
Avicula echinata, *M. C.*
Terebratula globata, *M. C.**
Pecten vagans, *M. C.*
Pholadomya truncata, *Buckman.*

These fossils are usually in such abundance in the upper part of the stratum as merely to be cemented by a marly paste, and the rock, acted upon by the frost, is broken up into a heap of shells.

5. Great Oolite, with Stonesfield Slate (4.).

This is with us a widely-extended rock, and more especially in the South Cotteswolds, commencing a few miles to the north of Cirencester, and continuing, with but few interruptions, beyond Bath. Like the Inferior Oolite, it is variable in thickness, and made up of

* The same as the Inferior Oolite species, but more regular in form, and usually a more delicate-looking shell.

different members or stages, which, though tolerably persistent, are still liable to many variations; these, however, are much more apparent than real, as, though the beds vary much in colour and thickness at different places, yet it is astonishing how clearly representative rocks may be made out at distinct points.* Hence at Box we have an example of an excellent building-stone, which, from its fineness of grain, the freedom with which it can be worked, and the stability of its form under atmospheric changes, is rendered one of our best rocks for all fine architectural uses, and hence it is sent immense distances for quoinings of buildings, stone-carvings, and the like. The same stage, however, further north is very rough in texture, and by no means a weather-stone; besides, it can only be used in small pieces, on account of its decidedly oblique lamination, the lines of which are equally apparent in the Bath stone, though the latter holds firmly together in these planes.

The following is the best general analysis of this rock, in descending order, I have been enabled to make by comparing sections in the Minchinhampton, Cirencester, and Bath districts:—

Subdivisions of the Great Oolite.

	ft.	in.
C. 6. Yellowish oolite, with more or less of oblique lamination, sometimes separated into two or more stages with thin partings of sand or marl; occasionally a hard compact freestone throughout; about	45	0
5. Bed of marl, mostly yellow, occasionally dark blue, sometimes in clunchy lumps, containing *Lima cardiiformis* and *Ter. maxillata* in quantity,—in many places a hard white stone	4	0
4. Hard limestone in blocks, with *Purpuroidea*, *Pachyrisma*, &c.	6	0
3. White limestone, breaking up into square blocks, occasionally with oblique laminæ=Bath Oolite	30	0
2. A rougher freestone (frequently blue-centred =the "black rock" of the quarrymen). Ragstone	25	0
1. Flat slabs of siliceous limestone, with square sharp edges, fissile on exposure, frequently highly charged with vegetable remains=Stonesfield Slate. This becomes sandy and incoherent towards the bottom	15	0
Fuller's Earth		
Total	125	0

As regards the upper bed (6) of this section, it may not be out of place to state, that, while enjoying the pleasure of two or three field-

* These, however, are only to be known by constant work and comparison both of section and fossils.

rambles with Mr. E. Hull, of the Geological Survey, during his investigations in the Cirencester district, we could by no means agree as regarded the allocation of the upper beds of the Great Oolite; for, while I put this particular mass of freestone, and it is purely so, into the Great Oolite division, he claims it as part of the Forest Marble. My reasons for classifying this bed with the Great Oolite are as follow:—

1. It is always found to occupy a position below the Bradford Clay, as long since marked by Mr. Lonsdale; and, though this latter bed is frequently wanting, yet the clays and sandy fissile slabs of the true Forest Marble rest immediately on the Great Oolite in its absence.

2. These freestone-beds form an unbroken series, frequently without even a clay-parting to the Fuller's Earth, for the thickness of as much as 120 feet, which has been so often proved in well-sinking in the Cirencester district. To divide a freestone-rock in the middle seems therefore hardly warranted, unless marked by some distinctive fauna of a decided kind, which, as far as I know, has not even been pretended; so that neither lithological structure nor fossil contents warrant this division.

3. The sudden appearance of clays and shales upon a freestone rock, as is the case with the Fuller's Earth upon the Inferior Oolite, and the Bradford or Forest Marble Clay on the Great Oolite, and more especially when accompanied by such a decidedly different fauna as the Bradford Clay presents, all argue such a physical change as fully to justify a division.

4. The Bradford Clay, where present, introduces so many new fossil forms,—many of which belong also to the Forest Marble, as laid down by myself, yet do not descend into the oolite-bed in dispute,—that both upon physical and fossil evidence, I claim for the Great Oolite all the mass of freestone between the Fuller's Earth below and the Bradford or Forest Marble Clays above.

Now, unless such a plan of division be adopted, the base-line of the Forest Marble is made arbitrary; for, although it is true that these upper beds are affected to a greater or less extent by oblique lamination, this is a most unsafe guide, inasmuch as the whole of the Great Oolite is at places liable to this, and even the large blocks of Box (Bath) oolite are formed of oblique laminæ, which would result in a shattered obliquely-cleaved rock if quarried near the surface; but the great value of Box stone results from its being mined from galleries, and not quarried in open work, when all the Great Oolite beds split up more or less obliquely.

Again, the same bed differs widely according to the nature of the band upon its surface; hence, if the yellow Bradford Clay rests upon it, it is a lightish yellow stone, splitting obliquely some months or years after an exposure, as in the road-cutting at Tetbury Road Station; the same is the case where the yellow Forest Marble clay rests upon the oolite, as in the section at the Royal Agricultural College. These blocks, however, were hard and compact when first quarried, so much so as to render blasting necessary; but at Chesterton, and again at the "Blue quarry" on the canal near Cirencester, there is a dark blue Forest Marble clay on the rock in question, and the masses of stone beneath are so tough and *blue-centred* as to appear like a stone of a different geological horizon; these conditions will be made plainer by comparing the following sections :—

Section at Tetbury Road Station, near Cirencester.

	ft.	in.
1. Forest Marble, slates and sands	2	6
2. Bradford Clay, full of fossils	7	0
3. Great Oolite. A fine-grained and bright-coloured Oolite-stone, with oblique lamination becoming apparent after quarrying; to bottom	10	0

The Gas House Quarry, ½ mile north of Cirencester.

	ft.	in.
1. Thin bed of broken brash	0	9
2. Bradford Clay with *Ter. digona*, &c.	2	0
3. Freestone, with oblique laminæ, separated into two stages at one end of the quarry by a thin band of clay	20	0
4. Calcareous sandy bed with *Ostrea Jurassica*	0	9
5. Bath Freestone, quarried in blocks, to bottom of quarry	15	0

Mr. Flux's Quarry, only about 300 *yards from the preceding,—*

	ft.	in.
1. Blue Forest Marble clay	4	0
2. White marlstone	0	9
3. Blocks of Freestone, blue in the centre	3	0
4. White Freestone, with oblique lamination, to bottom of quarry	6	0

Blue House Quarry, on the Thames and Severn Junction Canal.

		ft.	in.
	1. A stiff yellowish mottled clay with *Ostrea*	4	0
	2. Band of hard stone, full of shells and corals	2	0
Probably Bradford clay.	3. Dark-blue clay with several species of *Serpula* on oysters, &c.	3	6
Probably Bradford clay.	4. Band of yellow marl made up of decomposed shells, =Bradford clay (?)	1	0
	5. Blocks of hard stone, blue in the centre, enclosing oolite pebbles.	6	0
	6. "Soft Freestone" of workmen; not worked; bottom of quarry.		

As regards the fossils of the Great Oolite, it will hardly be necessary in this place to state more than general conclusions, inasmuch as the excellent Monograph upon the Mollusca of this rock by Lycett and Morris (Palæontograph. Soc.) leaves little to be desired respecting their forms and specific details. Speaking of the prevailing families, these authors have the following remark, which puts some important facts connected with the fauna of this rock before us in a strong light :—

"One of the most forcible impressions conveyed to the mind by a survey of the Testacea of this formation, when compared with those of the other members of the oolitic system, is the great scarcity of the Cephalopoda.......When the Phasianellæ and Naticæ, which are now known to be zoophagous, are added to our species of flesh-eating Mollusca, it will at once be perceived how amply nature provided for the maintenance of the balance of the testaceous animals during the deposition of the Great Oolite of England. The great mass of the Testacea are bivalves, and in species they exceed, by about one-fourth, the united number of the Gasteropoda, Cephalopoda, and Echinodermata*."

Hence then the fossils of the Great Oolite, taken as a whole, more nearly conform to that which pertains to the shelly freestone and building-stone of the Inferior Oolite; and, as before remarked, it is curious to find how many shells are common to the two; however, in as far as hand-specimens of these two building-rocks are concerned, we can usually find some distinctive fossils, the more common of which will be found in most of the species of *Tancredia* of Lycett, *Pecten vagans, Lima cardiiformis, L. duplicata,* and *Natica, Purpura, Alaria, Melania,* and others of the univalve class, so many of which are not only distinctive, but of common occurrence.

The Brachiopoda, which are so abundant in the rag beds of the Inferior Oolite, are few in species in the Great Oolite, and usually only occur in the occasional marly partings; the bed, however, marked 5 is tolerably persistent over a wide area, and at Bibury contains whole masses of the *T. maxillata,* of a peculiarly large and, for the most part, old and rugose form. The same shell occurs abundantly at Foss Bridge on the Cirencester and Northleach road, but here only in the young state—a circumstance which might lead to the consideration of it as a distinct species; whilst at Northleach the same band of marl contains this small form, together with occasional examples of a *Terebratula,* referred by Mr. Hull† to *T. digona,* but differing in being broader, thicker, and not so square at the base. This form, however, I take to be the representative, if not derivative of

Terebratula indentata, *Sow.* Lias.
—— cornuta, *Sow.* Lias-marlstone.
—— emarginata, *Sow.* Inf. Oolite.
—— digona, *Sow.* Bradford Clay.
Terebratula obovata, *Sow.* (with its allies). Cornbrash.
—— ornithocephala, *Sow.* Oxford Clay.

I know this view will be dissented from by naturalists in general; still I cannot help thinking that, when collectors compare all the forms they can get without looking after merely typical specimens (which by the way are often exceptions), their tendency, like mine, will be in this direction.

Among the higher animals, Fishes may be referred to as presenting an important characteristic of the Freestone of the Great Oolite, when compared with the Inferior Oolite. In the latter, fish-remains are very uncommon; but in the former, teeth of various genera of the following families may be found in almost every quarry:—

Pycnodonts.—Vomerine bones, with whole rows of teeth, not uncommon; single teeth dot the stones very commonly.

Cestracionts.—Large quadrangular teeth of *Strophodus* are common throughout the Great Oolite, with others.

Hybodonts.—Separate teeth of various species, with the rest.

* 'Monograph of the Mollusca from the Great Oolite,' Morris & Lycett, p. 5.

† Memoirs of Geological Survey, Geology of Country around Cheltenham, by E. Hull, Esq., p. 62.

Of Saurians, we meet with teeth of the *Ichthyosaurus, Plesiosaurus,* and *Megalosaurus,* but parts of the skeleton are rare.

The Stonesfield Slate is remarkable for its peculiar mechanical condition, being readily fissile into thin stone-tiles after exposure, and possessing a comparatively low specific gravity, so that from appearance and lightness it makes a capital roofing-material; it is much quarried at Birdlip, Miserdine, Sevenhampton near Cheltenham, and in the Stow district; at the two latter places more especially it offers an abundant list of fossil remains, of a curious character, such as

Plants, both aquatic and terrestrial.

Insects, of several families.

Saurians, including the *Megalosaurus* and the *Pterodactylus.*

Fishes, especially fine palatal teeth of *Psammodus.*

Cirrhipedes.—Pollicipes ooliticus, Buckman.

Echinoderms.—Astropecten Cotteswoldiæ, Buckman, and *Astropecten Bakeri,* Buckm.: a single specimen of the latter is in my cabinet from the lower beds at Minchinhampton; and with these a large series of shells, amongst which are *Ammonites gracilis,* Buckm., *Belemnites fusiformis,* Park., and *B. Bessinus,* D'Orb.

In proof of the fossil riches of Great Oolite of Minchinhampton alone, the following enumeration of my friend Mr. J. Lycett may not be out of place.

	Species.
Conchifera	109
Monomyaria	44
Brachiopoda	8
Gasteropoda	142
Cephalopoda	9
Radiata	9
Total determined by Mr. Lycett	321 species.

6. Bradford Clay.

Our Bradford Clay may be described as a yellowish marl, as it always contains a large per-centage of lime; sometimes indeed it is a loose calcareous sand: it rests at the top or in hollows of the Great Oolite limestones.

In Gloucestershire this bed seldom attains to the thickness of 10 feet, and indeed is mostly altogether absent; but, when so, its position is indicated by an irregularity in the deposition of the upper beds of the Great Oolite, which marks the commencement of the new conditions that brought in the thick clays and siliceous limestones of the Forest Marble deposit. This irregularity, always more or less observable, may be regarded as the point of oscillation, indicating a change of circumstance; and thus it may well serve as a natural boundary-line of the Great Oolite and Forest Marble.

The position of the Bradford Clay will be readily made out by attention to the Section, Pl. VII.; and the graduation from the Great Oolite to the Forest Marble beds is well seen at the Hare Bushes Quarry, a mile east of Cirencester.

Section of the Hare Bushes Quarry.

	ft.	in.
a. Blue slabs, on the hill over the quarry. (Forest Marble.)		
1. Flaggy oolite	2	6
2. Band of clay and marl	1	0
3. Flaggy oolite	2	6
4. Marl, full of *Ostrea Jurassica?*	0	9
5. Flaggy oolite, as No. 3	1	0
6. Marl	0	6
7. Oolitic freestone, white, with a fine grain, cleaving obliquely in the upper beds; to bottom of quarry	20	0

It should be remarked, that these upper bands are very unfossiliferous; but, when fossils occur, they are mostly those of the Bradford Clay, such as *Terebratula digona* and *T. cardium*; and even these have not as yet been found at the Hare Bushes; indeed it is curious to observe, that to the north and east of Cirencester, indications of the fauna of the Bradford Clay are rare, if not absent; while the same horizon to the west and south of that place will present beds always charged with some of the Bradford Clay species, which, in as far as this locality is concerned, are very persistent as to their position.

As respects the fauna of the Bradford Clay, it will be found of a most distinct and interesting character. A section, of not quite 8 feet in thickness, and exposing but a small extent of surface, yielded, according to Mr. S. P. Woodward (who made a beautiful collection from this bed), a large list of fossils, of which he has given the following census:—

General view of the Bradford Clay Fossils of Cirencester, by S. P. Woodward, Esq., F.G.S.

RADIATA	species	29
Corals	15	
Crinoids	3	
Starfishes	1	
Sea-urchins	10	
ARTICULATA		8
Annelides	7	
Crustaceans	1	
MOLLUSCA		42
Conchifera	23	
Brachiopoda	10	
Gasteropoda	8	
Cephalopoda	1*	
VERTEBRATA		26
Fishes	19	
Reptiles	7	
Total of species		105

* Since the above list was made out, a single individual of a new Ammonite was found by John Coleman, Esq., now Professor of Agriculture, and Farm Manager, Royal Agricultural College.

Amongst these, the following species may be especially mentioned as either by their presence or quantity marking this stratum :—

Apiocrinus rotundus, *Park.*	Rhynchonella media, *M. C.*
Serpula grandis, *Goldf.*	Avicula costata, *M. C.*
Terebratula digona, *M. C.*	Cardium gibberulum, *Phil.*
—— coarctata, *M. C.*	Pecten vagans, *M. C.*
—— cardium, *M. C.*	Astræa, species.

7. Forest Marble.

Though somewhat irregular, both in structure and thickness, this is tolerably persistent over a wide tract of country in South Gloucestershire and North Wilts; in the neighbourhood of Cirencester nearly all the heights are capped with this stratum; and, as the town rests in a valley of depression, to be more fully explained hereafter, it will be seen that Forest Marble Clays are the water-bearing beds of the town, as shown in the sections through Cirencester.

This stratum consists of sands, clays, and cherty limestones, with occasional thin bands of a tolerably fine and much ripple-marked sandstone; the latter, however, being only what in other places are loose sands, have become indurated from some local and peculiar chemical cause; a quarry on the Somerford road presents the following section :—

	ft.	in.
1. Forest Marble clay	3	9
2. Forest Marble sandy tile-stones	4	0
3. Bed of fine sand, including "potlids"	8	0

These "pot-lids" or nodules, which sometimes assume most curious shapes, split up into tiles thin enough for roofing-purposes; they seldom include fossils of any kind, and indeed the siliceous beds of the Forest Marble are very free from shells.

The ripple-marked sandstones are exceedingly interesting as affording evidence that so many of the circumstances attendant upon a modern sandy beach were in full operation when these beds were being deposited; the irregularities on the surface of the stone are the result of the consolidation of the "ribbed sea-sand," and was, as now, due to the tidal wave, or arranged by the action of the wind. The powdering of these stones with a carbonaceous dust, and the indentations caused by the tracks of Crustacea, Conchifera, and Annelides, all plainly indicate the past condition of the sea-shore, and enable us to compare the past with the present with great exactitude.

The most common disposition of the upper beds of the Forest Marble may be gathered from the following sections,—premising, however, that each section will differ in details; what is sand at one place may be sandstone at another, while shales and marls are replaced by impure limestone.

Section, Pool Road Bridge on Great Western Line, 4 *miles from Cirencester.*

	ft.	in.
1. Cornbrash..................................	4	0
2. Forest Marble clay	3	0

		ft.	in.
3.	Forest Marble sandstones and impure freestone	1	6
4.	Clay	1	6
5.	Forest Marble ripple-marked slabs	2	6
6.	Clay to bottom of section.......................	7	0

Section at Ampney Crucis, near Cirencester.

1.	Cornbrash..................................	2	0
2.	Forest Marble clay	3	0
3.	Impure freestone with oblique lamination	3	6
4.	Clay	1	6
5.	Impure freestone, sometimes sandy and ripple-marked	3	0
6.	Clay, with occasionally intervening masses of impure freestone..................................	6	0
7.	Fissile freestone, breaking up obliquely into thin slabs	2	0

The fossils of the Forest Marble are mostly identical with those of the Great Oolite, and hence the great difficulty attendant upon a zoological division; however, there are some so distinctive as to lead to the hope that more extensive examinations of the fauna of this rock would enable the geologist at once to identify it, even where the deposit takes on the oolitic character.

The first bed of clay, after passing the freestones, introduces us to a peculiarly *thin* and *flat* species of Oyster*, which is so distinctive, and in such quantity, as to form a good index to the Forest Marble Clay all about this district.

The slabs of stone are marked by the presence of a *Mytilus* and *Gervillia* very distinct from Great Oolite species, and are further distinguished by some peculiarly interesting univalves.

The peculiarities of the ripple-marked sandstones are such as to render them easily distinguishable; for, though these are described as much like the Stonesfield Slate, yet the square edge, even surface, and fissile nature of the latter are far different from the rougher aspect of those of the Forest Marble.

8. Cornbrash.

This rock, though inconsiderable in thickness, is yet one of the most interesting in the Oolite series. It occupies a wide tract of country in South Gloucester and North Wilts, commencing about a mile from Cirencester, and skirting the Oxford Clay as far as Calne and Chippenham: its position between beds totally distinct in structure, in that it is an oolitic limestone between two thick strata of clay, and the fact that it re-introduces a large number of Inferior Oolite fossils, are remarkable circumstances in the natural history of this deposit.

It is a bed not more than 15 feet in thickness, and has the litho-

* May not this extreme thinness of shell be related to the paucity of lime in the argillaceous and siliceous matrix with which they are surrounded? The marly Bradford Clay contains an Oyster very thick and rugose in its shell, and with which this has been confounded.

logical structure of an Inferior Oolite ragstone, being similar in structure and chemical composition to the Gryphite and Trigonia grits of the Lower Oolite rock; this will be best explained by the following Table of Analyses of my friend and coadjutor Professor Voelcker*.

Analyses of Oolite-brashes, by Professor A. Voelcker.

	Inferior Oolite.	Great Oolite.	Cornbrash.
Carbonate of lime	89·20	95·346	89·195
Magnesia	·34	·739	·771
Sulphate of lime	·09	·204	·241
Alumina	4·14	1·422	2·978
Phosphoric acid	·06	·124	·177
Soluble silica	2·75	1·016	1·231
Insoluble siliceous matter	3·27	·533	4·827
Alkaline salts, undetermined.			
	99·85	99·384	99·420

It will be seen from this Table that the carbonate of lime is of equal amount with that of the Inferior Oolite; and hence, in as far as composition is concerned, we have in the Cornbrash a limestone-bed occurring in the midst of others of quite different character; and the result of a recurrence to the same physical conditions has been a return to an Inferior Oolite fauna†, even after a lapse of time sufficient to have formed as much as 300 feet of rock of diverse lithological structure, each rock containing its own set of fossils.

Our analytical Table also shows us a marked difference in the quantity of phosphoric acid which different oolite-brashes contain; and, as the term Cornbrash is derived from its agricultural capabilities, these with other considerations seem to demand a consideration of this deposit under the three following heads:—

1st. Its position and structure,

2ndly. Its fossil contents, and

3rdly. Its agricultural peculiarities.

1. Thin as is the Cornbrash, it occupies a considerable horizontal extent; this is accounted for from the general flatness of the country to the south and east of Cirencester, as also from the slight amount of dip in this direction.

About two miles on the Cricklade Road in the line of section (Pl. VII.) is a quarry which gives the following section, and has yielded a large proportion of the fossils hereafter to be tabulated.

Section on Cricklade Road.

		ft.	in.
Corn-brash.	1. Rubbly incoherent stone, full of shells	2	0
	2. Hard ragstone, with uneven splintery fracture	8	0
	3. Forest Marble clay; bottom of quarry.		

* See Proceedings of the Cotteswolds Nat. Club, vol. i. p. 263, &c.

† It is remarkable that every fossil figured by Phillips in his 'Geology of Yorkshire' illustrative of Cornbrash equally well illustrates the Inferior Oolite of Gloucestershire.

Section at Shorncot, near Cirencester.

	ft.	in.
1. Soil, mixed with clay-debris of Oxford Clay	3	6
2. Cornbrash, more or less mixed with marly bands ..	5	0
3. Ragstone, to bottom of quarry.		

Along the line of section its thickness can be ascertained with the greatest nicety, as the slightest depression causes the growth of rushes, indicating Forest Marble; and here deep ditches may be observable along the strike of the latter, which are useless and inoperative on the porous Cornbrash.

The section at Mr. E. Bowly's farm, Siddington, is a very interesting one, as the ground is considerably faulted; the fault as usual running along what has since become a valley of denudation.

The upper bed of this rock, when fresh quarried, is exceedingly hard, but, when filled with fossils, it soon crumbles down under the action of the atmosphere; if, however, the fossils are few in the rock, it remains intact, and has the harsh intractable feel of the rough Trigonia-grit of the Inferior Oolite, which it so much resembles.

The lower bed bordering on the blue Forest Marble clays are mostly blue-centred, but usually full of fossils, which is seldom the case in the middle of this thin stratum.

2. This rock is of great palæontological interest, not only from the extensive list of species to be found in so thin a bed, and the usual great abundance of these; but principally for the fact that so large a proportion of the fossils (and those too of commonest occurrence) are identical with species in the Inferior Oolite; and yet, in as far as my observations of the British Oolites have extended, these species are not usually to be traced in the beds intermediate between the Inferior Oolite and the Cornbrash.

In appending an analysis of these fossils, I would observe that, though this bed has a tolerably wide range in the neighbourhood of Cirencester and Fairford, yet it is astonishing how few new workings are commenced,—the fact being, that the stone was formerly much used for road-material, but improved transit has caused better materials to be brought from a distance; so that my list of fossils has been made up from a few and very shallow openings. The following is a

Summary of the Cornbrash Fossils.

	Species in the Cornbrash.	Species common to the Inferior Oolite and the Cornbrash.
Cephalopoda	8	 6
Gasteropoda	10	 3
Conchifera	30	 21
Brachiopoda*..........	8	 3
Echinodermata	8	 8
Zoophyta	3	...... ?
Annelida..............	4	 4
	71	 45

* This is the number according to Mr. Davidson's determination; I still, however, include several as synonyms. These are as follow:—

Of this list I shall only here remark upon the Cephalopods and Conchifers, reserving a more complete list of the whole of the Cornbrash species for a future paper.

Of these, the former are at present of great interest, as some have endeavoured to maintain that the Cephalopoda, of all shells, may be confidently appealed to as marking the stratum in which they occur in a more complete manner than any other shells; but, if we apply this to our Cornbrash specimens, we shall see that such an opinion is not founded on extensive observation; and indeed, as we expect, the Cephalopoda of all other molluscous animals, being more *migratory*, and being inhabitants of deep seas, could more readily travel than other families: and, though 6 out of 8 in the following list are not found intermediate between the Inferior Oolite and the Cornbrash in British geology, we have still no evidence that they are not so in the Continental *Jurassique*. At the same time I would again urge the fact, that English geologists have been too much in the habit of giving distinct names to fossils from distinct rocks, upon the assumption of a change which did not always exist in nature; and thus much ingenuity has been expended on species-making by local observers and theoretical geologists, each of whom has too often but a localized theory to support.

The Cephalopoda are as follows:—

	Inf. Oolite.	Cornbrash.
Ammonites Herveyi, *M. C.*	*	*
—— Brocchii, *M. C.*	*	*
—— subradiatus, *M. C.*	*	*
—— Humphresianus, *M. C.*	*	*
—— Jurensis ?, *D'Orb.*	*	*
—— discus, *M. C.*		*
Nautilus truncatus, *M. C.*	*	*
—— inflatus, *D'Orb.*		*

Here then the evidence is just the opposite to that advanced in favour of the new Liasic theory (see p. 103): the 6 are common to lower beds, whilst only one, *A. discus,* would appear to be peculiar to the Cornbrash; were this rock therefore only about 100 feet from the Inferior Oolite, it must upon this new theory be considered as of Inferior Oolite age.

As regards the Conchifers, I have appended the following, most of which have been considered peculiarly to mark the Inferior Oolite*.

Terebratula obovata.
—— *digona.*
—— *lagenalis.*
—— *sublagenalis.*
Terebratula ornithocephala.
—— *intermedia.*
—— *maxillata.*

I would here record my personal obligations to Mr. Davidson for his excellent monographs on the Brachiopoda, as, however we may differ as regards species, all must agree that the forms of this puzzling family are depicted and described with the greatest accuracy.

* See note at p. 120.

List of Fossils common to the Inferior Oolite and Cornbrash of Gloucestershire.*

1. Amphidesma securiforme, *Phill. York.* (Gresslya.)
2. —— decurtatum, *Phill. York.*
3. —— recurvum, *Phill. York.*
4. Astarte excavata, *M. C.*
5. Avicula inæquivalvis, *M. C.*
6. Cardium citronoideum, *Phill. York.*
7. —— dissimile, *M. C.*
8. ——, undetermined.
9. Isocardia concentrica, *M. C.* (Ceromya).
10. —— minima†, *M. C.*
11. Lima gibbosa, *M. C.* 491.
12. Modiola gibbosa, *M. C.*
13. —— plicata, *M. C.*
14. Mya literata, *M. C.*
15. Ostrea, undetermined (perhaps several species).
16. Pholadomya Murchisonæ, *M. C.* t. 545.
17. —— gibbosa?
18. Plagiostoma duplicatum, *M. C.*
19. Pecten.
20. Trigonia costata, *Park.*
21. —— clavellata, *Park.*

The only fossils I have yet found that may be said to be peculiar to the Cornbrash are the *Terebratula obovata* and *T. lagenalis*, and even these I cannot help viewing as distinctive in name only, my series of these shells presenting most remarkable gradations; however, the *T. obovata* by its quantity and allocation may confidently be appealed to in discriminating this stratum.

3. The agricultural peculiarities of Cornbrash are highly interesting; usually the term "*brash*" is one of reproach; and, if a farmer gets a good crop on "only a brash," he is not a little proud of his management; here, however, the term points out this rock as a corn-bearing brash, and this is in itself enough to show that a different practical value had been set upon brashes before the principles involved had been fairly made out, a fact which may be gathered from the following rent-charge:—

1st.	Rent of stonebrash,	Inferior Oolite,	from	7*s*.	to	20*s*. the acre.
2nd.	,, ,,	Great Oolite,	,,	14	,,	25 ,,
3rd.	,, ,,	Cornbrash	,,	20	,,	40 ,,

If we look at the average yield of grain per acre, we shall see that this difference of price is fully justified:—

Table of Produce.

	1. Stonebrash, Inferior Oolite.	2. Stonebrash, Great Oolite.	3. Cornbrash.
	Bushels.	Bushels.	Bushels.
Wheat	15 to 20	20 to 25	25 to 30
Barley	25 to 30	30 to 35	40 to 45
Oats	25 to 30	35 to 40	45 to 50

If we seek for the cause of these results, we shall at once find them by referring to the analysis before quoted, the fact being that the better brashes not only break down more readily under the action of the atmosphere, but they also contain more of the true fertilizing

* See also Cotteswolds Nat. Club Proceed., vol. i. p. 265.

† One of the commonest shells.

principles, among which the phosphatic matter is held to be the most important; and hence we may conclude, that the Cornbrash is more fertile than other brashes because it usually contains more of bones, or the principles of bones, diffused throughout the rock; this in itself would be a sufficient answer to those who would tell us that soils are but little indebted to geological formations for the qualities which they present,—a fact which may be true to a considerable extent in districts where the rock is covered up by local drifts; but in an elevated district, like the Cotteswolds, in which the high-backed hills present their washed and waterworn sides for farm-operations, we shall find that geological lines can be made out with the greatest possible accuracy by peculiarities both in wild and cultivated vegetation; and indeed we know that the very plantation of dwellings has been guided by similar circumstances, a fact which has been partially dwelt on in the description of the Fuller's Earth, p. 111.

10. Oxford Clay with Kelloway Rock (9).

This rock may be first traced on the top of the Cornbrash in a range of low hills a little to the south of Cirencester, as at Siddington, Driffield, and South Cerney; and these form the advanced guard of a sub-formation, which, still further to the south, takes up a wide range of country, and, in its turn, forms the slightly-raised terrace by which the chalk-hills of Wiltshire are reached. In the line of section, Pl. VII., this rock is traced, with the slightest ascertainable dip, to the top of Blunsdon Hill, making altogether a thickness of from 450 to 500 feet; and here it is overlaid by a mass of Coral-rag: but in the deviation-line (Section, Pl. VII.) to Swindon, at C, the Coral-rag appears to be absent, or to occur only in slight patches, and then the country is taken up with Kimmeridge Clay. Hence, then, the Kimmeridge and Oxford Clays often come together, so that it is almost impossible in this district to make out their line of demarcation. However, as we shall hereafter see, where either is in force, they can easily be distinguished by well-marked fossils; and, indeed, even stages of these clays can be made out, not by drawing the line too tightly, and rashly concluding from single fossils, but by a greater or less prevalence, or some peculiar admixture, of ascertained forms.

The following is a general section of the Oxford Clay, as it occurs in its northern extension:—

	feet.
3. Beds of dark blue, clunchy clay, very stiff, and highly tenacious=the "oak-tree clay" of Smith .... about	60
2. Thick bed of dark-blue or ash-coloured shales	50
1. Sandy clay beds, with occasional nodules of hard stone inclosed in sand and rich in fossils,=Kelloway rock.	20

In these beds the following fossils will, for the most part, be found, in the distribution indicated by the figures, though it must be understood that here only the most significant are given, the fossils of this rock being much more numerous than is generally thought* :—

3. Ammonites Mariæ, *D'Orb.*	Ammonites Duncani, *M.C.*
—— Athleta, *Phill.*	Belemnites hastatus, *Blainville.*
—— Goliathus, *D'Orb.*	—— Puzosianus, *D'Orb.*
2. Ammonites Gulielmi, *M.C.* } ? Jason, *Zieten.*	Ammonites Chamouseti, *D'Orb.*
—— Elizabethæ, *Pratt.* }	Gryphæa dilatata, *Phill.*
1. Ammonites Calloviensis, *M. C.*	Terebratula ornithocephala, *M.C.*
—— Kœnigi, *M. C.*	Trigonia—*costated* and *clavellated* forms.
—— sublævis, *M. C.*	
—— Gowerianus, *M. C.*	

The agriculture of the Oxford Clay is very variable ; where good farming prevails, and the necessary preliminary expenses incident to draining and otherwise ameliorating the mechanical texture of the subsoil have been entered into, highly rich tracts of land are seen ; but where these have been neglected, as in the well-known Forest of Braydon, there will be found some of the stiffest and poorest land in the country : this latter circumstance, coupled with the occurrence of occasional deposits of lignite in the thick clay-beds, has for centuries led to futile workings for coal, which are not abandoned even in the present day. A century since, a working of this kind was commenced in the Oxford Clay at Malmesbury, and, after sinking a shaft a little more than 100 yards, the works were abandoned —at the instance, it was said, of proprietors in the Somerset coal-district, "fearing lest the new works would injure them by competition ;" and a short time since the recommencement of the works was agitated: but it may be interesting, as marking what a century has done in this direction, to know that, previously to deciding upon so doing, the opinion of a geologist was sought in the matter; and, as I happened to be chosen to make a report upon the subject, it will not be wondered at, that I should recommend the works to be abandoned. However, people still think, from the wild aspect of much of the country occupied by the Oxford Clay—simulating, as it does, the appearance of a district in which mining and manufacturing has injured vegetation and caused agriculture to be neglected —that the surface indicates mining-ground ; and some of the lignite got out of the clay in the section made for the Great Western Railway is still preserved as good evidence of coal by some, who, occasionally finding similar lignite in the clay in brick-fields and elsewhere, credulously say, "if coal is so good and so thick near the surface, how much thicker may it not be found at the depth of a mine!"

11. Coral Rag.

This rock will be seen represented in Section, Pl. VII., at the top of Blunsdon Hill, where it attains the thickness of about 15 feet ; and in the deviation to Swindon small exhibitions of the stratum may

* A full list of these, it is hoped, will be given hereafter : there are many new forms.

be marked: in travelling along the Great Western line of railway, a section may be observed in deep cutting a little to the north of Swindon. Indeed, the Coral-rag may be occasionally observed capping the minor hills in advance of the long chain of the Wiltshire chalk-range. Occasionally, though our sections and those of Lonsdale and Fitton would make it appear that the Coral-rag is a continuous stratum, having the Oxford Clay below and the Kimmeridge Clay above, it seems in North Wilts to occupy only hummocks, and to be sometimes wanting altogether, when the line of demarcation between the two clays just named is exceedingly difficult to determine. The district now under review, however, is not the best in which to study this bed, as it is here only partially developed, and its accompanying drifts of the Calne district are entirely absent: in the words of Lonsdale, "The rubbly oolite constitutes the greater part of the Coral-rag of Wiltshire; it is formed of a nodular limestone of an earthy aspect, a brownish, yellowish, or blueish white colour, and abounds with fragments of echini and shells*." This very well describes the rock of my section.

Thin as the stratum is in this district, it is very rich in fossils, and amongst others found at Blunsdon are the following

Corals.

Thecosmilia annularis
Stylina tubulifera
—— Delabechii
Thamnastræa arachnoides
Isastræa explanata
} See Monograph by Edwards and Haime (Palæontographical Society).

Echinoderms.†

Cidaris Blumenbachii, *Münster.*
Diadema depressum, *Agassiz.*
Diadema subangulare, *Goldfuss.*
Nucleolites dimidiatus, *Phill.*‡

Bivalve Shells.

Modiola inclusa§,
Pecten inæquicostata,
Crassina ovata,
} *Phillips.*

Univalves.

Turbo muricatus, *Geol. York.*, pl. iv. f. 14.
—— funiculatus, *id.* pl. iv. f. 11.
Turritella muricata, *id.* pl. iv. f. 8.

Ammonites.

Ammonites perarmatus||, *M. C.* t. 352.
Ammonites triplex, *M. C.* t. 292.

It is worthy of note that the *Brachiopoda* seem not to be represented in the Coral-rag.

* Lonsdale on the Oolite District of Bath, Geological Society Transactions, 2nd ser. vol. iii. p. 241, &c. Read 6th Feb., 1829.

† The species are so common as to be found in handfuls; the test, however, is difficult to obtain perfect.

‡ Sometimes occurring in masses.

§ Abundant in galleries in the corals.

|| This and the following are frequently of great size.

Now, if we review the disposition of the masses of this rock, and examine its structure, we shall, I think, conclude that it was not deposited continuously on a uniform sea-bottom, but in separated lumps,—by the peculiar method of working of the coral-animal, to whose labours this bed is mainly due, and under circumstances in all probability similar to those of our modern coral-reefs. This, however, would of itself induce in the then existing sea a physical change of condition, which had its influence on the succeeding deposit, namely, the Kimmeridge Clay. The latter, though differing slightly from the Oxford Clay with which it is in contact, as on the road from Blunsdon to Swindon, is marked by a good set of fossils: these at times are the only guide, as the colour of both the Oxford and the Kimmeridge Clay is very variable, and besides, throughout their whole extent, both are remarkable for the quantity of fine crystals of selenite diffused through them; these very large at Ashton Keynes, in the lower beds of the Oxford Clay; and the Kimmeridge Clay at Swindon is full of beautiful crystalline groups of sulphate of lime.

12. Kimmeridge Clay.

Along the line of section, both in its direction to Swindon and Wanborough, this deposit will be seen to succeed the Oxford Clay, of which, indeed, it may, as far as the district under review is concerned, be considered as the upper beds, having the Coral-rag as an occasionally interpolated and local deposit.

The Kimmeridge Clay occupies a wide range of flat country around the hill on which Swindon stands, and here it is a dark, lead-coloured, unctuous clay, of a shaly consistence when first dug; the layers of the clay are parted by white nacreous matter, the only remains of thousands of Ammonites and other shells, which are only locally preserved. Every bed of clay that I have examined about New Swindon, where it is largely worked for brick-making, is full of crystals of selenite, and no less remarkable for the quantity of *Trigonellites latus*, valves of which, all sizes, are best studied here.

The Kimmeridge Clay at this place may be divided into two stages:—

2. The upper one of dark shales, in which *Trigonellites latus*, *Exogyra virgula*, and *Ammonites* prevail.

1. The lower of lead-coloured and blue clays, full of large masses of *Ostræa deltoidea* and abundant sheaths of *Belemnites excentricus*, Blainville, often of very large size.

The following list of fossils is by no means complete, and is only offered as evidence of the prevailing facies.

Reptilia.—A species of *Pliosaurus*, of immense size; fine portions of this are in the museum at Cirencester, and in that of the Royal Agricultural College.

Belemnites excentricus, *Blain.*
—— Beaumontianus, *D'Orb.*
Trigonellites latus, *Fitton*, Mem. t. 23, f. 11.
Ammonites serratus, *M. C.*
—— Goliathus, *Ter. Jurass.* t. 195.
—— Sallierianus, *id.* t. 208.

Rhynchonella inconstans, *M. C.*
Ostræa deltoidea, *M. C.*, occurring in masses.
Exogyra virgula, *Fitton*, Mem. t. 23, f. 10.
Panopæa depressa, *id.* t. 23, f. 9.
Serpula variabilis, *Fitton*, Mem. t. 23, f. 7.
—— triseriata, *id.* t. 23, f. 8.

13. Portland Oolite.

Swindon Hill, in the line of section, Pl. VII., may be described as an isolated mass of Portland Oolite, capped with the lower beds of the Wealden (Purbeck) series. This Oolite by no means occupies a continuous line along the base of the Wiltshire Hills, as the section through Stratton St. Margaretts shows it to be entirely absent along that line, where the chalk-group rests immediately upon the Kimmeridge Clay. As shown by Dr. Fitton, the Portland Oolite is exceedingly patchy; and the map illustrating his memoir "On the strata below the chalk*" well shows the isolated masses of this rock in Wiltshire.

The Portland rock seems to have been the first upraised land from the oolite-sea, and, as such, formed a theatre for the dwelling of land and fresh-water existences which mark the Wealden deposits: hence, the Wealden would be forming on the isolated peats of Portland at the same time that Greensand and Gault were being deposited in the surrounding seas; thus affording an example in proof that stratigraphical schemes which represent such beds as the Wealden, when on the top of the Portland Oolite, Coral-rag, and Bradford Clay (to confine our remarks to the Oolites), as of different age from the beds surrounding them, is not always correct. This view is founded upon the fact, that Portland Ooolite, with only a capping of Wealden, occurs in North Wilts in occasional knolls or sub-hills; but, where it is absent, the continuity of the succeeding beds is not at all altered, nor their conformability interfered with.

The Portland Oolite has been much denuded since its deposition, and upon its washed surface the dirt-bed, which dips into its hollows and fissures, has left its remains, as seen in the section at Old Swindon Hill.

The following sections will give a tolerably correct notion of the composition of the Portland rock at Swindon, the furthest limit of our observations in this memoir:—

A Section of the Upper Beds at the large Stone-quarry.

	ft.	in.			ft.	in.
6. Clay	8	0	Purbeck Strata.	2. Brownish Marl, mixed with pebbles and gravel, containing vegetable matter. (=Dirt-bed.)	3	0
5. White Marl-stone	2	6				
4. Band of Clay	1	0				
3. White Marl-stone	3	6				

	ft.	in.
1. Sandy Oolites with thick beds of sand: the sand in oblique laminæ: to the bottom of the quarry	20	0

The next section illustrates the nature of a sand- and stone-quarry at the base of Swindon old town:—

2. Portland building-stone, about	10 feet.
1. Portland Sands, with thin partings of stone, about	25 ,,

* Trans. Geol. Soc. 2nd ser. vol. iv. p. 103, &c.

From these data I infer that the Portland Oolite at Swindon is about 40 feet in thickness, and capped by about 18 feet of Wealden beds. It is not my intention to enter into a discussion about the Wealden character of these upper beds* ; I, however, quite agree that they are simply the outliers of a rock which assumes great importance farther south, as in the Vale of Wardour, where they have been so successfully worked and ably described by Dr. Fitton and my friend the Rev. P. B. Brodie.

As regards the fossils of the Portland rock, these will be found to be highly typical of an Oolitic deposit; and, if they be compared with those of the true Chalk, the latter would seem to indicate a sudden and extraordinary change in the fauna; the passage is, however, after all, tolerably gradual from the Oolites to Chalk, through the medium of the Greensand, such fossils as the *Trigonia, Panopæa, Cardium, Pinna,* and *Perna* being at least important genera common to both Greensand and Portland Oolite.

The following list of fossils of the Portland at Swindon, all of which I have obtained from the large quarry, are mostly determined from Dr. Fitton's list and illustrative engravings; they consist of

Ammonites giganteus, *M.C.*
—— biplex, *M. C.*
Terebra Portlandica, *Fitton,* Mem. pl. 23, f. 6.
Natica elegans, *id.* pl. 23, f. 3.
Buccinum naticoides, *id.* pl. 23, f. 4.
—— angulatum, pl. *id.* 23, f. 5.
Nerita angulata, *id.* pl. 23, f. 2.
Trigonia incurva, *Benett,* Wiltsh. Foss. t. 18, f. 2.
Trigonia gibbosa, *Fitton,* pl. 22, f. 4.
—— species?
Lucina Portlandica, *id.* pl. 22, f. 12.
Cytherea rugosa, *Fitton,* pl. 22, f. 13.
Cardium dissimile, *M. C.*
Perna quadrata, *M.C.*
Panopæa depressa, *M. C.*
Pecten lamellosus, *M.C.*

Large masses of coniferous wood are often found on the Portland measures; and occasionally well-preserved trunks of trees are exhumed at the Swindon quarries.

Here, then, I must content myself for the present with having described the more general characteristics of all the members of the Oolitic series of rocks; it will, however, be seen that the discussion of physical changes, such as a description of the many faults by which the country under review is intersected, the facts connected with our numerous valleys both of denudation and depression, the drifts by which the country is overspread, and which are so diverse in character, and other interesting physical phenomena have been, for the most part, unnoticed. This, however, is not from inattention to such important matters, but from want of time to put my notes together; and so, for such matters, as also for a comprehensive list of fossils of the Oolites, now in course of preparation, I must beg indulgence until the next session of our Society; indeed, from

* Besides Dr. Fitton's paper above referred to, see Mr. Brodie's and Mr. Austen's Notices of these beds, Quart. Journ. Geol. Soc. vol. viii. p. 53, and vol. vi. p. 467.

the length of this paper, these subjects may well form a future communication.

I would now, therefore, conclude with the hope that the present paper may not be without interest, at the same time that I would earnestly beg the kind indulgence of the Geological Society; since the many calls upon my time have prevented my rendering the subject so complete as I could wish.

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3. *On the* Geology *of the* Southern Part *of* Andalusia, *between* Gibraltar *and* Almeria. By Professor D. T. Ansted, M.A., F.R.S., F.G.S.

[The Publication of this paper is unavoidably deferred.]

[Abstract.]

The object of the author in this memoir was to direct attention to several points of interest and importance in the Geology of the south of Spain. These had reference to deposits of various ages, including the metamorphic rocks, both of the Sierra Nevada and the coast.

1. The mica-schists of the Sierra Nevada form a well-marked series, limited in position to the higher elevations. They are garnetiferous, and traversed by veins of serpentine. Bands of quartz alternate with the schists. On the south-west side deposits of highly argentiferous copper-ore have been recently worked, but they appear to be irregular. Specimens of greenstone were discovered by the author on the north side of the Sierra, but not *in situ*, and no such rock has been described. On the north side the mica-schist is covered towards the west by limestone, highly crystalline, and recently found to contain deposits of galena. Over these are thick beds of marl and calcareous beds of tertiary date, and irregularly over all is detritus of a comparatively recent period. On the south side is a deep ravine, thick beds of shale occupying the space between the schists and the limestones of the Sierra de Gador, long celebrated for numerous and rich lead-mines. Beyond the limestone to the south are metamorphic schists (not micaceous), and in some places the contact of the limestones and these schists is marked by a gradual transition. These schists are continued, with little break, parallel to the coast, and at no great distance from it, for at least a hundred miles; and at intervals they contain deposits of copper-ore not argentiferous. Near Malaga the author has observed a gradual passage from these schists into a conglomerate, and thence into the triassic and jurassic deposits subsequently described. The schists are argillaceous and chloritic, and as well as the mica-schists are traversed by serpentine-veins. No organic remains have been discovered in any of the schistose beds.

2. Over the schists on the coast, a little to the east of Malaga, at a point where there is a dislocation, a fœtid magnesian limestone is presented to view, and is regarded by the author as Permian. This limestone is black, semi-crystalline, unfossiliferous, entirely distinct from the dolomites of the Sierra de Mijas adjacent, and is immediately overlaid by a group of shales and sandstones, at the top of which is

the calamite-grit next alluded to. It corresponds in position with the conglomerates or passage-beds between the shales and red sandstones near Malaga.

3. Above the magnesian limestone just described, or immediately over the conglomerates, the author observed a considerable series of whitish marly sandstones, marls, red sandstones, white sandstones with vegetable-markings and occasional lenticular masses of gypsum, extending along the coast from some distance west of Malaga to the eastern side of the Sierra Nevada. Near Malaga, at one spot, calamites (*Equisetites*) have been obtained from a quarry of white sandstone used for building-purposes, near the top of the series. Specimens of these were exhibited. A band of lignite of no value has been opened in the lower part of the red sandstone series, near the hill of San Telmo.

4. Next in order are the blue and black limestones of the Sierra de Gador, and others of the north side of the Sierra Nevada, both passing into whiter and cream-coloured limestones towards the west, and in the neighbourhood of Gibraltar becoming pale, clear, and semi-crystalline. A few fossils have been found in this limestone at Gibraltar, some of which were shown. Others have been met with, but very rarely, at intermediate points between Gibraltar and Granada. Although the limestones of the Sierra de Gador and others in that vicinity are highly crystalline and metamorphosed, and are traversed by large veins and fissures containing enormous deposits of galena, the author is satisfied that they are not more ancient than the middle secondary period, and form a continuous series along the whole line of coast.

5. Cretaceous rocks have been described on the summit of San Anton, a few miles from Malaga, and they are believed to range into the interior. The author described the appearance of the red marble of San Anton, containing *Belemnites*, which are not yet specifically determined.

6. Older tertiaries are known to exist near Malaga. The author described a peculiar calcareous breccia, forming a semi-crystalline bed of limestone, reposing on the cretaceous and jurassic rocks, near Malaga, and covered by a very perfect compact oolitic limestone, capable of taking a high polish, and almost a marble. This bed lies over the limestone-breccia, and beneath or alongside a foraminifera-bearing limestone, composed of *Orbitoides* and *Alveolina*, and also extremely compact. It belongs to the Nummulitic limestone series. It was traced by the author to some distance.

7. The vicinity of Malaga presents a large space occupied entirely with newer tertiary rocks, and these extend at intervals up the water-courses and river-valleys, and along the coast both east and west. They have been already described to some extent by Col. Silvertop and other geologists, but it is only lately that the author was enabled to discover beds richly fossiliferous, which will enable the Palæontologist to decide absolutely with regard to the relative age of these rocks. The following sequence of the rocks belonging to the newer tertiary and recent periods is suggested by the author as justified by

the rocks in the south of Spain, and likely to be useful for future reference.

Recent	River-detritus.	
Raised beaches.	Angular fragments of slate and other adjacent rock	Coast near Malaga.
	Fine white sand and pebbles without organic remains	Guadalmedina, banks of.
	Marly incrustations with numerous recent shells	Sta. Catalina.
Upper Tertiary.	Coarse gravel with sand and pebbles... fossiliferous..............................	Caleta and Jabonero arroyos.
	Marly sands with land, freshwater, and rolled fossils	Tejares beds.
	Blue clay and marl loaded with foraminifera, univalve and bivalve shells, and bones of large pachyderms.	
Lower Tertiary.	Nummulitic limestone.	
	Oolitic limestone and limestone-breccia.	

The Tejares (or Brick-pit) beds consist of whitish sandy marls, with land and freshwater fossils overlying other sandy marls, and blue marly clays loaded with foraminifera, and in many places abounding with fossil shells, both univalves and bivalves, in a perfect state of preservation. Fragments of a jaw and vertebra of *Rhinoceros*, believed by Dr. Falconer to be *R. megarhynchus*, were exhibited at the meeting. The author has since received fragments of a large cetacean, and has been informed that very perfect remains of fishes have been found. The author brought home a large collection of these fossils, for which he was mainly indebted to the active cooperation of an English lady, resident in Malaga. He was also assisted by Don Antonio Linera and Don Pablo Prolongo, both of Malaga. The result of the minute examination of these fossils will be communicated later, but they seem to place the deposit amongst those of the Sub-Apennine period, the newest being probably not far distant in time from the newer tertiary deposits of Montpelier and Perenas, recently described by Christol. The beds of this group are laid bare at various places in the Vega or Plain of Malaga, and always present the same character. They have been subjected to elevation and are tilted at a small angle in various places, especially near the hills of triassic and jurassic rock in the interior.

The Caleta deposits (so called from the arroyo or river-bed in which they are seen) consist chiefly of sand- and pebble-beds, loaded with fossil shells, chiefly confined to a few species of *Pecten* and *Ostrea*, but including other bivalves and some univalves. These deposits are traceable up the bed of the Caleta for about a mile, and are also seen in the bed of the Jabonero, and in a plain that extends on its left bank. They are far less rich in species than the Tejares, but there are often beds entirely consisting of Pectens or Oysters, mixed only with a little loose sand.

The Catalina beds consist of a thin coating of hardish marly limestone, containing a few fragments of Pectens and other shells, little if at all different from those living in the adjacent seas, but at a level of 50 feet or more above that of the Mediterranean. These beds cover immediately the jurassic limestones without the intervention of any other tertiaries, and may probably be regarded as raised beaches.

The true raised beaches of sand, pebbles, and angular fragments, chiefly of slate-rock, are well exhibited close to Malaga on the east, and at various points between Malaga and Almeria, both on the cliffs where they approach the sea, and up the arroyos or water-courses to the point where these enter the more abrupt and mountainous country behind. Their elevation varies, but often exceeds 60 feet. The nature of these deposits, and the causes to which they are due, are considered by the author to offer matter for careful study in connection with the phenomena of denudation generally in all parts of the world.

8. The author then alluded to the economic geology of the district under consideration. It contains copper-ores, some of them argentiferous, but generally with too little silver to increase the value of the ore. These occur in bunches, and with few exceptions have not been worked to profit. They are confined to the schists. Lead-ores have been worked for centuries in the Sierra de Gador, and more recently in the adjacent limestone on the north side of the Sierra Nevada. These ores are galena and carbonate of lead, with little or no silver; but galena with antimony-ore occurs near Marbella, and lead-ores have been worked in the dolomite of the Sierra di Mijas. Iron-ore in vast abundance, and of admirable quality, is also obtained from behind Marbella. Building-materials of fine quality, both limestones and sandstones, are readily procurable near Malaga, the former from the jurassic, cretaceous, and older tertiary series, the latter from the calamite-grit. Good lime is procurable to any extent, and at moderate price, from the jurassic limestone. Good brick-clay, and fine clays for pottery, from which is manufactured the delicate terra-cotta figures for which Malaga is celebrated, are procured from the newer tertiary beds of the Tejares and others in the plains of the Guadalmedina. White sands for glass-making and other purposes are taken from the triassic beds near the calamite-bed. Gypsum of fair quality is found abundantly in large lenticular masses in the sandstones underlying the jurassic limestones, both near Malaga and near the Sierra Nevada.

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4. *Descriptions of* Fossil Invertebrata *from the* Crimea.* By William H. Baily, Esq., F.G.S., of the Geological Survey of Great Britain.

[Plates VIII., IX., X.]

The specimens described in this communication were principally collected by Capt. C. F. Cockburn, of the Royal Artillery, who has also supplied the Note on the Geology of the Neighbourhood of Sevastopol, which is appended to this paper.

* An abstract of this communication was read at the British Association Meeting, August 1856.

JURASSIC.

Amorphozoa.

1. Scyphia Cockburnii, sp. nov. Pl. VIII. fig. 1, *a*, *b*.

A convoluted sponge, having ten or eleven prominent plications or costæ, with a central nearly circular canal $\frac{6}{10}$ths of an inch in diameter.

The structure is somewhat obscure, but, where exposed, exhibits an irregular porous texture; its base appears to have been adherent.

Dimensions: length $1\frac{1}{2}$ inch, diameter $1\frac{1}{4}$ inch.

Locality. From red Jurassic limestone near Balaclava.

Dedicated to Capt. C. F. Cockburn.

Zoophyta.

Order Zoantharia=Aporosa.

Fam. Fungidæ.

2. Comoseris irradians, M.-Edw. & J. Haime, Brit. Foss. Cor. Pal. Soc. p. 101, t. 19. f. 1, *a–d*.

This and the several other fossil corals from the same locality, hereafter mentioned, can scarcely be distinguished lithologically or specifically from those obtained from the Coralline Oolite of Steeple Ashton, Wiltshire.

Loc. Soudaxioxia. Presented to the Museum of Practical Geology by the Imperial School of Mines at St. Petersburg.

Fam. Astræidæ.

2 *a*. Thecosmilia annularis ?, Flem. sp.; M.-Edw. ibid. p. 84. t. 13, 14. f. 1.

A mass of small Polypidoms, which may be referred to this species, in compact argillaceous limestone from Simferopol.

Presented by the Imperial School of Mines, St. Petersburg.

3. Isastræa Greenoughii, M.-Edw. Pal. Soc. p. 96. t. 17. f. 2.

Loc. Soudaxioxia.

Presented by the Imperial School of Mines, St. Petersburg.

4. Isastræa (Astræa ?) polygonalis, Mich.

Fragment of the worn surface of this coral exhibiting a tessellated appearance in red crystalline limestone, from the Bathing-place one mile west of Balaclava.

5. Isastræa explanata ?, Goldf. sp.; M.-Edw. Pal. Soc. p. 94. t. 18. f. 1.

A weatherworn mass of what appears to be this species in white crystalline limestone, from between the Monastery of St. George and Balaclava.

6. Thamnastræa arachnoides, Park. sp.; M.-Edw. Pal. Soc. t. 18. f. 1 *k*.

An adult specimen of a very flat and thin form, having the stars in

W. H. Baily del et lith.

Printed by Hullmandel & Walton.

JURASSIC AND CRETACEOUS FOSSILS FROM THE CRIMEA.

depressions; both sides well preserved; the under side covered with a small species of *Serpula*.

Loc. Soudaxioxia.

Presented by the Imperial School of Mines, St. Petersburg.

7. Calamophyllia Stokesii ?, M.-Edw. Pal. Soc. t. 16. f. 1 *a–d.*

Identical with or closely allied to this species.

Loc. From between the Monastery and Balaclava.

Another specimen, probably identical with this species, but too imperfect for determination, was obtained from the Gorge of Iphigenia.

8. Montlivaltia trochoides, M.-Edw. Pal. Soc. p. 129. t. 26. f. 2, 2 *a*. 3, 3 *a*. & t. 27. f. 2, 2 *a*.

A very perfect specimen of a single polypidom is contained in the British Museum collection. Presented by Mrs. Cattley.

Loc. Tchatyr-dagh or Tent Mountain.

Echinodermata.

9. Fragment of a spine of *Cidaris*?

Associated with *Terebratula numismalis* in Lower Jurassic limestone, equivalent to the Lias.

Loc. Woronzoff Road.

10. Spine of *Cidaris*?

In grey limestone from the lowest beds of the Jurassic series.

Loc. Gorge of Iphigenia.

11. Spines of *Cidaris Blumenbachii.*

Loc. Soudaxioxia.

Presented by the Imperial School of Mines, St. Petersburg.

12. Spines of *Cidaris glandifera.*

Loc. Between the Monastery and Balaclava.

13. Spine of *Cidaris*?

From red clay-veins in Jurassic limestone.

Loc. Between the Monastery and Balaclava.

14. Spine of *Cidaris*?

Barrel-shaped with small central cavity, in red-tinged compact Jurassic limestone.

Loc. The Bathing-place one mile west of Balaclava.

15. Joints of the stem of *Apiocrinites incrassatus,* Rœmer, Die Verst. Ool. t. 1. f. 12.

In red clay from the Jurassic limestone.

Loc. Between the Monastery and Balaclava.

Larger joints in a similar matrix with corals have been brought from the last-mentioned locality.

16. Portions of the stem of *Pentacrinites basaltiformis.*

Loc. Soudaxioxia.

Presented by the Imperial School of Mines, St. Petersburg.

17. Two plates of a Starfish, with punctated surface.

In grey limestone, with the spine No. 10, from the lowest beds.
Loc. Gorge of Iphigenia.

MOLLUSCA. BRACHIOPODA.

18. TEREBRATULA NUMISMALIS, Lam.

This characteristic Lias species was obtained from grey limestone and shale.
Loc. Woronzoff Road. Lower Lias.

19. TEREBRATULA ROTUNDATA?, Rœmer.

Allied to *T. ovoides,* Sowerby, in compact pinkish limestone.
Loc. Woronzoff Road.

20. TEREBRATULA JAMESII, sp. nov. Pl. VIII. fig. 2, *a, b.*

Shell inequivalved, ovate, longer than wide; rostral valve moderately convex, smaller valve somewhat flattened; beak prominent and truncated, with a rather large foramen; lateral margin of valves slightly curved, and a somewhat flattened front; surface smooth, punctated, and marked by concentric lines of growth.
Dimensions.—Length 1 inch, breadth $\frac{8}{10}$ths of an inch.
Loc. From dark-grey Jurassic limestone, Balaclava.
Collected by Major Cooke, R.E. Dedicated to Lieut.-Col. James, R.E.

21. TEREBRATULA, sp. Probably *T. subovoides,* Münst.

Found with the large barrel-shaped spine, No. 14, in red compact limestone.
Loc. The Bathing-place one mile west of Balaclava.

22. TEREBRATULA PEROVALIS?

From the matrix of *Ammonites fimbriatus,* Middle Lias.
Loc. Village of Biasali.
Presented by Imperial School of Mines, St. Petersburg.

23. TEREBRATULA. Lower part of a large species, probably *Terebratula Strogonofii,* D'Orb. Geol. of Russia, &c. p.489, in compact red limestone.
Loc. Gorge of Iphigenia.

24. TEREBRATULINA RADIATA, sp. nov. Pl. VIII. fig. 3, *a–d.*

Shell inequivalved, nearly hemispherical; beak produced, slightly recurved, truncated, with a large foramen and triangular deltidium; surface of valves beautifully punctate, and ornamented with from 20 to 25 longitudinally elevated striæ.

Dimensions.—Length $\frac{3}{10}$ths, breadth $\frac{2\frac{3}{4}}{10}$ths of an inch.

Loc. Balaclava. Six specimens of this elegant little Brachiopod were detached from the matrix which contained *Terebratula Jamesii.*

25. RHYNCHONELLA COOKEI, sp. nov. Pl. VIII. fig. 5, *a, b.*

Shell considerably wider than long; valves slightly convex; beak acute; foramen small, surface ornamented by about 30 acute plaits, having a central elevated mesial fold composed of 10 plaits.
Dimensions.—Height $1\frac{6}{10}$ inch, breadth $2\frac{1}{4}$ inches.

Allied to *Rhynchonella subtetrahedra*, Dav. (Monog. Brit. Ool. Lias, Brach., Pal. Soc. p. 95. pl. 16. f. 9–12), but differs in the greater number of plaits, and in its greater breadth compared with its length. It has a winged appearance, and belongs to the group *Alatæ* of Von Buch.

The specimens, of which there are two, were collected from the grey limestone of Balaclava by Major Cooke, to whom it is dedicated.

26. Rhynchonella pectinata, sp. nov. Pl. VIII. fig. 4, *a*, *b*.

Shell inequivalve, subtrigonal, slightly convex, longer than wide, widest at the front and gradually tapering upwards towards the beak; beak acute; foramen large, surrounded by the deltidium, and separated from the umbo; valves somewhat flattened and fan-shaped, without mesial fold or sinus; surface ornamented by about twelve large plaits or costæ.

Dimensions.—Height $\frac{7}{10}$ths, breadth $\frac{6}{10}$ths of an inch.

Allied to *R. pectunculoides*, Schlot., but differing in its greater length in proportion to its breadth, and in having more costæ.

Loc. Gorge of Iphigenia, in red crystalline limestone.

27. Rhynchonella senticosa, Von Buch; Davids. Brit. Ool. Lias, Brach., Pal. Soc. p. 73, pl. 15. f. 21.

Mr. Davidson describes this species from the lowest beds of the Inferior Oolite. M. D'Orbigny places it in the Oxfordian. Our specimen was collected by Major Cooke from the grey limestone of Balaclava, apparently equivalent to Inferior Oolite.

28. Rhynchonella acuta, Sow.

From the matrix of *Ammonites fimbriatus*.

Loc. Village of Biasali. Middle Lias or Marl-stone.

Presented by the Imperial School of Mines, St. Petersburg.

29. Rhynchonella variabilis?, Schlot.

Of this species the back of the rostral valve only is exposed, on a slab of coarse greyish limestone.

Loc. From the base of the rocks at the Gorge of Iphigenia.

Lamellibranchiata. Asiphonida.

30. Ostrea. Small species in a light-brown marl, with but few other traces of fossils.

Loc. From Karani. Lias shale?

31. Ostrea, sp. Associated with *Cardium æquistriatum*, No. 35, and *Terebratula numismalis*, No. 18.

Loc. Woronzoff Road leading to Kamara. Lower Lias shale.

32. Ostrea, sp. A coarsely plicated species in the red clay of the Jurassic limestone, associated with Corals, No. 4, spines of *Echini*, Nos. 13, 14, and *Terebratula*, No. 21.

Loc. Bathing-place one mile west of Balaclava.

33. Gryphæa dilatata, Sow.

Single valves of adult shells, with massive hinge-areas in a similar matrix with the Corals, Nos. 2, 3, and 6.

Loc. Soudaxioxia.

Presented by the Imperial School of Mines, St. Petersburg.

34. GRYPHÆA INCURVA, Sowerby.

Associated with *Ammonites,* Nos. 40, 41, and 42, in reddish marly limestone with ferruginous granules.

Loc. Village of Biasali. Middle Lias.

Section SIPHONIDA.

35. CARDIUM ÆQUISTRIATUM, sp. nov. Pl. VIII. fig. 6, *a*, *b*.

Shell subtrigonal, convex; umbones prominent and contiguous; anterior surface ornamented with concentric and very regular small ridges, posterior portion with radiating longitudinal lines, widely distant at the margins.

It differs from *Cardium truncatum* of the Lias in being less concave, and its radiating posterior lines are more widely distant, and the concentric ridges more defined and regular, the umbones being placed nearest the posterior side.

Dimensions.—Height $\frac{5}{10}$ths, breadth $\frac{6}{10}$ths of an inch.

Loc. Woronzoff Road. Lower Lias.

36. ASTARTE COMPLANATA, Rœmer, Verst. pl. 6. f. 28.

Associated with the *Cardium* last described, No. 35; *Ostrea,* No. 31, and *Terebratula numismalis,* No. 18.

Loc. Woronzoff Road leading to Kamara. In dark-brown shales. Lower Lias.

GASTEROPODA. HOLOSTOMATA.

37. NATICA, sp. A large species allied to *Natica Clio,* D'Orb. Ter. Jur. pl. 292, but too imperfect for description.

Loc. In red clay of Jurassic limestone between the Monastery and Balaclava.

Dimensions.—Height $2\frac{2}{10}$ inches, breadth $1\frac{6}{10}$ inch.

38. NERINÆA GRANDIS?, D'Orb.

A fragment of what appears to be this species.

Loc. Village of Djanatai.

Presented by the Imperial School of Mines, St. Petersburg.

CEPHALOPODA. TETRABRANCHIATA.

39. AMMONITES URALENSIS?, D'Orb. in Geol. of Russia.

A fragment of apparently a young individual of this species from red Jurassic limestone.

Loc. Bathing-place one mile west of Balaclava.

40. AMMONITES RAQUINIANUS?, D'Orb. Ter. Jur. pl. 106.

A fragment of what appears to be this species, although somewhat doubtful, obtained from the same matrix as the next species, No. 41.

Loc. Village of Biasali. Middle Lias.

Presented by the Imperial School of Mines, St. Petersburg.

41. AMMONITES JURENSIS?, Zieten; D'Orb. Ter. Jur. pl. 100.

A specimen most probably identical with this species, but in too bad a state for certain determination.

Loc. Village of Biasali. Middle Lias.

Presented by the Imperial School of Mines, St. Petersburg.

42. Ammonites fimbriatus, Sowerby; D'Orb. Ter. Jur. pl. 98.

From the same locality and matrix as *Gryphæa*, 33, and *Ammonites*, 40, 41, 42. Red marly limestone with ferruginous specks.

43. Trigonellites?

In the body-chamber of an Ammonite of the group *Ligati.* In compact grey Lias limestone.

Loc. Woronzoff Road below Kamara, leading to Vernutka Valley.

NEOCOMIAN.

Mollusca.

44. Requienia, sp. Closely allied to, if not identical with *R. ammonia* (Matheron), D'Orb. Ter. Crét. p. 250. pl. 578.

Loc. Numerous fragments of this spiral bivalve were obtained by Major Hudson, 39th Regiment, from the coarse crystalline limestones used in the construction of the road between Balaclava and the Plateau. It is associated with many fragments of *Nerinæa,* No. 46, and *Natica,* No. 45.

Presented by Major Hudson.

45. Natica prælonga, Desh.; D'Orb. Ter. Crét. p. 152. pl. 172. f. 1.

A fine cast of a large elongated *Natica* appears to be identical with the above species, having a portion of shell on the upper whorls sufficient to show that the sutures were nearly covered up by the shell, as was also the umbilicus, which in the cast has a deep impression.

Loc. and *matrix* similar to the last.

46. Nerinæa? (or *Chemnitzia,* D'Orb.), sp. nov.

A spiral shell, shorter than the generality of the genus *Nerinæa,* although too imperfect for description.

Loc. and *matrix* similar to Nos. 44 and 45.

47. Nerinæa, sp.

Several fragments of a large *Nerinæa,* somewhat allied to *Nerinæa gigantea,* D'Hombres Firmas; D'Orb. Ter. Crét. t. 2. p. 77. pl. 158. f. 1, 2, but not so angular at the sutures as that species.

Loc. and *matrix* the same as Nos. 44, 45, 46, and 47.

48. Nautilus pseudo-elegans, D'Orb. Ter. Crét. p. 7. pl. 8, 9.

This specimen may easily be mistaken for one found in our own country, its aspect being very like that of the same species from the Lower Greensand of Kent and the Isle of Wight.

Loc. Village of Biasali?

SENONIAN.

Mollusca. Brachiopoda.

49. Crania spinulosa, Nilsson. Pl. VIII. f. 7 *a–h*.

Some confusion having arisen respecting this species, and, as it has not been hitherto well illustrated, it has been thought advisable to refigure it from the beautiful specimens collected by Captain Cockburn, which have enabled us to give enlarged representations of both valves of this fine Brachiopod.

On submitting specimens to Mr. Thomas Davidson, he referred it to the *Crania spinulosa,* Nilsson, t. 3. f. 9 a–e, with the following remarks:—"It is different from the one so named by Goldfuss, which is the *Crania Hagenovii* of De Koninck. It agrees with Nilsson's figure in being of the same size, and externally covered with short tubercular asperities or spines; and the interiors of both dorsal and ventral valves agree with the Swedish author's illustrations. This species is less circular than *Nummulus Brattenburgensis* (= *C. nummulus*), it has also a small flattened false area in the attached valve; neither are there in any of the figures of that species given by Nilsson, Goldfuss, or Hœninghaus any of those tubercular spines depicted which may be observed in the specimens from Inkerman and in the drawing of *C. spinulosa* in Nilsson's work; on the contrary, the valves of *C. nummulus* are represented smooth.

Du Bois de Montpéreux, in his 'Tableau des fossiles de la Craie en Crimée,' at subdivision No. 8, 'Craie marneuse blanche,' catalogues *Crania nummulus* associated with *Ostrea vesicularis,* and this Mr. Davidson agrees with me in thinking to be most probably identical with our species.

Capt. Cockburn collected as many as thirty-eight specimens of the valves of this *Crania* (of which twenty-nine were lower or ventral valves, and but nine dorsal or upper valves) from the coarse white chalk of Inkerman associated (like the *Crania* mentioned by Dubois) with *Ostrea vesicularis* and other species.

Lamellibranchiata. Asiphonida.

50. Ostrea carinata, Lamarck; D'Orb. Ter. Crét. pl. 474.

Loc. Village of Badrax. Upper Greensand.

51. Ostrea vesicularis, Lamarck; D'Orb. Ter. Crét. pl. 486. f. 1, 2.

Loc. Village of Badrax. A mass from the Upper Greensand; two specimens from Lower Chalk; presented by the Imperial School of Mines, St. Petersburg. Seven specimens from Upper Chalk; Inkerman.

52. Ostrea frons, Parkinson.—*O. diluviana,* D'Orb. Ter. Crét. pl. 483.

Loc. Badrax. Upper Greensand.

Presented by the Imperial School of Mines, St. Petersburg.

53. Ostrea flabellata, D'Orb. pl. 475.

Loc. Badrax. Upper Greensand.
Presented by the Imperial School of Mines, St. Petersburg.

54. Ostrea hippopodium, Nilsson, t. 7. f. 1 a, b; D'Orb. pl. 482.
Loc. Badrax. Upper Greensand.
Presented by the Imperial School of Mines, St. Petersburg.
Loc. Inkerman. Upper Chalk.

55. Ostrea laciniata, D'Orb. pl. 486. f. 1, 2.
(*Chama*) *laciniata*, Nilsson.
Loc. Inkerman. Upper Chalk.

56. Ostrea curvirostris, Nilsson, t. 6. f. 5 a, b.
Loc. Inkerman. Eight single valves from Upper Chalk.

57. Ostrea, sp. nov.?
Loc. Inkerman. Two single valves. Upper Chalk.

58. Exogyra haliotoidea, Lamarck.
Chama haliotoidea, Sow. M. C. t. 25; Nilsson, t. 8. f. 3 a–d.
Loc. Inkerman. Upper Chalk.

59. Exogyra columba, Lamarck (Morris's Catalogue).
Ostrea columba, Desh.; D'Orb. Ter. Crét. pl. 477.
Gryphæa columba, Sowerby.
Loc. Badrax. Upper Greensand.
Presented by the Imperial School of Mines, St. Petersburg.

60. Avicula? Lithuana, Eichw.

This fine large oyster-like shell, which is at present placed in the genus *Avicula* (although doubtfully) by Bronn in his 'Index Palæontologicus,' has a straight hinge-line without ears, the right valve being convex with concentric laminæ, and the left flat (as in *Ostrea*) with widely distant radiating furrows; hinge toothless and central, with a large cartilage-pit.
Loc. Badrax. In Upper Greensand.
Presented by the Imperial School of Mines, St. Petersburg.

Section Siphonida.

61. Astarte?, sp.
Loc. Inkerman. Upper Chalk.

62. Crassatella, sp. Cast of the interior of a large species.
Loc. Inkerman. White Chalk.

63. Crassatella, sp. Casts of a large species, which differs in various particulars from the last, No. 62.
Loc. Inkerman Castle Rock. White Chalk.

Two specimens collected by Dr. Sutherland, of the Sanitary Commission for the Army of the East.

64. Cardium conniacum?, D'Orb. Ter. Crét. pl. 244.
Loc. Inkerman. Upper Chalk.

Two other species were collected by Capt. Cockburn from the same locality, which are too imperfect for description.

65. Lucina, sp. Cast of the interior of an orbicular shell, most probably belonging to this genus.

Loc. Inkerman. Upper Chalk.

66. Acropagia, Corbis?

Loc. Inkerman. Upper Chalk.

Gasteropoda.

The Gasteropoda of the Cretaceous formation are but poorly represented in this collection, the few specimens being scarcely fit for determination.

67. Acteonella or Globiconcha?, D'Orb.

Loc. Inkerman. Upper Chalk.

68. Natica, sp. In the British Museum there is a fine mould of the interior of a large *Natica*, from Upper Greensand, River Alma. Presented by Mrs. Cattley.

69. Natica, sp. A smaller species than the last.

Loc. Inkerman. Upper Chalk.

70. Turritella, sp. allied to *T. Bauja*, D'Orb.

Moulds of the interior of a spiral shell resembling this species.

Loc. Inkerman. Upper Chalk.

VERTEBRATA. 71. Lamna?, sp.

NUMMULITIC=SUESSONIAN (D'Orbigny).

Foraminifera.

Genus Nummulites, Lamarck, 1804.

72. Nummulites distans, Desh. Mém. Soc. Géol. France, vol. iii. p. 68, pl. 5. f. 20–22, & *N. polygyratus*, Desh. *loc. cit.* f. 17–19.

N. distans, D'Archiac et Haime, Anim. Foss. l'Inde, p. 91, pl. 2. f. 1–5.

A mass of whitish limestone made up of this and the following species.

Loc. Simferopol.

Presented by the Imperial School of Mines, St. Petersburg.

Detached specimens of this species were collected by Dr. Sutherland and Mr. Olver, Army Works Corps, close to the road at Inkerman on the British side.

73. Nummulites Raymondi, Defrance. D'Arch. et J. Haime, Anim. Foss. l'Inde, p. 128, pl. 7, f. 13–17.

Nummulites rotularius, Desh. Mém. Soc. Géol. vol. iii. p. 68, pl. 6. f. 10, 11. *N. mammilla*, D'Orb. Prodrome, p. 336.

This small species occurs under the same conditions as the last, the limestone of Simferopol being made up of these remains. It was also collected at Inkerman by Mr. Olver.

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ECHINODERMATA.

74. CONOCLYPUS CONOIDEUS, Agassiz, Cat. p. 109.
Clypeaster conoideus, Du Bois, Voy. au Caucase.
Loc. Simferopol.

MOLLUSCA.

75. OSTREA GIGANTEA, Brander. (*Ostrea latissima*, Desh.)
Loc. Simferopol.

76. CERITHIUM GIGANTEUM, Lamarck.
Loc. Simferopol.
Presented by the Imperial School of Mines, St. Petersburg.

MIDDLE OR NEWER TERTIARY.—(FALUNIAN, D'Orbigny.)

AMORPHOZOA.

77. SCYPHIA PORTLOCKII, sp. nov. Pl. IX. f. 1, *a*, *b*.

Sponge more or less elongated, forming a somewhat rounded and irregular tube, smallest in diameter at the extremities, perforated throughout its length by a single large canal opening at each extremity and having sharp raised edges; surface thickly covered with irregular pores.

Dimensions of one specimen:—length 1 inch, greatest diameter $\frac{1}{2}$ an inch, diameter of tube $\frac{2}{10}$ths of an inch. A second specimen measured but $\frac{6}{10}$ths of an inch in length, with a diameter of $\frac{1}{2}$ an inch.

Loc. Monastery of St. George.

Dedicated to Col. Portlock, Pres. Geol. Soc.

FORAMINIFERA.

77 *a*. POLYSTOMELLA CRISPA, Linnæus.

Mr. Rupert Jones has detected two specimens of this very minute Nautiloid form (still common in the Atlantic and Mediterranean) on the weathered surface of a limestone, made up of fragments of shells, principally bivalves, and collected by Lieut.-Col. Munro in the neighbourhood of Sebastopol.

MOLLUSCA. ASIPHONIDA.

78. MYTILUS APERTUS, Desh. Mém. Géol. Soc. France, vol. iii. p. 61, pl. 4. f. 6–11. *Myoconcha aperta*, D'Orb.
Loc. Kertch. In iron-ore. Collected and presented by Dr. M'Pherson.

79. DREISSENA (MYTILUS) ROSTRIFORMIS, Desh. Mém. Soc. Géol. France, vol. iii. p. 61. t. 4. f. 14–16.

This and the preceding species were found associated with the numerous and peculiar forms of *Cardium*, hereafter mentioned, in the deposits of iron-ore near Kertch. Collected by Dr. M'Pherson. There is also a specimen in the British Museum.

79 *a*. DREISSENA INÆQUIVALVIS, Nyst.
Mytilus inæquivalvis, Desh. *loc. cit.* pl. 5. f. 1–3.
Collected by Dr. M'Pherson. From iron-ore, Kertch.

Siphonida.

80. Cardium protractum, Eich. Voy. Hom. pl. 6. f. 6–8.

This small species is common at most of the localities.

Loc. Dock-yard, Sevastopol; Quarantine; Monastery; and Gorge of Iphigenia.

81. Cardium amplum, sp. nov. Pl. IX. fig. 2, *a–d*.

Shell thin, much broader than high, ornamented with about fifteen much elevated radiating ribs, which are strongly imbricated towards the margin, and unequally distant, widely separated and more curved towards the posterior slope of the shell, where the costæ become suddenly closer; umbones subcentral, margins crenulated, hinge-line long and but slightly curved; right valve with a slightly prominent cardinal and two lateral teeth.

Dimensions.—Height $\frac{5}{10}$ths, breadth $\frac{7}{10}$ths of an inch.

The only specimen of this small and delicate species is a very perfect right valve.

Loc. Monastery of St. George.

82. Cardium Demidoffi, sp. nov. Pl. IX. fig. 3, *a, b, c*.

Shell elongated, subtrigonal, ornamented with about twelve widely distant and sharp ribs, closely imbricated and less prominent on the posterior slope of each valve; umbones anterior and approximating, margins crenulated.

Dimensions.—Height $\frac{6}{10}$ths, breadth $\frac{9}{10}$ths of an inch.

Very abundant from the Monastery of St. George (in the bed R of the section); mostly casts of the interior. Our figured specimen has a portion of the shell still attached.

This species differs from *Cardium Fittoni* by its greater breadth in proportion to its height, and in having more numerous and less elevated ribs, without the sharp and prominent asperities of that species.

Dedicated to M. Anatole Demidoff, author of the fine work on Southern Russia and the Crimea.

83. Cardium Fittoni, D'Orb. in Murchison's Geol. of Russia.

Loc. Sevastopol; Monastery. Casts collected by Major Cooke and Capt. Cockburn; and, with the shell attached, from the Quarantine Harbour.

84. Cardium carinatum, Desh. Mém. Soc. Géol. de France, 1838, p. 54. pl. 2. f. 16–18.

Loc. Kertch. In iron-ore. Collected by Dr. M'Pherson.

85. Cardium squamulosum, Desh. ibid. p. 48. pl. 1. f. 14, 15.

Loc. Kertch. In iron-ore. British Museum Collection.

86. Cardium macrodon, Desh. ibid. p. 49. pl. 1. f. 3–6.

An interesting specimen of this nearly smooth *Cardium*, in which the shell has been converted into phosphate of iron, the interior containing crystals of carbonate of lime.

Loc. Kertch. In iron-ore. Collected by Dr. M'Pherson.

87. Cardium crassatellatum, Desh. ibid. p. 51. pl. 3. f. 7–10.
Loc. Kertch. In iron-ore. British Museum Collection.

88. Cardium paucicostatum, Desh. ibid. p. 52. pl. 2. f. 14, 15.
Loc. Kertch. In iron-ore. Two specimens collected by Dr. M'Pherson.

89. Cardium corbuloides, Desh. ibid. p. 54. pl. 1. f. 11–13.
Loc. Kertch. In iron-ore. Presented by Captain Cockburn.

90. Cardium Verneuilii, Desh. ibid. p. 55. pl. 2. f. 9, 10.
Loc. Kertch. In iron-ore.
Presented by Captain Cockburn and Dr. M'Pherson.

91. Cardium ovatum, Desh. ibid. p. 56. pl. 1. f. 19–21.
Loc. Kertch. In iron-ore.
Presented by Captain Cockburn and Dr. M'Pherson.

92. Cardium Edouardi, D'Orb. *C. incertum,* Desh. ibid. p. 56. pl. 2. f. 11–13.
Loc. Kertch. In iron-ore.
Collected by Dr. M'Pherson.

93. Cardium subedentulum, D'Orb. *C. edentulum,* Desh. ibid. p. 51. pl. 3. f. 3–6.
Loc. Kertch. In iron-ore.
British Museum Collection.

94. Cardium pseudocardium ?, Desh. ibid. p. 59. pl. 1. f. 1, 2.
Loc. Kertch. In iron-ore.
Presented by Captain Cockburn.

95. Cyprina Pallasii, sp. nov. Pl. IX. fig. 4, *a, b.*

Shell large and thick, subtrigonal, broader than high, concentrically striated, with an oblique angle on the posterior side of each valve; umbones approximate, oblique and tumid. Cardinal teeth 3, with a posterior lateral tooth.

Dimensions.—Height $1\frac{9}{10}$ inch, breadth $2\frac{1}{10}$ inches.

Loc. Monastery of St. George; the shells being well preserved in crystalline limestone, and casts of the interior (the shell having decomposed) from a more sandy deposit. Fine casts of what appears to be this species were collected by Major Cooke from the left flank of a parapet of the Redan, the stone used in its construction having been procured from a quarry adjacent: the fossils from this deposit are mostly in the state of casts.

96. Cyprina Georgei, sp. nov. Pl. IX. fig. 8, *a, b.*

Shell oblong-ovate, concentrically striated, with an oblique angle on the posterior side; right valve with two narrow cardinal teeth, having a deep pit on one side, and a posterior lateral tooth; muscular impressions oval, pallial line simple.

Dimensions.—Height 1, breadth $1\frac{1}{2}$ inch.

Loc. A single well-preserved specimen of the right valve only was collected from the Monastery of St. George.

97. Cyprina naviculata, sp. nov. Pl. IX. fig. 6, *a–c*.

Shell oblong, the anterior extremity rounded, posterior very acute; cardinal teeth 2, and a posterior lateral tooth.

Dimensions.—Height $\frac{3}{10}$ths, breadth $\frac{5}{10}$ths of an inch.

Loc. Quarantine Harbour. The fossils here have their valves united; a fortunate fracture in one specimen exposes the hinge.

98. Cyprina? triangulata, sp. nov. Pl. IX. fig. 9.

Shell suborbicular, concentrically striated; umbones prominent and oblique; muscular impressions oval, pallial line simple.

Dimensions.—Height 1, breadth $1\frac{3}{10}$ inch.

This species is doubtfully referred to the genus *Cyprina*, none of the specimens showing the hinge, being mostly casts; but, as it is one of the most numerous of the fossil bivalves from these deposits, it was thought advisable to figure and describe it.

Loc. It has been collected from Sevastopol by Major Cooke; from Iphigenia and the Monastery by Captain Cockburn (in bed R).

99. Astarte pulchella, sp. nov. Pl. IX. fig. 10, *a–c*.

Shell small, suborbicular, concentrically striated; two cardinal teeth.

Dimensions.—Height $\frac{1}{4}$th of an inch, breadth the same.

Loc. Nine specimens of this beautiful little species were collected, having both valves united, from the Gorge of Iphigenia (bed J of the section), associated with other small shells. The left valve of a specimen being fortunately removed, the mould and hinge are shown.

100. Astarte quadrata, sp. nov. Pl. IX. fig. 7, *a–d*.

Shell very thick, oblong, depressed, somewhat square, concentrically striated; umbones forming a sharp angle; hinge with two cardinal teeth, lateral teeth obscure; pallial line deep, simple.

Dimensions.—Height $\frac{8}{10}$ths of an inch, breadth 1 inch.

Loc. Four specimens of this very thick shell were obtained from the Monastery, being fragments of the upper part containing the hinge of both valves well preserved. Several supposed casts of this species (fig. 7, *d*) were obtained from the same locality.

101. Venus semiplana, sp. nov. Pl. IX. fig. 5, *a*, *b*.

Shell oblong, depressed, concentrically striated, posterior side subangular; umbones anterior and acute; hinge of right valve with three cardinal teeth (the central one prominent) and one lateral tooth.

Dimensions.—Height $\frac{6}{10}$ths, breadth $\frac{7}{10}$ths of an inch.

A single specimen of the right valve only, in good preservation.

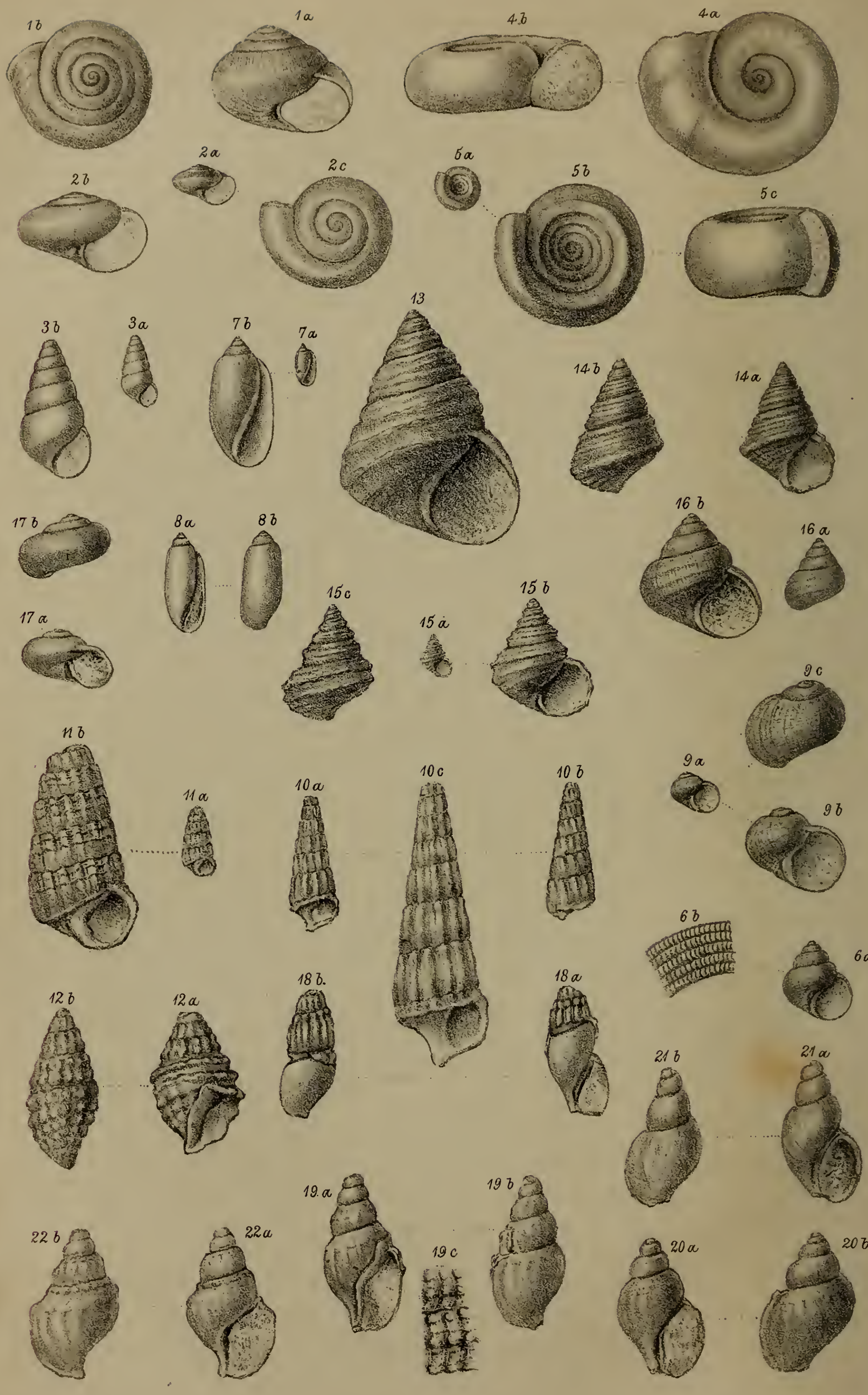
Loc. Gorge of Iphigenia.

102. Venus minima, sp. nov. Pl. IX. fig. 12, *a–c*.

Shell elongated oval; umbones anterior.

Dimensions.—Height $\frac{2}{10}$ths, breadth $\frac{1\frac{1}{2}}{10}$th of an inch.

Three specimens of this very small and beautifully preserved shell with both valves united, were collected from the Monastery and Gorge



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of Iphigenia in bed J of the section, associated with *Astarte pulchella*, &c.

103. SOLEN ?, sp. A single fragment of the posterior extremity of an elongated straight shell apparently belonging to this genus.

Loc. Quarantine Harbour.

104. POTAMOMYA IPHIGENIA, sp. nov. Pl. IX. fig. 13, *a–d*.

Shell thick, elongated and compressed; umbones nearly central; one cardinal tooth in each valve.

Dimensions.—Height $\frac{1}{4}$th, breadth $\frac{11}{20}$ths of an inch.

Three single valves showing the interiors.

Loc. Gorge of Iphigenia.

105. PHOLAS HOMMAREI, D'Orb. Voy. Hom. pl. 4. f. 16–18.

Loc. Monastery, and Gorge of Iphigenia; from bed P of the section.

GASTEROPODA. OPISTHOBRANCHIATA.

106. TORNATELLA MINUTA, sp. nov. Pl. X. fig. 7, *a, b*.

Shell small, cylindrical, smooth; spire short, acute, with four or five whirls; aperture long and narrow, inner lip callous, covering part of the body-whirl.

Dimensions.—Axis $\frac{2}{10}$ths, diameter $\frac{1}{10}$th of an inch.

Loc. Quarantine Harbour.

107. TORNATELLA INFLEXA, sp. nov. Pl. X. fig. 8, *a, b*.

Shell cylindrical; spire short, with three or four whirls; aperture long and narrow; body-whirl inflexed or bent inwards at the middle.

Dimensions.—Axis $\frac{1}{2}$, breadth $\frac{2\frac{1}{2}}{10}$ths of an inch.

This is a much larger species than the preceding, and differs in being of less diameter in proportion to its size.

Loc. Four specimens, all casts, were collected by Major Cooke, from the Redan.

PULMONIFERA.

108. HELIX DUBOISII, sp. nov. Pl. X. fig. 1, *a, b*.

Shell subglobose, perforated, and finely striated, having five volutions with an elevated conoidal spire; margin reflected, partly covering the umbilicus.

Dimensions.—Diameter $\frac{6}{10}$ths, elevation $\frac{6}{10}$ths of an inch.

This species occurs in considerable numbers, and was obtained from a marly deposit (bed C of the section), of a bright-red colour, at the Monastery of St. George, and of a yellow tinge from the Gorge of Iphigenia. It was associated with the two next following species.

It bears a considerable resemblance to the recent *H. arbustorum*, but is smaller, and the spire not quite so elevated.

Dedicated to M. Du Bois de Montpéreux, to whom we are indebted for so full a description of the geology of that country, in his great work on the Crimea and the Caucasian Provinces.

109. HELIX BESTII, sp. nov. Pl. X. fig. 2, *a–c*.

Shell small, depressed above, forming an obtuse angle on the body-whirl; under-side tumidly convex; about four whirls; umbilicus moderately sized and deep; slightly reflected peristome.

Dimensions.—Diameter $\frac{3}{10}$ths, elevation $\frac{2}{10}$ths of an inch.

This species was found associated with *Helix DuBoisii* and *Bulimus Sharmani*, &c., in light-brown marl.

Loc. Gorge of Iphigenia.

Dedicated to Edward Best, Esq., of the Geological Survey of Great Britain.

110. BULIMUS SHARMANI, sp. nov. Pl. X. fig. 3, *a*, *b*.

Shell small, obtusely turreted; whirls 5 to 7, more or less irregular in form and number; aperture oval.

Dimensions.—Height $\frac{4}{10}$ths, breadth $\frac{2}{10}$ths of an inch.

Loc. Gorge of Iphigenia.

Dedicated to George Sharman, Esq., of the Geological Survey of Great Britain.

111. PLANORBIS OBESUS, sp. nov. Pl. X. fig. 5, *a–c*.

Shell small, orbicular, and very stout, having six whirls, which almost cover each other; aperture compressed and oblique.

Dimensions.—Diameter $\frac{1}{4}$th, thickness of outer whirl $\frac{1}{10}$th of an inch.

Found associated with the previously described land-shells, Nos. 108, 109, and 110.

Loc. Gorge of Iphigenia.

112. PLANORBIS CORNUCOPIA, sp. nov. Pl. X. fig. 4, *a*, *b*.

Shell large, formed of four nearly round volutions separated by a deep suture, the outer volution having two or three transverse constrictions.

Dimensions.—Diameter 1 inch, thickness of outer whirl $\frac{9}{20}$ths of an inch.

Loc. Of this elegantly formed freshwater shell, the finest specimen is in the Woolwich Royal Artillery Institution, collected from before Sevastopol by Major Anderson, R.A. One other specimen was obtained by Captain Cockburn from the Gorge of Iphigenia (bed P of the section).

113. CYCLOSTOMA RETICULATUM, sp. nov. Pl. X. fig. 6, *a*, *b*.

Shell turbinated; surface spirally striated and crossed by very fine transverse lines; axis perforated; aperture nearly circular; whirls 4 or 5.

Dimensions of imperfect cast.—Axis $\frac{4}{10}$ths, diam. $\frac{3}{10}$ths of an inch.

This cast retains a portion of the shell attached, showing distinctly its reticulated sculpture.

Loc. Gorge of Iphigenia (bed C of the section). Associated with the land-shells before described.

PROSOBRANCHIATA.

114. TURBO, sp. Casts of a large turbinated shell, which may

be referred to this genus, too imperfect for description, were collected by Major Cooke from the Redan.

115. Trochus Corderianus, D'Orb. Voy. Hom.

Very abundant at the Quarantine Harbour, sixteen specimens having been obtained from that locality, the deposit in which they were imbedded being a fine-grained compact yellowish marl, particularly rich in specimens of this genus: they are mostly in beautiful preservation, the shells having become crystallized.

116. Trochus Fenonianus, D'Orb. Voy. Hom.

Loc. Quarantine Harbour.

117. Trochus Pageanus, D'Orb. Voy. Hom.

Loc. Quarantine Harbour.

118. Trochus Murchisoni, sp. nov. Pl. X. fig. 13.

Shell obtusely conical, elevated, having five or six volutions; slightly convex, with about three transverse somewhat granular ridges on each whirl; base convex, imperforate; aperture suborbicular.

Dimensions.—Axis $1\frac{2}{10}$ths, diameter $\frac{9}{10}$ths of an inch.

Loc. Quarantine Harbour.

Dedicated to Sir Roderick I. Murchison, Director-General of the Geological Society of Great Britain.

119. Trochus Andersoni, sp. nov. Pl. X. fig. 14, *a, b*.

Shell conical, with flat sides and elevated spire; volutions six, ornamented with about five irregular elevated ridges; base nearly flat; columella suboblique; aperture trapeziform.

Dimensions.—Axis $\frac{7}{10}$ths, diameter $\frac{5}{10}$ths of an inch.

Allied to *T. Voronzoffi* and *T. Pageanus*, D'Orb. Voy. Hom., but differs from the latter species by its smaller diameter, and in the ridges not being granulated.

Loc. Monastery of St. George.

Dedicated to Major Anderson, Royal Artillery.

120. Trochus Beaumontii, D'Orb. in Voy. Hom.

Loc. Monastery of St. George.

.21. Trochus Blainvillei, D'Orb. in Voy. Hom.

Cast of the interior.

Loc. Gorge of Iphigenia.

122. Trochus Hommarei, D'Orb. in Voy. Hom.

Loc. A fine and perfect specimen from the Quarantine Harbour collected by Capt. Cockburn, and a less perfect one from Sevastopol collected by Major Anderson, R.A.

123. Trochus pulchellus, sp. nov. Pl. X. fig. 15, *a, b, c*.

Shell very small, with an acutely elevated spire; whirls five, ornamented with three sharp much-elevated and crenulated transverse ridges; base convex; aperture suborbicular; umbilicus small.

Dimensions.—Axis $\frac{3}{10}$ths, diameter $\frac{2}{10}$ths of an inch.

Loc. Quarantine Harbour.

124. Trochus Sutherlandii, sp. nov. Pl. X. fig. 16, *a*, *b*.

Shell with a short pyramidal spire; whirls rounded, five in number; base convex, slightly umbilicated; body-whirl with four or five slight and unequally distant spiral carinations, crossed by numerous faint and regular transverse lines; aperture nearly circular.

Dimensions.—Axis $\frac{7}{20}$ths, diameter $\frac{3}{10}$ths of an inch.

Loc. Monastery of St. George.

Dedicated to Dr. Sutherland, of the Sanitary Commission, Army of the East.

125. Trochus Lygonii, sp. nov. Pl. X. fig. 17, *a*, *b*.

Shell depressedly conical, trochiform, volutions four, convex: suture broad; aperture subcircular; umbilicus large and deep.

Dimensions.—Axis $\frac{3}{10}$ths, diameter $\frac{19}{40}$ths of an inch.

Loc. Monastery and Gorge of Iphigenia, collected by Captain Cockburn; also casts of two small specimens from the Redan, collected by Major Cooke.

Dedicated to Lieut.-Col. Charles Lygon Cocks, of the Grenadier Guards.

126. Littorina monastica, sp. nov. Pl. X. fig. 9, *a–c*.

Shell globular, imperforate; spire small, obtuse; volutions three, spirally striated and crossed by faint transverse lines of growth; aperture large, nearly circular; inner lip callous, covering part of the body-whirl.

Dimensions.—Axis $\frac{2}{10}$ths, diameter $\frac{2\frac{1}{4}}{10}$ths of an inch.

Loc. Monastery of St. George.

127. Paludina achatinoides, Desh. Mém. Soc. Géol. France, 1838, p. 64. pl. 5. f. 6, 7.

Loc. Kertch. In iron-ore. Collected by Dr. M'Pherson.

128. Cerithium Cattleyæ, sp. nov. Pl. X. fig. 12, *a*, *b*.

Shell turreted; spire short; whirls five, with about three rows of largely granulated bands; aperture subquadrate; columella recurved and without a fold.

Dimensions.—Axis $\frac{7}{10}$ths, diameter $\frac{4}{10}$ths of an inch.

Allied to *C. Taitboutii*, D'Orb. Voy. Hom.; the tubercles are, however, more distinct and fewer on each whirl.

Loc. Monastery of St. George.

There are also two specimens in the British Museum Collection, presented by Mrs. Cattley, to whom this species is dedicated.

129. Cerithium cochleare, sp. nov. Pl. X. fig. 10, *a–c*.

Shell elongate, turreted, regularly tapering; whirls seven in number, with longitudinal ribs; aperture subquadrate.

Dimensions.—Axis $\frac{8}{10}$ths, diameter $\frac{3}{10}$ths of an inch.

Loc. Gorge of Iphigenia (bed J).

130. Cerithium truncatum, sp. nov. Pl. X. fig. 11, *a*, *b*.

Shell small, turreted, obtusely conical; whirls four; outline of the spire slightly swollen towards the middle, top obtuse as if truncated, ornamented with three bands transversely striated and elevated into costæ; aperture subquadrate.

Dimensions.—Axis $\frac{4}{10}$ths, diameter $\frac{1\frac{1}{2}}{10}$th of an inch.

Loc. Gorge of Iphigenia.

131. Pleurotoma Chersonesus, sp. nov. Pl. X. fig. 19, *a–c*.

Shell fusiform, turreted, lower whirl with ten longitudinal costæ, having two rows of nodules at the upper part of each whirl, transversely striated; aperture elongato-ovate, with a short sinus at its upper part.

Dimensions of imperfect specimen.—Axis $\frac{8}{10}$ths, diameter $\frac{4}{10}$ths of an inch.

Loc. Gorge of Iphigenia and the Monastery (bed R of the section).

132. Pleurotoma laqueata, sp. nov. Pl. X. fig. 18, *a, b*.

Shell turriculate and fusiform, volutions elongated and longitudinally costated, passing into two rows of obtuse nodules next the suture; aperture elongato-ovate.

Dimensions of imperfect specimen with two whirls.—Axis $\frac{6}{10}$ths, diameter $\frac{3}{10}$ths of an inch.

Loc. Monastery of St. George (bed R of the section).

133. Buccinum obesum, sp. nov. Pl. X. fig. 20, *a, b*.

Shell ovato-conical; whirls ventricose with distant slightly raised costæ; aperture oval; canal short and reflected.

Dimensions of cast.—Axis $\frac{8}{10}$ths, diameter $\frac{5}{10}$ths of an inch.

Loc. Monastery, and the Gorge of Iphigenia (bed R of the section).

134. Buccinum angustatum, sp. nov. Pl. X. fig. 21, *a, b*.

Shell elongated oval, narrow; whirls four or five, with about ten slightly raised and distant costæ; aperture oval; canal short.

Dimensions.—Axis $\frac{8}{10}$ths, diameter $\frac{4}{10}$ths of an inch.

Loc. Monastery of St. George.

135. Buccinum moniliforme, sp. nov. Pl. X. fig. 22, *a, b*.

Shell ovato-conical; whirls five, angular; spire elevated, with slightly raised costæ; the upper part of the whirl bears an angular band of elongated obtuse nodules, and a row of bead-like obtuse nodules next the suture of each whirl; aperture oval; canal short and reflected.

Dimensions.—Axis $\frac{8}{10}$ths, diameter $\frac{5}{10}$ths of an inch.

Loc. Gorge of Iphigenia.

136. Buccinum Doutchinæ, D'Orb. Voy. Hom. pl. 3. f. 20–22.

Loc. Monastery of St. George.

137. Buccinum Daveluinum, D'Orb. Voy. Hom. pl. 3. f. 23.

Loc. Monastery of St. George.

138. Buccinum corbianum, D'Orb. Voy. Hom. pl. 3. f. 24, 25.
Loc. The Quarantine, Monastery, and the Gorge of Iphigenia.

139. Buccinum dissitum, Eichw. Murch. Russia, pl. 43. f. 35, 36.
Loc. The Monastery, and the Gorge of Iphigenia.

A few remarks naturally arise from an examination of the species. Commencing with the oldest or Jurassic, these bear the greatest resemblance in specific identity to those of our own country; the characteristic examples of *Terebratula numismalis* from the lowest fossiliferous beds serving to point out the shales of the Woronzoff road to be equivalent with those of our Lower Lias, as the presence of *Rhynchonella acuta, Gryphæa incurva, Ammonites Jurensis,* and *A. fimbriatus* from the village of Biasali, indicates the Marlstone or Middle division of the Lias.

The fossils received from Balaclava (principally *Brachiopoda*) appear to be related to forms from the Lower or Inferior Oolite, although for the most part specifically distinct from any met with in England; *Rhynchonella senticosa,* an Inferior Oolite species, being the only one I have been enabled to identify from that locality.

Fossils from the intermediate formations of the Secondary age are absent in this collection, although several species, principally Cephalopoda, are catalogued as belonging to the Oxfordian division from Baktchserai by M. Du Bois de Montpéreux, and from Kobsel on the south coast of the Crimea by M. D'Orbigny.

In this collection are contained several species, principally Zoophyta, from Soudaxioxia, forming part of a series formerly presented to the Museum of Practical Geology by the Imperial School of Mines at St. Petersburg. These fossil corals are perfectly undistinguishable from similar species met with in the Coral Rag of Steeple Ashton.

The Neocomian or Lower Greensand group, as well as the upper division of the Cretaceous series, has some few fossils identical with British species. The principal part of the fossils from this formation are from Baktchserai, and are catalogued by M. Du Bois in his 'Tableau de Fossiles de la Craie en Crimée.'

An interesting form of spiral bivalve belonging to the *Chamidæ,* allied to our *Requienia* (*Diceras*) *Lonsdalii,* but more nearly to *Requienia Ammonia,* Matheron, occurred in great abundance, accompanied by a large *Nerinæa* allied to *N. gigantea.* Many fragments of these species were collected by Major Hudson, 39th Regiment, from a very coarse crystalline limestone used in the construction of roads between Balaclava and the Plateau.

The Upper Chalk of Inkerman has supplied several species (principally *Ostrea*) common to our own country; the most important and beautiful fossil, as well as the most abundant, from this locality is the *Crania spinulosa,* Nilsson, before alluded to.

The Nummulitic or Older Tertiary fossils are also principally catalogued by M. Du Bois in his 'Tableau,' as occurring at Baktchserai. This collection contains some large and characteristic species from Simferopol, amongst which are the large Echinoderm called *Conoclypus conoideus, Ostrea gigantea,* and *Cerithium giganteum.* Of the Foraminifera the principal species are *Nummulites distans,* Deshayes, and *Nummulites Raymondi,* D'Archiac (*N. rotularius,* Desh.). Several species of Mollusca included in M. Du Bois' list, such as *Cardium porulosum, Cerithium giganteum, Fusus turgidus, Voluta muricina,* and *V. luctatrix,* with *Turritella imbricataria,* are common in the Barton and Bracklesham beds of this country.

The Middle, or Newer Tertiary formation, which, under the name of Steppe Limestone, covers the largest extent of country in the Crimea, is abundant in fossils having peculiar characters different from those of any deposit in England, being closely analogous to forms at present existing in the great inland salt seas of the Aral and Caspian. The peculiar forms of *Cardium* and *Dreissena* found in the deposits of iron-ore near Kertch and in other parts of the Crimea, of brackish-water origin, are believed to indicate the former existence of a great inland sea, of which the Aral and Caspian are remnants, but which was larger than the present Mediterranean; a belief of which the illustrious Pallas was the first propounder.

The Mollusca from other Newer Tertiary deposits near Sevastopol are more marine in their character, the Bivalves belonging principally to the genus *Cyprina,* the Univalves to peculiar forms of *Buccinum* and *Trochus*: of the latter, 11 species were collected, 6 being identical with forms figured in the 'Voyage of M. Hommaire,' and described by M. D'Orbigny, from Kichinev in Bessarabia: they also occur in the Tertiary deposits of Podolia and Volhynia, indicating a probable contemporaneity of all these geological formations.

Table of Jurassic Fossils found in the Crimea.

Number of specimens.	Name.	Locality.	Lias.	Infer. Oolite.	(Oxfordian) Coral Rag.
	Amorphozoa.				
1	Scyphia Cockburnii, *Baily.* Pl. VIII. fig. 1 *a, b.*	Near the Monastery of St. George.	......	*	
	Zoophyta.				
1	Comoseris irradians, *Edw.*	Soudaxioxia..............	......	...	*
1	Thecosmilia annularis, *Flem.,* sp....	Simferopol	......	...	*
1	Isastræa Greenoughii, *Edw.*	Soudaxioxia.............	......	...	*
1	—— ? Astræa polygonalis, *Mich.*				
1	—— explanata ?, *Goldf.*..............	Between Monastery and Balaclava.	......	*	
2	Thamnastræa arachnoides, *Park.,* sp.	Soudaxioxia..............	......	...	*
3	Calamophyllia Stokesii, *Edw.*	Between Monastery and Balaclava.	......	*	
1	Montlivaltia trochoides, *Edw.*	Tchatyr Dagh	......	*	
	Echinodermata.				
1	Cidaris ? (spine)	Woronzoff Road	*		
2	——	Gorge of Iphigenia ...	......	*	
8	—— Blumenbachii (spines), *Goldf.*.	Soudaxioxia..............	......	...	*

Number of specimens.	Name.	Locality.	Lias.	Infer. Oolite.	(Oxfordian) Coral Rag.
1	Cidaris glandifera, *Goldf.*	Between Monastery and Balaclava.	......	*	
2	—— ?	do.	......	*	
2	—— ?	1 mile W. of Balaclava .	......	*	
2	Apiocrinites incrassatus, *Rœmer* (joints).	Between Monastery and Balaclava.	......	*	
8	Pentacrinites basaltiformis, *Mill.* ...	Soudaxioxia.............	......	...	*
2	Starfish (plates)	Gorge of Iphigenia......	......	*	
	Mollusca.				
4	Terebratula numismalis, *Lam.*	Woronzoff Road	*		
1	—— rotundata ?, *Rœmer*	Woronzoff Road	*		
1	—— Jamesii, *Baily.* Pl. VIII. fig. 2.	Balaclava..................	......	*	
1	—— subovoides ?, *Münst*............	Between Monastery and Balaclava.	......	*	
1	—— perovalis ?, *Sow*..................	Biasali	Marlstone.		
1	—— Strogonofii ?, *D'Orb*.............	Iphigenia..................	......	*	
6	Terebratulina radiata, *Baily.* Pl. VIII. fig. 3 *a–d.*	Balaclava...........	......	*	
2	Rhynchonella Cookei, *Baily.* Pl. VIII. fig. 5 *a, b.*	Balaclava..................	......	*	
1	—— pectinata, *Baily.* Pl. VIII. fig. 4 *a, b.*	Iphigenia..................	......	*	
1	—— senticosa, *Von Buch*	Balaclava..................	......	*	
1	—— acuta, *Sow*........................	Biasali	Marlstone.		
1	—— variabilis ?, *Schloth.*	Iphigenia..................	......	*	
	Avicula decussata, *Münst.* (*Du Bois*)	?	*		
3	Ostrea, sp.	Karani	* ?		
1	——, sp.	Woronzoff Road	*		
1	——, sp.	1 mile W. of Balaclava .	......	*	
2	Gryphæa dilatata, *Sow.*	Soudaxioxia................	......	...	*
1	—— incurva, *Sow*......................	Biasali Village............	Marlstone?		
6	Cardium æquistriatum, *Baily.* Pl. VIII. fig. 6 *a, b.*	Woronzoff Road	*		
4	Astarte complanata, *Rœmer*	Woronzoff Road	*		
	Pholadomya conformis, *D'Orb*.......	S. Coast, Crimea.........	......	...	*
1	Natica, sp.	Between Monastery and Balaclava.	......	*	
1	Nerinæa grandis, *D'Orb.*	Vil. Djanatai	......	...	*
	Chemnitzia Heddingtonensis, *Sow.*.				
	Belemnites latisulcatus, *Voltz.*	Kobsel.......................	......	...	Callovian.
	—— hastatus, *Blainv.*	Kobsel.......................	......	...	Low. Oxf.
1	Ammonites Uralensis ?, *D'Orb*.......	1 mile W. of Balaclava .	......	*	
1	—— Raquinianus ?, *D'Orb.*	Vil. Biasali	Marlstone.		
1	—— Jurensis, *Zieten*	do.	Marlstone.		
1	—— fimbriatus, *Sow*..................	do.	Marlstone.		
	—— Brongniartii ?, *Sow.* (*Du Bois*)	Baktchserai...............	......	* ?	
	—— giganteus, *Sow.* (*Du Bois*)......	do.	......	...	Portland?
	—— perarmatus, *Sow.* (*Du Bois*) ...	do.	......	...	*
	—— lunula, *Zieten* (*D'Orb.*)	Kobsel, S. Coast, Crimea	......	...	*
	—— viator, *D'Orb.*	do. do.	......	...	Low. Oxf.
	—— Tatricus, *Pusch*...................	do. do.	......	...	*
	—— Hommarei, *D'Orb.*	do. do.	......	...	Low. Oxf.
	—— Adelæ, *D'Orb.*	do. do.	......	...	Oxford.
	—— tortisulcatus, *D'Orb*.............	Kobsel and Soudagh ...	......	...	*
1	Trigonellites, sp. ?	Woronzoff Road	*		
	—— Theodosia, *Desh.*	?			
	Rhynchoteuthis antiquatus, *D'Orb.*	?	......	...	*

Table of Cretaceous Fossils found in the Crimea.
(*Lower Cretaceous or Neocomian.*)

Number of specimens.	Name.	Authority.	Locality.
	Amorphozoa.		
	Scyphia Oeynhausii, *Goldf.* ...	Du Bois de Montpéreux, Tableau de Fossiles de la Craie en Crimée	Baktchserai.
	—— furcata, *Goldf.*	do. do.	do.
	Manon capitatum, *Goldf.*	do. do.	do.
	Zoophyta.		
	Astræa tubulosa, *Goldf.*, & var.	do. do.	do.
	—— caryophylloides, *Goldf.*...	do. do.	do.
	—— continua, *Goldf.*............	do. do.	do.
	—— cristata, *Goldf.*	do. do.	do.
	Mæandrina	do. do.	do.
	Turbinolia	do. do.	do.
	Lithodendron	do. do.	do.
	Pavonia (? Fungia discoidea, *Goldf.*).	do. do.	do.
	Echinodermata.		
	Discoidea macropyga, *Desm.* ...	do. do.	do.
	Cidaris clunifera, *Agas.*	do. do.	do.
	—— vesiculosa, *Goldf.*	do. do.	do.
	——, n. s.	do. do.	do.
	Dysaster cordatus, *Baier*	Du Bois, Voy. au Cauc. pl. 1. f. 2–4.	Crimea.
	Bryozoa.		
	Ceriopora dichotoma, *Goldf.* ...	Du Bois, Tableau de foss. de la Craie.	Baktchserai.
	—— striata, *Goldf.*...............	do. do.	do.
	—— micropora	do. do.	do.
	Mollusca.		
	Terebratulina striata, *Wahl.* ...	do. do.	do.
	Terebratula biplicata, *Sow.*......	do. do.	do.
	—— flabellata, *Goldf.*	do. do.	do.
	—— diphya, *Von Buch*	do. do.	do.
	—— decipiens, *Du Bois*	do. do.	do.
	—— vicinalis, *Schlot*.............	do. do.	do.
	Rhynchonella alata, *Goldf.* ...	do. do.	do.
	——, sp.	do. do.	do.
	Ostrea colubrina, *Lam.*	do. do.	do.
	—— nodosa, *Münst.*	do. do.	do.
	—— frons ?, *Park.* (gregaria, *Du Bois*).	do. do.	do.
	—— exogyra, *Mich.*	do. do.	do.
	Pecten, sp.	do. do.	do.
	Lima ovalis, *Desh.*	do. do.	do.
	—— elongata, *Münst.*	do. do.	do.
	Spondylus	do. do.	do.
	Exogyra Couloni, *Defr.*.........	do. do.	do.
	—— lateralis, *Nils.*	do. do.	do.
	—— minima, *Du Bois*	do. do.	do.
	Gervillia solenoides, *Defr.*......	do. do.	do.

Table of Cretaceous Fossils (continued).

Number of specimens.	Name.	Authority.	Locality.
	Arca globosa, *Du Bois*	Du Bois, Tableau de foss. de la Craie.	Baktchserai.
	——, sp. nov.		
20	Requienia, sp. nov.	Baily	Near Balaclava.
	? Prionia globosa, *Ag*.	Du Bois, Caucas	Baktchserai.
	Corimya taurica, *Ag*.	do.	do.
	Triton, sp.	Du Bois, Tableau, &c..................	do.
1	Natica prælonga, *Desh*.	Baily; D'Orb. Ter. Crét. pl. 172 ...	Near Balaclava.
12	Nerinæa gigantea?, *D'H.-Firm*.	Baily; D'Orb. Ter. Crét. ii. pl. 158...	do.
1	——, sp. nov.	Baily	do.
	Ampullaria ? speculi	Du Bois, Tableau, &c..................	Baktchserai.
	Nautilus pseudo-elegans, *D'Orb*.	D'Orb. Ter. Crét. pl. 8, 9	Crimea loc. ?
	Ammonites hircinus, *Schl*.	Du Bois, Tabl., &c......................	Baktchserai.
	—— depressus, *Schl*.	do.	do.
	—— dubius, *Schl*.	do.	do.
	—— ascendens, *Du Bois*	do.	do.
	—— Tauricus, *Du Bois*	do.	do.
	Hamites parallelus, *Du Bois* ...	do.	do.
	—— annulatus, *Du Bois*	do.	do.
	—— intermedius, *Sow*.	do.	do.
	—— armatus, *Sow*.	do.	do.
	Ancyloceras (H.) plicatile, *Sow*.	do.	do.

(*Middle and Upper Cretaceous, or Albian, Cenomanian, and Hippuritic* D'Orbigny).

Number of specimens.	Name.	Authority.	Locality.	Formation.
	Amorphozoa.			
	Scyphia Oeynhausii, *Goldf*. ...	Du Bois, Tableau de Foss. de la Craie en Crimée.	Baktchserai	U. Chalk ?
	—— Sackii, *Goldf*.	do. do.	do. ...	U. Chalk.
	Echinodermata.			
	Pentacrinites, sp.	do. do.	do. ...	U. Chalk.
	Caratomus avellana, *Agas*.	Du Bois, Caucas.	....	U. G. S. ?
	Hemiaster ? stellatus, *Du Bois*..	do. do.	Baktchserai	Gault ?
	Bryozoa.			
1	Eschara, sp.	Baily	Vil. Badrax	U. G. S.
	—— stigmatophora ?, *Goldf*....	Du Bois, Tableau, &c............	Baktchserai	Gault ?
	—— ? (Aulopora) ramosa, *Hag*.	do. do.	do. ...	
	Ceriopora micropora, *Goldf*. ...	do. do.	do. ...	Gault ?
	—— dichotoma, *Goldf*.	do. do.	do. ...	U. G. S.
	—— diadema ?, *Goldf*.	do. do.	....	Ch. M.
	Mollusca.			
2	Terebratula semiglobosa, *Sow*.	Baily	Vil. Badrax	L. Ch.
	—— carnea, *Sow*.	Du Bois, Tableau, &c............	Baktchserai	L.&U.Ch.
	Rhynchonella, sp.	do. do.	do. ...	Ch. M.
	—— ? pectiniformis, *Faujas* ...	do. do.	do. ...	Ch. M.

Table of Cretaceous Fossils (continued).

Number of specimens.	Name.	Authority.	Locality.	Formation.
35	Crania spinulosa, *Nils.*	Baily	Inkerman...	U. Ch.
	Ostrea biauriculata, *Lamk.*	Du Bois, Tableau, &c.	Baktchserai	Gault ?
	—— ventilabrum ?, *Goldf.*	do. do.	do. ...	Gault & U. G. S.
1	—— frons, *Park.* (carinata, *Sow.*)	do. do.; Baily	Baktchserai, & Badrax.	Ch. M. & U. G. S.
9	—— vesicularis, *Lamk.*	do. do.; Baily	Baktchserai, Inkerman, & Badrax.	Ch. M., L. Ch., & U. Ch.
	—— flabelliformis, *Nils.*	do. do.	Baktchserai	U. Ch.
3	—— flabellata, *D'Orb.*	Baily	Badrax	U. G. S.
1	—— hippopodium, *Nils.*	do.	Inkerman...	U. Ch.
2	—— laciniata, *Nils.*	do.	do. ...	U. Ch.
8	—— curvirostris, *Nils.*	do.	do. ...	U. Ch.
2	——, sp.	do.	do. ...	U. Ch.
	Exogyra haliotoidea, *Lamk.*	do.	do. ...	U. Ch.
	—— columba, *Lam.*	Du Bois, Tableau, &c.; Baily...	Baktchserai & Badrax.	Gault & U. G. S.
	—— conica, *Sow.* (decussata, *Goldf.*)	do. do.	Baktchserai	U. G. S.
	Pecten orbicularis, *Nils.*	do. do.	do. ...	U. G. S.
	—— cicatrisatus, *Goldf.*	do. do.	do. ...	U. G. S.
	Pecten quinquecostatus, *Sow.* } Janira Podolica, *D'Orb. Prod.* }	D'Orb. Voy. Hom. p. 440. pl. 6. f. 21–24.	do. ...	U. G. S.
	Lima, sp. (with fine striæ)	do. do.	do. ...	U. G. S.
	—— canalifera, *Goldf.*	do. do.	do. ...	Ch. M.
	Spondylus spinosus, *Sow.*, sp.	do. do.	do. ...	U. Ch.
	Avicula Laripes (*Morton*) *D'Orb.*	in Murch. Russ. ii. p. 490. pl. 43. f. 5–7.	do.	
	—— ? Lithuana, *Eichw.*	Baily	Badrax	U. G. S.
	—— tenuicostata, *Rœm.*	Voy. Hom.	Baktchserai	Ch. M.
	Aviculina ?	Du Bois, Tableau, &c.	do. ...	U. Ch.
	Vulsella, sp.	do. do.	do. ...	Gault.
	Inoceramus Cuvieri, *Sow.*	Du Bois, Tableau, &c.	do. ...	U. Ch.
1	Cardium conniacum ?, *D'Orb.*	Baily	Inkerman...	U. Ch.
2	——, spp.	do.	do. ...	U. Ch.
3	Lucina, sp.	do.	do. ...	U. Ch.
1	Acropagia ?, sp.	do.	do. ...	U. Ch.
1	Astarte ?, sp.	do.	do. ...	U. Ch.
3	Crassatella, sp.	do.	do. ...	U. Ch.
1	Acteonella or Globiconcha	do.	do. ...	U. Ch.
	Natica? crassatina, *Lamk.*	Du Bois, Tableau, &c.	Baktchserai	Ch. M.
1	——, sp.	Baily	R. Alma ...	U. G. S.
1	——, sp.	do.	Inkerman...	U. Ch.
2	Turritella, sp.	do.	do. ...	U. Ch.
	Belemnitella mucronata, *Schlot.*	Du Bois, Tableau, &c.	Baktchserai	U. Ch.
	Nautilus	do. do.	do. ...	Ch. M.
	Ammonites asper, *Von Buch.* (—— constrictus, *Du Bois*) Scaphites constrictus, *Sow.* }	do. do. D'Orb. Pal. i. p. 522 }	do. ...	Gault ?
	Vertebrata. Pisces.			
1	Lamna ?	Baily	Inkerman...	U. Ch.

Table of Older Tertiary Fossils found in the Crimea.
(*Nummulitic* =*Suessonian,* D'Orbigny.)

Number of specimens.	Name.	Authority.	Locality.
	Foraminifera.		
*	Nummulites distans, *Desh.*	Deshayes; Baily.................	Near Simferopol and Inkerman.
*	Raymondi, *Desh.*	do. do.	
	Echinodermata.		
	Conoclypus conoideus (Clypeaster DuBoisii), *Ag.*	Cat. p. 109; Echin. Suiss. i. p. 64. pl. 10. f. 16; p. 67. pl. 10. f. 11–13; Du Bois, Voy. au Caucase.	Near Simferopol, River Salghir.
	Spatangus depressus, *Du Bois* ...	Voy. au Caucase, pl. 1. f. 16.	
	Amblypygus latus, *Ag.*	Du Bois, Caucase.	Salghir.
	Mollusca.		
	Terebratula vitrea?, *Lamk.*	Du Bois, Tableau, &c.	Baktchserai.
	Ostrea gigantea, *Brander*	Deshayes; Baily.....................	Near Simferopol.
	Pecten, sp.	Du Bois, Tableau, &c.	Baktchserai.
	Spondylus asperulus, *Münst.*.......	do. do.	do.
	Cardium porulosum, *Brander* ...	do. do.	do.
	Crassatella tumida, *Lamk.*.........	do. do.	do.
	Isocardia, sp.	do. do.	do.
	Trigonia, sp.	do. do.	do.
	Murex, sp.	do. do.	do.
	Fusus Ficulneus, *Lamarck*.........	do. do.	do.
	Oliva	do. do.	do.
	Voluta muricina, *Lamk.*............	do. do.	do.
	—— luctatrix, *Sow.*	do. do.	do.
	Mitra terebellum, *Lamk.*	do. do.	do.
	Ovula tuberculosa, *Duclos*	do. do.	do.
	Cerithium giganteum, *Lamk.*.......	do. do.	do.
	Turritella imbricataria, *Lamk.* ...	do. do.	do.
	Trochus giganteus, *Du Bois*	do. do.	do.

Table of Middle or Newer Tertiary Fossils found in the Crimea.
(*Falunian,* D'Orbigny.)

Number of specimens.	Name.	Reference.	Locality.
	Amorphozoa.		
2	Scyphia Portlocki, *Baily*	Pl. IX. f. 1 *a, b.*	Monastery of St. George.
	Foraminifera.		
	Polystomella crispa, *Linnæus*...	Syst. Nat. 3370	Near Sevastopol.
	Mollusca.		
1	Mytilus apertus, *Desh.*	Mém. Géol. Soc. Fr. 1838, t. 3. p. 61. pl. 4. f. 6–11.	Kertch, in iron-deposits.

Table of Middle or Newer Tertiary Fossils found in the Crimea (continued).

Number of specimens.	Name.	Reference.	Locality.
	Mollusca.		
	Mytilus Calypso, *D'Orb.* ... ⎫ —— subcarinatus, *Desh.* ... ⎭	Mém Géol. Soc. Fr. 1838, t. 3. p. 62. pl. 4. f. 12, 13.	Kertch, in iron-deposits.
1	Dreissena rostriformis, *Desh.*...	ibid. p. 61. pl. 4. f. 14–16	do. do.
1	—— inæquivalvis, *Desh.*.........	ibid. ibid.	do. do.
3	Cardium carinatum, *Desh.*......	ibid. p. 54. pl. 2. f. 16–18	do. do.
	—— planum, *Desh.*	ibid. p. 46. pl. 2. f. 24–30	do. do.
	—— depressum, *Desh.*	ibid. p. 47. pl. 2. f. 19–23	do. do.
	—— subemarginatum, *D'Or.* ⎫ (emarginatum, *Desh.*) ⎭	ibid. p. 48. pl. 1. f. 7-10	do. do.
2	—— squamulosum, *Desh.*	ibid. p. 48. pl. 1. f. 14, 15......	do. do.
	—— subcarinatum, *Desh.*	ibid. p. 49. pl. 3. f. 1, 2, 6	do. do.
1	—— macrodon, *Desh.*	ibid. p. 49. pl. 1. f. 3–6	do. do.
1	—— crassatellatum, *Desh.*......	ibid. p. 51. pl. 3. f. 7–10	do. do.
	—— Gourieffi, *Desh.*	ibid. p. 52. pl. 3. f. 1, 2	do. do.
3	—— paucicostatum, *Desh.* ...	ibid. p. 52. pl. 2. f. 14, 15	do. do.
	—— sulcatinum, *Desh.*	ibid. p. 53. pl. 2. f. 3–5	do. do.
	—— subplanicostatum, *D'O.* ⎫ (planicostatum, *Desh.*) ⎭	ibid. p. 53. pl. 2. f. 7, 8	do. do.
1	—— corbuloides, *Desh.*.........	ibid. p. 54. pl. 1. f. 11–13	do. do.
4	—— Verneuilii, *Desh.*	ibid. p. 55. pl. 2. f. 9, 10	do. do.
4	—— ovatum, *Desh.*	ibid. p. 56. pl. 1. f. 19–21	do. do.
1	—— Edouardi, *D'Orb.* ...... ⎫ (incertum, *Desh.*) ...... ⎭	ibid. p. 56. pl. 2. f. 11–13	do. do.
	—— subdentatum, *Desh.*	ibid. p. 57. pl. 1. f. 16–18	do. do.
1	—— subedentulum, *D'Orb.* ⎫ (edentulum, *Desh.*) ... ⎭	ibid. p. 51. pl. 3. f. 3–6	do. do.
	—— acardo, *Desh.*...............	ibid. p. 58. pl. 4. f. 1–5	do. do.
1	—— pseudocardium, *Desh.* ...	ibid. p. 59. pl. 1. f. 1, 2	do. do.
18	—— protractum, *Eichw.*	Voy. Hom. pl. 6. f. 6–8	Quarantine Harb. 2, Monastery 8, and Gorge of Iphigenia 8.
1	—— amplum, *Baily*	Pl. IX. f. 2 *a–d*.	Monastery.
20	—— Demidoffi, *Baily*	Pl. IX. f. 3 *a–c*	do.
4	—— Fittoni, *D'Orb.*	Murch. Russia.....................	Sevastopol 2, Quarantine 1, Monastery 1.
	—— (six other species of *Cardium* undeterminable, from Quarantine, Monastery, Iphigenia, and Sapoune Height).		
8	Cyprina Pallasii, *Baily*	Pl. IX. f. 4 *a, b*.	Monastery.
1	—— Georgei, *Baily*	Pl. IX. f. 8 *a, b*	Monastery.
3	—— naviculata, *Baily*	Pl. IX. f. 6 *a–c*	Quarantine Harb.
15	—— ? triangulata, *Baily*	Pl. IX. f. 9	Sevastopol 2, Monastery 11, Iphigenia 2.
9	Astarte pulchella, *Baily*.........	Pl. IX. f. 10 *a–c*	Iphigenia; bed J.
8	—— quadrata, *Baily*	Pl. IX. f. 7 *a–d*	Monastery.
1	Venus semiplana, *Baily*	Pl. IX. f. 5 *a, b*	Gorge of Iphigenia.
4	—— minima, *Baily*	Pl. IX. f. 12 *a–c*	Monastery 1, Iphigenia 3; bed J.
1	Solen, sp., *Baily*	....	Quarantine Harb.
3	Potamomya Iphigenia, *Baily*...	Pl. IX. f. 13 *a–d*	Gorge of Iphigenia.
10	Pholas Hommarei, *D'Orb.*......	Voy. Hom. pl. 4. f. 16–18	Iphigenia 3, and Monastery 7.

Table of Middle or Newer Tertiary Fossils found in the Crimea (continued).

Number of specimens.	Name.	Reference.	Locality.
4	Tornatella minuta, *Baily*	Pl. X. f. 7 *a*, *b*.	Quarantine Harb.
4	—— inflexa, *Baily*	Pl. X. f. 8 *a*, *b*	Redan, near Sevastopol.
22	Helix DuBoisii, *Baily*	Pl. X. f. 1 *a*, *b*	Monastery 10. Iphigenia 12.
2	—— Bestii, *Baily*	Pl. X. f. 2 *a–c*	Iphigenia.
4	Bulimus Sharmani, *Baily*	Pl. X. f. 3 *a*, *b*	Iphigenia.
	Limnæa peregrina, *Desh.*	Mém. Soc. Géol. Fr. t. iii. p. 63	Kertch.
	—— obtusissima, *Desh.*	ibid. f. 11	Kertch.
	—— velutina, *Desh.*	ibid. f. 12–14	Kertch.
1	Planorbis obesus, *Baily*	Pl. X. f. 5 *a–c*.	Iphigenia.
3	—— cornucopia, *Baily*	Pl. X. f. 4 *a*, *b*	Sevastopol 1, Iphigenia 2.
1	Cyclostoma reticulatum, *Baily*	Pl. X. f. 6 *a*, *b*	Iphigenia.
2	Turbo, sp., *Baily*	....	Redan.
16	Trochus Corderianus, *D'Orb.* ...	Voy. Hom.	Quarantine Harb.
1	—— Fenonianus, *D'Orb.*	ibid.	do. do.
1	—— Pageanus, *D'Orb.*	ibid.	do. do.
1	—— Murchisoni, *Baily*	Pl. X. f. 13	do. do.
1	—— Andersoni, *Baily*	Pl. X. f. 14 *a*, *b*	Monastery.
2	—— Beaumontii, *D'Orb.*	Vcy. Hom.	do.
1	—— Blainvillei, *D'Orb.*	ibid.	Gorge of Iphigenia.
2	—— Hommarei, *D'Orb.*	ibid.	Sevastopol 1, Quarantine 1.
1	—— pulchellus, *Baily*	Pl. X. f. 15 *a–c*.	Quarantine Harb.
1	—— Sutherlandii, *Baily*	Pl. X. f. 16 *a*, *b*	Monastery.
2	—— Lygonii, *Baily*	Pl. X. f. 17 *a*, *b*	Monastery 1, Iphigenia 1.
1	Littorina Monastica, *Baily*	Pl. X. f. 9 *a–c*	Monastery.
1	Paludina achatinoides, *Desh.* ...	Mém. Soc. Géol. Fr. 1838, t. iii. p. 64. pl. 5. f. 6, 7.	Kertch, in iron-deposits.
	Neritina ? Danubialis, *Desh.* ...	ibid. p. 65. pl. 5. f. 4–8	do. do.
5	Cerithium Cattleyæ, *Baily*	Pl. X. f. 12 *a*, *b*.	Monastery.
4	—— cochleare, *Baily*	Pl. X. f. 10 *a–c*	Iphigenia.
2	—— truncatum, *Baily*	Pl. X. f. 11 *a*, *b*	Iphigenia.
2	Pleurotoma Chersonesus, *Baily*	Pl. X. f. 19 *a–c*	Iphigenia 1, Monastery 1.
6	—— laqueata, *Baily*	Pl. X. f. 18 *a*, *b*	Monastery 3, Iphigenia 3.
16	Buccinum obesum, *Baily*	Pl. X. f. 20 *a*, *b*	Monastery 12, Iphigenia 4.
8	—— angustatum, *Baily*	Pl. X. f. 21 *a*, *b*	Monastery.
1	—— moniliforme, *Baily*	Pl. X. f. 22 *a*, *b*	Iphigenia.
1	—— Doutchinæ, *D'Orb.*	Voy. Hom. pl. 3. f. 20–22	Monastery.
1	—— Daveluinum, *D'Orb.*	ibid. f. 23	Monastery.
20	—— corbianum, *D'Orb.*	ibid. f. 24, 25	Quarantine 4, Monastery 7, Iphigenia 9.
3	—— dissitum, *Eichw.*	Murch. Russia, pl. 43	Monastery 1, Iphigenia 2.

Summary of Fossil Invertebrata from the Crimea.

						Mollusca.					
	Amorphozoa.	Foraminifera.	Zoophyta.	Echinodermata.	Bryozoa.	Brachiopoda.	Lamellibranchiata.	Gasteropoda.	Cephalopoda.	Total.	
Number of species previously known	...	1	...	...	...	...	27	24	...	52	Newer Tertiary.
New species	1	...	...	...	...	...	18	14	...	33	
Total	1	1	...	...	...	...	45	38	...	85	
Previously known..	...	2	...	3	...	1	8	10	...	24	Older Tertiary.
Previously known..	4	...	9	8	7	13	42	7	16	106	Upper Secondary (Cretaceous).
New................	...	...	...	...	...	...	7	4	...	11	
Total	4	...	9	8	7	13	49	11	16	117	
Previously known..	...	...	8	4	...	8	5	2	17	44	Lower Secondary (Jurassic).
New................	1	...	...	5?	...	4	4?	1	1	16?	
Total	1	...	8	9?	...	12	9?	3	18	60?	

Species before described, 226. New species, 60.

Note on the GEOLOGY *of the* NEIGHBOURHOOD *of* SEVASTOPOL, *and the* SOUTHERN COAST *of the* CRIMEA. By CHARLES F. COCKBURN, Esq., Captain, Royal Artillery.

During the occupation of part of the Crimea by the Allied Armies, I availed myself of the opportunity my short stay in that country afforded to collect a series of fossils and rock-specimens illustrative of the geology of the neighbourhood of Sevastopol and Balaclava; amongst them were characteristic specimens from the shales on the Woronzoff road, described by M. Du Bois de Montpéreux as the oldest fossiliferous deposits; resting on these are the Jurassic rocks, composing the mountain-chain which extends along the south-east coast from Balaclava to Kaffa, a distance of upwards of 100 miles. This formation, with the overlying cretaceous deposits, is, according to French geologists, analogous to that of the Caucasus. Of these Jurassic limestones, which are mostly of a hard and crystalline character, collections were made from the Gorge of Iphigenia and Monastery of St. George, and include a series of the intrusive volcanic rocks (syenite, porphyry, &c.) which have disrupted and pierced them in every direction.

From the quarries at Inkerman I succeeded in procuring many fine specimens of a large *Crania* (*C. spinulosa*, Nilsson) and several species of *Ostrea* common to the Upper Chalk of Europe. The beautiful white stone used in most of the public buildings at Sevastopol was obtained from these quarries: when first worked, it is soft, but becomes harder on exposure to the atmosphere.

From the Steppe-limestone, which belongs to the Newer Tertiary formation, and forms the whole plateau before Sevastopol, as well as the northern and greater portion of the peninsula, collections were made at the Quarantine Harbour, Monastery of St. George, and Gorge of Iphigenia; the condition of the deposits and their fossil contents at the two latter places being very similar.

These Upper Tertiary deposits, occurring in the various conditions of shelly and oolitic limestones and sands, sometimes associated with volcanic ashes, tufa, &c., are mostly marine, but sometimes of freshwater origin, and more or less fossiliferous. This series is well exposed at the Monastery of St. George, near which may be seen the point of junction between them and the Jurassic formation.

From a fine-grained yellowish calcareous deposit of the Upper Tertiary at Quarantine Harbour, I obtained several species of *Trochus*, with other well-preserved shells, herewith described.

Section of Newer Tertiary Strata, at the Cliff (about 400 *feet high) West of the Monastery of St. George.*

[About 50 feet of the upper part, including R and Q, are undescribed.]

R. Compact shelly limestone, containing pebbles. *Cardium protractum*, *C. Demidoffi*, *Cyprina ? triangulata*, *Pleurotoma*, and *Buccinum*.

Q.

(P, N, L, and J to C are tuff-like calcareous rocks.)

P. White, very crystalline, unstratified (10 feet); upper part oolitic, with small spiral shells. *Cerithium truncatum*, *C. trochleare*, *Pholas Hommarei*, and *Planorbis cornucopia*.

O. Seam of clay.

N. White, honeycombed; fossils as in bed I.

M. Seam of clay.

L. White (2 feet).

K. Thin seam of clay.

J. White, somewhat crystalline, made up of small fossils (4 feet). *Astarte pulchella* and *Venus minima*.

I. White (3 feet); with numerous small fossils and rounded fragments of various rocks. *Astarte pulchella* and *Venus minima*.

H. White (4 feet); very much honeycombed, and divided half-way by a layer of quartzose and other fragments. No fossils. ("Porous, irregularly deposited." *Du Bois.*)

G. Coarse (1 foot).

F. Fine (1 ft. 6 in.).

E. Coarse (1 ft.).

D. Fine white (5 ft.). No fossils.

C. Red (6 ft.); full of *Helix Duboisii*, *H. Bestii*, *Planorbis obesa*, with *Bulimus Sharmani* and *Cyclostoma reticulatum*.

B. Yellowish-white layers (30 feet); unfossiliferous. (Whitish sand in layers, unfossiliferous. *Du Bois.*)

A. Somewhat honeycombed rock, with few fossils.

Volcanic rocks, at the base, with veins of limestone.

For detailed descriptions of the Geology of this country, see

1. Travels through the Southern Provinces of the Russian Empire in the years 1793 and 1794. By Peter Simon Pallas, M.D., F.R.S. London, 1842.

2. Du Bois de Montpéreux. Letter on the Geology of the Caucasus and the Crimea, addressed to M. Elie de Beaumont: Bulletin de la Société Géologique de France, tome viii. 1835–6, p. 371.
3. Mémoire Géologique sur la Crimée, par M. de Verneuil; suivi d'observations sur les fossiles de cette Péninsule, par M. Deshayes: Mémoires de la Société Géologique de France, tome iii. 1838.
4. Voyage dans la Russie méridionale et la Crimée, sous la direction de M. Anatole Demidoff. Partie Géologique de M. Huot. Paris, 1839.
5. Du Bois de Montpéreux. Voyage au Caucase chez les Tcherkesses, et les Abkhases en Chalcide, en Georgie, en Arménie, et en Crimée. Neuchatel and Paris, 1843.
6. Hommaire de Hell (Xavier). Les Steppes de la Mer Caspienne, le Caucase, la Crimée, &c. Paris, 1843–4.
7. Geology of Russia in Europe and the Ural Mountains. By Sir R. I. Murchison, M. Edouard de Verneuil, and Count Alexander Von Keyserling. London and Paris, 1848.
8. On the Geological Structure of the Crimea. By Baron S. Chaudoir. 1832. Proc. Geol. Soc. vol. i. p. 342.

EXPLANATION OF PLATES VIII., IX., & X.

Plate VIII. *Jurassic and Cretaceous Fossils.*

Fig.
1 *a*, *b*. Scyphia Cockburni, *Baily*.
2 *a*, *b*. Terebratula Jamesii, *Baily*.
3 *a–d*. Terebratulina radiata, *Baily*.
4 *a*, *b*. Rhynchonella elongata, *Baily*.
5 *a*, *b*. Rhynchonella Cookei, *Baily*.
6 *a*, *b*. Cardium æquistriatum, *Baily*.
7 *a–h*. Crania spinulosa, *Nilsson*.

Plate IX. *Newer Tertiary Fossils.*

1 *a*, *b*. Scyphia Portlocki.
2 *a–d*. Cardium amplum, *Baily*.
3 *a–c*. —— Demidoffi, *Baily*.
4 *a*, *b*. Cyprina Pallasii, *Baily*.
5 *a*, *b*. Venus semiplana, *Baily*.
6 *a–c*. Cyprina naviculata, *Baily*.
7 *a–d*. Astarte quadrata, *Baily*.
8 *a*, *b*. Cyprina Georgei, *Baily*.
9. —— triangulata, *Baily*.
10 *a–c*. Astarte pulchella, *Baily*.
11 *a–c*. Venus minima, *Baily*.
12 *a–d*. Corbulomya Iphigenia, *Baily*.

Plate X. *Newer Tertiary Fossils.*

1 *a*, *b*. Helix Duboisii, *Baily*.
2 *a*, *b*. —— Bestii, *Baily*.
3 *a*, *b*. Bulimus Sharmani, *Baily*.
4 *a*, *b*. Planorbis Cornucopia, *Baily*.
5 *a–c*. —— obesus, *Baily*.
6. Cyclostoma striata, *Baily*.
7 *a*, *b*. Tornatella minuta, *Baily*.
8 *a*, *b*. —— inflexa, *Baily*.
9 *a*, *b*. Littorina monastica, *Baily*.
10 *a–c*. Cerithium cochleare, *Baily*.
11 *a*, *b*. —— truncatum, *Baily*.
12 *a*, *b*. Cerithium Cattleyæ, *Baily*.
13. Trochus Murchisoni, *Baily*.
14 *a*, *b*. —— Andersoni, *Baily*.
15 *a–c*. —— pulchellus, *Baily*.
16 *a*, *b*. —— Sutherlandi, *Baily*.
17 *a*, *b*. —— Lygonii, *Baily*.
18 *a*, *b*. Pleurotoma laqueata, *Baily*.
19 *a–c*. —— Chersonesus, *Baily*.
20 *a*, *b*. Buccinum obesum, *Baily*.
21 *a*, *b*. —— angustatum, *Baily*.
22 *a*, *b*. —— moniliforme, *Baily*.

5. *On the* Gravels *at* Taunton, *in* Somersetshire. By J. D. Pring, Esq.

[Communicated by S. R. Pattison, Esq., F.G.S.]

[Abstract.]

The River Tone at Taunton occupies a small depression in the red marls, and runs through a vale overspread with red gravels and clays. Its affluents descend from greensand and liassic districts on the one hand, and from hills of Devonian rocks on the other.

In the excavations made at Taunton for sewering, and for the railway, the composition of the surface-beds throughout long spaces has been disclosed, and it is ascertained that at least two distinct and successive operations have produced them.

Immediately over the red marl lies a bed of coarse slaty Devonian gravel, with finer materials of the same kind, occasionally interstratified. In this no fragment of the upper rocks occurs. It has been deposited by the waters from the palæozoic districts alone.

This is covered by a liassic and flinty gravel, containing rolled *Gryphææ* and fragments of lias, with flints from the greensands. Near the surface the latter predominate.

Neither of these gravels ascends the slope of the hills: they are mere fluviatile accumulations. Remains of Rhinoceros and abundance of bog-timber were found at their base in the course of the excavation at the County Gaol at Taunton.

The West of England is remarkably free from the ancient post-tertiary drifts so prevalent in the north-eastern and midland counties. The present communication, with the plans forwarded for its illustration, is intended as a contribution towards the history of the comparatively minute changes which have aided in the formation of the present surfaces, and which, though not very interesting, are yet essential portions of the complete study of geology.

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6. Palichthyologic Notes, No. 10. *On* Palæoniscus superstes. By Sir P. de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S., &c. *With a Note on the Locality of the Fossil;* by the Rev. P. B. Brodie, F.G.S.

[Plate XI.]

The pretty little fish discovered by the Rev. P. B. Brodie in the Keuper beds of Rowington, and submitted to me for description, belongs undoubtedly to the genus *Palæoniscus*. The extremities are unfortunately deficient, but enough of the tail remains to show that it was completely heterocerque. The specimen (Pl. XI. figs. 1 & 2) measures one inch and three-quarters in length, by six-tenths of an inch at its greatest depth. The pectoral fins are lost, together with the head and the scapulo-coracoid arch. The other locomotive organs are well preserved, with the exception of the extremity of the caudal fin. The ventral fins occupy a very advanced position in front of the middle line of the body. They are small, and contain few fin-rays, but the anterior edge is bordered with fulcral scales of considerable thickness. The anal fin is situated near the hinder extremity of the body. Ten rays are seen in the specimen (fig. 3), of which the three first are short, pointed, and undivided. The remainder have transverse articulations at distant intervals, and dichotomize towards their extremities. The hinder portion of the fin is deficient. The dorsal fin is placed immediately above the anal fin. It contains about a dozen rays. Of these the fulcral rays are more numerous and more elongated than those in advance of the anal fin. In other respects the two fins are very similar. The portion of the tail which is preserved, shows the scales of the dorsal ridge elongating gradually along the upper margin of the pedicle of the tail to form the imbricated border of the upper lobe. Below these the scales of the trunk are visible, becoming more and more attenuated as they ascend upon the upper limb of the organ. The bases of a few of the anterior rays of the lower lobe are fortunately preserved *in situ*, showing that the appearances above noted are correctly assigned to the caudal region. There is, therefore, sufficient evidence to prove that the tail of this species was strictly heterocerque. I am further led to believe, from an attentive examination and comparison of the parts preserved, that, were the tail entire, it would be found to be as extreme in its heterocercy as in the Permian and other earlier members of the genus ; and in no wise a transitional form between that and the homocerque character of the Liassic fish. The scales are oblong, the longitudinal axis being rather longer than the vertical measurement. They are covered with a thick and smooth layer of ganoine, without any trace of superficial ornamentation or marginal serration. The dorso-ventral series are arranged in gentle curves, imparting an appearance of much elegance to this species. On comparing this with the known species of *Palæoniscus*, of which there are not less than forty, the remote position of the dorsal fin excludes all but the little *Palæoniscus catopterus* (Pl. XI. fig. 4) from the Permian beds of Roan Hill, in Ireland*. The subject of this description differs from that species in every other character. As it appears to be the last surviving representative of this genus which occupied so important a place in the fauna of the Carboniferous and Permian eras, I have ventured to name it *Palæoniscus superstes*†.

Note on the occurrence of a New Species of Fish in the Upper Keuper Sandstone in Warwickshire. By the Rev. P. B. Brodie, M.A., F.G.S.

Having lately described the Keuper in the neighbourhood of Warwick‡, I have but little to add respecting it ; but the recent discovery of a small fish (unfortunately imperfect, though better preserved

* Quart. Journ. Geol. Soc. vol. vi. p. 4.

† I have been unable to obtain any information with reference to a species of *Palæoniscus* from the Keuper of Coburg, mentioned by Herr von Schauroth, at the scientific congress at Gotha in 1851, under the name of *P. arenaceus*.

‡ Quart. Journ. Geol. Soc. vol. xiii. p. 574.

than any remains of fish previously detected in that formation) renders it desirable to refer to the position of the stratum from which it was obtained. The superior beds of sandstone worked occasionally at Shrewley, are not quarried at Rowington, though several thick bands of brown sandstone are seen on the road to Warwick in that village, and were formerly exposed in an old quarry, now filled up, in the same parish. About half-way down the hill on which the church stands, are certain beds of brashy stone, more or less sandy and marly, and having a very irregular fracture; in these I discovered the new species of fish which Sir Philip Egerton has described above under the name of *Palæoniscus superstes*.

The vicinity of the vicarage affords the following section in descending order:—

	ft.	in.
Thin beds of sandy stone in green marl; brashy bed . .	2	0
Sandstone } Green marl } Sandstone }	0	11
Green marly stone, with so-called fucoid impressions .	0	6
Several beds of ripple-marked sandstone, thickness not exposed.		

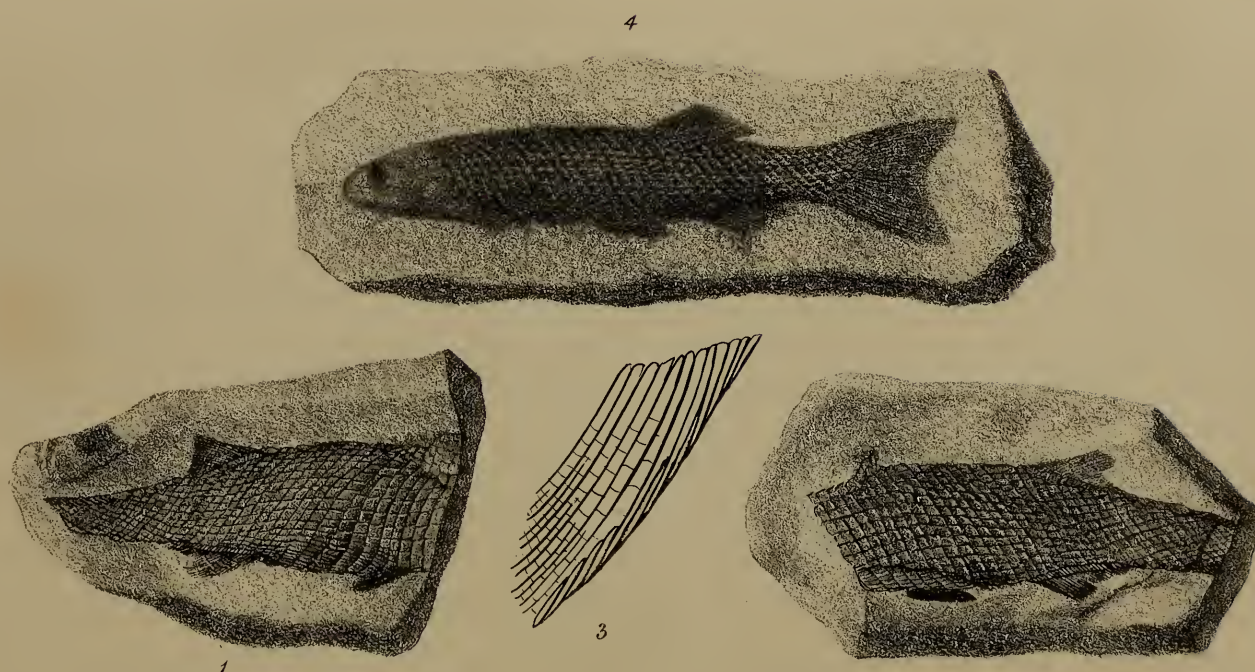
At a somewhat lower level on the canal-bank, at the west end, the section is continued as follows:—

	ft.	in.
Beds of rubbly sandstone and marl, much broken; with remains of plants *	5	0
Grey sandstone, divided by green marls, full of fucoids?	10 to 12	0
Hard sandstone	4	0
Green shaly marl (few inches).		
Red marl.		

Small teeth and spines of *Acrodus* have long been known in the Keuper in different parts of England, but this is, I believe, the first instance of the occurrence of a fish in anything like a perfect state; and no doubt it would have been entire, if the stone had not been unfortunately broken. The bed is so seldom worked, that there is little chance of examining any quantity of it; but, judging from the past, such specimens must be extremely rare.

P.S.—Not long after the discovery of the specimen above described, another and entire fossil fish was obtained from the lowest bed of the Keuper sandstone here. I regret that the possessor of the specimen is unwilling to allow it to go out of his hands, and that, in consequence, it has not been available for scientific description.—Feb. 20, 1858. P. B. B.

* In addition to the plants referred to in my last paper in the Geol. Journ. vol. xii. Part IV. No. 48, p. 374, from the lower beds of the Upper Keuper, I have obtained a slab of sandstone covered with vegetable impressions, and amongst them are several which appear to be the calyces of some flowering plant.



PALÆONISCUS SUPERSTES & P. CATOPTERUS

Jos. Dinkel lith. W. West imp.

EXPLANATION OF PLATE XI

Fig. 1. *Palæoniscus superstes* (from Rowington, Warwickshire), natural size.
Fig. 2. Ditto. Counterpart of the same.
Fig. 3. Anal fin, enlarged 4 times.
Fig. 4. *Palæoniscus catopterus*, from Roan Hill, Tyrone.

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7. *On the* Newer Red Sandstone, *and on some other* Geological Phenomena, *near* Loch Greinord, *in* Ross-shire. By James Nicol, F.R.S.E., F.G.S., Professor of Natural History, Aberdeen.

Newer Red Sandstone.—In several passages of his work on the Western Isles, Dr. Macculloch refers to the occurrence on the shores of Loch Greinord of two small spots of a red sandstone of newer age than the great mass of similarly coloured rock which forms so conspicuous a feature on the western coasts of the Highlands*. In his memoir on the Geological Map of Scotland he also several times mentions this formation†, which he considered as the only undoubted instance of the occurrence of the "Red Marl" of English geologists in the northern part of the island. Although evidently regarding these beds with much interest, he has not given any detailed description of them. In their valuable memoir on the formations in the North of Scotland, Professor Sedgwick and Sir Roderick I. Murchison likewise mentioned this deposit, and pointed out its resemblance to the New Red of England, and also to some beds seen below the Lias in Skye‡. This sandstone does not seem to have been subsequently noticed by geologists, probably from lying in a region so seldom visited by the scientific traveller. I have therefore been induced to lay before the Society the following notes collected in an examination of this deposit in the autumn of last year (1856).

The great headland of the Ruimore or Ru Rea that separates Loch Greinord from Loch Ewe consists chiefly of the older red sandstone of the west coast, covered more or less deeply by drift or detritus. On the shore of Lake Greinord the sandstone is well seen in thick, undulating, or slightly curved beds, dipping at 40°–45° to E. 5°–10° S. It is usually a fine-grained grit, of a reddish-brown colour, occasionally with a tinge of green, but becomes black when weathered. As this rock was fully described in my paper on the Red Sandstones of the North-west coast of Scotland, its mineral characters need not be noticed further§. Near Sands and Udrigill, the newer sandstone

* Macculloch's Western Isles, vol. ii. pp. 65, 99.

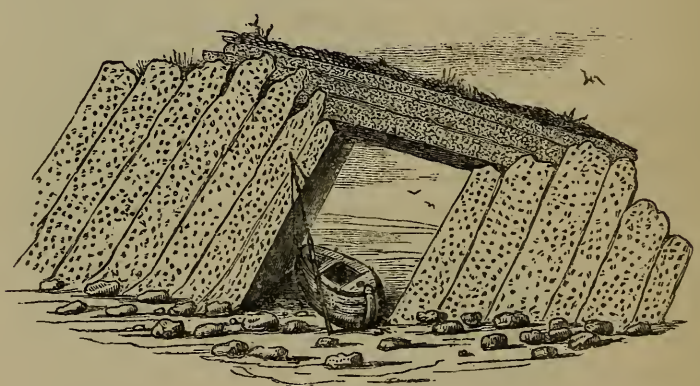
† Memoir on Map, pp. 31, 89, 94.

‡ Transact. Geol. Soc., New Series, vol. iii. p. 156.

§ Quarterly Journal of the Geological Society, vol. xiii. p. 17. In that memoir I considered this red sandstone as probably of Devonian age, or the equivalent of the true "Old Red" of other parts of Scotland. In the present paper, however, I have generally designated it only as the "Older Red Sandstone," in contradistinction to the "Newer Red" resting on it; thus avoiding any assumption in regard to its age. Sir R. I. Murchison, however, regards it as the representative of the Cambrian of Wales.

formation referred to is well exposed, resting unconformably on these older beds at a low angle. The first bed seen in the cliffs is a coarse conglomerate or breccia, composed of slightly rounded fragments. Some of these were evidently derived from the older red sandstone below. I had no hesitation in identifying others with the quartzite of the neighbouring mountains, though often of a softer texture, and more like a white sandstone than the hard vitreous rocks of Ullapool and Assynt. More interesting were the fragments of limestone, often of a blue colour and compact, at others reddish white and more crystalline, which made up a large portion of some beds. These again I regarded as derived from the limestone that overlies the quartzite series; and as the fragments were from two to four inches in diameter, and had apparently undergone less alteration than the rock where still seen *in situ*, I had hopes that they might contain some recognizable petrifactions. With this view I examined a large number, but did not succeed in finding any trace of organization.

Above this conglomerate or breccia, are strata of a soft friable sandstone, forming the larger part of the deposit. It is generally of a red colour, in other places reddish white, or again red mottled with green and blue. In some parts it contains much calcareous matter, effervescing strongly with acids, and appears to be easily acted on by the sea and atmosphere, the surface having that carious and corroded aspect so common among red sandstones.



These newer beds dip at about 10° to N.W. (true); and, as shown in the subjoined sections, have been deposited amid the broken ends of the older sandstones. The newer rock forms a natural archway (see fig.), supported on walls of the older rock, and partly converted by the fishermen on the coast into a rude hut to shelter themselves and their implements from the weather. As shown in the figure, the shore is here covered with huge boulders of the older red sandstones, of granite, and the green-coloured gneiss, or hornblende rock common in the mountains in the interior.

This newer sandstone is of very limited dimensions, being soon cut off towards the west by lofty cliffs of the older red sandstone forming the high land towards the extremity of the peninsula. It also does not extend far into the interior, where the older rock is soon seen rising through thick masses of drift containing large angular boulders of gneiss. This covering of detritus and the frequent breaks in the sections render it difficult to estimate the thickness of the newer sandstone, but it probably does not exceed 100 to 150 feet.

Age of Beds. Lias Boulders.—The absence of fossils renders it impossible to determine the exact age of this curious deposit, and its mineral character throws no light on the question. The position of the beds and the fragments contained in the upper formation, prove that it belongs to a far more recent period than the underlying red sandstones. The wide interval that separates it from the newer secondary rocks of Skye will also scarcely permit us to trace out even a probable connexion. The only indication of these newer formations which I could discover in the vicinity was on the other side of the peninsula, on the shore near Tinafuline, opposite to Island Ewe. The coast there is strewed with great numbers of fragments (from one or two inches to a foot or more in diameter) of a compact white limestone, and so numerous that the farmers in the neighbourhood have collected them to burn for lime. This rock is clearly distinct from the older limestones, or that imbedded in the newer breccia. Though the fragments are apparently little worn by transport, and so abundant, I could not find any rock from which they were derived. The limestone contains pieces of black carbonized wood, and a considerable number of fossil shells. The latter almost all belong to one or two species of *Ostræa*. Some of them resemble the *Ostræa irregularis*, Goldfuss, of the lias, and others the *O. Hebridica*, described by Professor Edward Forbes in his paper on Loch Staffin*. Another shell is perhaps a fragment of the *Potamomya? Sedgwickii* of that paper. There can be little doubt, therefore, that these fragments belong to the same formation as the oolite of the north of Skye; and, as they have evidently not been transported from a great distance, their occurrence indicates that these rocks must formerly have had a much wider extension than they now possess, the distance from Loch Staffin being about thirty miles in a direct line†. They also render it probable that the red sandstones are of the age of the Trias, or perhaps of the Lower Lias. These fragments of the oolite are, I believe, the most northern traces of its existence on the western shore of the mainland yet observed.

Deductions.—Assuming this, therefore, as the more probable age of the newer red sandstone, it follows that the older red sandstone had been raised up on edge and undergone considerable denudation previous to the deposition of the lias-beds of the Western Islands. The softer and less metamorphic condition of the enclosed fragments of the quartzite and limestone, than of the same rocks now seen *in situ*, might lead to some curious speculations. It would, however, be wrong at once to infer that these changes in the older rocks have

* Journ. Geol. Soc. vol. vii. p. 110, plate 5. fig. 4.

† Besides the shells and carbonized wood, this limestone contains curious grey-coloured patches with white spots, like little masses of volcanic ashes. These seem to me to show that volcanic action was going on in the neighbourhood at the time these beds were being formed.

been effected subsequent to the deposition of the newer sandstone. It is evident that any process of denudation would necessarily first affect the higher, or outer, parts of the strata, which, if the metamorphic action came from below, as we must assume, would of course be the softer and less altered. The parts left behind would, for the same reason, and also from the greater power of resistance, be the harder and more metamorphic. In conformity with this view, we observe that the smaller fragments of the older red sandstone embossed among the gneiss mountains on the east are far harder than the larger and more continuous masses of the same rock.

It must also be remembered that the denudation of the older red sandstone, though begun at this early period, was continued long after its close, or, to speak accurately, is still going on even at the present time. These small spots of newer (Triassic) red sandstone are indeed but very inadequate representatives of the enormous mass of matter which has evidently been removed from the once continuous platform of the older sandstones. The amount of the calcareous matter in the newer beds is important, as showing that, at the time of their formation, the upper or limestone portion of the series was furnishing more than a proportionate share of the material, and hence probably that the denuding processes had only been going on for a short time. But the same agents of change which affect the higher and older rocks must have acted also on this newer deposit; and we are therefore justified in regarding the portion that is now seen as a mere fragment of what it may once have been.

Glacier-moraines.—I have several times already referred to the immense number of large boulders of gneiss and other primary rocks spread over the surface of this district. In general they are arranged in no apparent order. There is, however, one remarkable exception, which I must shortly notice, as probably indicating the mode in which some of them at least have been transported from their native mountains. Near the top of the acclivity between Loch Greinord and Loch Ewe, the road crosses an enormous ridge of stones rising up abruptly from the moor. It runs in a line from E.N.E. to W.S.W., and at its northern extremity is met nearly at right angles by another similar ridge, running S.S.E. towards the high mountains north of Loch Maree. The outer or north-western side of the ridge consists of large loose angular stones, and the interior of the mound of similar stones mixed with sand or clay. These stones were principally white and grey gneiss, hornblende-rock, and red sandstone, but I also observed one or two specimens of mica-slate, containing garnets. They thus consist of the very materials which the mountains on the south-east would furnish to any powerful denuding agent. And the form and arrangement of the stones left no doubt in my mind that this agent had been a glacier, cradled in the mountain-valley in which Loch Fuir now lies. The first ridge would then form the terminal, the other the lateral moraine. Some other peculiarities confirm this view. The ground behind the ridge slopes down to a small lake, lying as it were in the mouth of the opening in the mountains whence the icy stream has flowed. The stones therefore must have been forced across this lake without filling it, and up the acclivity on which they now rest. Within the mound also, or between it and the lake, are many detached heaps of stones and detritus, as if left by the glacier in its retreat. The singular aspect of this remarkable accumulation of angular stones, at once arrests the attention of the spectator, and leaves no doubt that they must have been brought together by a very different agent (or, at least, acting in a very different manner) from the one, however powerful it might be, that laid down the large boulders irregularly scattered over the moor to the west.

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8. *On the* Upper *and* Lower Boulder-Clays *of the* Gorlston Cliffs *in* Norfolk. By Joshua Trimmer*, Esq., F.G.S.

During a recent visit to Norfolk, my friend, the Rev. Mr. Gunn, kindly drew my attention to a fact which cleared up some anomalies that had previously perplexed me while adopting the classification of previous observers respecting the tertiary deposits of the district, which are more ancient than the Boulder-clay.

The new fact then brought to my notice, while it removes those anomalies, confirms the views which I published in 1847 of the boulder-clay being the littoral deposit of an arctic sea advancing over sinking land†.

It appears that in the Gorlston Cliffs there are two boulder-clays separated by a mass of sand, which, on the authority of Woodward, has hitherto passed for the Crag, a term which has now become as indefinite as that of "drift" or "drifts." The lower boulder-clay is the tailing-off of that so well known for its blocks of Scandinavian origin, and which extends over the north of Europe and into the eastern side of England. The upper boulder-clay is characterized by an abundance of oolitic detritus. I had traced these oolitic boulders over the south of Norfolk to the point at which they crossed the chalk-ridge of the Swaffham Downs at Lopham Ford, and I had supposed that the oolitic and the Scandinavian erratics met on the same level; whereas Mr. Gunn's observations establish the fact that the former overlaps the latter, with a mass of sand interposed. In my examination of Norfolk during the three years preceding 1847, I had bestowed only a slight examination on those cliffs, as being out of the district on which I had undertaken to report; and the anomalies in the structures which had perplexed me were these. The base of the whole series at Cromer and Gorlston is the green fluvio-marine clay and the fossil forest which it supports; and, if the sands which succeed it are the Crag, we have the forest in one case above the Crag and in the other below it. This anomaly will be found noticed in my paper in the Journal of the Royal Agricultural Society, though I did not attempt to explain it.

* Owing to the lamented decease of Mr. Trimmer since the reading of this paper, it has not had the benefit of being revised by him previously to publication.—Ed. Q. J. G. S.

† Journ. R. Agricult. Soc. vol. vii. part 2; also Quart. Journ. Geol. Soc. vol. vii. p. 19.

On visiting the cliffs with Mr. Gunn, I found their structure to be as he had described it.

The oolitic boulder-clay which forms the summit of the cliff, and is covered, more or less, in the interior by masses and patches of the sands and gravels of the denuded upper erratics, rests on a thick mass of sand. This sand is clayey in its lower part, and frequently exhibits lenticular masses of blue clay, like that of the Cromer Cliffs. I saw some boulders of gneiss on the beach, and though, during a rapid examination, we found none actually imbedded, Mr. Gunn assured me he had seen them in the cliff.

From the Journal of the Royal Agricultural Society I reproduce the following description of the boulder-clay of Norfolk, where it approaches the Yarmouth estuary. I quote it in order to show how that description harmonizes with the discovery made by Mr. Gunn.

"Towards the termination of the cliffs near Happisburgh, the thickness of the boulder-clay diminishes, its upper surface sinks beneath the level of the sea, and disappears under the sand-hills and alluvium of the Yare. Detached portions of it are, however, met with in the 'hards' or 'holmes' which rise like islands from among the alluvial deposits. In composition this clay is somewhat different from the clay of Cromer Cliffs, and consists of a mixture of blue clay, such as occurs in those cliffs in the yellow clay and sand. In this form it is the grey clay-marl of East Flegg, described by Marshall. South of the Yarmouth estuary it is again visible between Gorlston and Lowestoft, occupying the upper part of the cliff with a large development of crag-sand beneath and a thin covering of the gravel and sand of the upper erratics above it.

"Following it up the valley of the Waveney, we find it holding the same relative position to the two sandy deposits, except where, by the denudation of the upper sand, the clay has been exposed over large areas in the southern boundaries of Norfolk, and over still larger areas in the north of Suffolk.

"Oolitic detritus increases in quantity as the boulder-clay is traced towards the west in the river-sections, and in the clay-pits which have been so abundantly opened throughout the district. This detritus consists of fragments of Kimmeridge Clay and other oolitic rocks, with their characteristic fossils, among which the vertebræ of the saurians and the 'turtle-stones' or septaria of the Oxford Clay are very abundant."

In the sand below the boulder-clay, Woodward had traced shells which he considered crag-shells, as far as Bungay in the valley of the Waveney. I had traced it still further to the west, but without shells, as far as Harleston. I also traced it up the valley of the Wensom as far as Swanton Morley.

Mr. Gunn considers that the shells are not *in situ*, but derived from the Crag. This, however, appears to me a point of very little importance. Among deposits in which the greater portion of the mammals and molluscs are of existing species, we should be led into serious errors by relying on particular species. We must be guided chiefly by physical evidence, and when we have recourse to organic remains, we must look to groups rather than to individual species. The intercalation of beds of shells *in situ* in the midst of the boulder-clay is not a solitary fact—similar deposits have been described in other localities. Neither is it at variance with the analogies of existing arctic seas, where, amidst a general absence of shells, there are instances of their occurrence, as in Baffin's Bay, described by Dr. Sutherland. As a general fact, the boulder-clay forms the lowest part of the erratic tertiaries. It is, however, occasionally intercalated with masses of sand and gravel, more particularly near the mouths of rivers.

I may here mention another instance of an upper and lower clay separated by a mass of sand. In the valley of the Weir, near Durham, the late Professor Johnston, in his 'Agricultural Chemistry and Geology,' described an upper and a lower clay separated by sand. On visiting the district, in company with my lamented friend, I found the river flowing through a deep mass of sand. At some little distance this was covered by boulder-clay, under its usual form. I was conducted to two sections where there appeared to be boulder-clay below the sand. I could not, however, satisfy myself that they were not landslips. The sections at the neighbouring collieries, where records are kept of all the beds sunk through, whether belonging to the coal-measures or to the superficial deposits, would clear up this point.

The passage of the oolitic erratics across the chalk-ridge near Swaffham is analogous to the passage effected by the Cambrian erratics across the Pennine chain at the Pass of Stainmoor, whence they have been distributed down the valleys of the Tees and Humber, and lodged on the summits of the oolite-cliffs at Scarborough and the chalk-cliffs of Flamborough Head. It is also analogous to the passage of the Lickey pebbles across the Cotswolds. In each case the different lines of erratic materials held their southern course separately so long as the dividing ridges were above the glacial sea; but when their cols or water-sheds became sufficiently submerged, the erratic blocks crossed them, and the blending lines continued their southern course so long as the more distant rocks from which they were derived were not too much submerged to continue to furnish materials.

One fact I would urge on the attention of those who see the effects of a glacier wherever they meet with scratched rocks and scratched detritus; it is, that in the erratic deposits of Norfolk, where we cannot invoke the presence of glaciers in the ordinary sense of the term, the local fragments derived from the shales of the Kimmeridge Clay and from the hard Chalk have the peculiar form and scratched surface which pervade the local detritus of our Alpine districts.

That we have evidence of glaciers in the valleys of Wales and Cumberland, as pointed out long ago by Buckland, and confirmed by Davison, is undeniable. It is undeniable also, as suggested by the latter, that they have had a large share in clearing the boulder-clay out of the principal valleys. We have evidence, too, of the retreat of the glaciers to higher levels during the return to a milder climate, as, for instance, at Llyn Idwal* in Caernarvonshire; while, in the adjoining small lateral valley opposite the Penrhyn Quarry, I have seen shells and granite brought up from the boulder-clay at a depth of 30 feet; no traces, or very slight traces of it being found in the main valley down which the glacier had descended. In Nantllo Valley also, at the base of the steep escarpment of Llwydd-mawr, there are two or three small mounds of the angular detritus of the adjacent precipice which indicate a very small glacier, although it hardly deserves that name, which may have reached their present position on ice. I never could comprehend it while I thought only of transport by aqueous action. Traces of the action of glaciers during the period of emergence we can comprehend, while we doubt the possibility of pointing out those which precede the period of submergence.

I question, however, if it be possible to point out the track of a glacier belonging to the period which preceded the submergence. The phenomena which have been mistaken for them are to be referred to the action of heavy masses of floe-ice advancing into the interior over sinking land. The period of submergence was one of foreign erratics borne inwards; the period of emergence, one of local erratics borne outwards.

The effects of terrestrial and marine ice of an arctic climate, whether we look to heated rocks, to scratched detritus, or to pot-holes, are so closely similar, as I gather from the accounts of arctic voyagers, that it is only by their relation to deposits containing shells, and by taking general views which shall embrace the whole of the erratic phenomena, including the presence of marine shells, and the conditions under which they occur, that we can decide between the effects of the action of terrestrial and marine ice.

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9. *Note on the* BONES *of the* HIND-FOOT *of the* IGUANODON, *discovered and exhibited by* S. H. BECKLES, F.G.S. By Professor OWEN, F.R.S., F.G.S.

THE specimens† exhibited by Mr. S. H. Beckles, F.G.S., and discovered by him in the Wealden-bed, south-coast, Isle of Wight, consist of bones of apparently the same individual of a more than half-grown Iguanodon, including the metatarsals and phalanges of the left hind-foot. This foot includes three toes.

To the inner (tibial) side of the innermost of the fully-developed metatarsals, there is attached a styliform rudiment of a more internal metatarsal: the distal end of this rudiment is broken off, but it gradually tapers to that end, and seems, like the splint-bones in the

* See also Prof. Ramsay's remarks on the glacial phenomena of N. Wales, Quart. Journ. Geol. Soc. vol. viii. p. 375.—ED.

† These specimens have been figured, and form the subjects of Plates 1, 2, and 3 of Prof. Owen's "Monograph of Wealden Reptiles," published in the volume of the Palæontographical Society for 1856.

metatarsus of a horse, to have terminated in a point, and not to have supported a rudimental claw. The outer side of the outermost metatarsal shows no mark of any other bone, rudimental or otherwise, having been there attached. The co-articulating surfaces at the proximal ends of the metatarsals show them to have belonged, as their position in the matrix indicated, to the same foot.

The innermost supports a toe of three phalanges, the middle metatarsal one of four phalanges, the outermost one of five phalanges. Only the ungual phalanx of the middle toe is wanting: and that no other phalanx is absent from this toe is shown by the modification of the distal articular surface of the penultimate phalanx; which, like that in the adjoining toes, is less concave transversely, or is more uniformly convex, than the distal trochlear surfaces of the more proximal phalanges.

The modifications of the claw-phalanx of the outer and inner toes accord with those of the larger and previously discovered claw-phalanges of the Iguanodon.

Guided by the analogy of the number of phalanges in the toes of the hind-foot of the Iguana, we may infer that the three toes that are normally developed in the hind-foot of the Iguanodon, are the second, third, and fourth; that the first or innermost is represented by a rudimental metatarsal, which was concealed beneath the skin of the foot; and that the fifth or outermost was entirely suppressed.

This modification of the hind-foot is interesting by its analogy to the tridactyle hind-foot of the Rhinoceros and Tapir; and still more so by its correspondence in the varying number of the phalanges, and their progressive increase, from the inner to the outer toe, with the foot of birds.

It adds to the probability of Mr. Beckles's idea of the Iguanodontal nature of the large tridactyle impressions which he has discovered and described in certain Wealden formations, and suggests caution as to inferring that tridactyle impressions, showing a progressive increase of digital joints from three to five, from the innermost to the outermost toes, must, therefore, necessarily belong to the class of Birds.

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10. *Notice of the Discovery of a* Large Femur *of the* Iguanodon *in the* Weald Clay *at* Sandown Bay, Isle of Wight. By T. F. Gibson, Esq., F.G.S.

[Abstract.]

In the year 1829 a paper was read before the Society by Dr. Buckland, giving an account of the first discovery in the Isle of Wight of the bones of the Iguanodon. The paper described particularly a metacarpal bone of this animal discovered by Dr. Buckland in Sandown Bay, "in the iron-sand," to use his own words, "which forms the shore there, a little east of Sandown Fort, between high and low water," and he states his belief that it was the largest bone of this description that had then been found.

In the month of October last, an unusually high tide and violent sea washed away a portion of the low bank which forms the boundary of the shore a little to the west of Sandown Fort, so as to render the section of the Weald Clay, which comes out at this point, perpendicular to the height of about 15 feet. This bed of clay lies immediately above the ferruginous sandstone in which Dr. Buckland discovered the metacarpal bone. About midway between the bottom and the top of the clay-bank, I found, lying in a horizontal position, a fossil bone of such unusual dimensions, that it appeared worthy of notice, as being the largest of its kind yet recorded. It measures four feet ten inches in its extreme length, and fourteen inches in diameter near the centre. It has suffered much from pressure, but is so far perfect, that Professor Owen, on inspection of a small clay-model of the bone, pronounced it to be, in all probability, the femur of an Iguanodon. Owing to the kindness of my friend Mr. Tite, who happened to be at Sandown at the time, and assisted me in some researches for further remains of the animal, which proved fruitless, I am able to exhibit the drawing of the bone, of the actual size, on the wall.

The clay-bed in which the bone was found is near the centre of the arch which, as is well known, is formed by the Wealden in Sandown Bay, dipping slightly westward. Where the same bed occurs on the reverse, or eastern dip, at a distance of about half-a-mile, large vertebræ and other portions of bone are frequently found, but always much rolled and broken.

On the GEOLOGY *of the* NORTH-EAST PART *of the* DOBRUTCHA. By T. SPRATT, Captain R.N., F.R.S., F.G.S.

On the FRESHWATER DEPOSITS *of the* LEVANT. By T. SPRATT, Captain R.N., F.R.S., F.G.S.

[The publication of these memoirs is unavoidably deferred.]

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPER.

On a New Genus *of* Cephalopoda, Tretoceras* (Orthoceras bisiphonatum, Sowerby); *and on the occurrence of the Genus* Ascoceras, Barrande, *in* Britain. By J. W. Salter, Esq., F.G.S., of the Geological Survey of Great Britain.

[Plate XII.]

[Read June 4, 1856†.]

This unique fossil is figured in the 'Silurian System,' pl. 21. f. 23. The anomaly presented by it, as a Cephalopod shell having apparently two distinct siphuncular tubes perforating the septa, has always appeared very great; since, however, so many species with large *lateral siphuncles* are known (*Cameroceras* and *Endoceras*), the analogy with these has always offered itself for consideration, and prevented inquiry as to which was the true siphuncle, and what might be the nature of the supplementary tube.

I think, however, that the structure of another and very rare group of *Orthocerata* will explain the peculiarities of this fossil.

That the remarkable lateral tube is not produced by the intrusion of any smaller *Orthoceras* into the cavity of a larger one—a circumstance very common indeed among these fossils, and one which has been often commented upon‡, is evident from the fact that the edges of the septa (*a*, *a*) where they abut upon the large tube are decurrent upon it; so that the perforation is a natural one. Nor is it comparable with the large lateral siphuncle of *Cameroceras*, seeing that there exists another and a true siphuncle close to it, and the tube itself is not at all annulated as in the shelly siphuncle of species of the group last mentioned.

There is one form indeed of *Orthoceras* (fig. 4) doubtfully referable to the genus (and which Mr. S. P. Woodward considers an evolute form of *Discites*§, M'Coy, or *Nautiloceras*, D'Orbigny) which offers a triangular section of the tube, the lateral edges being produced into

* Diploceras, the name given in the notice of this paper, Quart. Journ. Geol. Soc. vol. xii. p. 381, has been previously used by Conrad.

† For the other communications read at this Evening's Meeting see Quart. Journ. Geol. Soc. vol. xii. pp. 369, &c.

‡ There is a specimen in the cabinet of the Rev. T. T. Lewis of Bridstow, Ross, in which the tube of a large *Orthoceras Ludense* is literally crammed with smaller ones; nearly all the septa had been broken either by their intrusion or before their admission.

§ Manual of the Mollusca, pt. 1. pp. 86 & 450.

wing-like crests. It is the *Orthoceras paradoxicum* of J. Sowerby, from the Carboniferous Limestone of Ireland. Were the back of this species hollowed out a little more, and the wings extended upward in the direction of the dotted lines in our fig. 4, it would present a very close analogy with the section of *O. bisiphonatum* represented in fig. 3.

There is also in the Lower Silurian rocks of North America, a genus of *Orthoceratidæ*, *Gonioceras* of Hall*, which shows the same characters in an extravagant degree (fig. 5). *Gonioceras* is the most extreme modification in section yet observed among the chambered *Cephalopoda*. It has a beaded siphuncle, like that of *O. bisiphonatum*. If it were less extended laterally, and were the sharp edges curved round in the manner supposed in fig. 4, so as nearly to meet, we should have a form to all appearance exactly similar to that of the internal cast of *Tretoceras*. I for some time thought that we had in the genus now described (*Tretoceras*) an extreme form of this kind, and that it would rank next to *Gonioceras*. But there is one serious objection to that view, inasmuch as there is no indication in the uppermost or terminal chamber of a margin to the supposed excavation. On the contrary, the tube is evidently continuous with that terminal chamber (fig. 1 *b*), and the argillaceous matrix has flowed from one into the other, without any line of separation, such as must have been the case had the walls of the tube been formed by the outer surface of the shell.

We have then clear evidence that this anomalous shell possessed ordinary septa, pierced by an excentric beaded siphuncle, and also had a deep lateral cavity continuous with the terminal chamber and passing down side by side with the siphuncle,—the cavity affecting at least seven of the uppermost septa, if not the whole of them.

In a late communication to the Geological Society of France, the indefatigable M. Barrande has figured one among the many new Cephalopods of Bohemia, which will, I think, furnish the requisite analogy. He describes *Ascoceras*† as a flask-shaped cephalopod of the tetrabranch order, with the terminal chamber not only occupying the space above the air-chambers, but extending down one side of nearly the whole length of the shell, in the form of a wide and deep cavity; this broad cavity being embraced by the decurrent edges of the incomplete upper septa (4 or 5 in number). It also communicates at its base with a small siphuncle which pierces the minute terminal air-chambers.

There are no traces of a siphuncle in the incomplete upper septa which are thus formed on one side only of the produced hinder portion of the body of the animal‡.

M. Barrande ingeniously argues that this wide cavity on the

* Palæont. N. York, vol. i. pl. 14.

† Bull. Soc. Géol. France, 2nd series, vol. xii. p. 157, and our figure, Pl. XII. fig. 7. See also Quart. Journ. Geol. Soc. vol. x. part 2, Miscell. p. 26.

‡ Barrande supposes this portion to have contained some of the viscera, so that there would be, on this view, no abrupt distinction between the mass of the animal and the siphuncle itself.

ventral side of the animal is of the same nature as the large lateral siphuncles of the group named *Orthoceratites vaginati* by Quenstedt, and to one of which Conrad applied the term *Cameroceras.*

The posterior part of the mantle in these *Orthoceratites* must clearly have extended back to the distance of two or three septa, if not to the whole extent of the tube, since the shelly deposit is continuous throughout. And the same must have taken place in the more recent *Nautilus* (*Aturia*) *Ziczac.* This large siphuncle appears from Barrande's account and Hall's figures* to be always filled up posteriorly as the animal moves onward in the shell; so that the hinder portion of the body, though greatly elongated, does not necessarily attain an extravagant length.

It is, however, quite conceivable, that the hinder portion of the body might be only narrowed and contracted for a given distance, and yet communicate with a siphuncle of the usual form, but which does not elongate, at least in mature age, in proportion to the advance of the animal in the shell. And such, from Barrande's own figures and descriptions, appears to have been the case with the genus *Ascoceras* above mentioned; for, while the terminal air-chambers (and in some species of *Ascoceras* there were evidently more than one) are furnished with a small siphuncle, the latter does not in any way extend into the incomplete and arched septa which are formed in the inflated portion of the shell, but is continuous with the contracted posterior visceral cavity. In the form we now figure, however, both the enlarged cavity and the siphuncle exist, side by side, and the former is by this means shown to be independent of the latter, and not, as M. Barrande's view of the case would make it, a mere continuation of it. In *Tretoceras* there must have been a posterior elongation or lobe, something like those so commonly met with, of far less size, in the genera *Clymenia* (where it is dorsal) or in *Goniatites,* and especially in *Bactrites* (Sandberger), fig. 6, where it is ventral. The concurrence of the siphuncle with the position of this lobe may be only accidental, as in the case of the ventral lobe of *Goniatites* and *Ammonites,* while in *Clymenia* and *Aturia Ziczac* the lobes are independent of the siphuncle. But in *Ascoceras,* and especially in those *Orthocerata* with large ventral siphuncles, the coincidence is exact, in the one genus a small siphuncle being attached to the extremity of this lobe, while in the other the siphuncle is continuous with the lobe, and of equal diameter to it.

In any case the subject of our present notice is worthy of generic distinction, and the name *Tretoceras* (*τρητὸς,* pierced) seems applicable to its apparent structure.

Tretoceras, gen. nov. Pl. XII. figs. 1–3.

Elongate, with a subcentral beaded siphuncle, and with the septa pierced ventrally by a wide cylindrical sinus or tube distinct from the siphuncle.

Species unica. *T. bisiphonatum,* Sowerby, sp. (*Orthoceras*) in Murchison's 'Sil. Syst.' p. 642, pl. 21. f. 23.

* Palæont. New York, vol. i. pl. 44, &c.

Ascoceras.

As an interesting addition to the fauna of our Upper Silurian rocks, I subjoin a description of a species of the genus *Ascoceras* above quoted, p. 168. Three or four specimens have occurred in the Upper Ludlow rock, both from near the town of Ludlow, and from Herefordshire. It appears to be a larger and thicker species than the *A. Bohemicum*, Barr., and I propose to call it

Ascoceras Barrandii, spec. nov. Pl. XII. fig. 7.

A. clavatum, longi-ovatum, cylindricum ?, lente curvatum, striis transversis tenuissimis obliquis; septis ut in *A. Bohemico.*

Our species differs from M. Barrande's *A. Bohemicum* * chiefly by the considerable obliquity of the lines of growth. The form is somewhat more inflated, and the region occupied by the septa, if possible, more extravagantly sigmoidal in outline. Our specimen shows the surface of the penultimate ? † septum and the place of the siphuncle.

Although here described as a distinct species, it is possible that more specimens may prove it to be identical with the Bohemian fossil. Our specimens are flattened; and the greater obliquity of the lines of growth may be due to this circumstance.

Locality. Upper Ludlow rock, Ludlow (collected by Mr. Lightbody and Mr. J. Harley of Ludlow); at Stansbatch, Herefordshire (collected by Mr. J. E. Davis of Presteign), now in the Museum of the Geological Survey. I found one also at Hales End, Malvern; it is now in the cabinet of my friend R. B. Grindrod, LL.D., F.G.S., of that place. It appears to occur in the very uppermost layers of the Ludlow rock, immediately beneath the Bone-bed. Its place in Bohemia is lower down (in "Étage E." or the Wenlock-beds). In North America again, as I learn by a letter from M. Barrande, the genus has occurred in the "Hudson River Group" (Caradoc Sandstone)!

EXPLANATION OF PLATE XII.

Fig. 1. *Tretoceras bisiphonatum*, Sow. sp.; natural size. In the Museum of the Geological Society. *a*, shows the flattened and decurrent edges of the septa where they join the lateral tube. *b*, the cast of the tube itself undivided by any constrictions. *c*, the beaded siphuncle placed excentrically.

2. A restored figure: a portion of the shell is supposed to have been removed.

3. End-view of one of the septa, showing the excentric position of the siphuncle.

4. Outline of the septum of *Nautiloceras paradoxicum*, Sow., sp.; to show the possible analogy of *Tretoceras* with this form, if the ends were more incurved.

5. Outline of the septum of *Gonioceras anceps*, Hall; also for comparison. The shell, however, in both these forms would *line* the *whole concave* surface.

6. *Bactrites*, Sandberger; introduced to show the small ventral lobe in the septa.

7. *Ascoceras Barrandii*, Salter, with septa added in dotted lines.

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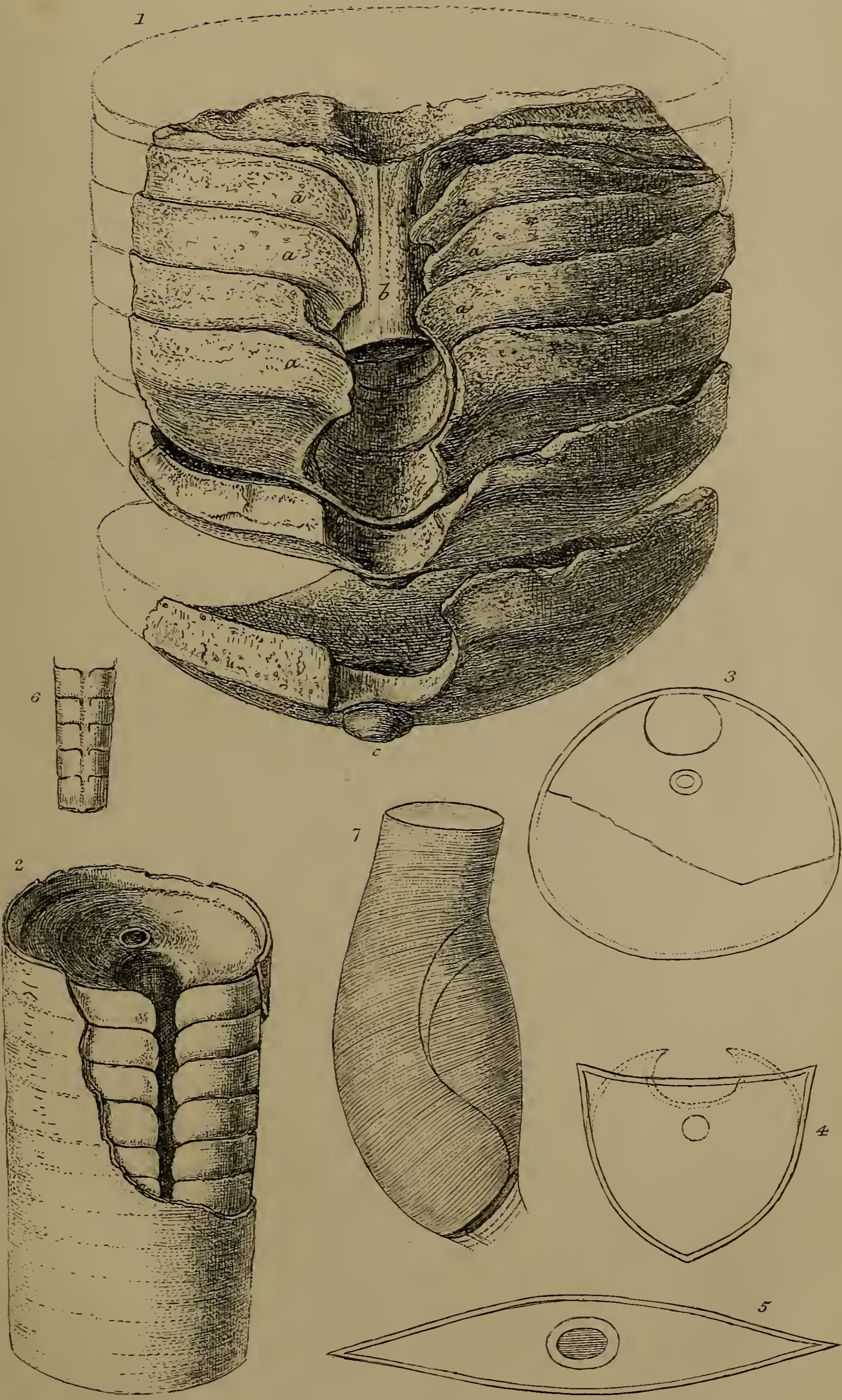
* Bull. Soc. Géol. France, 2nd ser. vol. xii. pl. 5. fig. 20.

† There were clearly more than two ordinary septa at the small end of the shell. This is seen in some of M. Barrande's specimens now in the British Museum.



TRETOCERAS, ASCOCERAS, &c.

DONATIONS

TO THE

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JUNE 17, 1857.

[Proceedings continued from page 176.]

11. *On the* GEOLOGY *of the* NORTH-EAST PART *of the* DOBRUTCHA. By T. SPRATT, Captain R.N., F.R.S., F.G.S.

HAVING had an opportunity, during the latter part of last year, of extending my geological inquiries in the eastern part of the Dobrutcha, and of obtaining a better idea of some parts of its character, I am induced to offer a few remarks as a continuation of my former paper on this locality*.

It is known that the northern extremity of the Dobrutcha is terminated by a chain of mountains that obtain an elevation of between 1000 and 2000 feet. They consist of highly-inclined limestones, shales, and schistose rocks. But the bold features usually assumed by the description and elevation of rocks of this nature are generally subdued here by their flanks and shoulders being covered by a considerable deposit of arenaceous marls, of reddish, grey, and brown colours. The marls are undoubtedly of a late date; but their origin I am not able to determine, from the total absence of fossils wherever examined by me.

In this remark I allude especially to the group of superficial, earthy or arenaceous, red and brownish marls of the Steppe, separable from the known freshwater marls; for I have recently

* See Quart. Journ. Geol. Soc. vol. xiii. p. 77.

ascertained that the former are not a continuation of the lower fresh-water deposits which I have already noticed at Kustenjeh, and as I once supposed.

I shall commence my remarks at the north end of the Dobrutcha by simply referring to the existence of these older rocks at Isatchka, Tultcha, and Besh Tepeh on the Danube; and, although some appear to be metamorphic from volcanic agency, they are no doubt of an early age; perhaps either Devonian or Carboniferous.

The only place where rocks of a similar age appear on the shores of the Black Sea, in the Dobrutcha, is at Kara Irman, near Cape Media. At this spot, which is near the south-west corner of the Raselm Lagoon, and where the delta of the Danube commences, there are dark shales of considerable thickness, and much resembling the shales and schistose strata occurring on the flanks and base of the Balkan, near Cape Emeneh.

The section (fig. 1, p. 206) of the coast-cliff, from Kara Irman towards Cape Media, is of much interest, from the contact of a limestone of Secondary age with these older shales; both being overlaid by the superficial, reddish-brown, earthy marls of the Steppe, without any intermediate group.

The dark shales and schists, *a*, of fully 500 or 600 feet in thickness, form a portion of the rocky shore at Kara Irman, at the angle of the coast, where a ridge of the Steppe projects into the Black Sea as a small promontory, and acts as a natural groyne to hold in check the alluvial deposits of the Danube. At this point there was formerly a scala, or landing-place, for communication with the villages of the neighbourhood, and the ancient town of Istia seems also to have been near here.

These dark shales dip to the northward, at an angle of 40°, the strike being S. 83° W.; and, although appearing along the coast for about a quarter of a mile, they are nowhere more than 3 or 4 feet above the sea, and are immediately overlaid by about 40 feet of the soft, reddish-brown, earthy marls of the superficial series of deposits, *e*. I had no opportunity of examining them minutely in search of fossils.

The cliffs of white compact limestone, b_1, contain corals and marine shells; they are only from 16 to 20 feet high. The beds lie nearly horizontally, and seem to have been originally deposited against the older shales; but they may have been thus brought in contact by a fault.

These limestones are shattered, and filled with small cavities, especially where the fossils are most abundant. A *Rhynchonella* seems to be the characteristic fossil.

The second mass of limestone, b_2, is a coast-cliff about one mile nearer Cape Media *; and the compact white limestone of which it is

* The specimens from Cape Media, forwarded to the Society by the author, consist of yellowish, cream-coloured, and grey limestones (hard and crystalline) with *Pectines*, *Terebratulæ*, *Rhynchonellæ*, a univalve, and Corals.

Some hard, yellowish, and grey limestones, sent by Capt. Spratt from Lake Raselm, much resemble those of Cape Media, and contain remains of *Ammonites* composed, although identical in mineral character with the first mass, in contact with the shales, is less fossiliferous and more distinctly stratified.

Both these masses are overlaid by about 2 feet of rubbly white marl (omitted in the Section), succeeded by the reddish-brown marls *e*, *e*, which are not more than 20 feet thick over the limestones; but are fully 40 and 50 feet thick in the intermediate spaces. As none of the *identified* freshwater marls cap these limestones, but only such as are of a doubtful age and origin, possibly connected with a disturbed or changing condition in the later period of the freshwater series, these limestones must have stood as ridges, rocks, or islets, when the freshwater lake, which I believe once covered the area of the Black Sea and Archipelago together, existed, and of which the lower deposits south of Kustenjeh, and the upper at Baljik, 400 feet above it, give some positive indications, as also, I think, the freshwater limestones or marls of Odessa and Kertch.

Between Cape Media and Kustenjeh is a freshwater lake, about 4 miles long and 2 broad. It is separated from the sea by a strip of sandhills, which extend between the extremities of two ridges of the Steppe, and terminate in a cliff at the south, towards Kustenjeh.

The inner shores of the lake are for the most part chalky cliffs, or marly banks, that were, without doubt, the sea-margin at some early period; so that this freshwater lake has been formed out of a small arm of the sea, by means of the alluvial sand having been moved along the coast from the Danube (by the prevailing winds and currents), and thus accumulated in nearly a direct line across the mouth of the bay. From the existing copious springs of fresh water on the shore of the bay, the enclosed arm of the sea, or salt lagoon, has become a freshwater lake. The bay was also originally a deep-water inlet of the Black Sea, since it has now a depth of 18 or 20 feet nearly all over the lake.

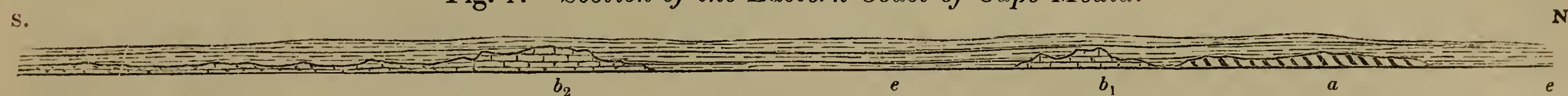
The north-west shore of the lake is chiefly low banks of brown marl, belonging to the superficial series. But the south-west shore presents geological features of considerable interest, more particularly between the villages of Kanara and Pallas *.

At about half a mile from the former village is a small islet covered by a grove of trees; but the islet is not more than 4 or 5 feet above the sea. Of this islet 2 or 3 feet is a rich soil, and the base a mass of inclined strata of compact cream-coloured limestone, much resembling that which I have noticed at Cape Media.

(*Ceratites* ?), *Pectines*, *Terebratulæ*, *Rhynchonellæ*, *Modiola*, a small Echinoderm, fragments of Crinoidal stems, and Corals. A somewhat similar cream-coloured compact limestone, sent by Capt. Spratt from Cape Karabournou, Roumelia, contains fragments of *Ostræa*, *Lima*, *Terebratula*, Corals, a fragment of a Crustacean, and casts of univalves and bivalves. A softish buff-coloured laminated limestone from Cape Dolashma, Lake Raselm, contains numerous small *Inocerami* in layers, and branching fucoidal bodies.—Edit.

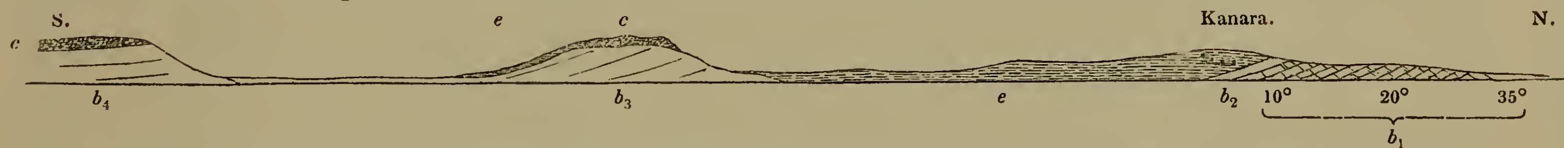
* These localities are shown on the map illustrating Capt. Spratt's "Route between Kustenjé and the Danube," published in the 'Journal of the Royal Geographical Society,' vol. xxvi.—Edit.

Fig. 1.—*Section of the Eastern Coast of Cape Media.*



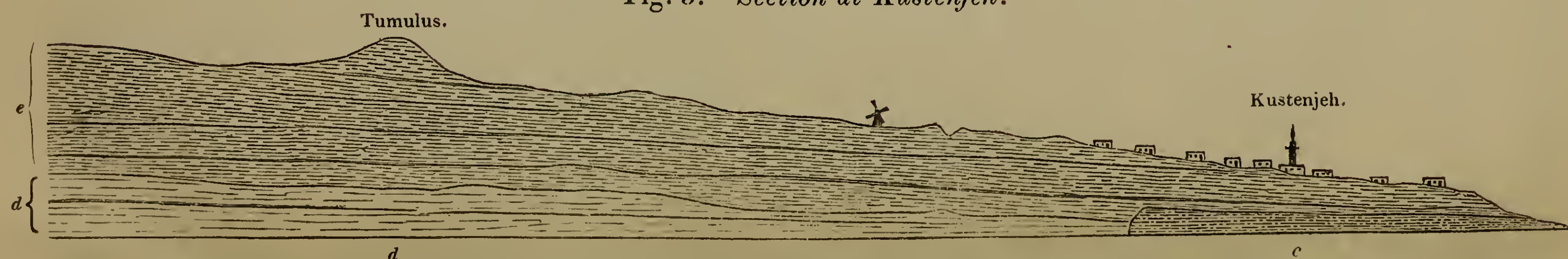
e, e. Brownish marls of the "superficial series." b_1, b_2. Fossiliferous limestone of Secondary age. *a.* Old schists. (The rubbly and chalky marl, overlying *b, b*, is omitted.)

Fig. 2.—*Section of the South-west Coast of Kanara Lake, near Kustenjeh.*



b_1. Limestone and shale of Secondary age. b_2, b_3, b_4. Chalk and chalk-marl. *c, c.* Sandstone of Tertiary age. *e, e.* Reddish marls of the "superficial series."

Fig. 3.—*Section at Kustenjeh.*



c. Older Tertiary shelly limestone. *d.* Freshwater deposits (50 feet). *e.* Reddish marls of the Steppe (100 feet).

A rocky point, which juts into the lake to the east of Kanara, seems also to be a part of the same limestone.

The opposite section, fig. 2, will explain the disposition of the formations :—

A cream-coloured compact limestone, b_1, interstratified with light-grey shales, in layers from 1 to 3 feet thick, together attaining a thickness of 500 or 600 feet, occupies the point; and at the extremity the strata dip to the S.W. by S., or S.W., at an angle of 35°. Here they are more crystalline than at 200 or 300 yards within the point; this indicates, perhaps, a proximate igneous rock not visible.

The dip of the strata diminishes as they recede from the point towards the village of Kanara, where they seem to be in contact with, and overlaid by, white chalky marl, b_2; but whether passing into and conformable with it, I could not ascertain, on account of the superficial marls of the Steppe, *e*, covering the whole.

Although I procured no fossils from the limestones, b_1, at Kanara Point or at the island, the beds seemed to be identical in mineralogical character with those at Cape Media, fig. 1; more particularly as the chalk-marls overlie them in apparent continuity of succession. The chalk-marls* appear, by the fossils that I procured from them, to be either of the Cretaceous or Upper Jurassic age.

About half a mile to the south-east of the village of Kanara rises a semicircular cliff of the chalk-marl, nearly 30 feet high (b_3, in the section, fig. 2). The chalk-marl dips to the south-east or southward, at from 5° to 8°, and is capped by about 15 feet of yellowish-brown sandstone, *c*, with oolitic rock. This appears to be an early tertiary deposit, and corresponds with some oolitic strata that occur at the base of Kustenjeh Point (see *c*, fig. 3), as also with the oolitic strata of the Malakoff ridge at Sevastopol.

The deposit, *c*, capping the chalk, is unconformable, and is evidently of an early Tertiary age †.

This chalk-cliff must have been an elevated point in the fresh-water lake of the Tertiary period, since it is covered and flanked only by the superficial marls of the Steppe series (*e* in both the sections). These also fill the valleys on either side of the ridge.

At about half a mile more to the south-east is another chalk-cliff, b_4, which extends along the coast for more than a mile, and beyond the village of Pallas. This cliff seems to be composed of an upper series of the Chalk, since the strata have the same dip as in the former section, and contain a large quantity of siliceous bands and nodules, though very few fossils. I could procure only a few fragments, as the whole series of strata composing this cliff are more indurated than in the chalk at Kanara.

* Portions of a Ventriculite, together with ferruginous ramose concretions and pyritous balls, are in the specimens of this soft white calcareous rock, sent by the author. It contains also cretaceous Foraminifera.—Edit.

† Specimens sent to the Society are—a hard oolitic white limestone with bivalves (*Lucina* ?); a cream-coloured compact crystalline limestone; and a hard yellowish limestone, full of casts of univalves and bivalves, chiefly two forms of fluted *Cardium* or *Adacna*.—Edit.

This cliff is also capped by about 10 feet of rubbly oolitic sandstone, *c*, like that at the cliff near Kanara, and containing similar fossils. If this, as I conjecture, be an Eocene bed, it is here a mere remnant of that group.

The chalk-cliffs gradually decrease in elevation from the village of Kanara, and altogether disappear a little beyond Pallas, where the superficial red marls replace them, and form the sea-cliffs to Kustenjeh.

This group of marls, of the superficial series, are well developed in the cliffs both to the north and south of Kustenjeh. To the north of it, the cliffs are more than 100 feet high, and entirely composed of these marls. Some of the strata are dark umber-brown, and contain nodules of soft chalk, also bands and crystals of gypsum; but there are no gravels—no indication here of their having been deposited in waters under any *violent* movement. To this the soft chalk-nodules are the only exception, showing probably an agitation or current, and appear to have been derived from the proximate chalk-deposits, before described. But I saw no heavy nodules of indurated chalk, or of chalk-flint, such as would indicate any violent aqueous movement. These deposits, filling up the denuded hollows and valleys which existed on the surface of the Cretaceous and early Tertiary ridges, are destitute of fossils, and seem to be due to a rapid deposition from highly-charged waters. And this also seems to be indicated by the absence of such a uniform and constant series of strata as may be expected to occur in slowly-formed deposits.

When I partially described the Kustenjeh marls*, I was not able to separate them into two distinct groups. But further researches more to the south have enabled me to discover that the probably freshwater deposits of the lower series, in which I procured a fragment of an Elephant's tusk, and some casts of a Cyclas-like bivalve, do not pass into the overlying series of reddish-brown marls.

My conjecture of the freshwater origin of the lower portion of the deposits to the south of Kustenjeh is confirmed by my discovering more terrestrial and probably freshwater-shells in them; and thus they are identified with the upper series of freshwater deposits, which I have noticed as covering a fragment of the early Tertiary at Baljik†, where they are more than 100 feet in thickness, and 500 feet above the sea. But at Kustenjeh they are only observed at the sea-level, and from 30 to 40 feet above it.

I therefore take this opportunity of correcting my former section of the Kustenjeh deposits by the one given at p. 209, with fuller details.

The lowest bed is about 5 feet of yellowish-white oolitic limestone, *c*, fig. 4, with marine fossils. This is apparently of the Eocene age, and much resembles the oolitic rocks near Varna‡ and Sevastopol. The

* Quart. Journ. Geol. Soc. vol. xiii. p. 78.

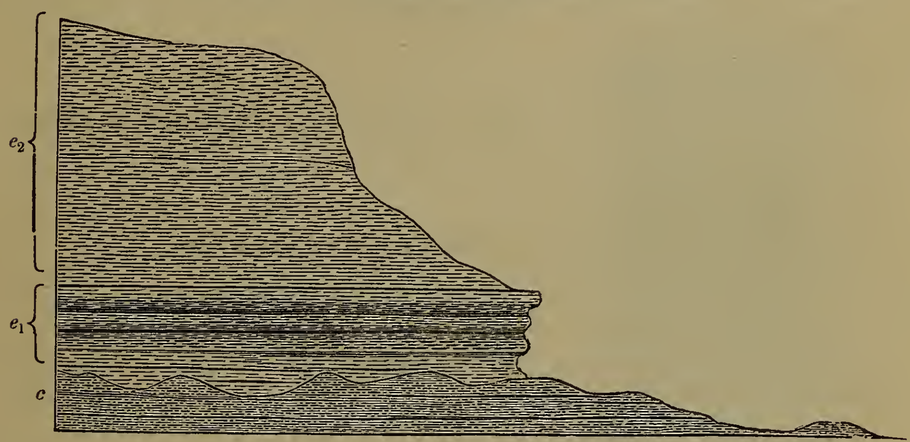
† *Loc. cit.* p. 77.

‡ In the opinion of M. Abich, For. Mem. G. S., who has carefully examined the fossils from the neighbourhood of Varna, these deposits are of Miocene age.—Ed. Q. J. G. S.

dip of the strata is apparently to the N.E., at an angle of 8° or 10°.

In examining minutely the deposits forming the Point of Kustenjeh, I found that this rock terminates abruptly on the north and south sides of the promontory, as if by a fault; and it is overlaid by deposits that seem to belong only to the red marls or superficial series, *e*, although the lower bed, immediately reposing on *c*, contains casts of a *Cyrena*? similar to what are found in the upper portion of the group *d*, fig. 3, where the beds and fossils indicate no such evidence of having been aggregated by moving waters.

Fig. 4.—*Section of Kustenjeh Point.*



e_2. Reddish marls. e_1. Shelly sandstones, 7 feet thick.
c. Older Tertiary oolitic limestone, marine.

On the older tertiary deposit, *c*, is a thinly stratified yellowish sandstone, e_1, 7 feet thick, and composed almost entirely of fragments of shells and oolitic particles. In it are bands and masses of casts of *Cyrenæ*? like those found in group *d*, figs. 3 & 5.

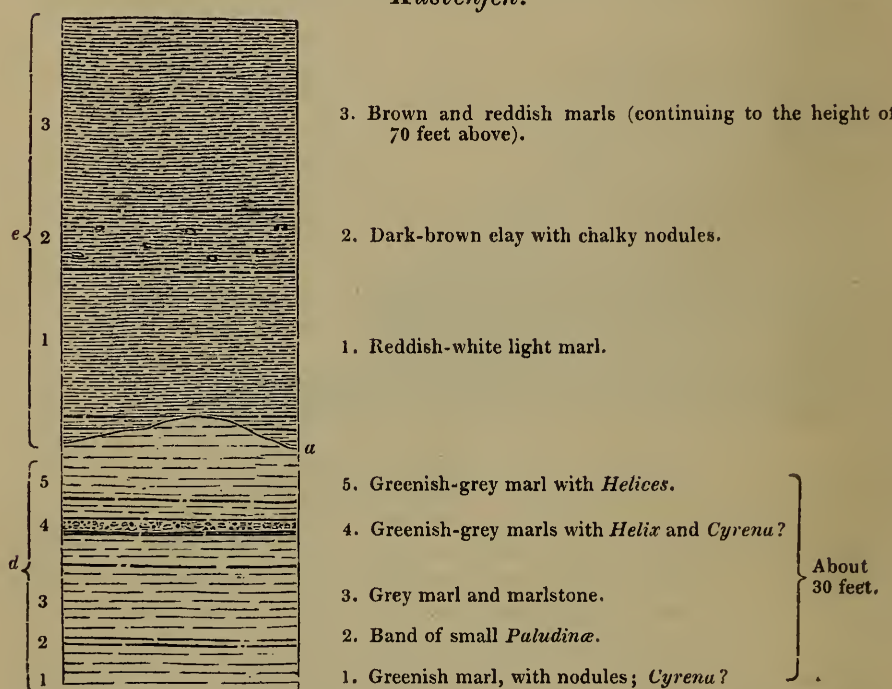
This deposit, e_1, from containing the oolitic grains and these bivalves, seems to be composed of the debris of groups *c* and *d*, under a sudden disturbance of the old lake, in which the rock *c* formed perhaps an islet or shoal during its previous tranquil condition.

The next bed, e_2, is about 30 feet of red marl or clay, without any indication of fossils or foreign fragments, and is a small portion of the superficial marls, *e*, of the Steppe, which I shall have to refer to in describing more particularly the evidence of the separation between the marls *d* and *e* of fig. 3.

This will perhaps be best done by giving a section (fig. 5) of a part of the cliff at about half a mile S.W. of Kustenjeh, where a fresh landslip or scaling showed me clearly the point of separation between the two series of marls, marked by the denudation of a portion of the lower group, as seen at *a*, and the subsequent filling up of the irregularities by the upper red marl series. This separation is difficult to identify where the upper series reposes upon a more indurated stratum of the freshwater series, as frequently occurs.

When both lie nearly horizontal, they appear to be conformable, as in the cliff about one mile south of Kustenjeh. Here I saw, in ascending order, 1st, 10 feet of a greenish-grey marl, with indurated nodules of marlstone, and sometimes chalky nodules, but not derived apparently from any foreign locality; also crystals of gypsum, and casts of a *Cyclas* or *Cyrena*; 2nd, an indurated band, from 2 inches to 1 foot thick, filled with casts of a small *Paludina*; 3rd, 5 or 6 feet of grey marl, with bands of marlstone; 4th, 20 feet of greenish-grey marls, with broken layers of marlstone, forming slabs and nodules, in which are found casts of a bivalve (*Cylas*?), also an occasional

Fig. 5.—*Section of part of the Cliff half a mile South-west of Kustenjeh.*



Helix, similar to the one found in the freshwater deposits over Baljik*; 5th, a more indurated stratum of the greenish-grey marls, from 2 to 3 feet thick, and replete with *Helices*. This is also sometimes pisolitic, and its indurated character is evidently due to the aggregation of the fossils. The shells, probably, were not accumulated by any violent action of the waters from currents or drift, but lived at the bottom during a late period of the lake, when it seems to have been very shallow, and perhaps, in consequence, subject to stronger superficial currents, from local winds and local torrents. Hence the associated land-shells and lacustrine shells were thus mingled together in accidental groups; as no doubt must occur often at the bottom of shallow tideless waters proximate to land prolific with vegetation and land-shells. This condition must have existed on the old chalk-ridges that formerly bordered the lake not far from these

* Quart. Journ. Geol. Soc. vol. xiii. p. 77.

cliffs, as I have shown previously. Chalky downs are always highly favourable to the prolific development of land-shells, as is well known to all naturalists. And I digress for a moment to suggest that, in this view, we have an explanation also of the origin of the white marly character and great thickness of the Baljik freshwater deposits, as having been derived from the denudation of these great chalky ridges by the torrents of every season's rain. Here also the land-shells (*Helix*) are as abundant in the upper series of the deposits as the bivalves and other freshwater shells that lived in the lake.

Referring to the section, I have to add that the fossiliferous bands of the lower freshwater series thin out sometimes to a thickness of a few inches at distances of a few hundred yards on either side: such is the case towards Kustenjeh, where, being less indurated, they have been superficially denuded, as shown in fig. 5, *a*.

At the locality where the last-described section was taken, however, the greenish marls present a flat surface, upon which immediately succeed the reddish marls of the upper series, which I have before described as being stratified in thick beds of dark-brown, grey, or reddish marls; they are nearly 100 feet thick in some parts. The upper marls are lighter and somewhat porous *.

In closing my remarks, I shall merely state that I have no doubt but that the continuity of the Kustenjeh freshwater deposits will be traced hereafter up to the elevated deposits of Baljik, as a continuation of the bottom of the same lake. And I venture to suggest that they are also identical with those of Odessa and Kertch, neither of which, however, I have had an opportunity of examining. Their connexion is to my mind also certain with those of the shores of the Sea of Marmora, by the valley of Brujuk Tchekmijeh, where I some time since found freshwater fossils in its deposits, together with a band of lignite. Also the lignite and gravel-beds examined by Mr. H. Poole † on the south side of the Sea of Marmora, near Brusa and Ismid, I believe to be of freshwater origin; and I connect them as indications of one great eastern freshwater lake that existed perhaps from the Miocene to a late Tertiary period. The actual limits of this lake westward as well as eastward have yet to be defined by

* The specimens from the "Upper series of the Steppe deposits," sent to the Society, comprise—1. red marl; 2. soft, yellow, laminated, argillaceous sandstone; 3. brownish, sandy, micaceous marl; 4. a brownish marl, like No. 3, but altered by atmospheric agency, perforated with minute irregular tubules (as is also No. 3), and containing small, soft, calcareous concretions; 5. like No. 4, but less calcareous, and redder; also buff- and salmon-coloured calcareous concretions, and soft white marl.

The specimens of the "Freshwater series" comprise—1. shelly, cream-coloured, compact limestone, full of casts of *Helices* and a *Bulimus*; 2. hard, grey, shelly limestone (weathered), concretionary or oolitic, and crystalline, full of casts of bivalves (*Cyrena*?), and containing a few casts of small univalves; 3. marly limestone, full of casts of *Cyrena*?, passing into a hard, grey crystalline limestone, with similar casts, and resembling No. 2; 4. greyish limestone, full of casts of *Cyrena*?, interior of the casts sometimes oolitic; 5. grey limestone, full of hollow black moulds of a small *Paludina*; 6. green clay, with a portion of an elephant's tusk.—Edit.

† Quart. Journ. Geol. Soc. vol. xii. p. 1, &c.

determining the precise age of the great volcanic centres, that, from Ararat to Lemnos, and Santorin to Vesuvius, have from time to time uplifted or submerged parts of its expansive bed.

In merely touching upon this view, I am induced to recall to mind the other isolated fragments of freshwater deposits that occur in Rhodes, Crete, Cerigo, and in the western basin of the Mediterranean, of Provence, Lombardy, Florence, Minorca, &c., as reviving an old idea of a chain of lakes having existed in the Mediterranean basin during this period, or rather during a portion of it.

In the sections here given it will be seen, that the superficial red earthy marls of the Steppe-series cover rocks of all ages, and that the freshwater marls, *d*, are often wanting. The probable explanation is, if the former were deposited in freshwater also, that the old land surrounding the lake became suddenly submerged at the commencement of this red marl series,—or that the level of the lake became suddenly raised by the escape of water from some more extensive and more elevated basin,—or that the waters were suddenly raised, having been pent up within more limited bounds, on account of the rising of some great mass of continent, such as a large part of Asia Minor, from out of the great eastern freshwater basin which I suppose to have existed.

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12. *On the* Freshwater Deposits *of the* Levant. By T. Spratt, Captain R.N., F.R.S., F.G.S.

The brief account recently published* of the extensive freshwater deposits which exist on the western shores of the Grecian Archipelago calls for a notice of those within my knowledge on the eastern shores.

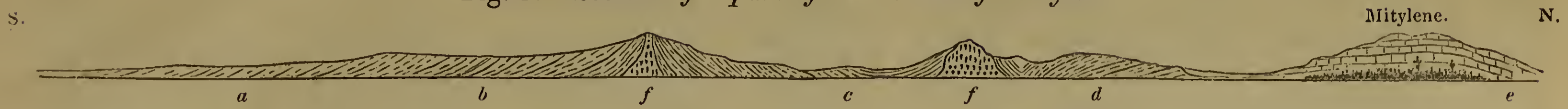
The freshwater tertiaries of Smyrna and Scio† have been traced by me as fragments along the eastern and southern coasts of Mitylene, as well as on the coasts opposite,—the detached and disturbed condition of these deposits being due to extensive outbursts of igneous rocks that form large districts within this island and on the main land opposite to it. For instance, the Moskonisi and Aivali districts, the Assos Range to Cape Baba, Touzla, and Alexandria-Troas, and, in Mitylene, the north-eastern part of the island, including Mount Lepethimus, as well as the entire peninsula west of Port Kelloni, are composed of volcanic rocks. Besides these there are several lesser protrusions of trap in numerous parts of the intermediate districts.

The vicinity of Mitylene presents an interesting association of the trap and the freshwater deposits, particularly to the south, as shown in the following section, fig. 1.

At Cape Vourkas we meet with the trap and tertiary strata in proximity, particularly on the east short of Port Kelloni, while the white freshwater marls are nearly vertical, and contain several specimens of a small *Helix*.

* Quart. Journ. Geol. Soc. vol. xiii. p. 177.
† Described in the Society's Quarterly Journal, vol. i. p. 156.

Fig. 1.—*Section of a part of the Island of Mitylene.*

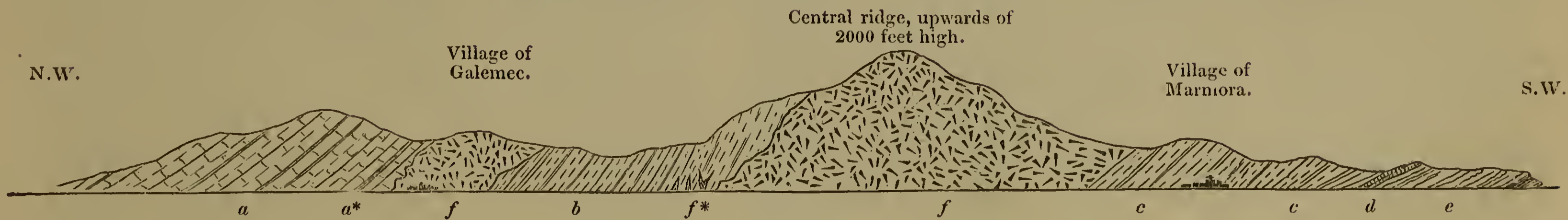


a. Grey sands and marl. *b.* Yellowish arenaceous limestone and marl. *c.* White and variegated strata. *d.* White and brown strata. *e.* Limestones. *f, f.* Igneous rocks.

Fig. 2.—*Section of the Island of Tenedos.*

a. White arenaceous limestone, 40 feet thick, fossiliferous. *b.* White sandy marl, containing Oysters and Pectens. *c.* White compact limestone, full of casts of a *Cyrena*? *d.* White, brown, grey, and black marls, marlstone, and sandstone, highly fossiliferous in some parts. *f.* Limestones, of Secondary age, reaching a height of about 100 feet.

Fig. 4.—*Section along the West Coast of the Island of Marmora.* (See p. 218.)



a. Veined marble, interstratified with shale. *a*.* White crystalline limestone, shown in a newly-opened quarry. *b.* Dark-green shales; dip 50° to N.E. *c, c.* Dark-grey and blue shales. *d.* Limestone. *e.* Contorted micaceous shales, dark-brown and green; dip 30° to N. *f, f.* Intrusive porphyritic granite. *f*.* Veins of granite, in the vertical and crystalline schists, near Steelan Monastery.

The Island of Tenedos is still more interesting and instructive in respect to the relative position of the freshwater deposits, and for their greater development, as seen in fig. 2, p. 213.

Here the freshwater deposits are found to be capped by about 40 feet of a white arenaceous limestone, containing marine shells of the present sea, both deposits lying nearly horizontal, and apparently conformable. The exact place of separation of these two groups is not easy to be detected; and it was some time before I discovered positive proof of the freshwater origin of the lower group of strata, *c* and *d* in the section.

Three-fourths of the island is comprised of these horizontal beds of freshwater and marine tertiaries, which together are fully 100 feet thick. The other fourth consists of a conical peak of trachyte (Mount Elias), rising like a dome over the extreme north-east cape of the island, and throwing off from its southern flanks ridges of secondary limestones and shales, somewhat frizzled by the contact; these are succeeded or overlaid by horizontal strata of the Tertiary series, as shown in fig. 2.

The fossils which I procured from the bed *d* are a small *Paludina, Planorbis, Neritina, Cyrena* (?), *Melanopsis*, and a ribbed bivalve (*Cardium*) similar to the one found in the Dardanelles deposits near Meitos and over Nagara Point.

The deposit *a* contains shells similar to those of the present sea; and, although they are upwards of 100 feet above the sea-level, they are apparently of a late Tertiary age (older or newer Pliocene), like the marine deposits which repose against the freshwater beds at the south-east extremity of the island of Cos.

To the north of Cape Baba, near the River Touzla, there are some coast-cliffs of this late marine tertiary, from 30 to 40 feet high, in which the beds seem to repose on the adjacent igneous rocks. The latter extend northward to the mountains at the back of Alexandria-Troas, where a granitic trap predominates, and from whence columns, in early days, and stone-shot for the guns of the Dardanelles, in later times, have been quarried. These quarries occur near the village of Chimali.

More to the northward, the blue semi-crystalline limestone and shales of the secondary group of rocks replace the volcanic rocks; and then succeed extensive districts of horizontal strata of the freshwater and marine tertiary deposits, as far as the Dardanelles, Sea of Marmora, and Constantinople, with an occasional protrusion of the trap here and here in the northern part of the Troad.

Connected with these jets of trap, between the Gulf of Smyrna and the Troad, outlying from the great centres of eruption, is an interesting point which I observed many years ago when examining and surveying the topography of the plain of Troy, to illustrate the Homeric history, and when I was accompanied by my learned friend Dr. Forchhammer of Kiel, who wrote an account of our trip for the 'Geological Journal.' Several masses of basaltic rocks peep through the tertiary strata forming the hills surrounding the plain of Troy;

but one of particular interest occurs at the site of Troy, where a ridge of volcanic rocks extends from the base of the Pergamus to the north-east of the village of Bounarbashi. The limestone-ridge, forming the Pergamus of Troy above it, and extending also to the ridges west of the village, indicates the effect of this volcanic outburst in the fissured condition of some portion of the mountain. But I refer particularly to the fact that the most copious and the most western of the springs which form the Scamander issues through two crevices or rents in a mass of red tufaceous rock that seems to be derived from and connected with these volcanic ejections. These two springs are the most copious of the whole at Bounarbashi, and together are capable of turning a water-mill after being collected in a basin at the mouth of the fissures.

These sources, coming through an apparent volcanic vent or rent, suggest most strongly that the water issuing from them in the Homeric time might then have been warmer by a connexion with the subterranean heat, although all the springs showed only 63° by the thermometer which I used in 1838. How beautifully, then, does Homer's description, as rendered by Pope, apply to the long-disputed question of the hot and cold springs of the Scamander!—

> "This, hot, through scorching clefts is seen to rise," &c.
>
> *Iliad*, xxii.

Curious and interesting, then, is this explanation of a long-doubted point of the Homeric description; and I introduce it here, not being aware that it has been noticed by any traveller since my reflections on it in 1838, as a point of geological interest in connexion with the igneous eruption above alluded to.

As the presence or absence of the above-mentioned great igneous centres have a marked influence upon the features of the country, I shall here notice that, excepting some trap-rocks, accompanied by slight local disturbances, as at Kefez Point, near the Arenkeui hospital and Chanak castle, none other occurs between the Artake Islands, in the Sea of Marmora, and Tenedos.

This district presents a great development of freshwater marls and limestones, nearly horizontal, and extending from the Troad to Lampsaki on the south side of the Dardanelles, and from Cape Hellas nearly to Rodosto on the north side, and from Rodosto to Constantinople, on the northern shore of the Sea of Marmora.

The strait of the Dardanelles entirely divides this great field of freshwater deposits, that have been apparently lifted in mass almost vertically, but divided asunder by the strait, as if separated by a great chasm; for steep cliffs or banks terminate the ridges that line both shores of the strait, in some cases displaying these deposits in a series of horizontal strata of grey and green marls, brown sands and sandstone, fully 700 or 800 feet thick.

As I never met with any marine fossils above the freshwater deposits of the Dardanelles, it appears that they were elevated above the newer Pliocene sea-level.

The localities* at which I have found freshwater fossils, in proof of my arguments, are as follows:—Cape Hellas, where the marls and sandstones contain *Cyrena* or *Cyclas*; under Yenisher, on the Asiatic side, I have found cast of *Uniones* and *Cyrenæ*? in the neighbourhood of Arenkeui†; over Nagara Point, *Unio* and a ribbed bivalve (*Cardium*) similar to that in Tenedos, with *Paludina* and *Planorbis*; the same at Meitos with fossil leaves and other plant-remains. Also *Unio* and a *Melanopsis* similar to that in Tenedos are to be obtained in great abundance in a bed of sandy marl over Kiled Bahar, the European castle of the Dardanelles.

[In a letter to the Assistant Secretary, dated June 12, 1857, Capt. Spratt states:—

"In a walk up to the village of Arenkeui, over the site of our hospital, I found the deposits to be precisely similar to those on the north side of the Dardanelles, and to consist of thick-bedded yellowish-brown sands and sandy marls, with an occasional stratum of sandstone. Towards the top, they pass into peaty marls, marl-stone, and fine sands, brown, red, or cream-coloured. The fossils occur at different elevations, and comprise both the *Cyrena*? and *Melanopsis* which occur at Tenedos and Baljik.

"The fossil teeth, found by Mr. Calvert, were taken from the lower part of the group of sandy marl immediately below the village."]

The following is a section across the Dardanelles, from the hill over

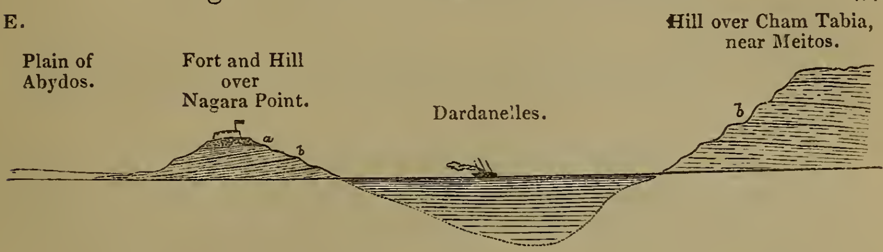
* The specimens sent by Capt. Spratt from the Dardanelles and Sea of Marmora comprise—1. Blue sandy clay with *Corbulæ* (?), Cape Hellas, entrance of Dardanelles; 2. yellowish earthy limestone, mainly composed of fine shell-grit, with plant-remains (like a portion of a leaf-scarred trunk), and *Unio* and *Paludina*, from the European side of the Dardanelles; 3. hard, grey, earthy limestone, full of *Cypridæ*, *Paludina*, *Unio*, and fluted *Cardium* (*Adacna*), from the European side of the Dardanelles; 4. soft yellowish limestone, with *Adacna*,—hard ferruginous, laminated sandstone, with *Adacna*, *Cyrena* (?), *Unio*, *Melanopsis*, opercula of small *Paludinæ*, and *Cypridæ*,—and soft buff shell-grit with *Cypridæ*, from Nagara Point; 5. buff-coloured shell-grit, with harder crystalline seams, containing *Melania* and *Nerita*, from Genokora Point, entrance to the Sea of Marmora; 6. white crystalline limestone with *Cyrena*, and subcrystalline, porous, and marly white limestone, containing casts of small bivalves and *Melanopsis*, and shells of *Neritina* retaining colour, from near Cape Stephano, Sea of Marmora; 7. from Ereke, Sea of Marmora, olive-green, irregularly laminated, micaceous sandstone, with dicotyledonous leaves and fragments of plants; 8. from Marmora Island, white quartzite (rounded fragments), whitish-grey syenite (waterworn fragments), and two varieties of mica-schist; 9. from Kutali, Sea of Marmora, pinkish-grey syenite.—Edit.

† Similar fossils, with numerous fossil bones, have been obtained by our Consul, Mr. Calvert; but I have not seen them, and I am informed that the Medical Staff and the Architect of the Arenkeui hospital have taken to England some of these Mammalian remains.—T. S.

Mr. Calvert, the brother of the Consul, has obliged the Assistant Secretary with the following particulars relating to these fossil bones. The sides of a ravine or valley between Arenkeui and where the Hospital was, and running down to the sea, are formed of horizontal beds of sand and sandstone; in the former a portion of an elephantine jaw, with two teeth in place, was found; and on the higher ground, about 3 miles from the edge of the valley, some fragments of fossil ivory were found near the surface. The bottom of the valley appeared to be formed of sandstone *débris*, covering blue clay and red marl.—Edit.

Meitos to Nagara Point, through an isolated tabular mass of conglomerate, which here caps the freshwater marls at an elevation of about 100 feet above the sea, but contains no fossils.

Fig. 3.—*Section across the Dardanelles.*



a. A conglomerate of rounded pebbles of limestones, schists, and shales, similar to rocks which occur near Lampsaki.

b. Marls and sands, containing freshwater fossils. (500 feet thick on the west side of the Dardanelles.)

This conglomerate, *a*, contains no fossils like those of the mass of similar conglomerate, 70 or 80 feet thick, which forms the Promontory of Gallipoli; the latter I have before noticed* as containing fragments of a large *Dreissena* and a *Cardium*, as well as being capped by a thin stratum of sandy marl, in which these fossils occur more abundantly, both entire and broken.

The south shore of the entrance to the Sea of Marmora, from Lampsaki to Cape Karabournou, opposite Kutali Island, and around to the mouth of the Granicus, is composed chiefly of steep ridges of older rocks (limestones and shales), with volcanic protrusions, and detached fragments of the Tertiary deposits.

The north shore from Gallipoli is composed of marls and sands, which seem to be identical with the freshwater series; and at Ganakhora, opposite to Marmora Island, about 50 feet of the marly deposits are capped by a bed of conglomerate, formed of rolled pebbles, with broken shells of *Dreissena* and *Cardium*, as at Gallipoli.

In a hasty visit to Erekli and Scliori, to determine the proper sites for lighthouses on that shore, I observed the same marly and sandy deposits; and amongst the ruins at the former locality, I found that some of the ancient buildings had been built of a concreted mass of bivalves like large *Dreissenæ*; I could not learn from whence it came, but I think Rodosto.

I could find no shells in the sandstones and marls at Scliori to indicate positively its freshwater origin; but I procured some fossil leaves, which were abundant near the upper part of the cliff to the east of the town. All along this shore, the Tertiary deposits have frequently a dip from 5° to 15°, but with no constant direction.

At Bujuk Tchekmejeh the marly cliffs contain a bed of lignite, with casts of freshwater shells in the associated marls. Cape Stephano is composed of white and yellow marls, about 25 feet thick, in some parts chalky and calcareous, with irregular nodules and concretions. I was doubtful whether this was not an early and lower member of

* Quart. Journ. Geol. Soc. vol. xiii. p. 82.

the freshwater series; but, as the quarries of Makri Keui not far distant are in a white lacustrine limestone, as Mr. Strickland long ago pointed out, I am inclined to consider the Stephano marls as freshwater also, since I have found no evidence of any marine tertiary in the shores of the Sea of Marmora. In some specimens which I procured from the quarries of Makri Keui are casts of a *Melania*, apparently resembling the one I procured from the neighbourhood of Vourla in the Gulf of Smyrna, figured in the 'Geological Journal,' vol. i. p. 163.

The above evidences of the freshwater origin of the deposits which line the north shore of the Sea of Marmora seem to justify my view of connecting the basin of the Sea of Marmora and the Archipelago, as having been a part of one great lake, which probably covered a great portion of the central part of Asia Minor, as shown by Hamilton and Tchihatcheff, penetrating by the valley of the Hermes and the other valleys separating the older chains and ranges, as Xanthus on the south, the Halys on the north, and the Hermes on the west.

The lignite-beds, briefly noticed by Mr. Poole*, in the Nikomedian and Brusa valleys, are, I think, a portion of the same lacustrine series, which seems to represent a long portion of the middle and later Tertiary periods; although the relative age is difficult to determine precisely, on account of the great permanency of genera and species of the air-breathing Mollusca peculiar to the freshwater fauna.

As the two basins of the Archipelago have each their central, but extinct, volcanos, or foci of eruption, in Santorin and Lemnos, so the Sea of Marmora has its focus in Pacha Liman and the Kutali Islands, which both seem to have been volcanos, from being entirely composed of granitic trap, and presenting a crater-like form. It is also an interesting fact, that, as there is very deep water in the neighbourhood of these sudden uplifts of igneous rocks, or abrupt uprisings of the bottom (as also occurs near Micero and Methana, two other evident volcanos of no very early date), so there is in the centre of the Sea of Marmora a sudden depth of 300 and 400 fathoms (representing, perhaps, a downcast proportionate to some neighbouring great uplift of the strata); and Marmora Island in its south-western half shows a large mass of granitic and porphyritic trap, associated with crystalline limestones and micaceous shales and schists that resemble rocks of the earliest age.

The section, fig. 4, p. 213, taken along the coast, and touching at several spots, tends to confirm these views.

The marble-quarries of Marmora are celebrated; and I found them as extensive as the Pentelic Quarries of Attica, with the marble, in some parts, quite as white, pure, and crystalline as the Parian, but generally more resembling the cippoline of Carysto.

As this condition occurs only when a volcanic dyke of the porphyritic trap comes in proximity with the limestone, as seen in the section, it seems to show that these rocks owe the oldness of their aspect to their metamorphic condition; and I am inclined to think that the eruption of igneous matter in contact with them may be of

* Quart. Journ. Geol. Soc. vol. xii. p. 1.

as late a period as that of Lemnos and the other volcanic centres which have torn up the bed of the lacustrine basin, because I observed the summit of one of the highest ridges of Marmora to be capped by horizontal beds of what appeared through the glass to be red and brown marls and gravels.

These fragmentary remarks on the Dardanelles and Sea of Marmora, made for the most part during the commencement of the late war, although incomplete, will serve to call the attention of geologists to the interesting field of inquiry as to the boundaries and age of this great Oriental (if not also, in part, Mediterranean) lake or chain of lakes, as (it seems to me) indicated by detached freshwater deposits along the ancient margins.

November 4, 1857.

Robert White, Esq., West Cowes, was elected a Fellow.

The following communications were read:—

1. *On the* Triassic *and* Permian Rocks *of the* Odenwald, *in the Vicinity of* Heidelberg, *and the* Corresponding Formations *in* Central England. By Edward Hull, Esq., A.B., F.G.S.

The resemblances and general relations of the Trias and Permian formations of the Thüringerwald and Hartz, with their representatives in England, have already been pointed out in the joint memoir of Sir R. I. Murchison and Professor Morris*. The present communication refers to a neighbouring range of hills, destitute, it is true, of that fine assemblage of palæozoic rocks below the Permian, which have been shown to abound in the Hartz and Thüringerwald, but, in the case of the more recent formations, presenting many points of analogy with their contemporaries, both in the regions referred to, and in Central England.

It has been shown by Professors Sedgwick and King, as also by the authors of the memoir on the Hartz, that the Permian groups of Germany and this country can be strictly contemporanized, stratum for stratum. In visiting the Odenwald, it was partly my object to ascertain whether a similar parallelism might be observed in the case of the Trias. In doing so, however, occasion was taken to examine the Permian formation, which, though only sparingly represented in the Odenwald, presents those peculiar lithological characters which appear to identify it, not only with formations in the Thüringerwald and Hartz, but also with the trappoid breccias of Worcestershire.

Since the establishment of three well-defined subformations in the Bunter Sandstone of England, a notice of which I had the honour of laying before the Geological Section of the British Asso-

* Quart. Journ. Geol. Soc. vol. xi.

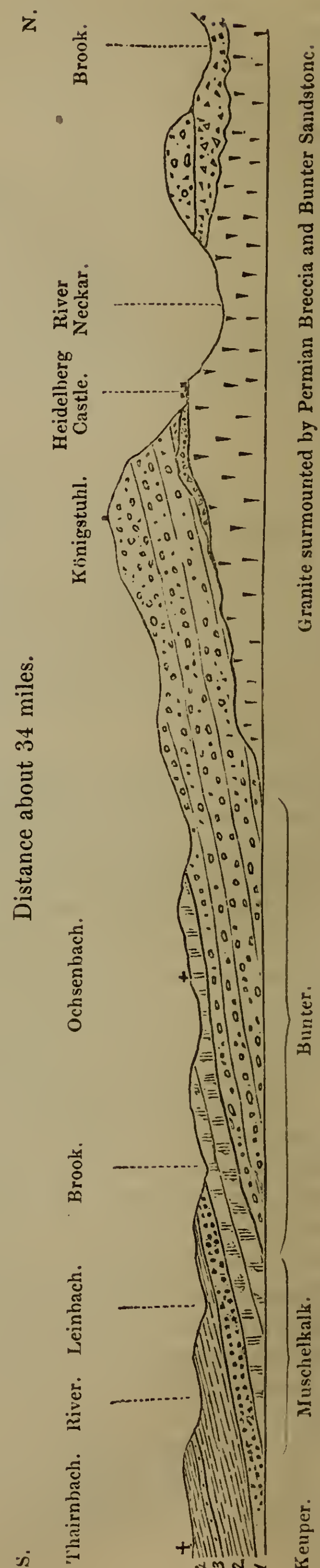
ciation in 1854, and which have been adopted by the Geological Survey of Great Britain, I have felt desirous of ascertaining whether these subdivisions are represented in Germany.

As far, however, as the present examination extends, there appear to be no grounds for subdividing the Bunter of the Odenwald. If, in England, this formation presents three successive stages, corresponding to the same number of periods in its history,—on the other hand, in this part of Germany, if we are to judge by uniformity of mineral character, there have been no corresponding periods*.

The Range of the Odenwald forms a barrier to the valley of the Rhine in a north and south direction. It is traversed by the deep gorge of the Neckar, along whose banks good sections of the Red Sandstone of the Odenwald are exposed to view, especially at Neckarsteiner and Eberbach. Near the mouth of the gorge stand the castle and town of Heidelberg, on a boss of granite,—one of those isolated masses which frequently protrude at the northern extremity of the Odenwald, and in greater force in the neighbourhood of Freiburg. This granite consists of several varieties, considered by Sir C. Lyell† as corresponding to successive periods of protrusion; but of its age, it can only be asserted that it is earlier than the Permian, and later than the Silurian epochs, as in the former case fragments of it are found in the breccias of the

Section across the Königstuhl, near Heidelberg.

Distance about 34 miles.



* Since the above was written, the author has been informed by Sir R. Murchison, that the German geologists have lately established a threefold division of the Bunter in other parts of Germany.

† Elementary Geology, 5th edit. p. 573.

Roth-todt-liegendes, and in the latter, according to the hypothesis of Sir R. Murchison, the Freiburg gneiss is a Silurian slate, altered by eruptive granite of probably the same date with that of Heidelberg*.

In the Odenwald this granite forms the basis upon which the superstructure of the Permian and Triassic formations has been raised. The geology of this Range has been illustrated by a map, accompanied by a memoir, by Dr. von Leonhard, of Heidelberg†, who kindly accompanied me to some of the best sections in the neighbourhood, and to whose work I beg to refer those who wish to become well acquainted with the geology of the Odenwald and Schwarzwald, as the description here given must necessarily be brief.

Permian.

The *Roth-todt-liegendes* of the Odenwald is finely exhibited in a road-cutting leading up the flank of the hill from the village of Handschucheim. A section of nearly 200 feet may be measured, and the upper surface is deeply covered by Loess, which rises on the flanks of these hills about 300 feet above the Rhine. The description which Murchison and Morris have given of this rock in the Hartz, will apply equally here, and we might go farther and affirm that the same description would apply to the Permian trappoid breccias of Worcestershire. In the Odenwald this formation consists of unconsolidated breccia in a bright-red marly matrix, presenting only rude traces of bedding. The fragments are of porphyry and granite, the former in excess; and the parent-masses are in immediate contact with strata to which they have supplied materials. At Raitbach and Sackingen, it has the appearance of a drift swept from off the Schwartzwald. At Baden, it is sometimes a coarse, sometimes a fine, breccia of granite, porphyry, clayslate, and gneiss, cemented by red marl. As in Worcestershire, the breccias of the Roth-todt-liegendes may be regarded as a drift‡ derived from the destruction of more ancient sub-aërial rocks, consisting of eruptive porphyries in the Odenwald and Germany generally, with which they appear intimately associated.

The resemblance of these beds to the trappoid breccias of Worcestershire cannot fail to have struck an observer acquainted with the formations of both countries. The resemblance is perfect, if we except the difference in the composition of the fragments, consequent upon the variations in the rock-masses from which they have been derived.

The trappoid breccias of the Enville and Lickey Hills do not, however, form the basement-beds of the English Permian system, as similar breccias do in the Odenwald. In the former districts they are underlaid by several hundred feet of red sandstones and marls, with calcareous bands. For these beds we shall probably find representatives in strata described by Murchison and Morris, as occurring immediately over the coal-strata of the Thüringerwald, and *below*

* 'Siluria,' p. 361.

† Geognostische Skizze von Baden, 1846.

‡ Of glacial formation according to Professor Ramsay; Quart. Journ. Geol. Soc. vol. xi. p. 185.

the breccias and conglomerates which form the grand mass of the Permian rocks in that region. The mineral characters bear out the analogy. They are described as "argillaceous and thick-bedded sandstones, of a dark-red brick-colour," a description which might be properly applied to what are here considered their representatives in England.

Hence we may infer, that before the introduction of those littoral conditions of land and sea, accompanied by the outburst of volcanic forces, which resulted in the production of the trappoid breccias of Germany, and, as maintained by Professor Ramsay, accompanied by glacial agencies in Britain, there appears to have been an introductory stage, in which deeper seas and more tranquil modes of deposition prevailed.

In Worcestershire these basement-beds of purple sandstones and marls attain a thickness of 400 feet. They repose unconformably on the coal-measures near Bridgnorth, Enville, and Hales Owen, and are succeeded by the zone of the trappoid breccias and calcareous conglomerates, so prominently exhibited in the Clent, Lickey, and Enville Hills *.

So far, the analogy in the order of succession of the Permian beds in both countries holds good.

Zechstein.—This formation is very sparingly represented at Heidelberg, and is generally altogether absent. It consists of a band of yellow magnesian limestone, with imperfect fossils. As the magnesian limestone of the North of England is universally admitted to be the representative of the Zechstein, it will be unnecessary to dwell longer upon it here.

Trias.

Bunter Sandstein.—The sandstone of the Odenwald has given rise to considerable controversy regarding its age, doubts having been entertained whether it might not be referable to the "Lower Bunter," or "Bunter Schiefer," of the German Geologists, a formation which Sir R. Murchison has truly shown to be of Permian age.

An examination of this sandstone from its base at Heidelberg for miles along the valley of the Neckar, up to the point where it is overlaid by the Muschelkalk, leads me to the conclusion that the whole weight of evidence is in favour of its Triassic age; and in this opinion I am borne out by the authority of Dr. von Leonhard, who has mapped and described it as such in his memoir on the Geology of Baden †.

At the Kaiserstuhl, which rises behind the town and castle of Heidelberg to a height of about 1300 feet above the Neckar, and 1723 feet above the sea, the sandstone attains a thickness of 1400 or 1500 feet. Throughout the Odenwald it is but very slightly inclined from the horizon, and gradually descends towards the boundary of the Muschelkalk at an inclination of 4 or 5 degrees.

* See Maps of the Geological Survey of Great Britain, Nos. 61, S.E., and 54, N.W.

† The Sandstone of Heidelberg is also marked as Trias in von Becker's "Geognostische Uebersichtskarte von dem Grossherzogthum Hessen," and in Sir R. I. Murchison and Prof. Nicol's Geological Map of Europe, 1856.

In composition, the sandstone strongly resembles the conglomerate-beds of the Bunter in Lancashire and Cheshire, the difference being principally in the less abundance of quartz-pebbles in the case of the Heidelberg beds. The colour is bright red, and occasional partings of marl occur in the planes of bedding. Rounded quartz-pebbles, similar to those of the English quartzose conglomerates, occur sparingly; and veins of brown iron-ore have been found,—a remarkable specimen being in Dr. von Leonhard's collection.

Several quarries have been opened at Heidelberg, Neckar-steiner, and Nussloch; and the stone has been used with good architectural effect in the construction of Heidelberg Castle, and other public buildings of the country *. The composition of the whole formation is almost uniform throughout; and in this neighbourhood there is no part thereof which can be referred to the "Lower Bunter Sandstein," or "Bunter Schiefer," as the beds immediately under the Muschelkalk are similar in all respects to those which rest upon the Zechstein and Roth-todt-liegendes.

The Bunter is finely exhibited along the gorge of the Neckar, and in quarries in the neighbourhood of Heidelberg and Nussloch, near its junction with the Muschelkalk. Throughout its depth the composition is uniform, affording no changes in mineral structure upon which to found sub-formations.

In England, on the other hand, in Salop, Cheshire, and Lancashire, where this formation is most fully developed, we find three sub-formations preserving well-defined boundary-lines, and, from their differences of mineral character, producing landscape-features characteristic of each sub-formation. For these I proposed the names Upper Variegated Sandstone, Conglomerate-beds, and Lower Variegated Sandstone; the middle member of the series separating the other two, which resemble each other strongly in mineral character †.

Now, it is to this middle sub-formation, or the "Conglomerate-beds" as they occur in Western England, that the Bunter of the Odenwald bears the most resemblance: hand-specimens from the two localities could scarcely be referred with certainty to their original beds; the only difference between them being the greater abundance of quartzose pebbles in the English sandstone.

Guided, then, by mineral resemblance, we might infer that the Bunter Sandstein of England is more complete than in this part of Germany; and that, of the three stages representing three epochs in the history of that formation in the one country, only the second of these was represented in the other.

Considering, however, that the sandstone of the Odenwald attains a thickness which the three subdivisions in England never exceed, and inasmuch as the strata of both countries were certainly disconnected at the period of their deposition, the evidence is not sufficient to warrant such an hypothesis; and I feel inclined to consider the formation in both countries as strictly contemporaneous.

* The author cannot assent to the wish expressed by a celebrated poet,—that the sandstone of this fine old ruin were "grey, and not red."—See 'Hyperion.'

† For descriptions of these sub-formations, see Rep. Brit. Assoc. 1854.

For these reasons, I have placed the three English sub-divisions so as to represent the whole mass of the Heidelberg sandstone in the annexed Tabular View.

Muschelkalk.—This formation being unfortunately absent in England, I shall not dwell upon it here, referring the reader to Dr. von Leonhard's work.

It folds in undulating layers around the lower flanks of the Odenwald, and is traversed by the Neckar near Mosbach. It consists of thin-bedded bluish limestones with partings. It is only locally fossiliferous, containing, amongst the more common species, the following:—*Avicula socialis*, Bronn; *Ceratites nodosus*, De Haan; *Terebratula vulgaris*, Brongn.; *Encrinites liliiformis*, Schloth. Hæmatite is extensively worked near Wiesbach.

As this formation has no representative in England, it will be sufficient to state that its proper position, were it present, would be immediately under the Waterstones or Lower Keuper Sandstone.—(See Tabular View.)

Keuper.—A true parallelism may be traced in the order of succession of the beds of this formation in England and around the flanks of the Odenwald, and is confirmatory of the conclusion at which, with Professor Ramsay and Mr. Howell, I had long since arrived, that the strata of sandstones and marls, with a base frequently brecciated and calcareous, and which are known in the Midland Counties of England as "Waterstones," are to be referred to the "Keuper formation."

In the Odenwald we find the representatives of these beds, composed of brown and grey grits, with shales, altogether reaching about 100 feet in thickness. In one place, near Wiesbach, a remarkable bed of calcareous breccia occurs, containing fragments of granite, porphyry, and, what is more remarkable, of Bunter Sandstein. A specimen containing this fragment has been shown me by Dr. von Leonhard. These beds undoubtedly represent our "Waterstones," which may therefore be correctly termed "Lower Keuper Sandstone."

The occurrence of this breccia in a position corresponding so closely with that of the breccias which in Worcestershire, Staffordshire, and Cheshire introduce the Keuper formation is interesting, as affording evidence of littoral conditions in both countries at the commencement of the Keuper period. These particular pebbles in the Keuper of Wiesbach, derived from the older rocks of the Odenwald, including the Bunter Sandstein, go far, I conceive, to prove *unconformity* to some extent between the two formations, arising from disturbances, accompanied by denudation, at the close of the Muschelkalk period. Similarly, it may be stated, that in some parts of Central England there are indications of unconformity between the Bunter and Keuper. I particularly refer to the neighbourhood of Ashby-de-la-Zouch, and of the Warwickshire Coal-field. In these districts there is an apparent independence or want of connexion between these formations; the conglomerates of the Bunter appearing and disappearing suddenly without any reference to the position of the Waterstones. And when we consider the long blank in the history of our English rocks, *Tabular View of the Triassic and Permian Rocks of England and Germany.*

Formations.	Germany. Subdivisions.	Germany. Localities.	England. Subdivisions.	England. Localities.
Keuper.	1. Variegated Shales	Odenwald, &c.	1. Upper Marls.....................	Western and Midland Counties, 200–800 ft.
	2. Upper Keuper Sandstein ...		2. Upper Keuper Sandstone ...	Central Counties.
	3. Red Shales, &c.		3. Lower Marls	Central Counties, 50–400 ft.
	4. Lower Keuper Sandstein ...		4. Lower Keuper Sandstone (or Waterstones)	Western and Central Counties, 30–350 ft.
Muschelkalk.				Absent.
Bunter.	1. 2. 3. Bunter Sandstein.		1. Upper soft variegated Sandstone	Western Counties, 400 feet.
			2. Conglomerates..................	Western and Central Counties, 50–400 ft.
			3. Lower soft variegated Sandstone	Western Counties, Derby and Notts, 50–400 ft.
Upper Permian.	1. Bunter Schiefer (Murchison).	Thüringerwald and Hartz.	1. Red and green gypseous Marls (Sedgwick).........	Yorkshire, Lancashire, and Notts, Worksop.
Zechstein or Middle Permian.	2. Stinkstein.......................	Thüringerwald.	2. Crystalline and concretionary Limestone (King) ...	Durham; Yorkshire.
	3. Rauchwacke....................		3. Brecciated Limestone (King).	Tynemouth Cliff.
	4. Dolomite, or Upper Zechstein		4. Fossiliferous Limestone (King)	Sunderland, Durham, and Notts.
	5. Lower Zechstein		5. Compact Limestone...........	Sunderland, Durham, and Notts.
	6. Kupfer-Schiefer		6. Marl-slate.........................	Durham; Notts.
Roth-todt-Liegendes. Lower Permian.	7. Dark Sandstones and Calcareous Grit (Murchison)	The Hartz.	7. Red Marls and Sandstones ...	Enville, Worcestershire.
	8. Trappoid Breccia and Conglomerate	Hartz, Thüringerwald, Odenwald, &c.	8. Trappoid Breccias and Calcareous Conglomerates...	Enville, Lickey, Staffordshire; Alberbury, Salop; Somersetshire?
	9. Dark argillaceous Sandstones, &c. (Murchison)...	Thüringerwald and Hartz.	9. Purple Sandstones, Marls, and Cornstones............	Borders of N. and S. Staffordshire Coal-fields; Salop; Warwickshire; Worcestershire.

filled up in Germany by the highly eventful period of the Muschelkalk, analogy would lead us to infer the occurrence of physical changes of level sufficient to produce slight local unconformity.

These Lower Keuper Sandstones are succeeded by a series of red shales and marls with gypsum, which compose the vine-clad banks around the villages of Rotherberg and Rauenberg, in thickness about 150 feet. To these succeed the Upper Keuper Sandstein, precisely similar both in mineral aspect and stratigraphical position to the beds which in Central England have for so long monopolized the title of "Keuper Sandstone." They also contain *Estheria* (*Posidonomya*) *minuta*.

Near Rotherberg, in a lane-section, these beds are finely exhibited. They consist of several alternations of very fine-grained white sandstone, with white, blue, and bituminous shales, in thickness about 10 feet.

Near Ensheim*, the same beds contain vegetable remains, amongst which the following may be mentioned: *Calamites arenarius*, Brongn.; *Tæniopteris vittata*, Brongn.; *Pterophyllum Jægeri*, Brongn.

The Upper Keuper Sandstein is succeeded by a considerable thickness of red, purple, and grey marls and shales, with occasional bands of sandstone, gypsum, and nodules of hæmatite. These beds correspond to the red marls which are superimposed on the "Keuper Sandstone" of the central counties of England, and, while they comprehend the more considerable mass of the formation, form the upper limit of the Triassic system of both countries.

Summary.—A Tabular View, condensing the remarks made in this paper, is given at p. 225. I have adopted the division of the Permian group into three members, as already pointed out by Sir R. I. Murchison†, as this formation, both stratigraphically and mineralogically, appears to assume a tripartite arrangement.

In England, the lower member, or *Roth-todt-liegendes*, is confined in its distribution to the Western and Midland Counties, and consists of an areno-argillaceous series, separated into two by an horizon of breccias and conglomerates. It has been shown that each of these subdivisions has its representative in Germany.

The middle member, represented in both countries by calcareous zones, is in England confined to the North-Eastern Counties; and is immediately overlaid by the upper member, composed in England and Germany of argillaceous or arenaceous materials. Thus there are three physically distinct members, the lowest of which is itself capable of a ternary division.

In the Bunter Sandstone we recognize three members in England, and, though we cannot observe any correspondence with them in the sandstone of the Odenwald, yet, recollecting the exact correspondence in the succession of the Permian and Upper Secondary formations in England and Germany, I do not despair of seeing the whole ultimately parallelized.

* Geog. Skizze von Baden, p. 60.

† See Quart. Journ. Geol. Soc. vol. xi. p. 426, and Table, p. 448; and 'Siluria,' p. 424 *et seq.*

The author regrets that it has not been in his power to extend these comparisons to the rocks of the Vosges on the opposite side of the Rhine valley. He hopes, however, that, unless anticipated, he may have the wished-for opportunity.

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2. *On the* Extinct Volcanos *of* Victoria, Australia. By R. Brough Smyth, C.E., F.G.S., Member of Council of the Philosophical Institute of Victoria, &c.

The district within which volcanic products and other evidences of recent igneous action are found extends from the River Plenty (a tributary of the Yarra), on the east, to Mount Gambier on the west. Its most northern point is McNeil's Creek (a tributary of the River Loddon), in 37° south latitude, and its most southern Belfast, in 38° 21′ south latitude (see accompanying Map, fig. 1). Its extreme length is 250 miles, and its extreme breadth about 90 miles.

It is said that there are crateriform hills near Lake Omeo, on the flanks of the Australian Alps, and at Lake Tyrrell, near Castle Donnington, on the River Murray; but I have not such precise information as would warrant me to mark those as belonging to or connected with the district now under consideration.

By referring to the map it will be seen that this district is bounded on the south by the sea, and on the north it crosses the Spur from the Australian Alps near the Ballaarat Gold-fields *. In the centre is a basin-like depression, the drainage of which is into Lake Korangamite.

The most distinctly marked crateriform volcanic hills are:

1. A hill near the source of the Merri Creek, on the dividing range, about 25 miles north of Melbourne. Respecting this, Mr. Selwyn, the Government Geologist, says:—"On the green hill north of the Kinlochue Inn, Sydney Road, the ancient crater is still distinctly visible. Several other and smaller hills of the same character, but on which no crateriform cavities are visible, occur near the source of the Merri Creek; and there is little doubt that these hills are the true source whence the whole of the basalt or lava which now occupies the country between the Plenty, the Yarra, and the Sydney Road has been derived." And on referring to his recent map of that part of the country, I perceive that, in cutting a roadway, volcanic ash and scoriæ were found. The altitude of this hill is about 700 feet.

2. Mount Aitkin.—This hill is about 1500 feet above the level of the sea. There is no deep well or crater, but the evidences of recent volcanic action are complete and satisfactory. The summit is covered with masses of naked basalt extending in two parallel ridges; and the course of the streams of lava may be traced from the hill. The surface is strewn with fragments of light vesicular lava. The basalt at the summit is not dissimilar to the rock which

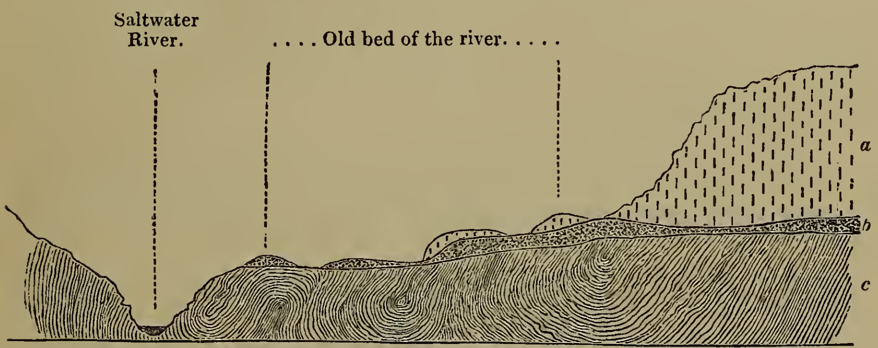
* See Quart. Journ. Geol. Soc. vol. ix. p. 75, and 'The Golden Colony,' 1855, chap. 16, for Mr. Wathen's account of a portion of this volcanic district.—Edit.

Fig. 1.—*Sketch-Map of a part of the Colony of Victoria, showing the Positions of the Extinct Volcanos, or Crateriform Hills with recent volcanic products.*

is commonly found on the plains; but at the base I found some labourers quarrying a hard, dense, bluish-grey basalt, with included crystals of quartz. The basalt through which the Saltwater River has cut a channel has undoubtedly proceeded from Mount Aitkin and the neighbouring peaks, and it now fills the old basin formed in the palæozoic rocks; but it does not appear to have altered the physical configuration of the country very remarkably. Indeed, when we look at the Keilor Plains, and examine the thickness of the basalt in many places, the fact is apparent that the surface of the ancient sedimentary strata must have been moderately even and uniform when it was covered by the igneous rock.

At Keilor a fine section of the basalt may be seen. Its relation to the palæozoic rocks is shown in the section, fig. 2.

Fig. 2.—*Section at Keilor.*



a. Basalt. *b.* Hard quartzose conglomerate. *c.* Contorted Silurian rocks.

The extinct volcano Mount Aitkin has broken through the Silurian rocks, and these may be seen in many places in its vicinity rising above the sheets of lava.

3. Mount Boninyong is immediately adjacent to the Ballaarat gold-fields. It has a distinct crater. Masses of very porous lava are found in the neighbourhood, so light that it is easy to lift fragments several feet square. The lava covers the older auriferous drift; and the newer drift, also containing gold, rests on the top.

4. *Larne-baramul**, or Mount Franklyn, is one of a group of extinct volcanos which are found both to the north, south-east, and west. On the steep side of the hill, the rock is in huge irregular blocks. Here, as in other parts of the district, the lava has followed the course of the channels which were already formed at the period of eruption, and the streams have extended to a great distance, much of the auriferous drift on the Loddon being covered up by the igneous rock.

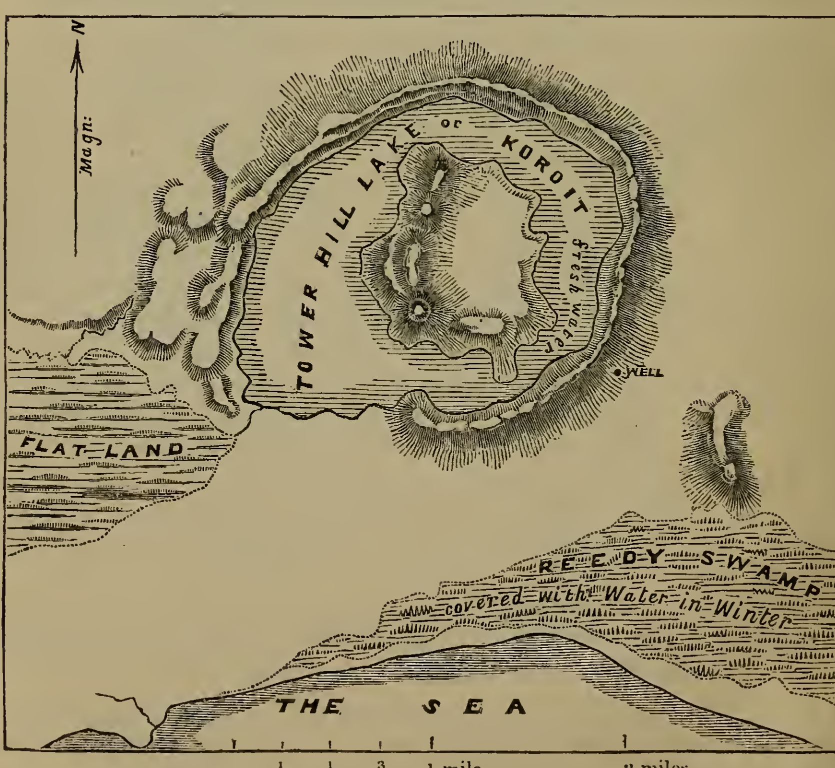
5. The MS. plan given of Mount Rouse explains its general character. In the vicinity of the mount there are numerous springs and swamps, and caves of considerable extent have been found.

* "Home of the Emu." Manuscript plans of Mount Franklyn, Mount Rouse, Mount Leura, and of Tower Hill Lake, from recent surveys, accompanied this memoir, and are deposited in the Society's Library.—Ed.

6. On the west side of Lake Korangamite there are several hills which are crateriform. Amongst the best defined are—Mount Myrtson, having a lake or swamp in the centre, Mount Wiridgil, and Mount Leura. The ordinary volcanic ash and scoriæ are found on these hills. Lakes Gnotuk and Bulleen-Merri, situated to the west of Mount Leura, are also, I believe, ancient craters. Lava, similar to that ejected from active volcanos, is strewn over the surface of the hills. It is often curiously twisted; and masses formed of regular concentric layers are found so similar in form to the trunks and branches of trees, that one was actually sent to me as a fossil tree. On the eastern side of Lake Korangamite there are other hills of an equally distinctive character, the most prominent being Mount Hesse, Mount Gelhbrand, and Warrion, or *Labaam*. In the Korangamite district we find the "Stony Rises." These occupy a large area both to the south, east, and west of the lake. They consist of rocky, often conical piles, about 25 feet in height, generally rising at an angle of 15°, 20°, or 25°, and so close together that they are impassable to wheeled vehicles, and only permit a tortuous and uneven path to the equestrian.

7. Tower Hill Lake is situate between the towns of Warnambool and Belfast, and close to the coast; see the accompanying plan. It bears some resemblance to Lakes Gnotuk and Bulleen-Merri.

Fig. 3.—*Sketch of Tower Hill Lake, near Warnambool, in the County of Villiers.*



The water in the lake is, I believe, some 25 feet above the level of the sea. A large tract of swampy land, which appears to have been recently upraised, extends from the southern base of the hill to the sea.

The average slope outwards of the hill is about 6°; and the inner slope, which forms the margin of the lake, is about 30°. In the centre of the lake there is an island, irregular in form, on which there are several peaks or extinct craters.

Mr. H. Cadogan Campbell, C.E., of Warnambool, has kindly favoured me with a description of the strata sunk through in digging a well on the south-east slope of the margin of the lake (see plan). He says:—"They first sank through about 3 feet of soil, and then for about 60 feet passed through layers of ash, alternately black and white, and of irregular thickness, though none above an inch or two. At the depth of 63 feet the workmen came upon the original surface of the ground, *covered with the common coarse grass now found growing*. It was not scorched, but merely like dry hay." He says again:—"Tower Hill is one of our most extensive volcanos; but it does not appear that much lava has been ejected from it. What has been thrown out has taken a course to the S.W.

"An immense quantity of ashes has been thrown out, forming layers of a tufaceous rock,—the greatest quantity to the eastward of the mountain, that being the side towards which the wind generally blows. . . . . This I have also observed at Lake Purmbeet, where a similar rock is formed from Mount Leura."

Underneath the ancient humus, the workmen sank 60 feet through a blue and yellow clay. Mr. Selwyn, the Government Geologist, has sent me the following note:—

"Geological Survey Office, 11th Aug. 1857.

"DEAR SMYTH,—I have just returned from a very hasty visit to the Western Ports and Tower Hill; and with reference to the recent discovery of frogs in sinking a well in that neighbourhood, it may be interesting to you to know that Tower Hill is certainly the most recent volcanic vent I have yet seen in Victoria.

"It appears, at least during its later eruptions, to have emitted vast quantities of ash and scoriæ; and these are seen near Warnambool, resting on beds of shell, sand, and earthy limestone containing numbers of the living littoral species of mollusca.

"In all other localities where I have examined the large sheets of lava which are so widely distributed over the colony, I have never found them resting on beds of newer date than upper miocene, but have frequently found them, as is the case at Portland, overlaid by beds apparently precisely similar to those which underlie at Warnambool the ash and scoriæ of the Tower Hill crater.

"Yours faithfully,

"ALFRED R. C. SELWYN."

"*R. B. Smyth, Esq., &c.*"

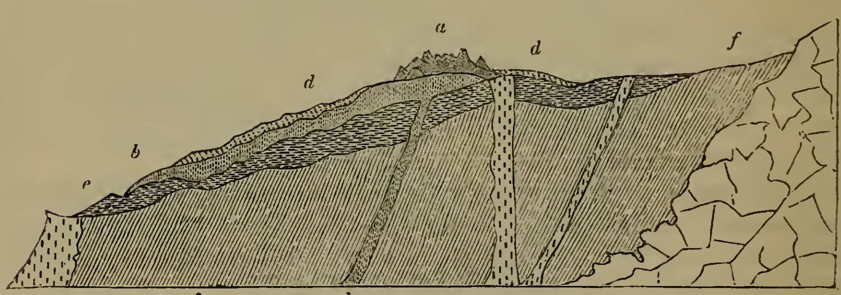
8. Mount Gambier, in South Australia, rising near the boundary-

line separating that colony from Victoria, is crateriform, and is in the midst of a low, flat, and sandy district, with low ranges of tertiary limestone. I am not aware whether it has erupted much lava.

It is impossible at present to define the exact limits of the areas occupied by the most recent volcanic rocks, or perhaps always to determine the age of the various basalts or lavas; but we may draw some useful general conclusions, nevertheless, from the information already accumulated.

Over nearly the whole extent of Victoria there are masses of intrusive basalt, in some places columnar, in others in rude angular blocks, breaking through both the granite and the palæozoic strata, which clearly, from the mode of their occurrence, are unconnected with the recently-extinct volcanos. Such masses are often found in close proximity to the newer basalt, as at Melbourne; and of these Mr. Selwyn's descriptions are most excellent. He draws a proper distinction between the older, close-grained basalt, as it generally occurs, much decomposed, and of a nodular structure, and the recent rock, which is commonly very vesicular and amygdaloidal*. From the similarity in lithological character, as he observes, it is, however, sometimes impossible to separate the one from the other. I have seen the newer basalt, in close proximity to a crater, both vesicular and very dense, and the latter undistinguishable from some specimens of undoubtedly older rock. Neither from their mineral constituents nor specific gravity is it possible to say, from a hand-specimen, whether the basalts are new or old. The following section (fig. 4) shows, in a synoptical form, the manner in which these formations occur.

Fig. 4.—*Diagram showing the relations of the Basalts in Victoria.*



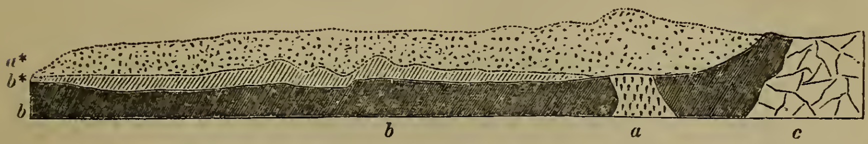
a. Porous lavas (recent). *b.* Younger basalts. *c.* Older basalts. *d.* Quartzose drift (Pleistocene?). *e.* Tertiary fossiliferous strata (Miocene?). *f.* Palæozoic rocks. *g.* Granite.

The older basalt, *c*, in all probability, was erupted by submarine volcanos; and we have no reason to suppose that it did not flow in considerable streams, and fill up inequalities in the ancient seabed. Extensive denudation (of which during that period we have abundant proofs) would account for the removal of the cappings or

* See Geological Surveyor's Report (p. 7). 1854.

streams of lava, and we should then have sections similar to the following (fig. 5), which, indeed, are constantly to be seen.

Fig. 5.—*Diagram explaining the denudation of the Older Basalts in Victoria.*



a. Older basalt, and *a**, its denuded portion. *b*. Palæozoic rock, and *b**, portion denuded. *c*. Granite.

At Flemington, near Melbourne, at Geelong, and at various localities bordering on the coast, marine tertiary beds, *e*, fig. 4, rest on the older basalt, and are the equivalents, Mr. Selwyn supposes, of the miocene beds*. The beds are composed of fine-grained and coarse-grained sandstones, passing into pudding-stone, cemented with oxide of iron, and containing numerous fragments of palæozoic rocks.

Amongst the fossils collected by me, and exhibited at the Paris Exhibition in 1854, were—

Terebratula, very common; some specimens not distinguishable from existing species; *Nucula*, very numerous, and in some localities almost exclusive; *Haliotis*, numerous; *Cypræa* and *Patella*, common; *Spatangus*, common; *Ovula*; *Voluta*; *Cerithium*, &c.

I found also what appeared to be obscure impressions of leaves.

These tertiary beds are very important. In many localities we find a white quartz-drift overlying the basalt; and in others, including large areas, there is a hard white quartzose rock, of very distinct lithological character, immediately underneath the newer basalt, and usually overlying the palæozoic rocks. It is undoubtedly tertiary; but neither this nor the white quartz-drift† contain fossils, as far as I can learn, and I have examined it over a great extent of country. Unfortunately, no very satisfactory sections are exposed which would show the relative ages of these three deposits; but in the vicinity of Flemington they are found in close proximity, and they appear to occur as follows:—

1st. Hard quartzose conglomerate, passing into a clear white siliceous rock, constantly found immediately overlying the palæozoic strata, and rarely of any considerable thickness.

2nd. Brown and yellow sandstones and conglomerates, containing numerous fossils; from 50 to 200 feet in thickness, and apparently resting on No. 1.

* These, I believe, have been distinctly recognized as such by Professor M'Coy, who has made an examination of the fossils.

† The auriferous drift at Bendigo, Ballaarat, and Castlemaine contains fossil wood, which is sometimes found at a depth of sixty feet. A gentleman, mining at Fryer's Creek, found a bone at a depth of eight or ten feet, which appears to belong to some marsupial. It would be premature at present to speculate on the ages of the auriferous drifts. Some are evidently old—perhaps eocene tertiary—others quite recent.

3rd. White quartzose drift and friable sandstones.

The older basalt is usually much decomposed, and contains large and beautiful specimens of semi-opal (*hydrate of silica*).

The newer or post-tertiary basalt is quarried extensively for building-purposes. It is of a dark bluish-grey colour, and, when broken, rarely shows any signs of decomposition. It is in some places covered with a quartz-drift and fine sand, of the same age, most probably, as the newer auriferous drift which occurs generally on the gold-fields *.

On the basaltic plains are found what are locally termed "dead men's graves." These are low narrow hillocks, lying close together, and really not very unlike the mounds of a cemetery. They are formed, I believe, in the following manner:—The basalt is split up into large blocks by the shrinkage-cracks, and, as the edges of the blocks decompose, they come to have a rounded form, the superficial hillocks answering to each block, and the depressions to the shrinkage-cracks. This explanation presented itself after an examination of some quarries in such localities.

The area occupied by recent basalts is, at a low computation, three thousand five hundred square miles. Much of the country is very fine agricultural land, and some of the ancient craters are well grassed and beautifully timbered. The flat plains are generally arid in summer and swampy in winter, but are used profitably for feeding cattle and sheep, and, under good management, produce excellent crops of oaten hay.

From a careful inspection of a large extent of country covered by basaltic rocks, and from information collected from various sources †, I incline to the opinion—

1st. That the newer basalt was erupted at a period when considerable areas, both north and south of the main coast-range, were submerged; but the appearance of much of the basalt shows that it must have cooled rapidly, and not under very great pressure.

2nd. These eruptions do not appear to have disturbed the "miocene" tertiary beds, which are generally found nearly horizontal.

3rd. That, from the occurrence near many extinct volcanos of porous lava, vesicular basalt, and obsidian ‡ associated with fragments of white pumice, it is probable that, subsequently to the deposition of the latest tertiary drift (pleistocene) which overlies the

* See Geological Surveyor's Third Report.

† More especially I am indebted to Mr. A. R. C. Selwyn, the Government Geologist, whose excellent maps, now embracing the whole of the county of Mornington, a large portion of the counties of Evelyn, Bourke, Dalhousie, and Talbot, and the unsettled districts north of Talbot, are now available; and, though they do not extend to the interesting volcanic district west of the River Werribee, they embrace the chain of extinct volcanos from the River Plenty to Mount Aitkin. In addition to allowing access to those maps (in themselves most valuable), Mr. Selwyn is at all times willing to afford the fullest information, and freely communicates facts ascertained during his explorations, even before he has had time to place them on record in his official reports.

‡ Fine specimens of obsidian, with small fragments of white pumice adhering to it, are found at Geelong. The best specimens in my collection were collected and sent to me by A. J. Skeine, Esq., District-Surveyor, &c.

newer basalt, some of these volcanos were active, but were not erupting lava in such large streams as at former periods.

4th. That the volcanic ash and scoriæ resting on the ancient humus found at Tower Hill, Mount Leura, and in the Korangamite district, belong to a still later period, when the igneous force was almost exhausted.

The greatest extent of country throughout which the igneous force has been exerted in this colony, and exerted for such a lengthened period—the areas covered by the streams of lava, which are in some places more than 25 miles in length, and of great thickness—the occurrence of auriferous deposits around the great centres of action —and the contiguity of the extinct cones to the great volcanic chain extending from the Aleutian Islands to New Zealand, and probably still further southwards,—all serve to render the question of the age of our most recent volcanic products one of the most interesting problems in geology; and, as a step in this direction, the late discovery at Tower Hill is obviously important.

It has been said that the aboriginals point to Mount Franklyn (*Larne-baramul*) as the spot from which smoke has been seen to issue, and much stress has been laid upon this fact; but, though there is no doubt that Mount Franklyn is a recently-extinct volcano, it is likely that the natives have framed such a story to satisfy the demands of their interrogators. There is no evidence within my knowledge which would show that any hills in Victoria have been active volcanic points within the historical period. To say that the ancient force is exhausted, or may not be again in operation, would be untrue. Slight earthquakes have been occasionally felt; and the settlers speak of one having occurred some ten years ago at Melbourne, which caused a considerable wave in the River Yarra.

During a long-continued depression of the barometer in September 1855, the shock of an earthquake was felt over a considerable area, sufficient to awaken sleeping persons, and to shake the walls of unstable buildings.

We have proofs, too, throughout the whole line of our coast, that many parts of it have been recently upraised. Large lagoons, now bordering on the sea, are only a few feet above the tidal level, and their beds are composed of clay and sand containing numerous shells of existing marine species,—true post-pliocene deposits.

This upheaval, like the preceding change of level, when the older basalt and palæozoic strata sank to receive on their surface marine tertiary beds, to be again upraised and again depressed, has been slow, and not violent.

It would be very interesting, and useful in a practical point of view, to ascertain whether this upheaval is still in progress; and I trust, when a proper system of tidal registration is initiated, that steps will be taken to determine it with accuracy.

November 18, 1857.

Isaac Fletcher, Esq., Cockermouth; Edward Saunders, Esq., George Street, Hanover Square; Joseph Cooksey, Esq., West Bromwich; William Colchester, Esq., Dovercourt, Harwich; and John Evans, Esq., Hemel Hempstead, were elected Fellows.

The following communications were read:—

1. *On the* Estuary Sands *in the upper part of* Shotover Hill. By John Phillips, M.A., LL.D., F.R.S., F.G.S., Reader in Geology in the University of Oxford.

[Plate XIII.]

1. From the earliest days of geological inquiry in England, the range of Sandhills on the north side of the cretaceous basin of London, rich in ochre, fuller's-earth, and sands of many colours, has been the subject of frequent examination. As early as 1723, Holloway *, writing to Woodward, traces the Range, and describes its geographical relations and principal products; Smith, in 1800–5, mapped its course, identified it, as he thought, with the Iron-sand of Wilts, Kent, and Sussex, and placed it in his map (1815) between the Gault and the Portland Rocks. Conybeare † took a lively interest in the same rocks, and, from personal research, described them in Shotover Hill, and through a considerable tract to the north-east, referring them, as Smith had done, to the Iron-sand, a group in which he, like Smith, included the Hastings Sands. At this time, however (1822), the term "Iron-sand" included portions both of Lower Greensand and Hastings Sands, the complete distinction between these two groups not being as yet reached.

2. Dr. Fitton, whose memoirs on the Greensands and other strata below the Chalk have preserved the honour of England in regard to the geology of some parts of the Secondary rocks, appears, as early as 1827 ‡, to have traced Purbeck deposits at one point beyond the northern outcrop of the chalk-hills of Buckinghamshire, viz. at Whitchurch, near Aylesbury, where white fissile calcareous beds overlie the Portland rocks, and contain *Cyclades* and *Cypridæ*. He slightly mentions Shotover, and speaks of the Portland beds at Brill and Garsington, but without any hint of Hastings or Purbeck deposits in these localities.

3. In the year 1831 I was the companion of my great predecessor, Buckland, and his friend Conybeare, in an examination of the strata in Shotover Hill and Brill Hill. We traced in succession the members of the Coralline Oolite and Portland Oolite groups, and searched in vain for organic remains amidst the ochraceous sands of the uppermost deposits of these hills.

4. In 1833 (Dec. 4), Hugh E. Strickland, then beginning to unfold those qualities which so much endeared him to his many friends,

* Phil. Trans. xxxii. p. 419. † Geol. Engl. and Wales, pp. 136–143.
‡ Geol. Proc. June 1827, i. p. 26.

sent to Mr. Greenough a notice of the occurrence, on Shotover Hill, of imperfect casts of fossils which he believed to belong to the fresh-water genus *Paludina*. They were discovered by one of my earliest friends, the Rev. H. Jelly, of Bath, in a sand-pit on the brow of the hill, much above the level of the Portland rocks *.

Dr. Fitton's great "Memoir on the Strata below the Chalk †" refers to the same fact, adding, that the shells appear to belong to five species, three like *Paludina*, one small bivalve like *Cyclas*, and one larger bivalve like *Unio*; but, according to Dr. Fitton, the specimens found were all too imperfect to admit of precise determination, and were none of them so unlike some of the species which occur in the Lower Greensand as absolutely to exclude them from that formation ‡.

5. In 1847 I accompanied Mr. Strickland in a walk up Shotover Hill; but we found no shells in the Iron-sands, nor did it then appear that my friend had much expectation of adding to the facts he had already communicated. He must, however, during the period between 1847 and 1854 have been more successful; for I find in the Oxford Museum a remarkable specimen of *Unio*, which he discovered not far from the summit of the hill; and it is known that, in explaining to his class the geology of the vicinity of Oxford, he insisted on the probable freshwater origin of the Shotover Sands, and even traced out in imagination the course of the river-action to which they were due.

6. In 1854 I first conducted my class to Shotover, and engaged thirty or forty busy hands to renew the search in the Iron-sands. We were more successful than our predecessors, and have on this and subsequent occasions gathered a few *Conchifera* and *Gasteropoda*, and plenty of coniferous wood. What seem to be cavities left by *Cypridæ* also occur, among other cavities due to a different cause, in the ferruginous portion of the thick mass of sands and their clays which overlie the Portland Rocks; but I cannot say their recognition is certain.

In ascending Shotover from Oxford we meet (see Sections, Pl. XIII. figs. 1 & 2)—

A. The Oxford Clay, with its usual characters. This deposit has been penetrated, by a boring for water at St. Clement's, to a depth of 400 feet. (Add 70 for the higher beds up to the calcareous grit.) The lower parts, which are seen but rarely in the Oxford district, yield *Ammonites calloviensis*; the upper parts, *Ammonites vertebralis*. *Gryphæa dilatata* appears in the upper half; and bones of *Plesiosaurus* occur both in the upper and the lower parts.

B. Calc-grit, or sands with cherty and shelly bands, containing the usual fossils—*Pinna*, *Ammonites vertebralis*, &c.

C. Coralline oolite, with shelly rag-beds. In this tract the oolite is superior, the shelly rag inferior.

* Geol. Proc. ii. p. 6. The specimens are preserved in the Geological Society's Museum.

† Geol. Trans. 2 ser. iv., 1836.

‡ Memoir, p. 275.

Isastræa.	Pecten lævis, &c.
Cidaris.	Belemnites abbreviatus.
Nucleolites.	Ammonites catena.
Clypeus.	—— perarmatus.
Lima.	Chemnitzia.
Ostrea gregaria.	Turbo, &c.

The top of the rock is waterworn.

D. Kimmeridge Clay. Here only about 100 feet thick. At its base are scattered a few *Coprolites*; a few feet upward we find *Thracia depressa, Gryphœa virgula*; still higher, two "flats" of *Ostrea deltoidea*; and at a height of 15 feet a limestone-band, partly septariate, yielding *Rhynchonella inconstans*, and occasionally Pliosaurian, Ichthyosaurian, and Steneosaurian bones, which also occur below it.

E. The Portland Sands, with included rock-bands and hard nodules, rich in shells, 70 or 80 feet. The most cemented masses of rock in the lower part have been quarried. The uppermost part is green sand; and small grains of silicate of iron are scattered through the whole of the rock. There is an included bed of clay, 3 feet thick. Fossils of the Portland series are traced through the whole, even up to the top, such as—

Ostrea expansa.	Cardium dissimile.
Trigonia gibbosa.	Pecten lamellosus.
Astarte cuneata.	Perna.
Pholadomya.	Nerinæa.
Trochus giganteus.	Terebra portlandica.
Turritella excavata.	Natica elegans.
Ammonites triplex.	Buccinum naticoideum.
(No Belemnite is seen.)	—— angulatum.

F. Iron-sand-and-Ochre-series to the top of the hill, 80 feet. The whole consists of yellow and white sands, varied with brown and even black colour,—sandstones, sometimes cherty;—nodular and geodic formations of oxide of iron,—bands of white clay,—and local accumulations of ochre. Mr. Conybeare presents the following section * :—

Beds of highly ferruginous grit, forming the summit of the hill	6 feet.
Grey sand	3
Ferruginous concretions	1
Yellow sand	6
Cream-coloured loam	4
Ochre	0 6 in.
Clay	thickness not given.
Ochre	
Ferruginous sands, cherty and argillaceous loams of a deep cream-colour	40 feet.

Thus above 60 feet are assigned to the group of Iron-sands. It is in the lower group, which also contains ochre, that the shells occur which were first noticed by Mr. Jelly. He found them about 30 feet above the Portland Rocks; but my observations lead to the conclusion that they occur in all parts of the deposit, from the very

* Geol. of England, p. 139.

base to nearly the top of the hill. They have, however, never been seen by me in the very uppermost sandstones, about 20 feet thick.

The layers of these cherts, sandstones, geodes, clays, loam, and ochre are very irregular in extent and thickness, yet not in such a way as to suggest more than gentle current-action. There is very little false-bedding; the layers are mostly undulated, and the concretionary tendency of the oxide of iron has produced ramifying and geodic masses much harder than the rest. The shells are now almost confined to these hard irony masses, perhaps because there only preserved from destructive solutions. The white sands and white clays are in continuous deposits, the latter in very thin laminæ.

The organic remains hitherto found in the Upper Sands of Shotover, and especially in the irony parts of the deposit, consist of—

I. Coniferous wood in fragments.

II. *Crustacea.*

Cypris? It seems to be recognized in some of the minute hollows which abound in the iron-bands.

III. *Conchifera.*

1. Unio Stricklandii, new species. Outline transversely ovate, without posterior sinuosity; beaks depressed; ligament very prominent; posterior area marked by numerous and regular rugæ. (Pl. XIII. fig. 3.)

It differs from *U. valdensis* in figure and in the characters about the ligament and posterior slopes. The beaks are much eroded.

Breadth above 2 inches; length a little above half the breadth.

Found by Mr. Strickland 20 or 30 feet below the top of Shotover Hill.

2. Unio subtruncatus?, Sow., Fitton's Memoir, pl. xxi. fig. 15. Shell very thin, with delicate transverse striæ. (Pl. XIII. fig. 4.)

The shell figured in Fitton's Memoir agrees exactly in shape, but does not show the external surface.

3. Cyrena media, Sow. M. C. pl. 527. fig. 2: so it appears to me. (Pl. XIII. fig. 5.)

Other forms of Conchifera occur, but are not clearly made out.

IV. *Gasteropoda.*

1. Paludina elongata, Sow. M. C. pl. 509. figs. 1, 2. *Rare.*

2. Paludina Sussexiensis?, Mant., Fitton's Memoir, pl. xxii. fig. 6. *Rare.* (Pl. XIII. fig. 6.)

Some specimens are shorter than the figure, and have a little the air of *Natica.*

3. Paludina? subangulata, n. sp. (Pl. XIII. fig. 7.) Ovato-conical, the volutions slightly angular or subcarinate, and striated spirally above the carina, not below it. *Frequent.*

The obscure carina sometimes appears on shells quite deficient of spiral striæ; they are perhaps worn specimens.

4. Paludina? Ovato-conical; the volutions very rounded, and covered with spiral striæ, which sometimes appear larger and smaller alternately, and are crossed by distinct lines of growth. (Pl. XIII. fig. 8.) *Frequent.*

This shell looks as much like *Cyclostoma* as any of the spirally-threaded *Paludinæ* known to me. The spiral threads are, in some specimens, more prominent about the middle of the volution.

There is a colour-band on one of my spiral shells; but I cannot determine the species.

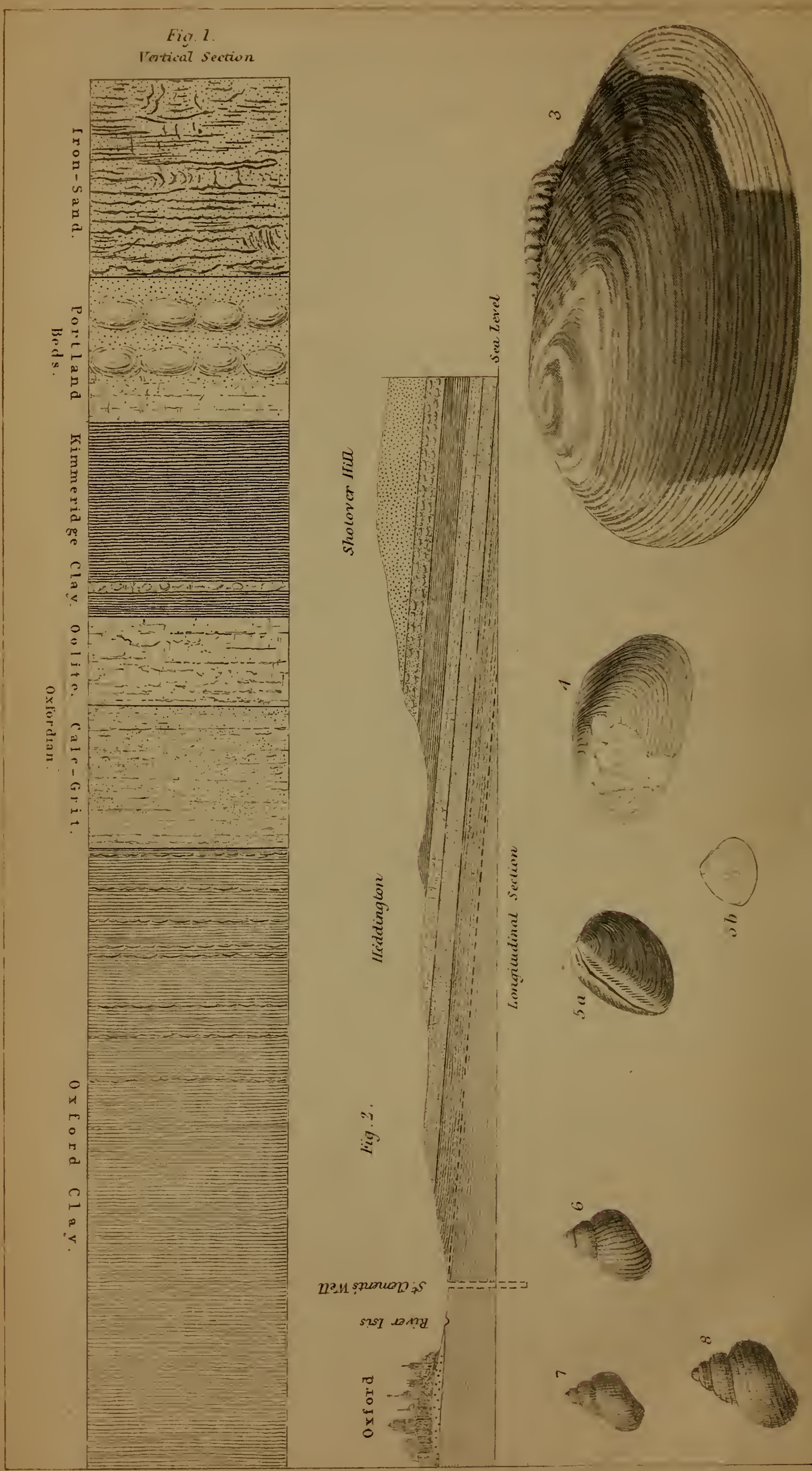
On this list (which omits only some forms too imperfect for notice) it may be remarked,—1. That very few more organic forms are to be expected from the western side of Shotover, the part as yet chiefly examined; for the specimens include perhaps only two or three not found by Jelly and mentioned by Strickland and Fitton. 2. That none of the marine forms usual in Lower Greensand occur in it. 3. That, while the general analogy is to estuarine and freshwater species, and while some of the species seem to be either the same or very nearly the same as known Mid-Wealden types, there are characters in some of the spiral shells worthy of remark, as tending perhaps towards *Littorina* as much as to *Paludina.*

Admitting, on the evidence which has been adduced, that the Iron-sands of Shotover, nearly to the top, were accumulated under the influence of river-currents, which scattered the remains of fresh-water organic life among them, we find this conclusion strengthened by the facts, that at Combe Wood, a little further to the south-east of Shotover, these sands cover a Purbeck deposit,—"Malm," with *Paludina elongata* and another species, *Planorbis?*, two species of *Mytilus, Modiola,* and *Cypris.* Below is the Portland-rock.

Similar facts occur at Garsington, near Oxford, and at Stone and Whitchurch in Buckinghamshire.

The sands on the Hill of Stone, near Aylesbury, are principally of the same type as those of Shotover; they rest on Purbeck clays, and "Malm" or "Retch," which cover the Portland. Thus the Iron-sand of Shotover is connected with the more extensive deposits of Buckinghamshire and Bedfordshire; and the ancient generalization of Holloway, who united in one deposit the sands, ochres, and fuller's-earth of Woburn and Shotover, is confirmed.

Smith, who regarded these sands as of the same great group as the Hastings Sands—in this agreeing with Conybeare—records the occurrence, at Steppingley Park, near Woburn, of Gault over the sands, and containing its characteristic Ammonites. Thus we find the "Iron Sands" to be inferior to Gault, and superior to Purbeck beds; they may at present, with much probability, be referred to the Hastings Sands; it is, however, possible that they may be an estuarine deposit of the Lower Greensand age. Gault with characteristic *Ammonites, Belemnites, Nuculæ,* &c., occurs at Culham, a few miles south-west of Shotover. It is there separated by only eight feet of Greensand (whose geological data are not yet certainly determined)



Sections and Fossils of Shotover Hill.

from Kimmeridge Clay well characterized by fossils. On the Kimmeridge Clay, about a mile to the north-east, Iron-sands are seen to rest; a little further, in the same direction, Portland-beds come between the Kimmeridge Clay and the Iron-sands, and the series of Shotover is complete. In the district between Swindon and Aylesbury the strata between Oxford Clay and Gault are subject to irregularity of thickness and local discontinuity; in a general sense they may be said to *overlap* to the north-east, in which direction the Calc-grit, Oxford Oolite, Kimmeridge Clay, and Portland-rock disappear one by one, but the Iron-sands are continuous. It is to be hoped that the Geological Survey, in its progress to the north-east, will furnish new data, and especially additional evidence from organic remains, for the determination of the physical condition of this region in the later Oolitic period. I regard it, however, as certain, that much of the so-called "Iron-sand" on the northern outcrop of the London Basin must be ranked among estuarine deposits.

EXPLANATION OF PLATE XIII.

Fig. 1. Vertical section of the strata in Shotover Hill.
Fig. 2. Section from Oxford to Shotover Hill.
Fig. 3. Unio Stricklandii, *Phillips*. [The lighter tint indicates the restored portions at the extremities.]
Fig. 4. Unio subtruncatus (?), *Sowerby*.
Fig. 5. Cyrena media, *Sowerby*: *a*, oblique view, enlarged; *b*, side-view, nat. size.
Fig. 6. Paludina Sussexiensis (?), *Sowerby*.
Fig. 7. Paludina (?) subangulata, *Phillips*.
Fig. 8. Paludina?

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2. *On the* PALÆOZOIC ROCKS *and* FOSSILS *of the* STATE *of* NEW YORK. Part I. *The Mineralogical and Palæontological Characters of the Strata*. By J. J. BIGSBY, M.D., F.G.S.

[This communication is printed further on.]

DECEMBER 2, 1857.

SPECIAL GENERAL MEETING.

A proposition for the alteration of the Bye-Laws respecting the Admission-fees and Contributions to be paid by future Fellows having been proposed and seconded, and an Amendment, to the effect of postponing the consideration of the proposition for twelve months, having then been proposed and seconded, a ballot was taken, and the President announced that the Amendment was carried.

ORDINARY MEETING.

James Russ, Esq., Canonbury Park; John Mansell, Esq., Dorsetshire; Edward Meryon, M.D., Clarges Street; Major Anthony Charles Cooke, R.E., Ordnance Survey Office, Perth; James Templeton, Esq., St. David's Hill, Exeter; and Christopher Lonsdale Bradley, Esq., Prior House, Richmond, Yorkshire, were elected Fellows.

The following communication was read :—

On some Peculiarities in the MICROSCOPICAL STRUCTURE *of* CRYSTALS, *applicable to the Determination of the* AQUEOUS *or* IGNEOUS ORIGIN *of* MINERALS *and* ROCKS. By H. C. SORBY, Esq., F.R.S., F.G.S.

[The publication of this Paper is unavoidably postponed.]

(Abstract.)

IN this paper the author showed, that when artificial crystals are examined with the microscope, it is seen that they have often caught up and enclosed within their solid substance portions of the material surrounding them at the time when they were being formed. Thus, if they are produced by sublimation, small portions of air or vapour are caught up, so as to form apparently empty cavities ; or, if they are deposited from solution in water, small quantities of water are enclosed, so as to form *fluid-cavities*. In a similar manner, if crystals are formed from a state of igneous fusion, crystallizing out from a fused-stone solvent, portions of this fused stone become entangled, which, on cooling, remain in a glassy condition, or become stony, so as to produce what may be called *glass-* or *stone-cavities*.

Applying the general principles resulting from his examination of these phenomena to the study of natural crystalline minerals and rocks, the author showed that the fluid-cavities in rock-salt, calc-spar, gypsum, and some other minerals usually indicate that these minerals were formed by deposition from solution in water at a temperature not materially different from the ordinary ; also that the constituent minerals of mica-schist and the associated rocks contain many fluid-cavities, indicating that they have been metamorphosed by the action of heated water, and not by mere dry heat and partial fusion.

From the study of the stone- and glass-cavities in slags and lavas, and from the examination of the microscopic characters of quartz-veins and felspar, which contain both fluid- and stone-cavities, the author arrived at the conclusion that granite is not a *simple igneous rock*, like a furnace-slag, or erupted lava, but is rather an *aqueo-igneous rock*, produced by the combined influence of liquid water and igneous fusion, under similar physical conditions to those existing far below the surface at the base of modern volcanos.

DECEMBER 16, 1857.

Charles Wright, Esq., Wigan ; John W. Woodhall, Esq., Scarborough ; and Dr. Eugene Francfort, Clapham Road, were elected Fellows. Dr. H. Abich, St. Petersburgh, was elected a Foreign Member.

The following communications were read :—

1. *On a remarkable Specimen of* Neuropteris; *with Remarks on the* Genus. By C. J. F. Bunbury, Esq., F.R.S., F.G.S.

The rarity, in a fossil state, of the young unexpanded or half-expanded fronds of Ferns has been remarked by more than one botanist. Fern-fronds in that early stage of development are very easily recognized by the peculiar and beautiful manner in which they are rolled up, forming a spiral curve, like the head of a crosier. This *circinate vernation*, as it is called, appears to be universal in all Ferns, with the exception of the small tribe of *Ophioglossaceæ*; and, in those numerous kinds which have perennial or evergreen foliage, fronds in this state may be observed at most seasons of the year. Their rarity as fossils is therefore rather remarkable. That they do occur is evidence, as Dr. Hooker observes*, "that the evolution of the fronds followed the same law then as now." Adolphe Brongniart has figured, in his great work†, a fine specimen of such a circinate frond belonging to *Pecopteris Miltoni*; two are represented in Göppert's 'Systema Filicum Fossilium'‡, and one in Geinitz's beautiful work on the Coal-formation of Saxony§. But all these belong to the genus *Pecopteris*; I am not aware that a similar state of any *Neuropteris* has yet been recorded. I therefore wish to lay before the Society a description and drawing of a specimen in my own collection, which may perhaps contribute to settle our notions of the true affinities of that genus.

Upper portion of a Young Frond of Neuropteris *from near Oldham, Lancashire.*

a

b

a. The crosier-like frond, terminal part. *b.* Outline of a leaflet.

* Memoirs Geol. Survey, vol. ii. part 2.
† Histoire des Végétaux Foss. pl. 114. fig. 1.
‡ Pl. 36. fig. 8. § Pl. 8. fig. 10.

The specimen was procured from Glodwick Colliery, near Oldham, in Lancashire, and formed part of a set of fossils sent to me by Mr. Wright, at the request of Mr. Horner. The material is a dark-coloured, hardened, ferruginous clay, very slightly schistose. The frond in question is unfortunately (as almost always happens) incomplete, the lower part of the stalk being broken away; but otherwise its state of preservation appears to be as perfect as that of any specimen of the kind hitherto noticed. We see the *rhachis* or main stalk of the frond exhibiting the graceful crosier-like curve so characteristic of the young fronds of Ferns; and the leaflets, regularly ranged along its concave side, successively overlapping one another from below upwards, and becoming progressively smaller and more crowded towards the extremity of the fragment. Their veins, which are well preserved, and as much as can be seen of their outline, in particular the shape of their base, agree with those of the numerous leaflets of *Neuropteris* which are scattered through the same stone. The species appears to be *Neuropteris gigantea*, Ad. Br., or a variety of it. The *N. gigantea*, indeed, in the most complete specimens, shows a doubly pinnated frond, whereas this fragment is merely once pinnated; but it may be only a portion of a frond; and, besides, it is not very uncommon to find the same Fern varying with pinnate and bipinnate fronds, as is the case for instance with *Pteris hastata*, Swartz, *Gymnogramme tomentosa*, and some Adiantums. The *rhachis* of the specimen is not so well preserved as the leaflets, but appears to have been hairy. This specimen is, I think, interesting, as affording a strong confirmation of the opinion that the fossil *Neuropterides* were true Ferns. Some have been tempted to doubt this, because of the constant absence of their fructification,—a fact certainly remarkable, when we consider the abundance of their fronds in many coal-fields. But, in addition to their venation and form, which are truly those of Ferns, we now find that they have the very remarkable and characteristic *vernation* of that order. Let the specimen here described be compared, in particular, with the young frond of *Nephrolepis exaltata*, Presl (*Aspidium exaltatum*, Swartz); it will be found that the position of the young leaflets relatively to one another and to the stalk is almost precisely the same.

This character shows, I think, conclusively, that *Neuropteris* has nothing to do with the Coniferous order, in which there is never any approach to a circinate vernation. Even in *Salisburia*, the leaves of which are in form and veining so much like those of Ferns, their arrangement in the young state is quite different: their lobes are folded together, and somewhat rolled inwards; but they are erect from the first, without the least curvature of the stalk. The only phanerogamous plants that resemble Ferns* in the *vernation* of their leaves, are some *Cycadeæ*†; and in the absence of fructification it is

* Perhaps I ought to except the genus *Drosera*, in which also the leaves are truly circinate in vernation; but, as they are otherwise totally unlike Ferns, and can never be confounded with them, they do not enter into this comparison.

† The *Cycadeæ* are described, at least, as having circinate vernation; but Dr. Hooker informs me that this character is not constant in the family. I have not myself had much opportunity of observing them in a living state.

certainly not very easy to prove positively that the Neuropterids may not belong to that family. The leaves of Cycads have generally, indeed, simple veins; but in those of *Ceratozamia Mexicana* the veins are *occasionally*, though not generally, dichotomous. In the curious and anomalous *Stangeria*, a true Cycad, the leaves have so perfectly the characters of Ferns, that the plant was originally taken for a *Lomaria*, the veining and other characters of the leaves being exactly those of that genus. If the leaves of the *Stangeria* had been found fossil, in the imperfect state in which fossil plants generally occur, it would, I believe, have been impossible to show that they did not belong to a Fern. The leaves of all known Cycads, however, are simply pinnated, whereas those of the Neuropterids, in all cases where they are pretty completely known, are doubly pinnated. In their apparent texture, moreover, in the characters of the leaf-stalks, in the variations of form of the leaflets in different parts of the frond, and in their whole appearance, the Neuropterids of the Coal-measures are so completely Ferns, that, in the absence of any evidence to the contrary, we may safely consider them as such; and I have little doubt that their fructification will in time be found to confirm this conclusion.

If we inquire to what recent Ferns the fossil genus *Neuropteris* was most nearly allied, we shall hardly, I fear, arrive at any very certain conclusion. The older writers compared the commonest Coal-measure species to *Osmunda regalis*, but merely because of a general vague resemblance. A venation nearly approaching to that characteristic of *Neuropteris* is seen in the *Pteris hastata*, Swartz (*Allosorus hastatus*, Presl), and some nearly allied species. These Ferns have also a general resemblance in form to many species of *Neuropteris*, and particularly in the great differences of outline and form in different leaflets of the same frond. But a similar veining occurs in some of the broad pinnuled species of *Gymnogramme*, such as *G. tomentosa*, Ferns widely different in their fructification from *Allosorus*. Again, while *Allosorus hastatus* and *A. flexuosus* have nearly the venation of *Neuropteris*, *Allosorus calomelanos* (a very near ally of these two species) would, if found fossil, be referred to *Cyclopteris*. The veins, in fact, afford but slippery characters, although the best that are generally within our reach, for the arrangement of fossil Ferns. We know, moreover, that in those cases where the fructification of fossil Ferns has been found in a good state, it has often indicated affinities quite different from those which would have been inferred from the veins or the outline. Thus, the *Alethopteris aquilina* has a striking resemblance in form and venation to some species of *Pteris*, yet its fructification, as shown by Geinitz, seems to place it in quite a different tribe of Ferns, namely the *Gleicheniaceæ*. Again, the *Pecopteris exilis*, Ph., with the aspect of some small *Polypodium* or *Nephrodium*, has (as I have elsewhere shown) the peculiar spore-cases characteristic of the *Schizæaceæ**. I should not, therefore, be surprised to find that the Neuropterids differ considerably in their real

* Quart. Journ. Geol. Soc. vol. vii. p. 188.

affinity from those recent Ferns to which they have most likeness in outline and veining.

I have scarcely seen a genuine *Neuropteris* from any formation more recent than the Triassic age. The beautiful and curious fern from the coal-field of Richmond, Virginia, which I described* under the name of *Neuropteris linnææfolia*, can hardly be considered as properly belonging to this genus; its leaflets have no trace of midrib, nor has it the general appearance of a *Neuropteris*. It agrees better with the technical characters of *Cyclopteris* or *Adiantites*; but it appears to have no very close natural affinity to any other fossil Fern yet known, and will probably hereafter form the type of a new genus. With respect to the age of the deposit in which it was discovered, I learn from Sir Charles Lyell that the most recent observations tend to refer the Richmond coal-field to the Keuper rather than to any member of the Jurassic series.

The *Neuropteris ligata*, and *N. recentior* of the "Fossil Flora," from the Jurassic strata of Scarborough, have evidently nothing to do with this genus, but were very properly referred by Professor Phillips to *Pecopteris*. Indeed the *N. ligata* is identical with *Pecopteris denticulata*, Ad. Br. The *Neuropteris lobifolia*, Ph. (*N. undulata*, L. and H.) is more ambiguous in its characters, and may fairly enough be referred to this genus. It cannot, however, be considered by any means as a characteristic *Neuropteris*.

In saying that I do not know of any well-characterized *Neuropteris* from a formation later than the Trias, I purposely leave out of the question the enigmatical Anthracitic formation of the Alps, which many geologists refer to the Liassic period. It contains several forms of *Neuropteris*, to all appearance identical with those of the Coal-formation. If really Jurassic, it is altogether anomalous and exceptional in its palæobotanical characters. Since my paper † on the subject was read before this Society, I have had the opportunity of examining some additional specimens from this Alpine Anthracite deposit, and from a different locality ‡; and I must still say of them as I said before, that all which are in a fit state for examination belong to forms elsewhere characteristic of the Coal, while there is an entire absence of all the characteristic Jurassic forms. Professor Heer, after a careful examination of very ample materials, came to the same conclusions §. Until this anomaly be satisfactorily explained, it is evident that we cannot safely rely on fossil plants as certain indications of the age of any formation.

The five beautiful and rare species of *Neuropteris* discovered in the Grès bigarré of the Vosges (see Schimper and Mougeot's Monograph, plates 36–39), agree perfectly with the artificial characters of the genus, though they may, not improbably, be considerably removed in natural affinity from the Carboniferous kinds ‖.

* *Op. cit.* vol. iii. p. 281. † See Quart. Journ. Geol. Soc. vol. v. p. 130.

‡ Namely, from Mont de Lans, in the Department of the Isère. The specimens were shown to me by Dr. Ewald, at Berlin.

§ See his excellent paper on this subject, translated in Quart. Journ. Geol. Soc. vol. vii. 2nd part, p. 91.

‖ Schimper and Mougeot, Monogr. p. 76.

I will conclude with a few remarks on some of the species of *Neuropteris*. But first I must observe that the number of described species is probably much too great, and that the greater proportion of them would probably be found, if completely known, to be variations or modifications of a few real specific types. Many of them have been described from very imperfect specimens, often indeed mere fragments. Now in those kinds of *Neuropteris* which are best known, we see that (as in very many recent Ferns) the size, outline, and position of the leaflets vary very much in different parts of the same frond. In some of those recent Ferns which I have compared with them, we see a remarkable degree of variation, both in the same frond, and in different fronds from the same root. In making use, therefore, of such imperfect materials as we most often have before us in the case of fossil plants, we are exceedingly liable to create *false species*, and to describe under several distinct names different fragments which may even have grown originally from one root. I doubt whether any judicious botanist would venture to establish new species of recent plants from materials so scanty as those on which very many fossil species have been founded.

I may take this opportunity of observing that my *Odontopteris subcuneata** is probably the terminal portion of the frond of some large *Neuropteris*, though I cannot positively assign it to any described species; at any rate, a species ought not to be founded on so imperfect a fragment as the only one I have seen of this supposed *Odontopteris*. In the absence of a midrib, it resembles the *Neuropteris auriculata*, a plant the extreme variableness of which has been well shown by Geinitz†. This author has pointed out, that some of the many various forms of leaflets belonging to that species have been described as belonging to the genus *Cyclopteris*. In like manner the round lateral leaflets of *Neuropteris cordata*, which I have figured‡ from Cape Breton specimens, have altogether the characters of *Cyclopteris*.

Those common Ferns of the Coal-measures which have generally been referred to *Cyclopteris* (*Cyclopteris obliqua*, *C. orbicularis*, *C. dilatata*, and some others), and of which Brongniart has formed his genus *Nephropteris*, are most probably, as that author has remarked, young or anomalous fronds of different species of *Neuropteris*, analogous to the barren fronds of the recent genus *Platycerium*.

1. *Neuropteris gigantea*, Ad. Brongn. I believe the *N. Martini* of Goeppert (the *Phytolithus Osmundæ regalis* of Martin) to be identical with this species, which is one of the most common in the Derbyshire coal-field. Among the specimens received from Mr. Wright, from Oldham, Lancashire, I find a variety (as I believe it) of *N. gigantea*, having the leaflets remarkably curved upwards, almost hooked, or what botanists call *scimitar-shaped*. It occurs intermixed with the common form, with which it agrees in all other characters that can be observed. I call it *Neuropteris gigantea*, var. *falcata*.

* Quart. Journ. Geol. Soc. vol. iii. p. 427.

† Steinkohl. in Sachsen, p. 21.

‡ Quart. Journ. Geol. Soc. vol. iii. pl. 21. fig. 1 A and 1 B.

2. *Neuropteris flexuosa*, Ad. Brongn. After the examination of a great number of specimens of this, from Somersetshire, Savoy, Spain, Pennsylvania, and Cape Breton, I am unable to satisfy myself whether it be permanently distinct from *N. gigantea*. They are indeed *in general* easily enough distinguished by the form of the base of the leaflets, which in *N. flexuosa* is more oblique and less symmetrical than in the other, with its lower margin extended into a decided angle or auricle, while the upper one is rounded off. The wavy main stalk is also a usual characteristic of *N. flexuosa*. But both these characters vary in degree, and I have seen specimens in which they are quite ambiguous. The character on which Brongniart lays so much stress, that of the closely-placed overlapping leaflets, is (as I long since remarked) by no means constant. Whether the *N. gigantea* and *N. flexuosa* be truly distinct or not, they seem to have inhabited different localities, for I am not aware that I have in any case seen well-characterized specimens of *both* from the same coal-field. As they may in general be pretty easily distinguished, though intermediate forms do now and then occur, it will be convenient for the present to keep them separate.

M. de Verneuil lately showed me specimens of *N. flexuosa* from the province of Palencia (in the kingdom of Leon), Spain. It seems to be most abundant in the coal-mines of North America. The only well-characterized British specimens that I have seen are from the Somersetshire coal-field, and from that of Pembrokeshire; while, on the other hand, the *N. gigantea* seems to abound particularly in the Midland coal-fields of England.

3. *Neuropteris rotundifolia*, Ad. Brongn. I cannot but believe this to be a mere variety of *N. flexuosa*, as I have seen on the very same fragment leaflets corresponding with the characters of both. The analogy of innumerable instances among recent Ferns (of *Pteris rotundifolia*, Swartz, for one) shows us how little importance ought to be attached to such variations in the outline of the leaflets as those on which the distinction of these two species is founded. At any rate, the *N. rotundifolia* is much too doubtful a species to be of any value as a geological characteristic. Nor, with respect to locality, is it peculiar to the Calvados; there is a good specimen of it from Northumberland, in the museum of this Society.

4. *Neuropteris rarinervis*, C. Bunbury (Quart. Journ. Geol. Soc. vol. iii. p. 425.).

I suspect that this species is not uncommon, and that it has often been confounded with *N. tenuifolia*. The two are certainly much alike; but, if we may trust to the figure and specific character of *N. tenuifolia* in Brongniart's great work, they differ materially in their veining. Some of the specimens labeled *N. tenuifolia* in the Society's collection, namely those from Merthyr Tydvil, seem rather to belong to *N. rarinervis*; and I am inclined to refer to the same species some fragments that I possess from the district of Osnabrück. If this plant be compared on the one hand with *N. tenuifolia*, and on the other with the *Pecopteris* (*Cladophlebis*) *pteroides*, we shall see how they connect together the two artificial genera *Neuropteris* and *Pecopteris*, and how difficult it is to draw a line of distinction between the two. *Neuropteris rarinervis* has perfectly the general aspect of a *Neuropteris*; indeed, if the difference of its veins were overlooked, it might easily be taken for a variety of *N. flexuosa*, with smaller leaflets than usual. *Cladophlebis pteroides* has more the appearance of a *Pecopteris*; yet in venation the two agree almost exactly.

5. *Neuropteris Loshii*, Ad. Brongn. The plant from Felling Colliery, figured as *N. Loshii* in Lindley and Hutton's 'Fossil Flora,' is separated by Sternberg and Goeppert under the name of *N. Lindleyana*; chiefly, it would seem, because its leaflets are not cordate at the base. Considering how variable a character this is in recent Ferns, I cannot think it a sufficient ground of distinction in this instance; and I have little doubt that Lindley and Hutton's plant was rightly referred to *N. Loshii*, which seems to be a widely-spread fossil Fern, very abundant in the coal-fields of the Midland counties of England.

Neuropteris Loshii is found also in the Permian system, namely, in the red sandstone (*Rothliegendes*) of Saxony; there are fine specimens of it from that formation in the museum at Dresden, some of them showing, more satisfactorily than any others that I have seen, how very distinct it is from the *N. heterophylla*.

Gutbier and Geinitz, in their work on the Permian fossils of Saxony, have noticed and figured* specimens of *N. Loshii*, showing what they consider as appearances of fructification; but there is so much irregularity in the position of these markings, that I cannot help doubting whether they are really of that nature.

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2. *On the* Boring *through the* Chalk *at* Harwich.
By Joseph Prestwich, Esq., F.R.S., Treas. G.S.

Owing to the insufficient supply and indifferent quality of the water at Harwich, several attempts have from time to time been made to improve that supply by means of deep wells in the Tertiary sands and the Chalk. None of these having been attended with the desired success, although in 1824 and 1826 two borings were carried down to a depth of 293 feet and 192 feet in the Chalk, a public work of great spirit has lately been undertaken under the superintendence of Mr. Peter Bruff, C.E., to bore deep into, and, if necessary, through the Chalk. I saw this well in August 1856. It had not then traversed the Chalk. In November last, however, the Rev. J. H. Marsden informed our Assistant-Secretary that the boring had been successfully† carried through the Chalk, Upper Greensand, and Gault, and that immediately beneath the latter a "black rock" had been found, of which he sent up a specimen. Mr. Marsden shortly afterwards favoured us with the following section (Column 2), on which, as the geological results are so curious and important, I purpose making a

* Verst. Perm. Sachs. pl. 4. fig. 2.

† So far as the work was concerned, but without, I regret to say, having at present found a supply of water.

few remarks, as well as on a suite of specimens which Mr. Bruff kindly submitted for examination.

The well, which is situated near the Pier and a few feet only above the level of the river, was commenced in July 1854, and in May 1857 had reached its present great depth.

Section of the Boring at Harwich.

1.		2.	Feet.
Drift	25 ft.	Earth	10
		Red gravel	15
Tertiary Strata	51½ ft.	London clay	23
		Coarse dark gravel	10
		Plastic clay	7
		Bluish clay with green sand	3½
		Green and red sand intermixed	5
		Blue clay	3
Chalk	888 ft.	Chalk with flints	690
		Chalk without flints	160
		Chalk, rocky, in thin layers	38
Upper Greensand and Gault		Greensand and Gault	22
		Gault without sand	39
		Black slaty rock	44½
			1070

It thus appears that, after passing through the Chalk and finding the Upper Greensand well marked and in regular order, and then the Gault, but in diminished thickness, the workmen came, at a depth of 1025 feet, to a mass of strata denoted as a black slaty rock. Unfortunately this rock, as far as I have examined it, contains no fossils; we have therefore only its mineral and physical characters to guide us. These however are tolerably marked.

The Upper Greensand is very calcareous and rather argillaceous. The Gault also consisted of the usual calcareous clay; but the underlying rock does not effervesce at all with acids. It also has a rough slaty fracture, and becomes harder and of a darker grey in descending. It contains a little mica. Some portions, however, have a more glossy and greenish hue; but the greater part is a common grey clay-slate. The specimens brought up by the boring-tools consist of round cylinders, about 3 inches in diameter, which break so as to show the lines of bedding or of cleavage, or possibly of both; for I find that three specimens, from depths of from 1040 to 1060 feet, split at angles respectively of 55°, 53°, and 58° with the surface, whereas one specimen from a depth of 1066 feet and another of similar character, but without depth mentioned, give angles of about 84°. In one of the latter specimens there is also a trace of another divisional plane with a slight variation of mineral character more resembling lines of lamination or bedding; and, on measuring the angle formed by these two lines in this specimen, I find it to be about 30°: and, as the three specimens higher up give only one divisional plane, which is inclined with an average dip of 55° to the level furnished by a line at right angles to the axis on the vertically bored cylinders, this would seem to show that there is one set of parallel divisional planes throughout, and that there are traces of another inclined to the first at an angle of 30°; and, allowing for the smallness of the specimens and the difficulty of very exact determinations, it seems probable that these two planes may possibly be, the one a plane of dip of about 55° and the other a rough cleavage-plane of about 84° to the horizon. Of the direction of the dip I have no evidence. The overlying beds themselves here have a not unimportant dip; for in an old well in the vicinity the chalk is 64 feet deep, and in another 70 yards north, and on the same level, it is 88 feet deep, showing that the chalk and tertiary strata here dip about 9° southward,—a fact further corroborated by the circumstance that the chalk rises out at sea at the distance of a few miles southward, off Walton. These facts render it almost certain that this rock cannot belong either to the Cretaceous or the Oolitic series, but probably belongs to some of the older slaty rocks.

This Harwich well has an important bearing upon the character of the evidence furnished by the Kentish Town well. The discovery there, under the chalk, of greenish and red sandstones and clays was so unexpected, that, although it was evident that they closely resembled some parts of the New Red Sandstone (and, without evidence to the contrary, such similarity of lithological character must be accepted as the best proof that could be obtained), still the question could not be considered as fully settled without some more positive evidence, the more especially as M. Jus showed me some fragments of cretaceous *Ammonites* and *Belemnites* brought up with the red clays; but, as I then observed, they might have fallen down the side of the bore-hole from the cretaceous beds above. Some clay which I had washed on purpose yielded no fossils*.

Nothing further has been done to the Kentish Town well; but the evidence which we have now obtained from the boring at Harwich, combined with that of the Calais boring, is corroborative, and of such weight, that I do not hesitate to modify materially my former opinion of the continuous range of the Lower Greensand under London, and to adopt in great part Mr. Godwin-Austen's very ingenious and philosophical hypothesis of the extension of an underground tract of the older rocks, ranging from the mountains of the Ardennes in Belgium to the Mendip Hills in the West of England. Before the result of the Kentish Town well was known, Mr. Godwin-Austen had arrived at the conclusion that a tract of old rocks underlies the Wealden; but he probably was as little prepared as I was for so remarkable a confirmation of his hypothesis as that furnished by the well at Kentish Town, as there, not only were all the Oolitic series wanting, but the Lower Greensand itself was absent. I fear, therefore, that there is, under the central part, at all events, of the London Tertiary area, a tract or ridge of the older rocks immediately underlying the Chalk and Gault, on different portions of which the three wells of Calais, London, and Harwich have touched, the one on the Carboniferous series, the other on the New Red Sandstone, and the last on some slate-rock to which, in the absence of organic remains, it is not yet possible to assign its exact position in the palæ-

* Quart. Journ. Geol. Soc. vol. xii. p. 10.

ozoic series. At the same time I must observe that it was impossible, without actual experiment, to have arrived at this conclusion; for the Lower Greensand crops out with so much regularity in the districts immediately south and north of London, and with characters so much alike, that it was not possible to infer *à priori* the interruption caused by the old underground ridge, nor can I even now believe that there is a total want of continuity. It is evident that the Lower Greensand must be continued underground to some unknown distance between Reigate and London on the one side, and Woburn and London on the other, and also that the Lower Greensand of Cambridge must range for a certain distance in the direction of Ipswich. It is a question of what was the size of the old palæozoic land—was it a ridge, with breaks in it at intervals, or a broad tract? The first is, I think, the more probable; for I cannot imagine but that, from the very peculiar mineral character of the mass in Bedfordshire and Surrey, there must have been, in places, continuity between these areas, and I therefore infer that the Lower Greensand may yet be found under the Chalk at many places, and that, although not immediately under the north of London, it yet will be found at no great distance both to the north and south of that spot.

Note.—Mr. Bruff has just sent me up a specimen of the slate (from the depth of 1050 feet), containing an impression of what appears to be a large *Posidonia*. If so, that will remove all doubt as to the age of this rock, as this shell is, with the exception of one species which occurs in the Lias, confined to the Palæozoic rocks.—April 1858.

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3. *On a* Boulder *of* Granite *found in the* "White Chalk," *near* Croydon; *and on the* Extraneous Rocks *from that* Formation. By Robert Godwin-Austen, Esq., F.R.S., G.S.

CONTENTS.

Part I.

Introduction.—So recently as 1811, when Mr. James Parkinson published his work on the 'Organic Remains of a Former World,' petrifactions of animal- and plant-structures were called "adventitious" or "extraneous," whilst all mineral materials, whatever their character or the composition of the beds in which they occurred, would have been considered as properly belonging to such beds and in their natural positions. A true perception of the origin of the sedimentary strata of the earth's crust has produced a complete change in such views; the remains of animals, such as Mollusca, are inseparably connected with the deposits formed beneath the areas of water in which they lived.

Materials, whether organic or inorganic, can be said to be "extraneous" only with reference to the special conditions of accumulation implied by the beds in which such materials occur. A solitary deep-sea mollusc amidst an assemblage of shallow-water forms is an "extraneous" one; and, on the other hand, the boulders and shingle of a coast-line, or ponderous shells from the marginal zone, are foreign to deep-sea sedimentary beds. Such is the sense in which the term "extraneous" has been employed in the following pages.

Whenever, in the examination of old sea-beds, such phænomena as these present themselves to the geologist, their investigation will be attended with interest and advantage: the solution of such anomalies invariably conducts to some further knowledge of the conditions and agencies of the period when such things happened.

The evidences of abnormal agency are to be met with in the sedimentary deposits of all periods.

Locality and Position of the Croydon Boulder.—The Boulder which, together with some other associated materials, forms the subject of the present communication was found in a chalk-pit, worked by Mr. Pettiver, by the side of the old London and Brighton road, near Purley, about two miles south of Croydon.

The road at this place runs along a deep valley in the chalk; and it may be here observed that the upper and higher surface of the adjacent district is much eroded into furrows and covered with detritus, but that the sides of the valley are altogether free from either. The valley is one of those which have been excavated since the removal of the lower tertiary strata from off the district. The bottom of the valley is filled with a thick accumulation of gravel, being an extension of that which is to be seen near the Croydon Station, but which gravel does not rise to the level of the floor of the quarry where the boulder was found.

The portion of the Chalk-formation in which the pit is worked, is the lower part of that containing flints.

The boulder in question was originally discovered by the men employed in the quarry, who exposed it in raising chalk for lime; it was removed and put aside, but the place it had occupied would not seem to have been much disturbed. The first person to whom it was subsequently shown was Mr. Simmonds, who, judging from its external ochreous appearance, took it for a huge nodule of iron-pyrites. He accordingly recommended the men to break it, when, to his astonishment, he found it to be a mass of crystalline rock resembling granite.

In an account of the discovery, lately communicated to Mr. Rupert Jones, Mr. Simmonds says: "Thinking it sufficiently interesting, and never having seen anything of the kind myself after considerable experience in the Chalk, I thought it right that others should be witnesses of the fact whilst the hole from whence it came was open.

I accordingly invited my friend Dr. J. Forbes Young to accompany me to the place, which he did.

"We set the men to work round the spot; and they found at the bottom a quantity of coarse sand-like materials, which on examination proved to be decomposed rock of the same kind. They also dug from the same place several large fragments of greenstone in a state of decomposition and surrounded by debris of their own class."

It was after this, and some time in the month of August, that I received a communication from my friend Mr. Rupert Jones, respecting the discovery in question. I lost no time in visiting the locality indicated; and from what I then saw, as well as from the evidence I collected, I felt perfectly satisfied that the boulder, together with its associated materials, when first discovered, was fairly imbedded in the solid chalk, and that their mode of occurrence was suggestive of various considerations deserving of notice.

Previous notices of extraneous materials in Chalk.—Though I cannot find that the occurrence of such materials as these has ever been made the subject of any special communication to this or any other like Society, yet it must not be understood that extraneous materials in the body of the White Chalk formation have not been noticed. I have several times had such specimens brought to me; they are also to be met with in numerous private collections; and some of them I am enabled to exhibit here this evening, through the kindness of their possessors*.

Major-Gen. Portlock has noticed several remarkable examples of blocks of hard black basalt, isolated in the Chalk of Ireland (see 'Report on Londonderry,' &c., pp. 93, 94). In 1840, Mr. Griffith also called attention to the occurrence of flattened spheroids of syenite in the Chalk of Antrim.

There are also two other short recorded notices. "In this country," observes Dr. Mantell ('Geology of the S.E. of England,' p. 78), "the Chalk very rarely contains traces of older deposits. The only instances of extraneous rocks that have come under my observation are pebbles of quartz, and some fragments of green schist."

Mr. Dixon ('Geology of Sussex,' p. 69) says, "Small pebbles and large rolled fragments of sandstone and quartz-rock are occasionally discovered in the centre of the Upper Chalk. Mr. Coombe found one specimen weighing near fourteen pounds at Houghton, Sussex; and I have seen others from the same pit of two and three pounds weight; several also have been sent me by Mr. Catt from the pits near Lewes."

Description of the specimens exhibited.—I may here observe, that shortly after the published notice of the verbal communication I made of the Purley discovery to the Geological Section of the British Association at Dublin, I was informed by Mr. W. Cunnington, of Devizes, that a specimen of *slate* imbedded in flint had been found in Wiltshire. I had next an opportunity of examining a collection of extraneous materials from the Chalk, belonging to this Society, and

* Specimens from the Museum of the Geological Society, and from the Collections of the Rev. T. Wiltshire, F.G.S., W. Cunnington, Esq., F.G.S., W. Harris, Esq., F.G.S., and H. Catt, Esq., were exhibited when the paper was read.

others the property of Mr. W. Harris. These were interesting, as, in addition to the crystalline rock-pebbles, there are some small specimens which have the appearance of being volcanic scoriæ. Dr. Forbes Young also kindly communicated some facts relating to the Purley discovery, and placed at the disposal of the Society the several materials which he had collected at the pit; the largest fragment measures about 12 inches in each of its two longest diameters, and weighs upwards of 24 pounds.

Mr. Catt's collection contains three specimens of rather soft, marly, micaceous sandstone, of a greenish-grey colour, one pebble of opake quartz, two of transparent quartz, and one of coloured quartz: these are all small. There is a much larger sub-rhomboidal fragment of dark clay-slate, with the angles rounded, and lastly, a block of fine-grained sandstone (quartzite), weighing thirteen pounds fourteen ounces. All these fragments have been derived from old sedimentary (palæozoic) strata.

The largest block shows the bases of several attached bodies, such as *Diblasus* or *Isis*, a *Serpula*, a Bryozoon (*Diastopora ramosa*?), and the lower valve of a *Spondylus lineatus*. This block had been rolled about on a beach, after these forms had attached themselves.

Mr. Cunnington's specimen consists of a fragment of thin fissile slate (very like common roofing-slate) imbedded in a chalk-flint. The slate has apparently been broken in the direction of the cleavage, and at the time when the flint was broken, so that the original form of this fragment cannot be determined.

As the cases where the occurrence of such materials has been observed are likely to be far less numerous than those which have escaped observation, or not been recorded, and as the pits where chalk is quarried present only a most trifling portion of its mass when compared with the horizontal extent of that formation, we may fairly infer that the differences of such extraneous materials must be much greater than we have heretofore supposed.

Form of the Boulder.—When I visited the Purley chalk-pit, I was informed that the large block had been still further broken up at the time of Dr. Young's visit, so that the destruction of the principal mass was then almost complete; some portions had been carried away by various persons, whilst others had been put into the kiln, by way of experiment, for the purpose of ascertaining whether they would burn into lime, like the chalk. The largest fragment which I was able to secure rather exceeded five pounds in weight.

On the spot where the blocks had been broken up, I found a considerable quantity of loose fragmentary materials identical with one of the larger portions, and derived from the more decomposed parts.

According to the account given by the quarrymen, the block, when first exposed, presented a rounded surface,—a statement which is confirmed by the appearance of all the fragments which have been preserved, which also show it to have been boldly egg-shaped. When I first visited the quarry, I was told that the cavity (or the lower part of it) which the block had occupied remained in the same condition as when it was first lifted out of it. On carefully removing the loose chalk that had fallen in, there was presented a basin-shaped depression in the hard chalk, measuring rather more than a foot across; the slight depth of this cavity compared with its diameter, showed that it was the cast of the *lower* portion of the boulder. The original form of the boulder may be also shown by fitting on the larger fragments to the remaining principal mass; it will then be clearly seen that it is a rounded water-worn block, just such as may be met with by thousands on any coast-line of our own seas, which is composed of rocks of like mineral character, as about the Scilly Isles, the Channel Islands, or those of Brittany.

Character and composition of the Boulder, and of the associated Sand and Greenstone.—The Purley boulder is a crystalline granitoid rock, having its components very uniformly distributed: those now remaining are quartz and felspar, from which, perhaps, some other mineral has been removed; what this may have been will be considered in the sequel. Whether the rock-mass here in question had or had not undergone such a change before it was imbedded, cannot now be determined with any certainty. It will, however, be observed that the Purley block, which is by far the largest mass which as yet has been found imbedded in the Chalk, and which therefore, as far as size is concerned, would be well fitted to resist the process of decomposition and the removal of one component, presents a cellular character throughout, whereas the smallest pebbles and fragments of other granitoid rocks exhibit no such structure.

On showing a fragment of the large Purley block to Mr. D. Forbes, he thought that he recognized it as corresponding in composition and external characters with a peculiar granitic rock which was introduced into the Scandinavian sedimentary series about the later palæozoic period. On the whole, therefore, I am disposed to consider that the rock was in precisely the condition in which it is now seen at the time it was imbedded, and that, if it has experienced any decomposition, it was previously to its removal from its original site.

That all the extraneous rocks which had been met with in the Chalk should have occurred as isolated fragments, was somewhat remarkable; and the only case of an approach to anything like definite relative position amongst them was the discovery of several about the same time at Houghton, in the same pit, and whilst the men were at work on the same bed; so that the fragments there may have been scattered about at the same time: but in the case of the Purley boulder the case was very different. I will first refer to Mr. Simmonds' account, quoted above, p. 254; he notices the occurrence of sandy granitic matter, and fragments of decomposed greenstone, associated with the boulder.

When I subsequently visited the spot, the Chalk-rock had not been so widely disturbed but that I was enabled to observe what offers a direct corroboration of the previous statement. The large boulder had left a clean and distinct cast of a part of its rounded surface in the compact Chalk. Some of the larger fragments of greenstone according to the description of the pitmen, "had been stuck about it, and over it;" but on looking closely, I saw that there was a mass of sand extending from the level of the cast of the boulder and beneath the solid chalk. Instead of removing the sand, I got the workmen to raise off the chalk with a pick: in doing this, some of the sand separated with the raised chalk; but the principal portion remained, and showed that at one part it had been in close juxtaposition with the block, and that it ended abruptly in the chalk at the opposite end of its mass; in this sand there was a fragment of greenstone much decomposed, and which has since fallen to pieces.

From the account of the workmen, and from what I saw, as well as from the materials which have been preserved, it is clear that, together with the larger granitic boulder, there was also a collection of blocks of smaller dimensions; and all these were also water-worn. Most of them were composed of a peculiar and very different rock, consisting of augite, with tabular double crystals of felspar, such as might be called a melaphyre or porphyritic augite: the largest of these, from the portions which remain, must have been of considerable size, weighing as much as twenty to twenty-five pounds, but, in common with all the other specimens of the same rock, it was much decomposed; there was a central portion which was only partially so, and from which the compact specimens now exhibited were derived: the smaller pebbles were wholly decomposed, and readily fell to pieces, forming a sharp sand. Most of the loose material lying on the floor of the quarry, where the blocks had been broken up, consisted of this decomposed greenstone, but which, from the iron in the original rock, was of a browner colour, and had not been derived from the larger granitic boulder.

In the specimen of greenstone from this spot, which I myself found, it was clear that the process of decomposition, with respect to these fragments, had been subsequent to inclusion, as, in their decomposed condition, they could not have been rounded as we there found them.

In addition to these large portions of rock, there was also a compact mass of siliceous sand. Some of this had been thrown aside as of no interest; but a portion was still *in situ*, and included a small decomposed fragment of greenstone: when the sand was broken down, this last so fell to pieces and mixed itself with it, that it was natural that a casual observer should have supposed, first, that these crystalline rocks were all alike in composition, or granitic, and, next, that the finer materials were only its decomposed portions.

An examination of this portion of the mass of materials will be sufficient to establish that it is fine water-worn beach-sand, derived from the waste of a coast-line of some crystalline rocks.

Observations and Inferences.—Referring to the whole suite of smaller rock-specimens from the White Chalk which have been met with from all quarters, we may determine thus far, that, in respect of form or condition they have this in common with the larger specimens from Purley, *they are all water-worn*, either in the form of shingle or rounded boulders,—that, as regards their mineral character, *they have been derived largely from granitic and greenstone masses*; whilst they differ in this, that they have occurred as *isolated* blocks or pebbles*, with the exception of those of Houghton (Sussex), where they were met with scattered over the same level or sea-floor.

* M. Deslongchamps, of Caen, pointed out many years since, that modern Crocodiles are in the habit of swallowing pebbles; and he suggested that certain

These several considerations have distinct bearings.

The marginal sea-belt is under all circumstances both well-defined and distinctly marked. It commences from the lowest range of wave-oscillation, where that meets the line of sea-bed, and extends upwards to the utmost reach of breakers at high water. The power exerted over this space commences at the point where the wave becomes one of translation, and increases progressively to where it breaks; from this its moving power decreases, being that only which is exerted by the upper portion of the wave as it is dashed forward. In all seas, therefore, the breadth of this zone will be primarily dependent on the slope of the sea-bed, and next on the range of the local tides.

The amount of power thus exerted is very variable; and it is applied under very different combinations of the foregoing conditions; so that it happens that the materials of the marginal zone are unceasingly being transferred one way or another upwards and outwards, at intervals corresponding to those when the forces are brought to bear in those directions. It is in this way that in tidal seas we have two distinct divisions of the marginal zone,—an upper, which is *constantly* disturbed, and composed of clean shingle; a lower, consisting of like materials as to size, and which is only *occasionally* broken up. In the intervals the constituents of this lower marginal zone become covered with its characteristic animals and plants. The conditions under which portions of the submarginal zone are transferred upwards, though variable, are yet to be easily observed from any part of a coast-line. On our own shores abundant materials will always be met with in the upper track, which bear marks about them of having belonged for some previous time to the submarginal zone.

These marks or characters have a bearing on the history of some of the pebbles found in the Chalk. To this zone belongs the great belt of marine vegetation which attaches itself to the shingle and gravel, as also do certain species of *Balanus, Serpula, Anomia,* and small Oysters; and such pebbles, even long after they have been washed up from the lower to the higher zone, retain the traces or some remains of these incrusting forms. Of the smaller specimens of shingle which have been taken from the White Chalk, some are in the condition of clean pebbles, whilst others have still adhering to them some portions of such shells. So far as the evidences of the zone of origin of all the extraneous materials of the Chalk can be indicated from such characters as we have here been considering, we may feel sure that they all have belonged to the *upper marginal zone,*—that, though in some cases they may have travelled down, and found a temporary resting-place in the submarginal region, yet *their subsequent place was at the upper level, before they started away to find their ultimate position in the deposits of calcareous mud.*

Ordinary wave-disturbance along the marginal sea-line cannot dis-

smoothly rounded stones, which are occasionally found in the fine-grained oolitic strata of Normandy, may have been voided by Crocodilians of that period. I am indebted to Mr. Bowerbank for the information that Sharks also swallow small stones; hence another agency by which the shingle of the White Chalk period may have been transferred to areas of deep sea.

perse the coarser materials of that zone beyond the limits of depth which have been here indicated.

Part II.

Mode of deposit, extent, and nature of the Fossils of the White Chalk.—It next remains that we should consider what are the conditions which are indicated by the White Chalk.

Two naturalists lately lost to us, and both well fitted to give an opinion on such a subject — A. d'Orbigny and E. Forbes, have said that *the pure White Chalk must have been the deposit of a deep and open sea.* Apart from the evidence to be derived from its included animal remains, there is also that of its mineral composition, dependent on the specific gravity of its component particles, and which shows that it belongs to the extreme outward zone of distribution, as compared with the sand-zones, or those of ooze or mud. In these fine sedimentary beds, and in the isolated blocks and shingle which they occasionally include, we have the two terms of the series of mechanical products of all seas and of all periods, namely the abyssal and the marginal; and from the presence of these two we may feel assured of the co-existence of every other intermediate form of sea-bed. The White Chalk had its equivalents of mud-depths and sand-zones; and its own remarkable extent as a deposit is due solely to the peculiar condition of the ocean of that time, which furnished so much calcareous material for abrasion and removal. Systematic geologists have been so disposed to describe the White Chalk as an independent portion of the cretaceous series, that the occurrence of these extraneous materials is of as much use in showing that it is merely one subordinate member of an assemblage of marine deposits, as the materials themselves are in indicating the physical and geographical arrangements of that remote period.

The area over which that uniform deposit of pure calcareous matter known as chalk was deposited may be accurately defined. It will be unnecessary to follow it over the whole of its extent; but in Western Europe it included the south-eastern half of Britain—from Devonshire to Yorkshire as far as a line much in advance of the present chalk-escarpment. In Denmark it occurs in Lælland and Moen, whence it trends south-east, across Prussia and Northern Russia. In France the area of true White Chalk extends south from Calvados to the Loire, and from the whole of the Paris Basin eastwards; in Belgium it appears under precisely the same characters as in France and England. Beyond this area, the deposits which were synchronous with the White Chalk put on other mineral characters.

In every sea or ocean the zones of sedimentary deposit hold a general parallelism to one another, so that if the form or direction of one can be ascertained, that of the rest necessarily follows. It is by the evidence of the included fauna that we are certified that districts surrounding the area which we have here defined were its equivalents in the Cretaceous series. For the present, the *form* of the area of deep and open sea deposits during the period of the Upper Cretaceous series may be taken as here drawn.

The period of the Upper Chalk and its equivalents corresponds to that of the greatest extension of the area of the cretaceous sea or ocean; and the only means we have by which to define the extreme boundary-line of this area is by following out the gradation of sea-bed in the direction in which it passes into sands and coarser accumulation, but preserving at the same time its characteristic fauna. *Marginal* beds of this age occur on the southern portion of Norway and Sweden. In Westphalia and Rhenish Prussia, sands are the equivalents of White Chalk. On the west of the European area the cretaceous strata of Valognes, though composed of sand and siliceous conglomerate or shingle, are yet Upper Chalk. Such is also the case with the sands of the West of England, which form the extreme limit of the cretaceous series about the Bovey Valley. In this way not only the form and extent of the cretaceous ocean in its greatest range, but also the character and composition of its coast-line, can be determined with approximate certainty, for a given number of points.

Belemnitella mucronata, which makes its first appearance in our Upper White Chalk, marks the equivalent of the White Chalk in other places, whatever the mineral composition of the beds may be.

I have elsewhere shown* what was the extent of that first portion of the cretaceous sea which gradually extended itself from the Mediterranean area, across France, or what is now part of the south-east of England. From this first stage, the history of the cretaceous formation consists of a progressive increase of area in water, together with a change in time of its inhabitants or fauna; so that, over the whole of the cretaceous area, the lowest beds show littoral or shallow-water conditions, both mechanically and zoologically: and what is known as the grouping of forms characteristic of the great subdivisions of the formation disappears when the marginal beds are carried out to their widest range or limit, and holds good only for the central portions of the area, where the series of depositions represents both the changes which are due to the successive conditions of depth as well as those which animal forms exhibit in *time*, and where consesequently the results of these changes are presented in order of superposition.

In this way it happens that the assemblage which figures in our lists as the fauna of the White Chalk is truly that of the upper or newest cretaceous period,—but in part only, and is not characteristic of those marine conditions of which that deposit is the result. *The remains met with in the pure White Chalk area belong for the most part to a much higher sea-zone.* This view of the character of the remains met with in the Chalk must have often suggested itself to naturalists who may themselves have collected from that formation. Thus the stony remains of the *Anthozoa* have all been broken off at the base, and are without any support in the beds in which they occur. The *Bryozoa* belong to a condition of sea-water very different from that of those calcareous mud-beds. The Echinoderms show characters of having undergone decomposition. Again, the most common and characteristic forms of the White Chalk are frag-

* Quart. Journ. Geol. Soc. vol. xii. p. 68.

mentary, as regards the *Testacea* more particularly; and taken altogether they imply a drifting power, whereas the nature of the sea-beds indicates only conditions of tranquil deposition. Recognizable forms from the Chalk bear so small a proportion to its mass—the formation nowhere throughout its vast thickness presents old sea-floors over which a fauna lived*—that I am disposed to consider the greater part of the animal remains which it contains as having been raised off shallower zones, floated away, and scattered outwards over the deeper ones.

This view of the Chalk-deposit—namely, that all the larger materials which it contains, whether organic or inorganic, belong to a higher sea-zone—is one which admits of a great amount of illustration, and deserves separate treatment. It may be sufficient for the purpose for which the view is here introduced, to state that all those forms of *Bryozoa* which, when living, are fixed at the base only, such as *Idmonea, Pustulopora, Desmeopora,* and many others, all occur *detached* in the body of the Chalk. This is also well seen with respect to the *Anthozoa*: the examination of a large collection of *Monocarya centralis* showed me that they all had been broken off before they were imbedded.

With respect to the zone from which the Chalk forms have been mainly derived, it is sufficient that it should have been a higher one, where the accumulation of mineral matter was necessarily very different to what it was at extreme depths. I will therefore only call attention to a few Chalk forms, and which also belong to sand-deposits usually considered older than the Chalk:—

Stellaster elegans, Forbes. In Chalk. Sussex. In sands below the Chalk at Folkestone, and in the sands of Blackdown.

Serpula plexus. Chalk, and abundant in the Blackdown and Haldon sands.

Pecten æquicostatus. Chalk, and abundant in the Blackdown and Haldon sands.

Plagiostoma parallelum. Greensand, Gault, Chalk.

Considering the poorness of the White Chalk fauna, the proportion of bivalved Mollusca having a byssus is remarkable. Such shells are now widely distributed by floating weed.

The occasional occurrence of large dead shells of *Dolium* or *Cassidaria,* of which a single specimen is as yet recorded from our White Chalk, requires for its explanation an agency at least equal to the transport of ordinary shingle. The species seems to be identical with one from the cretaceous sands of Mans, where it is scarce. *Dolium* would not belong to such a zone; but the animal has the power of swimming by inflating its disk, and in this way it may occasionally be floated away from the marginal sea-line, and so perish, and sink in deeper water. The form *Dolium* evidently belongs to

* The occurrence of a large block of Coral in the White Chalk caused me to form at one time a different opinion. I have now no doubt but that it was a transported mass from some distant reef. Proc. Geol. Soc. vol. iv. p. 169.

the southern cretaceous fauna, as do also the fragments of Hippurite which have been found in the Chalk of Sussex and Kent.

Means of transport of extraneous materials in the Cretaceous Sea.—The nature of the White Chalk formation, and the fact of the presence there of extraneous blocks and pebbles, lead naturally to the inquiry as to the agency by which they have been conveyed there. Most geologists will doubtless at once call to mind the account which Mr. Darwin* has given of a rounded block of greenstone which he found on the outer coast of a small atoll belonging to the Keeling group. The Keeling Islands are 600 miles from the nearest land (Sumatra); they consist wholly of coral-formation, and Mr. Darwin came to the conclusion that the block (which was rather larger than a man's head) had become entangled in the roots of a tree which had been washed into the sea, floated thus far, and finally liberated on the beach where it was found.

If only one single block could have been conveyed thus far by such an agent, much more similar material must have been dropped and lost than ever reached so remote a coast-line. The sedimentary deposits of open oceans, such as the Indian or Pacific, where so many of the lines exposed to coast-abrasion consist of coral-formation, must be identical in composition with our White Chalk, so that the rocks which are being conveyed away from the mainlands of those seas may be presented at some future time under precisely the same conditions as the extraneous materials now are in our Chalk: the correspondence between the two cases is so close, that it is difficult to avoid the consequence, that one case explains the other, and is evidence of like agency at very distant times.

Mr. Darwin's Keeling observations would fully account for the presence of all the extraneous materials which have been met with in the White Chalk and other deep-sea sediments up to the time of the Purley discovery.

The peculiarities of this case are these:—Apart from the large boulder there was a smaller one, weighing upwards of twenty pounds, some coarse shingle, and a quantity of loose sea-sand; and these had all sunk down together without separating: for this they must have been firmly held together, both during the time they were being floated away, as also whilst falling from the surface to the depths of the cretaceous sea.

If we suppose, in the case we are now considering, that all the coarser materials were so firmly bound up in the knitted roots of some tree which which had grown on a sea-margin, as afterwards to be carried about, until the tree became water-logged and sank, it is difficult to conceive how the finer sand should not have been washed out; and, as wood is well preserved in chalk, we might expect that traces of the tree itself (and it must have been a considerable one) would have been discovered in immediate juxtaposition with these materials: such, however, was not the case †.

* Journal, 1839, p. 549.

† Fossil wood, and even lignite, has been found by Mr. Simmonds in the chalk of the neighbourhood.

The conditions which have to be satisfied in this particular case are, the removal of a large boulder, together with coast-line shingle and sand, and their transference to a deep and distant sea-bed, *in precisely the same relative positions in which they lay together in the parent beach.*

Sir C. Lyell, who had his attention drawn to the fact of the occurrence of pebbles in chalk by Mr. Catt, has adopted* the observations of Mr. Darwin, in preference to such other means of transport as floating weed or floating ice. Sir Charles's objection to the agency of floating ice is, that it is inconsistent with the conditions of climate indicated by a sea abounding in chambered Cephalopods.

At all past periods the globe must have had its climatal zones; and, taking Mollusca as our guides, we know that, for the secondary and tertiary periods at least, the order or gradation was placed very much as it is at present. We know, too, what is the distribution of the extinct Cephalopods over the European area; and on these joint grounds it may be stated confidently that no sure conclusion as to climate can be derived from the Ammonites and Belemnites of our secondary formations.

For the Oolitic period (Lower Mesozoic) the geographical distribution of Cephalopods is rather northern than southern, whilst for the Upper Mesozoic (or Cretaceous) they decrease, both as species and individuals, towards the upper chalk.

Apart from these considerations, the fauna of a sea is no indication as to whether ice from polar regions may not occasionally be floated into it. All that is requisite is that the area of water should have an extension into polar regions; and then the liberated ice must at all times have been distributed according to the same laws as influence it now. Polar ice, it must be remembered, is now occasionally floated down, and its load scattered, as low as the Azores and Canaries, where its detritus becomes imbedded in deposits containing the forms of the South Lusitanian fauna.

The condition of one hemisphere of our globe at the period of the greatest extension of the Cretaceous ocean, represented in the map exhibited to the Meeting, shows—1st, how, as far back as the cretaceous period, the waters of the great and old Atlantic valley extended into the Polar basin; and next, what was the extent and character of the subaërial surface, the coast of which supplied the mineral material for the sedimentary beds of those seas over the European area.

I know only of two other agencies by which the coarse materials of the marginal sea-zone can be conveyed away so as to be distributed over the deeper sea-beds, viz. sea-plants and coast-line ice.

Sea-plants being lighter than water, it happens that, when the sea-bed of the zone of *Fuci* or *Laminariæ* is composed of loose materials, such as shingle, the mass of weed attached to small blocks or pebbles becomes buoyant enough to float them; in this way, when the plants have attained their full growth, and gales of wind set in, the plants lift great quantities of deep shingle from off its bed, and carry it into the upper sea-line. With a gale and a falling tide, the weed may, in

* See Manual, 5th ed. p. 243.

like manner, convey marginal shingle outwards; but the transport in this direction is far less in amount than it is in the other.

Such a process as this has been in operation at all geological periods; and some years since I indicated it as the only one by which large detached valves of such shells as Oysters (*Exogyra gryphæa*) could have found their way into the fine sandy beds of the Lower Greensand formation.

Sea-plants have their limits of growth; and the bulk of each mass will be limited by the support or surface of attachment: conversely, therefore, there is a limit to the size and weight of the materials which can be lifted by such an agency. As far as my own observations go, the floating power of large masses even of Bladder-fucus does not disturb shingle-stones weighing much above 1 lb. A good deal of the extraneous shingle from the White Chalk is undoubtedly under this weight, and so far therefore admits of being thus accounted for: but the agent becomes wholly inadequate when considered with reference to blocks of 12 and 14 lbs. weight, such as have occurred in Sussex; still less could any conceivable mass of sea-weed have ever carried the Purley boulder.

But, even if it be assumed that sea-plants of that time could have lifted the largest boulder, and that a tangled mass of them could have floated away at the same time all the smaller stones associated with it, the difficulty as to the mass of loose sand still remains.

Sea-plants, when detached from their proper zone, are constant agents in transferring the animal forms belonging to it, as well outwards as upwards; and it was in this way most probably that the White Chalk acquired the very peculiar assemblage which it contains. This agency, like that of floating trees, is not to be excluded with reference to past times, and may possibly have been engaged in transporting some of the smaller pebbles, which are met with in beds into which they could not have been drifted. Naturalists, who are well aware how many forms are to be found amidst the roots of sea-plants when these are washed up to the marginal zone, will see that these must act as the distributors of the fauna of the same sea-zone when the plants are drifted away outwards.

Masses of ice floating at sea have two distinct sources of origin; and, as a consequence of this, they are also distinct in the external characters of the records they leave. The larger masses known as icebergs, which are the *terminal portions of the glaciers of Polar regions, which have reached down to the sea,* have been reported by a long list of observers to be laden with detritus: in this case the detritus is sub-aërial, and its form angular. Yet I have not seen a single angular fragment from the White Chalk, nor from any part of the Cretaceous series.

There is another form of floating ice, in which, though it is far less imposing in respect of its mass, it is of infinitely greater power as a means of transport. This ice has its origin *along the coast-lines of Polar lands*; it incorporates itself with all the materials of the beaches to which it is attached; it acquires increased buoyancy from the snow-ice which collects on its surface; and, when the annual period of the breaking up of the coast-ice arrives, great masses are drifted away, bearing with them in their under surfaces compact masses of frozen beach, which separates itself as the ice decays.

We have only to imagine a case where a portion of such a floe, so laden, should have wasted as it travelled into warmer regions, so that it no longer retained sufficient buoyancy to float the mass of boulders, shingle, and detritus attached to it; and what remained would then sink together, and become buried in whatever the substance of the sea-bed beneath the spot might happen to be.

Geologists have long since become aware of the power of coast-line ice as a moving agent: even in our climate and country its mode of action is exhibited; it may be well seen every winter over the northern European area, whilst for its fullest powers, as displayed in high northern regions, we have graphic pictures in the narrative of Dr. Kane. I know of no other agent but that of coast-ice by which a mass of incoherent materials could have been held together, as a characteristic portion of a sea-beach, and so deposited at a vast distance from the nearest land. Such, I conclude, was the nature of the agency by which the assemblage discovered in the chalk at Purley was kept together and conveyed.

Form and composition of the Land of the Cretaceous Period.—The upper Mesozoic group (cretaceous) in its northern expansion outspanned the limits of the lower Mesozoic (oolitic). We have abundant evidence that strata of Great Oolite and Oxford Clay entered into the coast-line of the Lower Greensand sea; but the materials carried into the area of the chalk-deposit have as yet consisted mainly, if not exclusively, of Crystalline and Palæozoic formations.

Such was the character of the dry land which bounded the cretaceous gulf or bay extending west from the Cotentin, across our south-eastern area, towards Sweden.

It remains only to notice, and that most cursorily, the composition of those areas of land which existed as such at the time of the greatest extension of the Cretaceous ocean, and which continue as such at the present time.

On the west the cretaceous strata of Noirmoutier indicate littoral conditions, as also do those of Aix (oolitic) or Charente Inférieure. Such is the case also with respect to the sands, shingle-beds, and calcareous strata of the Cotentin. The intervening country between these two localities, which forms the western district of France, consists of gneissic and granitic rocks, with old sedimentary slates and sandstones (quartzite). The west of England is similarly composed. We may place the whole of the area between these two adjoining peninsulas in the condition of land-surface at the end of the Cretaceous period, and may extend this old land far into the present Atlantic area.

The small outlier of Cretaceous sand near Bideford shows that the Cretaceous sea must have had an extension considerably to the west of its present limits. The course of the outline of this sea across our island may be passed over for the present, as the extraneous materials in the White Chalk do not resemble any of the crystalline rocks of our series. In the south of Sweden, on the contrary, the cretaceous beds along a line drawn from Engelholm on the west, to Karlskrona on the east, rest on granite, gneiss, claystone-porphyry, and old sedimentary slates and sandstones.

It perhaps may be thought by some that, by the aid of such a collection of extraneous materials as has been now brought together, it would have been easy to have determined almost with certainty the precise portions of the old cretaceous coast-line from which they had been derived ; such, however, at present is not the case.

M. Brongniart has noticed the very great resemblance which exists between the crystalline rocks of the Cotentin and Scandinavia ; and either district could have furnished the large block of quartzite now in Mr. Catt's collection. On the whole, however, and guided mainly by the peculiar greenstone-porphyry, and the condition of the large boulder from Purley, from which the mica has been removed, as it has from great masses of a Scandinavian granite, I am disposed to look to that quarter as the source of the extraneous materials of our Chalk-formation.

There is a difficulty, however, which I feel will suggest itself to some, with respect to the agency of floating ice in transporting the materials imbedded at Purley : it may be asked whether in such case we should not long since have become familiarized with the operations of such an agent with reference to the Chalk-period, seeing the extent to which that formation is quarried. Such an objection is in part negative only : much evidence akin to that at Purley may have presented itself, and yet not have been noticed. But, even should the assemblage met with at Purley be the first of its kind that has ever been met with till now, we may feel sure that thousands of like cases are concealed in the mass of the Chalk, from the incalculable improbability which exists that the Purley phenomenon should be the only one of its kind throughout the formation. It is only with reference to such mixed assemblages of boulders, shingle, and sand, that the agency of ice is required.

The physical arrangement of the circumjacent portions of the earth's surface at the Cretaceous period preclude the idea that floating coast-ice could have been either a constant or a very powerful agent of transport with reference to the White-chalk area of Europe. The line of coast, from which it has been suggested that the Croydon boulder was derived, lay a little to S. of the 60° of north latitude ; and, though coast-ice is a powerful agent there at present, the intensity of cold must have been modified then by the expanse of sea that lay immediately to the south. The requisite degree of cold need not have been greater than what has occasionally been experienced on our own eastern coast, when ice has lifted and floated away far greater weights.

Many general results will some day be arrived at from the study of the extraneous mineral materials of our old oceanic deposits ; by their means we shall certainly arrive at a definite outline for the ocean of the Cretaceous period.

January 6, 1858.

The Rev. Arthur W. Ingram, M.A., Hawington, and Timothy Curley, Esq., Hereford, were elected Fellows.

The following communications were read:—

1. *On* Cephalaspis *and* Pteraspis. By Thomas H. Huxley, F.R.S., F.G.S., Professor of Natural History, Government School of Mines.

[Plates XIV. XV.]

The genus *Cephalaspis* (Agassiz) was originally established to include four species of Devonian fishes,—*C. Lyellii, C. rostratus, C. Lloydii,* and *C. Lewisii*; but the differences between the first and the last of these species were so great, that the founder of the genus himself suggested the probability of their future separation.

The two groups of species are said by Prof. Agassiz to be contrasted not only by their forms, but also by their minute structure. In regard to form, the cephalic disc of *Cephalaspis Lyellii* is stated to possess an almost semicircular anterior outline, while its postero-lateral angles are greatly prolonged backwards. The middle part of the occipital region, Prof. Agassiz adds, is cut off almost square (coupée presque carrément). As regards this last point, however, my own observations are at variance with his description.

Several specimens in the museum of this Society show that the middle of the occipital margin is not truncated, but is greatly produced backwards, the margins of the produced portion being concave. The same peculiarity is clearly distinguishable in the specimen of *C. Lyellii* now in the British Museum, and figured by M. Agassiz, pl. 1. *a*. 2: indeed the artist has faithfully depicted the real contour of the occipital margin in the figure cited. The well-known occipital spine is supported by this produced portion of the disk.

The discoid bodies, corresponding to all appearance with the cephalic disc of *C. Lyellii,* upon which alone the species *C. Lewisii* and *Lloydii* were established, differ widely from *C. Lyellii,* being oval in contour and not prolonged into postero-lateral cornua.

The structural differences observable in the disk of *C. Lyellii* on the one hand, and of *C. Lewisii* and *Lloydii* on the other, are thus stated by Prof. Agassiz:—

"In *C. Lyellii* the head is covered with a pavement of polygonal plates, altogether similar to that which covers the head of *Ostracion*. Each plate is convex in the centre, and is marked by radiating grooves ending at the margin in denticulations, by which the scales interlock. These scales appear to be osseous and to have their external surface enamelled. At the circumference of the disk they become confounded together, and the enamel presents wrinkles parallel to the edge." Elsewhere these plates are said to be "true scales juxtaposed."

In the 'Recherches,' M. Agassiz describes "fibrous bones of the head" under the "scales," and he particularly mentions and figures the radiating direction of these "fibres;" but in the 'Monograph of the Old Red Sandstone Fishes' I find the following general remarks applied to the whole of the *Cephalaspidæ*:—

"It would appear from the condition of the specimens preserved, that all the cranial bones were only protecting plates, which covered a cartilaginous cranium similar to that of the Sturgeons; at least I have never been able to discover any cranial bones deprived of that characteristic granulation, which indicates that the plates were in direct relation with the integument. Therefore, I think there can be no doubt that all these granular plates rested by their inner and smooth surface on a cranial cartilage, such as is found in cartilaginous fishes and in the embryos of osseous fishes."—*Monog. Grès Rouge*, p. 3.

Nevertheless, in speaking of the genus *Cephalaspis*, a few pages further on, Prof. Agassiz states that he has nothing to add to his previous account of the genus; so that I am puzzled to know what view I ought to ascribe to him at present. We shall see by-and-by that the last-quoted is the only one warranted by the facts of the case.

The disk of *Cephalaspis Lloydii* is said to consist of an external striated enamel, of a middle layer "composed of granules similar to those of the bones of Chondropterygious fishes," and of an internal layer made up of superimposed lamellæ. Prof. Agassiz considers that this structure "singularly recalls that of the test of the *Crustacea*."

Notwithstanding these, partly real and partly imaginary, differences between his different species of *Cephalaspis*, Prof. Agassiz found in *Cephalaspis rostratus* (a species which I have had no opportunity of observing) a form and structure of so transitional a character that he included them all under the same genus.

That so close an affinity obtains between all the species of *Cephalaspis* has, however, been disputed latterly by M. Rudolph Kner, who in 1847 published a memoir in Haidinger's 'Naturwissenschaftliche Abhandlungen' for the purpose of proving that *C. Lloydii* and *C. Lewisii* are not piscine remains at all, but that they are the internal shells of a Cephalopod allied to *Sepia*, for which he proposed the name of *Pteraspis*.

M. Kner's reasoning is based upon his examination of the structure of a fossil (evidently closely allied to *C. Lloydii*) from the Silurian rocks of Gallicia. The form of this fossil, says M. Kner, is very similar to that of *C. Lloydii*; but it is larger, having a length of about four inches by a width of two. It consists of three layers. The innermost is shining, bluish-green, enamel-like, and presents four or five distinct lamellæ. This layer forms one continuous surface marked in the centre by a longitudinal depression, smaller at one end than at the other, and by obscure radiating lines. The upper part of the conical depression is covered with minute pores or depressions, which are visible in the deeper as well as in the more superficial layers, but become evanescent in its lower part.

Between the layer of enamel and the prismatic layer which succeeds it, there lies a thin dull layer, in some places of a brownish colour. This is followed by an excessively delicate lamina of enamel which lies upon the prisms.

The layer of prisms is one line thick, and in section presents a number of more or less hexagonal disks. The enamel passes for a short distance between the prisms. Externally the prisms lie on a granular layer, to which the outermost very delicate "epidermic" lamina marked with parallel striæ succeeds.

M. Kner asserts (supporting his statement by the authority of Heckel) that in no known fish does any such epidermic or prismatic layer exist, and assuredly no such continuous internal enamel-layer, as in the fossil; and he then proceeds to compare the latter with the cuttle-bone.

M. Kner would hardly have published his views, had he subjected his sections to a more minute and careful microscopical examination. But, even apart from the characteristically piscine structure of these disks, very strong objections suggest themselves. In fact, to get at any sort of resemblance, M. Kner has to compare the outer layer of the fossil with the inner of the cuttle-bone, and *vice versâ*; and even the superficial resemblance in the striation of the two bodies is anything but close.

In Dunker and Von Meyer's 'Palæontographica' (B.iv. H.3. 1855) Roemer gives an account of a fossil, which he refers to the *Sepiadæ*, under the name of *Palæoteuthis*. Whether this body is or is not a Cephalopod, is a point I will not enter upon here; but Roemer in referring to Kner's Memoir, expresses the opinion that the *Pteraspides* are *Crustacea*.

Mr. Salter and myself described two new species of *Cephalaspidæ* allied to *C. Lloydii* (Ag.), in a note* appended to a paper read before this Society by Mr. Banks, in December 1855. Without acceding to Kner's views respecting the zoological affinities of such Cephalaspids, we adopted his name. The facts to be detailed in the present paper will, I believe, fully justify this step; and I shall hereafter speak of *C. Lloydii* and its allies under the generic name of *Pteraspis*.

Professor Pander† has recently described two Silurian species of *Cephalaspis* (*C. verrucosus* and *C. Schrenckii*) both from Rootsikülle. The former somewhat resembles *C. ornatus* (Egerton), having a highly ornamented and tuberculated upper surface. In the broad tuberculated antero-dorsal plates, separated from the head by a suture, it foreshadows *Auchenaspis*, Eg. *C. Schrenckii* has hexagonal ornamented plates upon its disk.

Professor Pander appears to think that the margins of the disk represent jaws, being led to this conclusion, apparently, by their production into short quadrate serrations, which he regards as teeth. Sections of these "jaws" and "teeth," examined microscopically, exhibited "a homogeneous base, in which clear and dark cells of the most various forms—rounded, elongated, and angular, with fine radiating branches, lay scattered, and were frequently disposed in concentric

* Quart. Journ. Geol. Soc. vol. xii. p. 100.

† Monographie der fossilen Fische des Silurischen Systems. 1856.

layers, where a tubercle rose above the general surface. Although they have not the same regular form as ordinary bone-lacunæ (such as occur in *Pterichthys* and *Coccosteus*), yet they can hardly be called by any other name. The very thin narrow teeth, closely united with the margins of the jaws, and coalescent with them, have a porous basis, and shining, broad, sharp upper and lateral edges. If both surfaces are carefully rubbed down, the basis is seen to consist for the most part of a homogeneous transparent mass, full of small dark cells, from which the very fine tubuli radiate in all directions, branch out, unite with the neighbouring ones, and by their many anastomoses form a most complex network. Towards the shining surface, as well as anteriorly and posteriorly—at least, certainly, towards one surface—the cells cease; the tubuli, winding irregularly in the base, take a straight course, and ascend apparently with an enlarged diameter, without convolutions and rarely branching, towards the external sharp angle." (*l. c.* p. 46.)

I am not aware of the existence of any other account of the minute structure of *Cephalaspis* and *Pteraspis* beyond these; and I will therefore now proceed to the immediate subject of this paper, which is, to describe that structure more fully and, I hope, more accurately than previous observers have done,—to compare *Pteraspis* and *Cephalaspis*, pointing out their real differences and resemblances,—and finally to consider the bearing of the structural facts upon the question of the zoological position of these ancient fishes.

Cephalaspis. (Pl. XIV.)

In but few of the specimens of *Cephalaspis Lyellii* which I have had the opportunity of observing, has the external surface of the cephalic shield been well exhibited, or preserved over any considerable surface. Where best shown it is somewhat uneven, and presents that curious apparent division into polygonal (usually hexagonal) areæ which has been described by Professor Agassiz. On examining the apparent sutures closely, however, they have not presented to my observation precisely the appearance figured in the pl. 1 *b*. fig. 2. of the 'Recherches.' They appear rather as if short, delicate, reddish-brown lines had been ruled across the line of junction of the sides of the hexagons, for some way towards the centre of each hexagon; and these lines are so gently convergent as to seem nearly parallel. Neither do I remember to have met with such strongly marked central elevations as those represented in the figure cited.

The inner surface of the disk has presented itself well preserved in more than one specimen. It never exhibits any trace of the apparent sutures of the outer surface (compare Agassiz's 'Recherches,' pl. 1 *b*. fig. 3, where this fact is clearly shown), but appears whitish, enamel-like, and very smooth where it is not furrowed by certain shallow and narrow depressions which radiate from the region of the orbits and occiput towards the margin, before reaching which they repeatedly subdivide and anastomose. I do not doubt that these are the impressions of the vessels which ramified under the disk during life. Sometimes, by the elevation of the substance of the disk into a wall on each side of one of these depressions, the latter may become almost converted into a canal, so as to retain a portion of the matrix. This however is a rare occurrence.

When the concave inner surface of a disk and the convex cast of another specimen are compared, it is at once seen that the "radiating fibres" of the one correspond with the grooves and furrows of the other. The surface of the cast is remarkably darker than the surrounding matrix, and might not unreasonably at first be supposed to be of a different nature. When the inner surface of the disk is carefully examined with a magnifying glass, a number of reddish-brown minute dots appear scattered irregularly over its surface. It will be seen immediately that these are the internal openings of vascular canals which enter the substance of the disk.

If a vertical section of the cephalic shield of *Cephalaspis Lyellii* is carried through the orbits and perpendicularly to the axis of the body, it will be seen that the disk is exceedingly thin, hardly anywhere attaining $\frac{1}{40}$th of an inch in thickness, except at the margins and the spine, which are thicker. At the lateral margin the thin lamella is bent abruptly and almost horizontally inwards for about a quarter of an inch. It then suddenly thins so much as to be little more than a flexible membrane, which in the specimen now under description is pressed up into close proximity with the dorsal part of the shield (fig. 4).

The thinness and fragility of the disk of *Cephalaspis* render it difficult to obtain good sections for microscopical examination. The best I have seen (Pl. XIV. fig. 1.) is taken at an angle of about 45° to the longitudinal axis of the head, and intersects the occipital spine just beyond its origin. The section of the spine is in the best condition, and may be described first.

It is about $\frac{1}{40}$th of an inch thick in its thickest part, which corresponds with the median ridge of the spine, and presents three regions or layers, distinguishable from one another partly by their minute structure, and partly by the different mode of distribution of the vascular canals by which the tissue is permeated in each. The innermost or deep layer (*d*) is made up of superimposed lamellæ not more than $\frac{1}{2000}$th of an inch thick, each of which sometimes appeared to be still more finely laminated.

Interspersed among these, at greater or less distances, are numerous osseous lacunæ, whose long axes are parallel with the planes of the laminæ (fig. 3). The length of these lacunæ varies greatly, but may be taken at $\frac{1}{2000}$th of an inch on the average; some, however, are twice or three times this length, while others are much less. The transverse diameter is equally variable; but none that I measured exceeded $\frac{1}{3000}$th of an inch in this direction. The form of the lacunæ is very irregular in consequence of the long branching and anastomosing canaliculi which are given off not only from their ends but from their sides. In some parts the innermost layer appears almost black when viewed by transmitted light, in consequence of the quantity of air retained in the multitudinous lacunæ and canaliculi.

Large vascular canals, measuring from $\frac{1}{200}$th to $\frac{1}{400}$th of an inch in diameter, whose inner openings correspond with the brown spots on the inner surface, traverse the innermost layer very obliquely, in their course towards the middle layer (fig. 1, *e*.) Their branches are few, and for the most part run parallel with the main trunk; but they give off a great multitude of minute canaliculi, which anastomose with those of the nearest lacunæ. Such of these canals as I have seen in section were oval, their long diameters being parallel with the planes of the lamellæ. In the specimen described the walls of the canals are lined with a reddish matter (like oxide of iron); and a similar substance obstructs many of the canaliculi.

The middle layer (*c*) is distinguished from the inner by the rarity or entire absence of the lacunæ, and by the indistinctness of the lamination as compared with that of the deep layer. Such striations of the nearly homogeneous base as seem to indicate lamination are, in the middle and inner parts of the middle layer, so disposed as to be nearly perpendicular to those of the deep layer, appearing to follow the course of the vascular canals.

The latter are continuous with the large vascular canals of the deep layer, but they are smaller and form a close network. Each of the large canals, on reaching the middle layer gives off several branches, which run nearly parallel with the surface (and therefore greatly inclined to the course of the great canals), and anastomose with those around, above, and below them. In this particular part of the disk, in fact, a large canal gives off as many as three tiers of these lateral branches, separated from one another by not much more than their own diameter, and all ramifying and anastomosing with one another. These lateral vascular canals have at first a diameter of about $\frac{1}{900}$th of an inch; but many of their anastomotic branches are much smaller.

Sooner or later all these branches appear to end in a close "superficial network," *b*, which lies in the boundary between the middle and the superficial layers. The latter or third layer of the disk (*a*) sometimes appears structureless, at others presents an obscure vertical striation, as if it were, like enamel, made up of minute fibres. The superficial vascular network sends into it a great number of minute short processes, which branch out abruptly at their ends, like a thorn-bush or a standard rose-tree, and end in excessively fine tubuli, like those of dentine. The tubuli appear empty and are much finer than the vascular processes, which are usually full of the dark red matter before referred to. Hence, when the section is viewed by transmitted light, the vascular canals are very distinct, and appear to end abruptly in the deep half of the superficial layer, while the tubuli have the aspect of fine, clear, sparsely ramified lines, by no means so readily visible. In some cases they seem to open on the surface. This substance, it will be observed, corresponds very closely in structure with the "cosmine" of Professor Williamson. I have been unable to find any trace of a "ganoin" layer external to it.

The superficial layer does not form a continuous whole, but is seen in the section to be divided into masses of various length by interspaces or gaps, which extend as far as the superficial vascular network, the canals of which appear indeed to open into the bottom of the interspaces.

A structure in every essential respect similar to that just described is to be found in all other completely ossified parts of the cephalic shield, whether dorsal or ventral. In other regions of the dorsal part, however, the lamination of the inner layer is far more marked; and as a general rule the middle layer in these parts of the shield is thinner and contains fewer layers of lateral vascular ramuscules. The like is true of the inner part of the ventral region, in which only a single layer of close-set vascular canals makes its appearance (Pl. XIV. fig. 5). The flexible part of the ventral layer appears to be composed of the lamellar inner layer only; and the thick margins of the disk resemble the spine in structure.

The structure of the ventral layer, enclosed as it is on both sides by the matrix, is usually very well displayed in sections, and the better, on account of the dark reddish-brown hue which is acquired by the matrix, for some little distance from its line of contact with the animal substance. But neither in these nor in any other sections can any trace of bony substance be discovered beyond that which enters into the composition of the thin cephalic shield itself. I believe, therefore, that the so-called "fibrous bone" is nothing but the surface of the matrix impressed by the inner surface of the disk, and stained of a darker colour than elsewhere.

If flakes of the inner layer of the shield be detached and well soaked in hot Canada balsam, they become transparent, and their structure is well displayed in a superficial view (fig. 3). At their broken edges, the lamellæ of which they are composed are seen cropping out one beyond the other; but their most striking feature consists in the long lines of lacunæ which lie in parallel and equidistant series in each layer, so that under a low power it appears to be composed of broad flat fibres arranged side by side. The axes of the lacunæ of each layer are directed nearly at right angles to those of the layers above and below, so that under a low power the section appears cross-hatched by a series of dark lines. The great vascular canals are well seen traversing the successive lamellæ very obliquely.

In flakes of the disk similarly treated, but containing more of the middle and outer layers, fig. 2, it is obvious that the great canals divide into the branches of the middle layer which have already been seen in the vertical section, chiefly, if not only, along lines corresponding with the apparent sutures between the so-called "polygonal scales." The canals of the middle layer are very singularly arranged, passing from their origin, across these sutural lines and nearly parallel with one another, towards the centre of the adjacent "scales." The appearance of distinct "scales," and of the curious lines along their boundaries, is entirely due to this vascular distribution, the canals with their reddish lining showing very distinctly against the whitish general substance. In these views, again, the fissures by which the superficial layer is interrupted in the sectional view are seen to be nothing more than the expression of the valleys between the irregular and inconspicuous tubercles into which the superficial layer is raised (Pl. XIV. fig. 2).

Pteraspis. (Pl. XV.)

A fragmentary specimen of *Pteraspis Banksii* (belonging to Mr. Marston) affords by far the best view I have yet met with of the general structure of the shield of this genus. A cast of the outer surface is exhibited, and for the greater part of its extent the substance of the shield is absent; but in the centre a patch is left, exhibiting all the layers in their natural condition and relations (fig. 2).

The innermost layer (*d*) is composed of a reddish-white nacreous substance, exhibiting a distinct appearance of lamination at its free edges: its surface is somewhat uneven, and presents scattered rounded apertures about $\frac{1}{400}$th of an inch in diameter. The edges of these apertures were not unfrequently somewhat raised; and their cavities were full of a reddish matter. External to the innermost layer is the middle layer (*c*), composed of vertical plates of a laminated substance of similar appearance to the inner layer, and varying in thickness from $\frac{1}{200}$th of an inch downwards. These plates are so disposed as to form a network, enclosing polygonal (4–5–6-sided) cells of an average diameter of about $\frac{1}{50}$th of an inch.

The inner apertures of these cells are closed by the inner layer. Externally, they are also closed by a substance of the same nature as their walls, but perforated by a variable number of apertures somewhat smaller than those in the inner layer (*b*). The inner surface of this substance presents in many cases a striation more or less parallel to the sides of these apertures; and when it is broken away the thickness of the layer which closes the outer apertures of the cells is seen to be permeated by numerous small canals which give it a sort of worm-eaten or reticulated appearance. I will call this the "reticular layer." Lastly, outside the reticular layer is a white substance, very imperfectly visible in this specimen, in which no canals are visible, and which constitutes the external layer (*a*).

A view, the precise complement of that just described, is afforded by another of Mr. Marston's specimens of *Pt. Banksii*. This exhibits, for the most part, a cast of the internal surface; but towards the edge a considerable portion of the shield is left in a very perfect state of preservation, and with its external surface intact. The external layer is produced into strong ridges, the summits of which are turned outwards and their bases juxtaposed. The summits of the ridges are as much as $\frac{1}{160}$th to $\frac{1}{170}$th of an inch apart. In some cases they were sharply angular, in others more rounded. Where this layer was broken away, the reticular layer beneath it, and the polygonal cells of the next layer were well displayed. The bottoms of these cells were seen to be closed by the inner layer, and in this apertures were visible, corresponding with those on its inner surface. I have not examined transverse sections of this species; but the structure of *Pt. Lloydii* is so similar, that its transverse section perfectly elucidates the appearances presented by *P. Banksii*.

I have seen no specimen exhibiting the unaltered external surface of *Pt. Lloydii*; but its internal surface and its other layers, where the inner one is broken away, are well displayed in two specimens belonging to the Geological Society. The inner layer is thin, whitish, and nacreous, and presents, scattered over its surface, apertures of a similar character and size to those shown by *Pt. Banksii.*

The next layer appears, at first, to be very different, inasmuch as it seems to be composed of irregular reddish prisms with white interspaces. The prisms have a diameter of $\frac{1}{80}$th of an inch, more or less.

The reticular layer is hardly distinguishable in this view; but when the apparently prismatic substance is broken away, either a thin filmy outer substance is visible, or a peculiar striation. A thin section of the shield of *Pt. Lloydii* (fig. 1), taken perpendicularly both to its plane and to its long axis, exhibits the following appearances when viewed with a low power by reflected light.

The total thickness of the section is about $\frac{1}{40}$th of an inch, and of this amount about $\frac{1}{110}$th of an inch is occupied by the inner layer, $\frac{1}{140}$th of an inch by the second layer, $\frac{1}{300}$th of an inch by the next, and $\frac{1}{200}$th by the outermost layer.

The outer layer (*a*) appears to consist of a series of papillary elevations which have a broad free end, and are attached by narrow bases, so that a triangular interspace with its apex outwards is left between every pair of elevations. The matrix filling these interspaces, and for some distance in the immediate vicinity of the outer surface, is much darker than elsewhere, and has a deep brown hue. The attached ends of the elevations pass into a whitish substance, which, under this power, looks similar to their own. It is traversed by many reddish canals, which send diverticula into the elevations (*b*); and hence this substance clearly represents the "reticular layer" of *Pt. Banksii.* At intervals of about $\frac{1}{70}$th to $\frac{1}{110}$th of an inch or thereabouts, thin septiform processes are given off from the reticular layer, and pass perpendicularly inwards to the inner layer; they thus subdivide the second layer into a series of irregularly quadrate spaces, corresponding with the prisms seen in the superficial view.

The inner layer is, like the rest, whitish, and is traversed parallel with its surface by four or five much whiter streaks, so that it appears to be composed of only a corresponding number of lamellæ; but on allowing the light to pass through the section, it is at once obvious that each of these apparent lamellæ is in reality made up of many of the primitive laminæ which constitute the inner layer, and that the bright and dull white streaks are due entirely to a difference of texture or composition in the successive groups of laminæ.

Under a high power the laminæ are seen to have a thickness of about $\frac{1}{4300}$th of an inch, and to run nearly parallel with, and closely applied to, one another. They present an indistinct vertical striation, but exhibit no canals nor lacunæ. The septa of the second layer are composed of similar laminæ, but less distinct, and curved in various directions, usually more or less parallel to the walls of the large cavities which they bound. A fragment of the inner layer (fig. 4), rendered transparent by Canada balsam, and viewed by transmitted light, shows that it contains no lacunæ; nor have I been able to detect any distinct structure in its laminæ, unless an obscure and very delicate striation, visible here and there, may be regarded as such.

A similar disposition of curved laminæ can be traced in the "reticular layer;" but in the elevations of the external layer, such laminæ are no longer distinctly visible, although here and there traces of them may be seen. Each elevation, in fact, nearly resembles the tooth or dermal defence of a placoid fish. It contains a central cavity, commonly filled with a dark red matter, which usually occupies the centre of the basal half of the elevation and then suddenly ends in a number of excessively minute branches, which pass towards the surface, ramifying as they go, and closely resembling the canals of dentine or cosmine. They appear to terminate on the surface, on which I have been unable to discover any trace of laminated structureless ganoin. The central canals of the elevations open internally into the network of vascular canals which lies in the reticular layer. These canals rarely exceed $\frac{1}{700}$th to $\frac{1}{800}$th of an inch in diameter, and they are rendered particularly obvious by the dark red granules with which their walls are dotted.

Internally they open directly into the interspaces of the septa which connect the reticular with the inner layer, and the granules are continued on to the walls of the septa, which are themselves occasionally traversed by short canals. The interspaces (e) are full of a more or less transparent inorganic matter, identical with that of the matrix. It follows, therefore, that the "bony prisms" or "granules" which have been described have no existence, these so-called prisms being nothing but the matrix which has filled up the cavities of the polygonal cells, visible in their natural empty condition in *Pt. Banksii.* Canals resembling those of the reticular layer, as I have said, traverse some of the septa and put their chambers in communication.

In the section under description, the inner layer is for the most part devoid of canals; but one (f) is exhibited very beautifully. It has in the middle a diameter of about $\frac{1}{380}$th of an inch, but is wider at both ends, and traverses the inner layer almost perpendicularly. The laminæ are bent outwards for a certain distance, where they impinge upon its walls.

The structure just described is that of the central part of the section. At one of its ends, near the margin of the disk, the arrangement of the vascular channels is more like that in *Cephalaspis,*—the reticular layer assuming a much greater development, and the areolar character of the sinuses of the second layer becoming greatly obscured.

On comparing together the appearance of a section with those presented by the internal and external views of *Pteraspis,* there can be no doubt that the elevations of the outer layer of the one are the sections of the ridges of the other; and it is remarkable that there should be so striking a difference in the form of these ridges in *Pt. Banksii* and *Pt. Lloydii.* The ridges seen in concave casts probably always correspond with the whole interspaces between the ridges of the outer layer in *Pt. Banksii*; but it is quite conceivable that in *Pt. Lloydii* the ridges, in consequence of their peculiar form, might sometimes be held by the matrix and sometimes not; so that at one time the ridges of the cast would be very narrow, corresponding only with the intervals between the summits of the ridges of the disk, sometimes broad, and corresponding with the intervals between their bases.

Comparison of Pteraspis *and* Cephalaspis.

If the exposition which has just been given of the structure of *Cephalaspis* and *Pteraspis* be correct, it follows that neither the resemblances nor the differences in the structure of these two genera have hitherto been rightly apprehended.

The sole important differences consist, 1st, in the absence of osseous lacunæ in *Pteraspis*—their presence in *Cephalaspis*; 2nd, in the different general character and arrangement of the vascular sinuses; 3rd, in the different mode of arrangement of the external layer. These differences appear to me to be in themselves fully sufficient to warrant a generic distinction, but not more; for they are not greater than may be found among closely allied genera.

It will be observed that the account of the structure of *Pteraspis* given by M. Kner coincides, so far as it goes, with mine; and the examination of one of his *Pteraspides* (of which Sir Philip Egerton, with his usual liberality, has permitted me to have a section made), though not so satisfactory as I could have wished, still leads me to entertain no doubt that his fossils are really *Pteraspides*, and closely allied to *Pteraspis Lloydii.*

In this specimen, however, the histological characters which have been described are almost all undistinguishable. All that remains of the *Pteraspis* is a yellowish substance, without any definite structure, which appears in the section to form loops broader at their free than at their attached ends, and to send in longer or shorter reticulated processes of a similar character into the interior of the matrix. The interspaces of the loops are filled up with crystalline masses of carbonate of lime (?).

The length of the loop-like processes is about $\frac{1}{210}$th of an inch, and the breadth of their wide end about the same; the width of their necks is not more than $\frac{1}{330}$th, or thereabouts.

Now these are, as nearly as may be, the average dimensions of the sections of the ridges of *Pteraspis.*

No one can, I think, hesitate in placing *Pteraspis* among Fishes. So far from its structure having "no parallel among Fishes," it has absolutely no parallel in any other division of the animal kingdom. I have never seen any Molluscan or Crustacean structure with which it could be for a moment confounded. Its relations with *Cephalaspis*, on the contrary, are very close. In each the shield is excessively thin, and composed of three or four layers:—1st, an "internal," composed of lamellæ parallel with the surface, and traversed more or less obliquely by vascular canals; 2nd, next to this is a "middle layer," containing the network of wide canals or areolæ; 3rd, the "reticular layer," described in *Cephalaspis* as part of No. 2, from which it is not distinctly marked in that genus; 4th, the "external layer," consisting of a cosmine-like substance raised into ridges or tubercles.

The "bony granules," or "prisms," supposed to be characteristic of *Pteraspis*, the "polygonal ossicles" and the "fibrous bony layer," supposed to be peculiar features of *Cephalaspis*, have, as I have shown, no existence. Supposing that the shield of *Pteraspis*, like that of *Cephalaspis*, covered the animal's head (though there may be some ground for entertaining a doubt on this point), then it may be said that the presence of orbits in one, and their absence in the other, indicates a wide difference between the two genera. It must be remembered, however, that there is precisely the same difference between *Pterichthys* and *Coccosteus*, which are admitted by all to be closely allied.

Though I have had no opportunity of examining the Russian species, I believe I do not err in regarding what Pander describes as the teeth of *Cephalaspis* as merely an excessive development of the marginal tubercles of the outer layer. It does not appear to me that there is any evidence that the mouth was situated at the margin of the shield; on the contrary, the inward prolongation of the reflected ventral layer leads me to suspect that the under surface of the head of *Cephalaspis* resembled that of *Loricaria* or of *Acipenser*.

Zoological position of CEPHALASPIS *and* PTERASPIS.

Leaving for the present Professor Pander's "Conodonts" out of view, *Cephalaspis* and *Pteraspis* are among the oldest, if they are not the very oldest, of known fishes; and it is therefore highly interesting to inquire into their position in the scale of ichthyic nature.

Palæontologists in general, following Agassiz, classify them as "Ganoids;" but it is to be feared that few persons who have not paid special attention to recent Ichthyology and to Comparative Anatomy have a clear conception of what is meant by the term "Ganoid."

The founder of the Order, allowing himself to attach an undue weight to mere secondary characters, included under the head of "Ganoidei" a heterogeneous assemblage of Fishes characterized by very few common characters, save their hard and shining scales, and the abdominal position of their ventral fins, but embracing the Siluroids, the Gymnodonts, and the Ostracionts, while the genus *Amia* was allowed to remain among the *Clupeidæ*.

If these are all Ganoids, and if such are the characters of the Order, then doubtless *Pteraspis* and *Cephalaspis* are Ganoids.

Since the publication of the admirable and philosophica researches of Johannes Müller, however, the term *Ganoidei* has been received in a very different sense by the great mass of naturalists. Müller showed that the great majority of the recent Fishes classed as Ganoid by Agassiz, viz. the Siluroids, the Gymnodonts, the Ostracionts, &c., were in no essential respect different from the *Teleostei*, or true bony fishes, while the true recent Ganoids formed a small but extremely remarkable assemblage, characterized by a structure in many respects intermediate between that of *Teleostei* and that of the *Elasmobranchii* (or what are commonly called cartilaginous fishes). Müller showed, furthermore, that the character of the surface and the histological texture of the scales are of little systematic value, and reduced the diagnostic marks of a Ganoid, visible in the external skeleton, to two —the presence of "fulcra" and the articulation of the scales by gomphosis. The rest of the essential characters of the Ganoids are entirely derived from the soft parts—the brain, the heart, the branchiæ, and the air-bladder. A Ganoid is in fact distinguished from any other fish by the following peculiarities.

The optic nerves form a chiasma; the bulbus aortæ is rhythmically contractile, and provided with several series of valves; the branchiæ are free; there is an air-bladder connected by an open duct with the intestine; the ventral fins are abdominal. These essential characters are shared by only six genera of existing fishes—*Lepidosteus, Polypterus, Amia, Acipenser, Scapirhynchus,* and *Spatularia* —which are no less singular in their distribution than in their anatomy. All are essentially freshwater fishes; all are found in the northern hemisphere; three—*Lepidosteus, Amia,* and *Spatularia*—are exclusively North American; *Polypterus* is only known in the Nile, while *Acipenser* is common to Europe, Asia, and North America.

Now what evidence have we that either *Cephalaspis* or *Pteraspis* are in the proper sense Ganoids? There is nothing about their dermal covering peculiarly characteristic of Ganoids; and as to the rudimentary state of ossification of the vertebral column, there are Teleostean fishes (e. g. *Helmichthys*) quite as imperfect in this respect as any Ganoid.

Without doubt there is a singularly close resemblance, in the structure of the dermal plates, between *Cephalaspis* and *Megalichthys*— the last being very probably a true Ganoid; but the point of difference is noteworthy: *it is precisely the characteristic ganoin-layer which is absent in Cephalaspis.*

On the other hand, the arrangement of the hard tissues in *Pteraspis* reminds one almost as strongly of *Ostracion,* an undoubted Teleostean.

The existing fishes to which *Cephalaspis* presents the nearest resemblance in form, viz. *Loricaria* and *Callichthys,* are Siluroid Teleosteans, and not Ganoids; and, if we take the immediate allies of *Cephalaspis* and *Pteraspis,* viz. *Coccosteus* and *Pterichthys,* their analogies with Siluroids, such as *Bagrus* and *Doras,* are as strong as those with *Acipenser.*

A careful consideration of the facts, then, seems to me to prove only the necessity of suspending one's judgment. That *Cephalaspis* and *Pteraspis* are either Ganoids or Teleosteans appears certain; but to which of these orders they belong, there is no evidence to show.

If this conclusion is valid, it is clear that the ordinary assumption, that the earliest fishes belonged to low types of organization, falls to the ground, whatever may be the relative estimation in which the different orders of fishes are held.

But it is said that the great development of the dermal skeleton, combined with the rudimentary condition of the endo-skeleton, shows that these early fishes occupied a low place within their own group.

Mere *à-priori* argumentation on such questions as these would be a waste of time; but, happily, we can put the principle involved in this reasoning to the test by direct observation. This principle clearly is, that the development of the exo- and endo-skeletons stands in some ratio to the general perfection of the organization of a fish.

Now the existing genera of Ganoids are, as I have said above, characterized by certain anatomical peculiarities common to all; and, in every essential of organization, no one can be said to be superior or inferior to another. The same kind of brain, heart, and respiratory organs are to be found in all; nevertheless, Nature seems to have amused herself with working out in this small group every possible variety and combination of endo-skeleton and exo-skeleton.

Lepidosteus has a greatly developed exo-skeleton, and the most Salamandroid vertebra known among fishes.

Polypterus has an equally well-developed exo-skeleton, and a well-ossified but piscine vertebral column.

Amia has scales as thin and flexible as those of a carp, with a well-ossified skeleton like that of an ordinary Teleostean fish.

Acipenser and *Scapirhynchus* have large enamelled dermal plates, constituting a well-developed exo-skeleton, with a cartilaginous vertebral column and persistent chorda dorsalis;

While, finally, *Spatularia*, with its mainly cartilaginous endo-skeleton, has a smooth skin, without dermal plates at all.

In the face of these plain anatomical facts, what is the value of the argument from the development or non-development of the skeleton to the grade of organization of a fish?

EXPLANATION OF THE PLATES.

Plate XIV.

Cephalaspis.

Fig. 1. Vertical section of the shield of *Cephalaspis*, magnified 100 diameters. *a*. Outer layer. *b*. Reticular layer. *c, d*. Middle and innermost substance. *e*. Vascular canals. *f*. Matrix.

Fig. 2. Horizontal section of the same, viewed from the outer side, showing the peculiar arrangement of the vascular canals along the so-called "sutures," magnified 50 diameters.

Fig. 3. Thin scale of the inner substance showing the osseous lacunæ of two laminæ, magnified 200 diameters.

Fig. 4. Outline of a vertical section through the shield of *Cephalaspis*, showing its inflected margin (*a*) and inferior flexible wall (*b*), magnified 2 diameters.

Fig. 5. Section of the inferior wall at the point of transition of the ordinary substance of the shield (*a*) into the thin flexible under layer (*b*), magnified 100 diameters.

Plate XV.

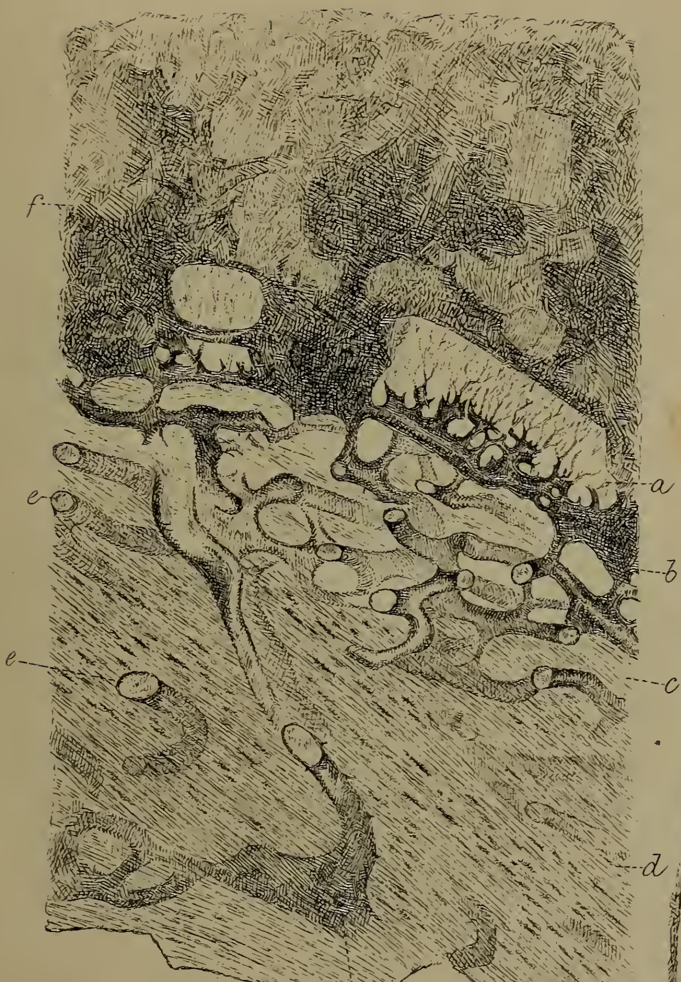
Pteraspis.

Fig. 1. Vertical section, magnified 100 diameters. *a*. "Enamel"-ridges forming the outer layer. *b*. Reticular layer. *c, d*. Middle and inner substance. *e*. Cavity filled with matrix—one of the supposed "ossicles." *f*. Vascular canal. *g*. Matrix.

Fig. 2. Portion of the shield of *Pteraspis Banksii*, viewed from within: letters as in fig. 1: magnified 10 diameters.

Fig. 3. Vertical section of inner layer of *Pteraspis*, showing the laminæ and one of the vascular canals, magnified 100 diameters.

Fig. 4. A flake of the inner layer viewed from within, magnified 25 diameters. *a*. Vascular canals.

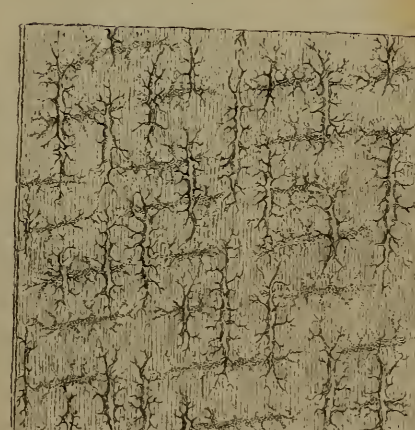


1

4

5

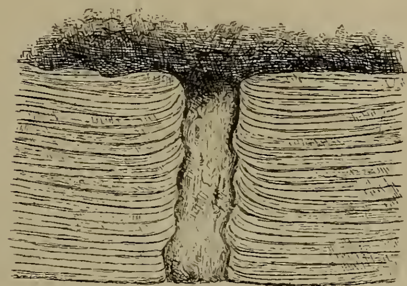
2



3

CEPHALASPIS

1



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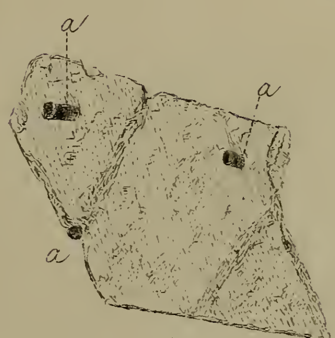

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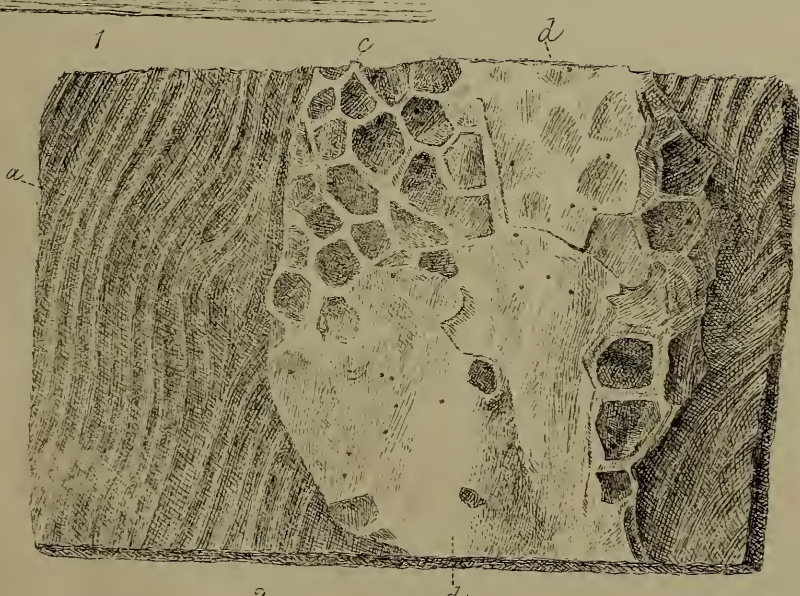

2

PTERASPIS

W. West Imp.

2. *On a New Species of* Plesiosaurus *from* Street, *near* Glastonbury; *with Remarks on the Structure of the* Atlas *and* Axis Vertebræ, *and of the* Cranium, *in that* Genus. By Thomas H. Huxley, F.R.S., F.G.S., Professor of Nat. Hist. &c.

The locality where the *Plesiosaurus*, which forms the subject of the present brief notice*, was obtained is already famous for its richness in such remains. In fact, the limestone beds of the Lower Lias at Street have already yielded at least three species of *Plesiosaurus*—*P. Hawkinsii*, *P. macrocephalus*, and *P. megacephalus*; and it seemed so unlikely that a fourth species should have inhabited the same area, that I was for a long while unwilling to admit the distinctness of the form at present under consideration.

The evidence which I shall bring forward, however, seems to me to admit of no other conclusion.

The specimen is a remarkably fine one. The limestone matrix in which it is imbedded being hard and free from pyrites, every part is well preserved; and the value of the fossil is further enhanced by two circumstances:—first, the very slight amount of disturbance which the bones have undergone, so that the vertebræ from the third cervical to the last caudal are all in their natural positions; secondly, the perfectly lateral view of the body which is presented. The only important defects are the absence of the paddles, and the flattening and apparent loss of the lower jaw which the head has suffered.

The total length of the skeleton is about 7½ feet. The left side is exposed, and the neck and tail are strongly bent upwards, as if the creature had died in a state of opisthotonic rigidity. The head is twisted, so that its upper surface only is visible, and it is at the same time bent back, at right angles to the neck. In consequence of this, the occipital condyle and the atlas are well separated. The two anterior cervical vertebræ were originally partially covered by the crushed right os quadratum; but by removing the latter both atlas and axis have been very clearly exposed.

As the Museum of Practical Geology is indebted to the judgment and energy of my friend and colleague Mr. Robert Etheridge, F.G.S., for the acquisition of this fine *Plesiosaurus*, I think I cannot do better than name it after him, *P. Etheridgii*.

The following are the most important characters of this species:—

1. The length of the skull (measured from the end of the premaxillaries to the occipital condyle†) is less than one-thirteenth of the whole length of the body. As the anterior teeth have nearly disappeared, it is not certain that the skull may not have borne a slightly larger proportion to the body; but the anterior slope of the premaxillaries clearly shows that the allowance to be made on this ground, if any, must be very small.

* The specimen will be fully described and figured in the Decades of the Geological Survey of Great Britain.

† The "length of the head" measured from the end of the snout to the posterior extremity of the lower jaw is commonly taken as the unit of comparison. But the end of the os quadratum and the lower jaw are so readily displaced as to render this anything but a safe standard.

2. There are thirty cervical vertebræ—vertebræ, that is, which present facets for articulation with ribs on the lower half of their centrum; the ribs being short and compressed superiorly, or hatchet-shaped*.

3. Three times the length of the skull equals the length of the anterior twenty-three cervical vertebræ; four times the same length equals the anterior twenty-eight cervical vertebræ. It follows therefore that the neck is between four and five times as long as the skull.

4. There are about 90 vertebræ, of which 30 are cervical, 23 dorsal, 2 sacral, and 34 or 35 caudal.

5. The humerus and the femur are as nearly as may be equal in size.

6. The vertical diameter of the centra of the anterior cervical vertebræ is greater than the longitudinal, the proportion being at least as three to two in the third cervical. In the thirtieth cervical the two measurements are nearly equal, though the vertical predominates a little. So far as they are visible in the transverse sections exposed by fracture of the limestone slab, the articular faces of the centra are nearly circular.

7. The cervical costal pits are elliptical, about half as long vertically as longitudinally, and from the third to the twenty-sixth inclusive are divided lengthwise by a well-marked longitudinal depression; but there is no subdivision into two distinct facets. In all these vertebræ the pits look outwards and a little downwards, their axes are parallel with those of the vertebræ, and they are completely sessile.

In the last three cervical vertebræ the costal pits are directed more and more backwards as well as outwards, and take the form of flattened facets. At the same time their anterior edges are raised up by an outgrowth of the body of the vertebra.

8. The articular facets of the anterior dorsal vertebræ are nearly circular. In the anterior eight or nine dorsal vertebræ the transverse processes arise partially from below the level of the upper margin of the centrum. In the tenth they appear to arise completely above it, their upper margins being on a level with the upper edges of the posterior zygapophyses. In the eighteenth they begin again to descend, so that in the first sacral more than half the root of the transverse process is below the level of the superior margin of the body.

9. The neural spines of the cervical vertebræ are inclined a little backwards, and have their anterior edges bevelled, so that their apices are more or less pointed. Those of the dorsal and sacral vertebræ are vertical, with their anterior and posterior margins parallel and their apices squarely truncated.

10. The articular faces of the caudal vertebræ are nearly round, and their centra larger vertically than longitudinally. The neural spines slope backwards a little, but their anterior edges are straight

* The neurapophysial sutures are not visible; but as there is reason to believe that the neurapophyses do not extend upon the bodies of the cervical vertebræ beyond their dorsal half, the character of a cervical vertebra here used is probably equivalent to that employed by Prof. Owen (*loc. cit.*).

and their ends truncated. The three or four last caudals have apparently neither spines nor neurapophyses.

There are more than thirty named species of *Plesiosaurus*. Of these, however, far more than half are founded upon detached bones, and I am not aware that entire, or nearly entire, specimens of more than four species, viz. *dolichodeirus, Hawkinsii, macrocephalus,* and *brachycephalus,* have as yet been described. This point is worthy of notice, when we consider that the proportion of the head to the body constitutes an important datum in the determination of the species of this genus. I will compare *P. Etheridgii* first with those of which complete or nearly complete skeletons have been observed.

In *P. brachycephalus,* according to Prof. Owen, the head equals one-eighth of the body in length; in *P. macrocephalus* the length of the head equals one-half that of the neck; they are therefore at once excluded.

The classical authority on *Plesiosauri,* Mr. Conybeare, states that the head of *P. dolichodeirus* equals one-thirteenth of the entire body, or one-fifth of the neck, while the head and neck together are to the body as six to seven*. These proportions approach those of *P. Etheridgii.* But they are not the same; and besides, the neural spines of the cervical vertebræ of *P. dolichodeirus* are quite differently shaped from those of *P. Etheridgii.* And though the total number of vertebræ in *P. dolichodeirus* is the same, viz. 90, 35 are said to be cervical, 27 dorsal, 2 sacral, and 26 caudal. Clearly then the specimen described has nothing to do with *dolichodeirus.*

Plesiosaurus Hawkinsii approaches it much more closely in size, form, and general proportions.

Several magnificent specimens of this species are to be seen at the British Museum, and afford excellent materials for the determination of its distinctive characters. Nevertheless the account of its characters in the 'Report,' already cited, presents some difficulties to the reader. At page 57, for instance, it is stated that in this species "the neck equals three lengths of the head, and the neck and head together equal the trunk and tail." If this be true, of course the length of the head must equal one-eighth of that of the whole body. Nevertheless, at page 61 of the same 'Report,' it is said that the head equals less than one-tenth part of the body.

Again, at page 61 (and by implication at page 63?), *P. Hawkinsii* is said to possess twenty-nine cervical vertebræ; but at page 57 the

* In his well-known memoir (Geol. Trans. ii. 1, 1824) Mr. Conybeare states at page 382, "the neck is fully equal in length to the body and tail united;" but at page 385 he says, "taking the head as 1, the neck will be 5, the body as 4, and the tail as 3: the total length being, as before remarked, 13 times that of the head." Prof. Owen, in his 'Report on the British Fossil Reptilia,' quotes Mr. Conybeare's first statement, but omits to refer to the last. Prof. Owen further states (Report, p. 61) that in *Pl. dolichodeirus* the head is four times the length of the neck. I suppose this to be a misprint, and that what is meant is, that the neck is four times the length of the head; but even this is at direct variance with Mr. Conybeare's assertions and figures.

number given is thirty-one* ; and thirty-one is stated to be the number in this species in the same author's memoir on *P. macrocephalus* (p. 523). No less contradictory are the statements as to the number of dorsal vertebræ. At pages 57 and 58 of the 'Report' they are by implication estimated at twenty-five; but at page 66 they are said to be twenty-three. I can nowhere find the slightest indication that Prof. Owen imagines the number of cervical or dorsal vertebræ to be variable in the same species of *Plesiosaurus*. The opposed statements which I have quoted are wholly devoid of the comment which would have been naturally evoked by the discovery of so remarkable a fact.

The specimens of *Plesiosaurus Hawkinsii*, on which the description of the species, contained in the 'Report on British Fossil Reptilia,' is chiefly based, are, I believe, those now contained in the Collection of the British Museum. Of these specimens three, viz. that numbered $\frac{2000}{18}$ and figured by Mr. Hawkins in his plate 24, that numbered 14,549 and figured in plate 28 of the same work, that numbered 14,541 and figured in Hawkins's plate 27, are but little disturbed, and retain the head and neck *in situ*.

In a fourth specimen, 14,550, which is in many respects extremely valuable and instructive, the head is unfortunately displaced and the anterior cervical vertebræ are absent.

Besides these four specimens, there is a fifth *Plesiosaurus*, numbered 2000 and named *dolichodeirus*; it is however certainly either *Hawkinsii* or *Etheridgii*, and I believe the latter, although the absence of the head and anterior cervical vertebræ renders it hazardous to give a confident opinion.

I will speak of these specimens in the order here named, under the heads of Nos. 1, 2, 3, 4, and 5. But I must first remark, that no one of them affords the means of determining the number of the dorsal vertebræ with so much certainty as in *P. Etheridgii*. To ascertain the number of the dorsal, or dorso-lumbar, vertebræ in any vertebral column, it is obviously necessary that we should be able to assure ourselves of these facts:—1st, that we know which is the last cervical; 2nd, that we know the first sacral; and 3rd, that we know how many vertebræ intervene between these.

In No. 1 the vertebral column is so obscured by the ribs and pectoral and pelvic girdles, that no one of these points can be ascertained with accuracy. In No. 2 the anterior part of the sixth vertebra from the skull is gone, and it is impossible to be certain that a whole vertebra may not have disappeared; at the same time an uncertain number of vertebræ have been displaced from the middle region of the back.

* At least, this is the only conclusion consistent with the definition of a cervical vertebra at page 58. Prof. Owen there proposes to consider as *cervical* those vertebræ whose centrum exhibits the whole or a part of the costal articular surface. At page 57 he states with respect to *P. Hawkinsii*, "In the first or anterior 31 vertebræ the centrum supports the whole or part of the costal pit." Therefore, according to the definition, these 31 vertebræ are cervical.

In No. 3 the dorso-sacral vertebræ are hidden in the same way as in No. 1.

In No. 4 the head and anterior cervical vertebræ are removed, and the dorsal region is dislocated, the hinder part of the vertebral column overlapping the anterior.

No. 5 alone exhibits the posterior part of the cervical and the whole dorsal region undisturbed. Either the sixteenth or the seventeenth vertebra in the series, counting from the first (broken) one, is here certainly the first dorsal—I believe the seventeenth.

The forty-second vertebra is certainly caudal; hence as there are two sacrals, $42-(17+2)=23$, which is the number of dorsals in *P. Etheridgii*, to which this specimen has in other respects a close resemblance.

Under these circumstances I can only suppose that Prof. Owen has some other evidence than that mentioned in his 'Report' for the following statement:—

"From the 32nd to the 56th vertebra inclusive, the costal articular surface is wholly impressed on the neurapophysis."—(Report, p. 57.)

Now, as Prof. Owen states in his memoir on *P. macrocephalus* (p. 527), that in the sacral vertebræ of *P. Hawkinsii* "a small part of the costal articular surface is contributed by the centrum," it necessarily follows that these twenty-five vertebræ (32nd to 56th inclusive) are neither sacral nor cervical, but dorsal. It is true that at page 66 of the 'Report' Prof. Owen affirms that there are only twenty-three dorsal vertebræ; but I cannot venture to set this cursory contradiction against a definite anatomical statement like the foregoing.

I have been most desirous to arrive at a clear understanding of Prof. Owen's definition of the species *P. Hawkinsii*; but after long and careful study I can only arrive at the following alternatives:—

Either 1. The apparently contradictory statements which I have quoted have been made through the use of a double definition of a "cervical vertebra,"—meaning thereby in one case a vertebra with a certain kind of rib, in the other a vertebra with a certain kind of costal articular facet;—

Or 2. Believing the number of cervico-dorsal vertebræ to be constant in the same species, Prof. Owen conceives that the special dorsal modification may commence either at the 30th or at the 32nd vertebra, according to individual variations.

On this hypothesis it must be assumed that the smaller number of dorsal vertebræ assigned to this species was found in that individual which exhibited the larger number of cervicals, and *vice versâ*. The numbers in the one case would be $31+23=54$, in the other $29+25=54$.

Or 3. Prof. Owen imagines that the total number of cervico-dorsal vertebræ may vary between 52 $(29+23)$ and 56 $(31+25)$ in different individuals of the same species.

I am not aware that a shadow of evidence exists in favour of the occurrence of so remarkable a variation as the last-named in any vertebrate animal so highly organized as the *Plesiosaurus*. If the second be the right interpretation of Prof. Owen's views, then *P. Hawkinsii* will always have the same number of cervico-dorsal vertebræ, and that number is according to Prof. Owen at least fifty-four, and at most fifty-six. I have shown, however, that in *P. Etheridgii* there are only fifty-three cervico-dorsal vertebræ.

I beg to repeat, however, that I can find no proof of the existence of fifty-four cervico-dorsal vertebræ in any *P. Hawkinsii* in the British Museum. Under these circumstances it became necessary to inquire whether the proportions of the head, body, and neck might not furnish the needful marks of specific distinction. Measuring these in the same way as *P. Etheridgii*, I find with regard to No. 1 that—

1. Taking the length of the skull (from the occipital condyle to the end of the snout) as 1, the whole body measures between 10 and 11. Taking the head from the end of the snout to the end of the lower jaw as 1, the whole body measures between 8 and 9.

2. Three times the length of the skull equals the anterior 25 vertebræ; four times the same length equals the anterior 31 vertebræ.

In No. 2 the end of the tail is gone, and therefore the proportions of the skull to the entire body cannot be ascertained; but three times the length of the skull measured along the neck reaches the middle of the twenty-fifth cervical vertebra, and four times equals the 31 vertebræ as before.

In No. 3 the length of the skull is rather less than one-eleventh of the whole body; while the length from the snout to the angle of the jaw is rather less than one-ninth of the whole body. The proportions of the head to the neck are as in No. 1.

In No. 1 the rib of the 29th cervical vertebra is hatchet-shaped; the shape of the ribs of the 30th and 31st vertebræ is not certainly discoverable, nor can the character of their articular surfaces be clearly made out.

In No. 3 the rib of the 29th vertebra is truly hatchet-shaped. Those of the 31st vertebra cannot be made out clearly, nor can that of the 30th on the left-hand side. On the right side the head of a rib lies against the posterior part of the neural arch of this vertebra; and, though its produced angle is more or less broken, its hatchet-shape can be clearly distinguished. The costal articular facets of both the 30th and 31st vertebræ are traversed by the neurapophysial suture.

In No. 2 the condition of the posterior cervical vertebræ is such as to render it very unsafe to speak decidedly as to the character of either the ribs or their articular facets.

So far as these specimens go, then, they favour the idea that *P. Hawkinsii* has 31 vertebræ cervical in Prof. Owen's sense of the term, and they assuredly do not countenance the notion that these vertebræ may vary in the same species. But if *Plesiosaurus Hawkinsii* has 54 or 56 cervico-dorsal vertebræ, and if 31 of these are cervical, then *P. Etheridgii* differs from it in the following particulars:—

1. The number of cervical vertebræ is at least one less.
2. The number of cervico-dorsal vertebræ is one or three less.

3. The head is shorter in proportion to the body.
4. The head is shorter in proportion to the neck.

I think then there can be no doubt as to the specific distinctness of *P. Etheridgii* from all the *Plesiosauri* as yet mentioned.

With regard to the other species, I judge from the descriptions and from such specimens as I have seen, that *P. Etheridgii* is very different from *megacephalus, macromus, pachyomus, arcuatus, subtrigonus, trigonus, brachyspondylus, costatus, dœdicomus, rugosus, trochanterius,* and *affinis*. I doubt at present whether it would be possible to distinguish the detached vertebræ of *P. Etheridgii* from those of *P. Hawkinsii*; but I believe, having examined the series of vertebræ in the College of Surgeons' Museum, on which some fourteen species have been founded, they are all different from those of *P. Etheridgii.*

The measurements of the different parts are as follows, in inches and tenths :—

	in.	tenths.
Head.		
From end of intermaxillary to end of occipital condyle	6	5
End of intermaxillary to anterior margin of orbit	2	15
End of intermaxillary to anterior end of parietal foramen	4	2
Width of orbit	1	2
Length (oblique longest diameter)	1	5
Extreme length of head from end of intermaxillary to end of quadratum	6	8
Neck.		
Length of first seventeen cervical vertebræ, measured along their bodies	12	9
Length of following thirteen	15	1
Giving as entire length of neck	28	0
Sixteenth cervical vertebra.		
Centrum.—Longitudinal diameter	0	9
Vertical to base of neurapophysis*	1	1
Thence to top of neural spine	1	4
Neural spine vertically	0	8
Neural spine longitudinally	0	7
Costal pit.—Longitudinal measure	0	5
Vertical measure	0	3
Costal pit to base of neurapophysis	0	6
Dorsal region.—Total length	26	5
Sixth dorsal vertebra.		
Centrum.—Longitudinally	1	25
Vertically (anterior face)	1	3
Transversely	1	6
Neural spine.—Vertically	2	1
Longitudinally	0	9
Transverse process.—Length	0	75
Antero-posterior diameter	0	5
Vertical diameter	0	75
Sacral region.—Total length	2½ in.	

* Reckoned as the deepest part of the depression under the zygapophysis, no suture being visible.

	in.	tenths.
First sacral vertebra.		
Centrum.—Vertically	1	3
Transversely	1	65
Upper edge of centrum to summit of neural spine	2	2
Neural spine—Vertically	1	55
Longitudinally (about)	0	7
Lower edge of body to origin of transverse process	0	75
Thickness of transverse process	0	82
Length	0	25
Sacral rib.—Length	1	3
Thickness of distal end	0	6
Caudal region.—Total	26	0
Eleventh caudal vertebra.		
Centrum.—Length	0	9
Vertical	1	15
Transverse	1	35
From upper edge of centrum to summit of neural spine	2	8
Length of neural spine.—Vertically (about)	1	1
Longitudinally	0	65
Ribs.—11th measured along its curve	11	0
Diameter of head	0	7
Diameter of body	0	45
Humerus.—Long	7	2
Thickness of anterior end from above downwards	1	9
Expanded distal end { long	3	3
Expanded distal end { thick	0	5
Femur.—Long	7	15
Anterior extremity from above downwards	1	8

The Structure of the Atlas and Axis.

Thanks to the investigations of Sir Philip Egerton, the structure of the axis and atlas of *Ichthyosaurus* is placed beyond doubt. But our knowledge of the corresponding parts of *Plesiosaurus* cannot be said to be by any means so well based, since it rests, so far as I am aware, upon the examination of a single and imperfect specimen, which has been described in the following terms by Professor Owen:—

"A recent opportunity of examining the atlas and axis of the *Plesiosaurus,* kindly afforded me by my friend Professor Sedgwick, has not only strengthened this view of the general nature of the 'subvertebral wedge-bones,' but has made me incline to the second hypothesis of the special homology of the first or anterior of the wedge-bones which is proposed in my 'Report on British Fossil Reptiles,' viz.:—That it answered to the part described as the body of the atlas, in the existing Saurians and Chelonians; which therefore may be regarded, like the first subvertebral wedge-bone, as the cortical part only of such vertebral body, like the plate of bone beneath the biconcave central part of the body of the atlas in the Siluroid fish.

"The atlas and axis in the *Plesiosaurus* (fig. 3) preserve the general proportions of the other cervical vertebræ, and are consequently longer than their homologues in the *Ichthyosaurus*; but they are similarly anchylosed together, and measure 4½ centimetres (nearly 2 inches) in length, 3 centimetres across the anterior concave surface of the atlas, and 3½ centimetres across the less concave posterior surface:

the neural arch of each vertebra has coalesced with its centrum, and a long obtuse process is formed below by a similar coalescence of the first and second wedge-bones with each other and their respective centrums. The limits of the anterior wedge-bone, *ca, ex*, are traceable: it is proportionally larger than in the *Ichthyosaurus* (fig. 2), in which it is likewise larger than the succeeding wedge-bones. It forms in the *Plesiosaurus* the lower third part of the atlantal cup for the occipital condyle B *ca, ex*: the anchylosed bases of the neurapophyses (*n a*) form the upper border of the cup, and the intermediate part or bottom of the cavity is formed by the centrum of the atlas (*c a*), or rather by that part which, like the biconcave centrum in the Siluroid fish, is developed from the central portion of the notochord.

"The smaller or second wedge-bone (*c x, e x*) is lodged in the inferior interspace between the atlas and axis, but has coalesced with both bones, as well as with the large anterior wedge-bone or cortical part of the body of the atlas, *c a, e x*. This anterior wedge-bone developes a thick but short, rough tuberosity from its under part, but there is no distinct second tuberosity from the second wedge-bone; both indeed have so coalesced together, as to parallel the continuous ossification of the under part of the notochordal capsule beneath the central parts of the bodies of the axis and atlas in the Siluroid fish (fig. 1, *c a e x, c x e x*, &c.). There is no transverse process from the centrum of the atlas of the *Plesiosaurus*; but the fractured base of a depressed parapophysis, *p* (lower transverse process), or anchylosed rib, projects from each side of the proper centrum of the axis."—(Professor Owen on the Atlas, Axis, and Subvertebral Wedge-bones in the *Plesiosaurus*.—Annals Nat. Hist. vol. xx. p. 219, 1847.)

This is all the evidence of the nature of the atlas and axis in *Plesiosaurus* which is given in the paper quoted, its author seeming not to be aware that important materials for checking his conclusions were offered by the specimens of *Plesiosaurus Hawkinsii* which he had already described. This is the more to be regretted, as the structure of these specimens is to my mind quite irreconcileable with Professor Owen's views.

What I have observed in *Plesiosaurus Etheridgii* and in *Plesiosaurus Hawkinsii* leads me, in fact, to form a very different conception of the structure of the atlas from that just cited.

Viewed in front, the deep hemispherical articular cup of the atlas of *Plesiosaurus Etheridgii* is seen to be divided by a triradiate mark (formed by the limestone of the matrix) into three portions; of these, one is inferior, the other two lateral and superior. The inferior piece I take to correspond with the so-called anterior or first wedge-bone of *P. pachyomus*; but it forms a more considerable portion of the articular cup than in the latter case, if I may judge by the figure. Viewed anteriorly, this inferior piece has a semicircular contour, while seen from below its anterior edge is straight, and the posterior produced laterally into a sort of cornu which overlaps the sides of a second so-called "subvertebral bone." The posterior margin is much excavated in the middle, receiving the convex anterior contour of this second "subvertebral bone."

The supero-lateral pieces are separated by an interval in the median line, wider than the close suture between them and the first wedge-bone. At the bottom of this interval a small portion of bone appears, which I believe to belong to the os odontoideum.

After contributing their share towards the articular cup for the occipital condyle, the supero-lateral pieces bend backwards so as to overlap the anterior zygapophyses of the axis. They seem to terminate above by a smooth and rounded edge. The antero-lateral margin of these portions of the atlas is nearly straight, the upper third or thereabouts being inclined at a great angle to the rest: the postero-lateral margin is greatly excavated, on account of the backward projection of the supero-lateral pieces above and of the cornua of the inferior piece below. The body of the axis is concave posteriorly, the sides are convex from above downwards. Below it is rather concave from behind forwards. Its posterior margin is straight; the anterior is also straight, except for a short distance inferiorly, where it is much beveled off. Traces of a rib, which probably articulated with the os odontoideum, exist on both sides of the anterior part of the body of the axis.

Between its anterior edge and the posterior excavated margin of the parts of the atlas just described, there is an interspace of $\frac{1}{5}$th of an inch. This is filled by a mass of bone with a convex edge, and separated by a deep groove from the axis and the rest of the atlas. Superiorly this bony mass is overlapped by the supero-lateral piece of the atlas—inferiorly by one of the cornua of the inferior piece; but on cutting this cornu away, I found it rested on a sort of articular face furnished by the inferior continuation of the bony mass. But this passed below, without any visible line of demarcation, into the second "subvertebral" bone. This bone is convex below and in front (where it fits into the excavated margin of the inferior piece of the atlas), and behind slopes backwards to articulate with the beveled face of the axis.

I have nowhere seen the structure of the anterior articular cup, and the sutures which unite the supero-lateral and inferior pieces of the atlas, displayed as they are in this specimen*; but many of the other peculiarities are as well shown in one or other of the specimens of *P. Hawkinsii* in the British Museum.

Thus the under surfaces of the atlas and axis are exhibited in the specimen I have called No. 1. They are a good deal broken away, so as to display a longitudinal and nearly horizontal section of these vertebræ. The axis has nearly the same form and size as in *P. Etheridgii*; the inferior piece of the atlas appears to be bent upwards, and to be broken inferiorly and posteriorly; but between the two is seen a thin bony disk, not more than a third as long as the axis, and which I take to be the section of the bony plate-like mass interposed between the axis and the three anterior pieces of the atlas in *P. Etheridgii*. No. 2 shows the right side of the axis and atlas very well, but the latter is somewhat crushed and distorted; nevertheless

* I may observe, that I performed all the more delicate operations required in bringing out these parts myself.

the anterior concavity is well seen. The suture between the cortical and neurapophysial portions is not traceable; the latter slopes back as in *P. Etheridgii*, and is visible on the left as well as on the right side. The peripheral piece appears to be prolonged anteriorly instead of posteriorly, but I believe this to arise from crushing merely.

The edge of an interposed bony plate is seen, as in *P. Etheridgii*, between the posterior edge of the three anterior portions of the atlas and the body of the axis. The neural spine of the axis is long and recurved; there is a rib with a short and broad head, which is articulated for the greater part of its extent either with the axis, or more probably with the os odontoideum; its anterior angle extends forwards as far as the inferior piece of the atlas.

Putting these different views and sections of the atlas and axis of *Plesiosaurus* together, it seems to me that they are consistent with only the following interpretation:—

1. The atlas and axis are, as Prof. Owen states, anchylosed.

2. What I have called the inferior piece of the anterior part of the atlas, corresponds with what Prof. Owen terms the anterior subvertebral wedge-bone; but I find its shape to be exceedingly different from that ascribed to the corresponding piece in *P. pachyomus*.

3. The sutures between this and the supero-lateral pieces are situated at a higher level on the face of the articular cup in *P. Etheridgii*. They are here, in fact, radii from the centre of that cup, while in the figure of *P. pachyomus* the sutures meet below the centre.

4. Prof. Owen describes no distinct supero-lateral pieces or median suture; and, not having seen them, he considers the upper two-thirds of the cup to be formed by a distinct mass, with which the neurapophyses have coalesced. In *P. Etheridgii* this mass is certainly nothing more than the bases of the neurapophyses themselves, which contribute, as in the Crocodile, to form the articular surface for the occipital condyle.

5. Prof. Owen conceives that the upper two-thirds of the articular cup (all but its extreme margin?) constitute the homologue of the os odontoideum, which is (as Rathke* proved eighteen years ago) simply the separately ossified central portion of the body of the atlas; the so-called body of that bone (the homologue of the inferior piece in the *Plesiosaurus*) being a distinct peripheral ossification.

I have just shown, however, that in *P. Etheridgii* the os odontoideum must be sought elsewhere, and I have not the slightest doubt that it is that osseous plate whose convex lateral edges are seen between the anterior portions of the atlas and the axis, and which ends below in the so-called second subvertebral bone.

6. I have not as yet met with any neural spine in the atlas of

* Rathke, Entwickelungs-geschichte der Natter, 1839, pp. 119, 120; also "Ueber die Entwickelung der Schildkröten," 1848. In the former essay, Rathke says of the "processus odontoideus," "Therefore this process is not an outgrowth of the epistropheus, but the body of the atlas; while that bone which is reckoned as the first cervical vertebra is not a perfect vertebra, having no true body. What is called its body is nothing but a modified inferior spinous process."

Plesiosaurus corresponding with the flattened and separate homologue of this part of a vertebra which is found in the atlas of the Crocodile; but the complete correspondence of the *Plesiosaurian* atlas and axis (in this reading of their structure) with those of the *Crocodilia* is highly interesting, as it harmonizes perfectly with the strongly crocodilian affinities manifested by many other parts of the organization of the *Plesiosaurus.* I reserve a lengthened comparison of the two structures for my Memoir, merely adding that Cuvier found the atlas and axis of his "Crocodile d'Honfleur" (a Teleosaurian) "soudés ensemble," the posterior face of the axis being concave*; and that, according to Von Meyer's figures, the atlas and axis of *Nothosaurus* were very similar to those of *Plesiosaurus*†.

The Structure of the Cranium.—The length to which these remarks have already extended, and the impossibility of rendering any account of the structure of the cranium intelligible without a large number of illustrations (which will be more fitly reserved for my forthcoming memoir), lead me to throw what I have to say into a few propositions, whose full proof will be adduced hereafter.

1. The structure of the Plesiosaurian cranium is best to be understood by comparing it with that of *Teleosaurus*‡, when its numerous crocodilian affinities become at once apparent.

2. In the *Teleosauria* (*Teleosaurus temporalis*) there is a singular aperture closely resembling in form and position the external nostril of the *Plesiosaurus,* though in the *Teleosauria* there is every reason to believe that the nostrils were, as in the Gavials, at the end of the snout. The bony margins of the aperture are, however, somewhat differently constituted in the two genera.

3. In the *Teleosaurus* the jugal bone is long and slender. In *Plesiosaurus Etheridgii* and others, I find a bony style of greater or less length, broken posteriorly, but having otherwise precisely the same relations and form as the jugal of the *Teleosaurus*§. This process is particularly well shown in a cranium (named *P. dolichodeirus*) in the Museum of the Society, and is figured by Mr. Conybeare in his restoration.

* Ossemens Fossiles, ed. 4. t. ix. pp. 306–7.

† Hermann von Meyer says (Die Saurier des Muschelkalkes) of *Nothosaurus*: "The atlas had a remarkably depressed superior arch, whose spinous process was inclined backwards at an angle of about 25°. The posterior articular processes were directed backwards; and below, a short lateral part, analogous to a hook-like cervical rib, appears to have been attached. . . . . The atlas and axis do not seem to have been anchylosed." (p. 30.) On comparing Von Meyer's figures, the similarity of the atlas and axis to those of *Plesiosaurus* is remarkable. The interspace left between the axis and atlas corresponds to that for the os odontoideum, and the projecting piece figured at the lower anterior edge of the axis may, I think, very possibly be the free lower end of the os odontoideum.

‡ My statements respecting the structure of the skull of *Teleosaurus* are based on my examination of two very beautiful specimens of *T. temporalis* in the Tesson Collection, now in the British Museum. I am informed that these crania were worked out from the matrix by M. Selys Deslongchamps, to whom therefore the credit of the discovery of any new points is properly due.

§ Hermann von Meyer figures a very similar process in *Simosaurus*, pl. 65. figs. 1 & 2.

4. Contrary to what is commonly stated, the post-frontal appears to me, in *P. Etheridgii* and *Hawkinsii* at any rate, to articulate with a bone, the homologue of the squamosal* of the Crocodile.

5. The squamosal of the *Plesiosaurus* seems to have been confounded by some with a process of the parietal.

6. The temporal fossa is divided by the post-frontal in the manner so characteristic of, though not absolutely peculiar to, the Crocodilian reptiles. The great superior fossæ correspond with the large superior temporal fossæ of the Teleosaurian, and even the narrowness and crested form of the upper surface of the parietal (supposed to be distinctive of the *Plesiosaurus*) are very closely approached in such *Teleosauria* as *T. temporalis*.

7. The exoccipital sends outwards and downwards a process which reaches the great quadratum, and between this below, the quadratum externally, and the squamosal above, there is a large aperture in the *Plesiosaurus*.

In the triassic *Enaliosauria*, however, the corresponding interval is, judging by Hermann von Meyer's figures of *Nothosaurus*, smaller in proportion, or, as in *Simosaurus*, absent (?). On the other hand, it is larger in the *Teleosauria* than in the existing *Crocodilia*.

8. The basi-sphenoid appears upon the base of the skull for a great space in the *Plesiosaurus*, while in the ordinary Crocodile it is not visible at all, being hidden by the pterygoids. Even in the Gavial, however, the basi-sphenoid shows itself fully on the base of the skull, while in the *Teleosaurus* it is as much exposed as in the *Plesiosaurus*, and presents a median ridge with a deep fossa on either side. There are a similar ridge and fossæ in *Plesiosaurus*, the latter having, I imagine, been mistaken for the posterior nares.

9. I believe the posterior nares were situated far forwards in the *Plesiosaurus*; for in the first place, the object of their being situated as in the Crocodile is not intelligible teleologically; and on morphological grounds we should expect to find them anteriorly situated, for the Gavial has them more forward than the Crocodile, and the *Teleosaurus* than the Gavial. In the latter, indeed, they are so far forward, that the pterygoids do not enclose them below at all. They are nearly on a line with the middle of the orbits.

10. The pterygoids of the *Plesiosaurus* send processes backwards to abut against the quadratum†. The ends of the corresponding bones are broken off in the *Teleosauria* I have examined.

11. The descending process of the basi-occipital is single in the ordinary Crocodile, but in the *Teleosaurus* it is divided into two widely separated tubercles as in *Plesiosaurus*.

12. The supra-occipital is widely separated from the edge of the occipital foramen by the exoccipitals in the Crocodile. In the *Teleo-*

* This is the bone commonly but erroneously termed the "mastoid" in the Crocodile. Rathke and Hallman have long since satisfactorily shown that the homologous bone has no relation with the true mastoid.

† These processes are particularly well shown in the very instructive specimen labeled 14,550 in the British Museum. I propose to figure this as well as some others in my Memoir.

saurus it comes close to that edge. In the *Plesiosaurus* it forms part of it.

13. The petrosal bone is covered externally by the quadratum in the Crocodile. In the *Teleosaurus* it is almost completely exposed, as in the *Plesiosaurus*.

These facts seem to me to have an especial interest when we consider the palæontological relations of the *Teleosauria* to the long-necked *Enaliosauria*, on the one hand, and to the *Crocodilia* on the other. Anatomically, as chronologically, the Teleosaurian bridges over the gap between *Nothosaurus* and *Alligator*.

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3. *On the* Coal *found to the South of* Concepcion, *in* Southern Chili. By Dr. C. Forbes, R.N. (In a Letter to the President.)

[Abstract.]

The coal* is found in seams alternating with shales and overlaid by calcareous sandstone ; fire-clay underlies the whole. The shales contain fine impressions of dicotyledonous leaves ; and some of the sandstones above the coal abound with casts of a Mactra-like bivalve ; and others with *Turritellæ*. From this association of fossils, Dr. C. Forbes believes that the coal is decidedly not of palæozoic age, and may be tertiary.

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4. *On a quantity of* Crabs *thrown up on the Beach in* Payta Bay. By Dr. C. Forbes, R.N. (In a Letter to Prof. Ansted, F.G.S.)

[Abstract.]

For some time previous to the occurrence of a severe earthquake-shock, on or about the 30th August 1857, the Bay of Payta swarmed with crabs of a kind not generally observed, and ten days after the earthquake they were thrown up on the beach, in a raised wall-like line, 3 to 4 feet wide, and to the height of about 3 feet, along the whole extent of the bay, and above highwater-mark.

At the same time as the upheaval of the crabs took place, the water of the bay became changed, from a clear blue, to a dirty blackish-green colour, much resembling that off the Island of Chiloe, Concepcion, and the southern parts of Chili. Ten days afterwards, Dr. C. Forbes found that living specimens of the crabs were still numerous in the bay, but all appeared to be sickly, and numbers came ashore to die.

There were no appearances of any alteration of the relative position of sea and land in the vicinity, nor had any ebullition of gases been observed ; although probably to both these causes combined the phenomenon described was due.

* For notices of the coal of Chili, see also Darwin's 'South America,' p. 125, and Mr. W. Bollaert's paper in the Roy. Geograph. Soc. Journ. vol. xxv. p. 172.

January 20, 1858.

William Adams, Esq., Ebbw Vale, Monmouthshire, and the Rev. Francis H. Morgan, M.A., Hemel Hempstead, were elected Fellows.

The following communications were read :—

1. *On the* Evolution *of* Ammonia *from* Volcanos. By Charles G. B. Daubeny, M.D., F.R.S., F.G.S., Professor of Botany in Oxford, &c.

In the year 1849, Wöhler ascertained that the copper-coloured crystals found so frequently in the ferruginous mass, technically called "bear" or "horse," which accumulates in the hearths of the iron-smelting furnaces, and which Dr. Wollaston a long time before had pronounced to consist of titanium, were in reality composed of the cyanide and nitride of that metal, containing 18 per cent. of nitrogen and 4 per cent of carbon.

It has been since found, that the same nitride is also obtained in the process recommended by Rose for procuring the metal, when chloride of titanium together with sal-ammoniac is heated in a glass flask; in which case metallic scales, which had been formerly regarded as consisting of metallic titanium, but which now turn out to be a compound of it with nitrogen, are left in the vessel after the other matters had sublimed.

The facts just mentioned, however interesting to a chemist, would not be of a nature to bring before this Society, were it not for their bearing upon one part of the Theory of Volcanos, namely on the evolution of ammonia, and the consequent presence of ammoniacal salts amongst the products of their operations.

This, then, is my excuse for proposing to occupy a few minutes of your time on this occasion with some comments upon these facts, and upon the inferences to which they appear to conduct us.

I should, perhaps, in the first instance remind you, that sal-ammoniac, or ammonia combined with muriatic acid, ranks amongst the commonest products of volcanic action, and is found in such quantities, efflorescing on the surface of newly ejected lavas at Vesuvius, as to be regarded worth collecting for the purposes of the arts.

The mode of its production has given rise to much speculation; but I shall confine myself to three hypotheses that have been suggested to account for it: namely, to one by Professor Bischoff, of Bonn; a second by Professor Bunsen, of Heidelberg; and a third by myself.

The first of these may, it is presumed, be dismissed in a few words.

It is founded upon the assumption that bituminous, coaly, or other organic matters exist in the neighbourhood of volcanos, by the decomposition of which ammonia comes to be generated *.

* See his 'Elements of Chemical Geology,' Engl. Transl. p. 212.

In reply to this, it may be sufficient to remark, that we have no evidence of the existence of such materials in volcanos generally, and that, if the ammonia evolved had been derived from such sources, it ought to be accompanied with bituminous exhalations, with carburetted hydrogen, and with other products arising from the distillation of such materials which have never been observed to be present *.

I will proceed, then, to consider the second hypothesis, that of Professor Bunsen; namely, that the lava, in flowing over the herbage existing on the surface of the land which it invaded, had caused the conversion of the nitrogenized matter present in it into ammonia, which, meeting with muriatic acid, a gas constantly present in volcanos when in a state of activity, was sublimed through the crevices of the lava-current in the form of sal-ammoniac.

Now, without pausing to consider how far the largeness of the quantity of sal-ammoniac evolved may be consistent with such an hypothesis, I will merely observe that its validity depends altogether upon the question whether the salt is confined to the lava-currents, or has been met with likewise amongst the products derived from the crater itself.

In my memoir on the eruption of Vesuvius in 1844, published in the 'Philosophical Transactions,' I have already stated the latter to be the fact; but it has since been denied with reference to the volcanos of Iceland by Bunsen, and disputed in the case of Vesuvius by Scacchi, one of the most distinguished observers of volcanic phenomena at present in Naples.

It nevertheless appears at length to be substantiated on good authority, by the recent researches of Palmuri with respect to the products of the eruption or series of eruptions which has been going on for several months past, and which has not yet terminated.

We are therefore driven to resort to some other solution, which must be independent of the supposed presence of organic matter in any form; for undoubtedly nothing of the kind can exist within the focus at which the volcanic operations have been for so long a period carried on.

The hypothesis I myself brought forward some years ago to account for the phenomenon, and which assumed that gaseous hydrogen, although incapable of combining with nitrogen under ordinary pressures, might unite with it under that exercised upon it in the interior of the earth, is not open to the same objections as the two already commented upon; but it is unlikely, perhaps, to meet with much countenance, until the experiment of bringing the gases

* Carburetted hydrogen was stated by myself ('Volcanos,' p. 267; from personal observations made in 1824, embodied in my memoir on Sicily, published in 'Jameson's Journal') to be abundant in certain lakes situated near the base of Etna, as well as at Macaluba in the centre of the island. This M. Deville, in his Memoir ('Ann. de Chim.' Jan. 1858, p. 62), has confirmed, stating with great apparent accuracy the proportion which this gas bears to others present. But these latter evidently belong to the class of "Salses," and must be distinguished from true volcanos, in which carburetted hydrogen has, I believe, never yet been detected.—See my Remarks on Macaluba, 'Volcanos,' 2nd edit. p. 539.

together in a highly condensed condition shall have been tried in an unexceptionable manner.

Perhaps indeed, if, as Professor Bischoff states, a mixture of the two gases has been submitted to a pressure of 50 atmospheres without combining, the question is not likely soon to be set at rest, since it would not be easy to apply an artificial pressure equal to that to which they would be subjected at the bottom of the ocean; where, at the depth of a mile and a quarter, the pressure is equal to 2809 lbs. to the square inch, or to at least 187 atmospheres*.

Might not the experiment be tried by sending down to a great depth in the ocean a vessel charged with a mixture of the two gases, furnished with a piston, which should exert upon the contents a pressure equal to that of the weight of water incumbent?

But the affinity which certain metals possess for nitrogen seems to me to afford a more solid ground upon which to build a theory to account for the fact before us.

Not to speak of the simple combustibles, phosphorus and sulphur, and the metalloids, potassium and sodium, which form combinations with nitrogen,—zinc, copper, and iron may be instanced as bodies capable of combining with it,—the nitride of the latter even disengaging ammonia when heated in contact with water.

As these combinations, however, require for their production the previous formation of ammonia, through the medium of which alone they are known to be brought about, they cannot be appealed to as proving that the metal in question is capable of uniting with gaseous nitrogen, and are only cited as indications that nitrogen possesses a wider range of affinities than had formerly been attributed to it.

To meet the requirements of my hypothesis I must go a step further, and appeal to the late researches, which, it seems, that Wöhler, in conjunction with M. H. Sainte-Claire Deville†, of Paris, has instituted with regard to the metal titanium, undertaken with a view of elucidating the discovery, which he had announced in 1849, concerning the combination which this body forms with nitrogen. Now, it appears from the recent researches of these two chemists, reported upon in the 'Comptes Rendus' for October 1857 (and which I now find detailed in a more extended form in the 'Annales de Chimie' for the present month, January 1858), that titanium absorbs nitrogen from the air, even in preference to oxygen; titanic acid being reduced at a high temperature whenever air is admitted, and a nitride of titanium being formed in consequence. Such indeed, it is stated, is the affinity of this metal for nitrogen, that titanium can only be obtained pure by heating the titanic acid in an atmosphere of pure hydrogen; for if the operation be conducted in the presence of nitrogen, a nitride is sure to be produced. The union, indeed, takes place with so much energy as to generate light and heat, and thus to constitute a genuine case

* The pressure of the atmosphere may be estimated at about 15 lbs. to the square-inch; the pressure of the sea at $1\frac{1}{4}$ mile is $187 \times 15 = 2805$.

† Ann. de Chimie, Jan. 1858, p. 61.

of combustion, in which nitrogen, and not oxygen, acts as the supporter. After the operation is concluded, a metallic matter, of a copper-red colour, sprinkled with brilliant crystalline laminæ, is produced; and, in proof that this contains nitrogen, it may be sufficient to state, that hydrate of potass extricates from it sufficient ammonia to saturate a large amount of muriatic acid.

It is even not necessary to bring the metal into contact with pure nitrogen; for if a closed charcoal-crucible containing titanic acid be kept at a high temperature for some hours, sufficient nitrogen penetrates the porous texture of the vessel to displace the oxygen, and to form with the metal a nitride, capable, as in the preceding instance, of being decomposed by hydrate of potass into ammonia and titanic acid. It is true, that in order to effect a combination between the metal and the nitrogen, the titanic acid must first be reduced, and consequently the presence of carbon in some form or other would appear to be an essential condition. But if such a reaction be conceived as taking place, not near the surface, but at such depth as that at which the advocates of the Chemical Theory of Volcanos would place the still unoxidized, or but partially oxidized, nucleus of the globe, no reducing agent would then be required to bring about the supposed union*.

Other experiments are given by Wöhler, all tending to establish the same point; but enough probably has been said to show that, at an elevated temperature, titanium exerts a strong affinity for nitrogen, and that the compound which it forms evolves ammonia under the agency of the fixed alkalies. Now, that titanium is present in most volcanos, is obvious from the occurrence of titanite in several places in Auvergne, at Kaiserstuhl in Germany, at Teneriffe, in Mexico, and amongst the recent as well as the older products of Vesuvius and its neighbourhood. And, if it be objected that it is found in an oxidized and not in a metallic form, the same remark applies equally to all the other bases which are present along with it.

It may, however, be fairly asked, whether its probable quantity within the mountain be sufficient to account for the large amount of ammonia often disengaged?

This, indeed, is a question to which I should be loth to give an affirmative reply; and therefore, whilst maintaining that the affinity of titanium for nitrogen does furnish us with a *vera causa* for the presence of ammonia amongst volcanic products, I am more disposed

* This ammonia would, of course, combine with muriatic acid so soon as ever it came into contact with that body; but the experiments of Gay-Lussac, which most chemists have repeated, show that, at a high temperature, a chloride in contact with silica or alumina has its chlorine set free, whilst its base forms a compound with the silicic or other acids present.

The existence, therefore, even of common salt at the spot where the nitride was formed, would not prevent the alkalies from exerting their proper action upon the nitride, and giving birth to ammonia.

The only difference in the result would be, that, in this case, the formation of sal-ammoniac would be immediate, whilst otherwise, it might take place during the passage of the gas upwards to the external air.

to insist upon the fact, as supplying us with an argument from analogy, that other bodies which are present in volcanos may, through a similar reaction, be instrumental in bringing about the same result.

It seems hardly possible that the affinity for nitrogen should be confined to titanium alone; and indeed I have pointed out, that under different circumstances it may be proved to extend to several of the commoner metals.

Is it not, therefore, more probable, that in the interior of the globe, where high pressure and other circumstances may modify the nature of those reactions which take place under our eyes, nitrogen combines directly with other bodies besides titanium—with iron for instance, or possibly even with hydrogen; and that it is in this manner that that amount of ammonia which often finds its way through the orifices of a volcano may be generated, seeing that its abundance is often such as would lead us to doubt whether the nitride of a metal comparatively so rare as titanium could alone afford it; at least, if the quantity found on the surface in such localities is to be regarded as an index of the proportion which it bears to the other principles present in the interior of the volcano?

P.S.—Since writing the above, my attention has been called by a friend to a more recent paper by M. Ste.-Claire Deville, reported upon in the 'Comptes Rendus,' which also I find given *in extenso* in the January number of the 'Annales de Chimie' for this year 1858. From this it appears that boron also, like titanium, has the property of combining directly with the nitrogen of the air, and that the compound which it forms with it possesses alike the property of evolving ammonia under the influence of the alkaline hydrates*.

This fact is the more significant, from the occurrence of boracic acid in the craters of certain volcanos, as in the Æolian Islands, accompanied in this instance, as I have myself found, with muriate of ammonia; and, where the two are thus associated, we should not be disposed to look for the source of the ammonia further than to the nitride of boron generated within the interior of the volcano.

Boracic acid, however, does not seem to be usually present in the lavas of Vesuvius, for it has been only once observed amongst the products of its eruptions, namely by Monticelli and Covelli in 1817. I should, therefore, be unwilling to attribute the formation of ammonia in this volcano generally to the agency of boron, and am rather disposed to appeal to the fact as another proof that gaseous nitrogen, instead of that chemical indifference which has been commonly attributed to it, possesses in fact a somewhat wide range of affinities,

* The discovery of the compound of nitrogen and boron was made in 1841 by Mr. Balmain, who, however, combined the two only by indirect methods. Mr. Warington also in 1854 (Report Brit. Assoc. 1854, Sections, p. 76) pointed out the existence of this very combination in the crater of the Island Volcano, suggesting that the sal-ammoniac so abundant in that locality might be due to the decomposition of the nitride by the action of steam. But the more recent researches alluded to in my text first established that this nitride might be formed by the direct union between boron and nitrogen.

and therefore may, without violence to analogy, be supposed to give rise to various nitrides, each of which is capable, under certain conditions, of disengaging ammonia.

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2. Experimental Researches *on the* Granites *of* Ireland. By the Rev. Samuel Haughton, M.A., F.G.S., Fellow of Trinity College, and Professor of Geology in the University of Dublin.

Part II. (*Continued*).—On the Granites of the North-east of Ireland*.

I. Potash-Granites of the North-east District.
II. Soda-Granites of the North-east District.

In the concluding part of my paper on the Granites of the North-east of Ireland†, I have expressed the opinion that the granites of the neighbourhood of Newry are divisible, like those of Leinster, into two types, viz, potash- and soda-granites; and that, if a line north of east be drawn through Newry, the granites south of this line are potash-granites, including the Mourne granites, while the granites to the north of this line are soda-granites. As I have obtained additional confirmation of this opinion since the reading of my paper, it will be useful here to sum up the facts known relative to the two kinds of granite in the two districts under consideration.

I. Potash-Granites of the North-east District.

I shall exclude from this discussion the granites of the Mourne district north of Carlingford Bay, as they form a peculiar group, characterized by the presence of distinct crystals of albite, and nests of crystallized quartz.

The following Tables contain the analyses and atomic quotients of five granites of the potash-type, south and south-east of Newry:—

No. 1. Granite from the base of Slieve na glogh, medium-grained, composed of quartz, white felspar, and green mica.

No. 2. Granite from Grange Irish, near Carlingford, fine-grained, composed of quartz, white felspar, and hornblende.

No. 3. Granite from Wellington Inn, south of Newry, medium-grained, composed of quartz, white felspar, and green mica.

No. 4. Granite from Fathom Lock, east of Newry, porphyritic, of a general pink colour, with white nests and minute cavities lined with very small crystals of quartz.

The paste consists of a reddish felspar, with minute specks and streaks of dark-green chloritic hornblende, and small hexagonal crystals of quartz. The felspar-crystals are semi-transparent, of good lustre; size $\frac{1}{2}$ in. by $\frac{1}{8}$ in. The white roundish nests are probably white felspar, with flattish faces and scarcely any lustre. Epidote and green earth appear in the small cavities in connexion with the minute hexagonal crystals of quartz.

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* For Part I. and Part II. see Quart. Journ. Geol. Soc. vol. xii. p. 171 & p. 188.
† *Loc. cit.* p. 198.

No. 5. Granite from Jonesborough Mountain, south of Newry, presenting a general resemblance to that last described, with the exception that it contains no white nests or small cavities.

The paste is the same as the last (No. 4). The crystals of pinkish felspar are more distinct and numerous than in the last rock. No quartz is visible, except in connexion with some occasional and partially formed cavities. Blackish-green stains and patches accompany the quartz, as in No. 4.

Table I.—*Analyses of Potash-Granites.*

	1.	2.	3.	4.	5.
Silica	70·48	71·41	71·24	72·08	71·00
Alumina	14·24	12·64	14·36	14·36	13·60
Peroxide of iron ...	3·72	4·76	3·36	3·02	3·28
Lime	1·48	1·80	1·48	1·17	1·06
Magnesia	0·40	0·63	0·64	0·36	0·51
Potash	4·26	5·47	4·09	5·58	5·73
Soda	3·66	3·03	3·13	2·91	3·27
Protoxide of iron ..	......	......	......	1·50	1·30
Loss by ignition ...	1·59	......	1·50	......	......
Totals	99·83	99·74	99·80	100·98	99·75

The following Table shows the atomic quotients found from the preceding analyses in the usual manner :—

Table II.—*Atomic Quotients of Potash-Granites.*

	1.	2.	3.	4.	5.
Silica	1·566	1·586	1·583	1·600	1·577
Alumina............	0·274	0·243	0·276	0·276	0·261
Peroxide of iron...	0·046	0·059	0·042	0·038	0·041
Lime	0·053	0·064	0·053	0·042	0·038
Magnesia	0·020	0·031	0·032	0·018	0·025
Potash	0·090	0·116	0·087	0·119	0·122
Soda	0·118	0·098	0·101	0·094	0·105
Protoxide of iron .	......	......	......	0·041	0·036

Adding together the protoxides and peroxides in the preceding Table, we obtain the following :—

Table III.—*Atomic Quotients of Silica, Peroxides, and Protoxides in Potash-Granites.*

	1.	2.	3.	4.	5.	Average.
Silica	1·566	1·586	1·583	1·600	1·577	1·582
Peroxides ...	0·320	0·302	0·318	0·314	0·302	0·311
Protoxides...	0·281	0·309	0·273	0·314	0·326	0·301

The preceding results show that these granites have a general family resemblance, and that they should be grouped together. The quantity of green mica, hornblende, or chlorite is small; and, if it be neglected, we find, from the column of average atomic quotients, the following number of atoms of quartz and felspar in the potash-granites of the Newry district:—

$$Q = 0{\cdot}358$$
$$F = 0{\cdot}306.$$

From these numbers, we find the per-centages of quartz and felspar,

Quartz = 16·11 per cent.
Felspar = 83·91 ,,

100·02

If we take into consideration the mica or hornblende present in the granite, and consider it to be the same as the green mica of the Mourne range, described in page 191 of my former paper, we shall have the following equations to determine the number of atoms of quartz, felspar, and mica:—

$$Q+4F+5M=1{\cdot}582$$
$$F+3M=0{\cdot}311$$
$$F+2M=0{\cdot}301.$$

From these equations, we readily obtain

$$Q=0{\cdot}408$$
$$F=0{\cdot}281$$
$$M=0{\cdot}010.$$

Assuming the atomic weights of quartz and the green mica as 45 and 500 respectively (see p. 201. vol. xii.), we obtain finally the following:—

Mineralogical Composition of Potash-Granites.

Quartz......	=18·36
Felspar	=76·66
Green mica..	= 5·00
	100·02

II. Soda-Granites of the North-east District.

The soda-granites of the North-east of Ireland occur, as I have already observed, to the north of Newry, and are characterized for the most part by pinkish or reddish translucent felspar and black mica,—circumstances indicating the presence of iron.

The following Table contains the analyses of four of those granites.

No. 1. Granite from Newry Quarry, medium-grained, composed of quartz, white felspar passing into pale pink, translucent, and black mica.

No. 2. Elvan-granite from Newry Quarry, intersecting the former in dikes and veins, fine-grained, pink. Besides the elvan-dikes, dikes of dark green-stone also penetrate the granite (No. 1) in Newry Quarry.

No. 3. Granite from Goragh Wood station, north of Newry, medium-grained, composed of quartz, white felspar and black mica.

No. 4. Granite, of gneissose structure, from the cutting south of Goragh Wood Station, medium-grained, composed of quartz, red felspar, and green mica, arranged in a flaky gneissose manner.

TABLE IV.—*Analyses of Soda-Granites.*

	1.	2.	3.	4.
Silica	64·60	74·20	62·08	66·56
Alumina	14·64	10·84	15·92	13·52
Peroxide of iron	6·04	1·88	7·72	6·76
Lime	3·16	2·84	5·52	1·20
Magnesia	2·80	Trace	2·16	1·32
Potash	3·15	3·12	2·19	2·73
Soda	4·02	4·77	3·34	3·75
Protoxide of iron	......	......	......	0·18
Loss by ignition	1·13	0·83	0·89	2·19
Totals	99·54	98·48	99·82	98·21

The elvan-dike (No. 2) differs from the other three granites in the large per-centage of quartz, which is a general characteristic of elvans and felstones, but agrees with them in the relative proportions of the two alkalies.

Reserving the elvan-granite for a separate discussion, I shall now tabulate the atomic quotients of the other granites, which appear to belong to the same family of rocks.

TABLE V.—*Atomic Quotients of Soda-Granites.*

	1.	3.	4.
Silica	1·435	1·375	1·479
Alumina	0·281	0·306	0·260
Peroxide of iron	0·075	0·096	0·084
Lime	0·011	0·019	0·004
Magnesia	0·140	0·108	0·066
Potash	0·067	0·046	0·058
Soda	0·130	0·108	0·121
Protoxide of iron	......	......	0·005

Adding together the silica, peroxides, and protoxides from the preceding Table, I find—

TABLE VI.—*Atomic Quotients of Silica, Peroxides, and Protoxides in Soda-Granites.*

	1.	3.	4.	Average.
Silica	1·435	1·375	1·479	1·429
Peroxides	0·356	0·402	0·344	0·367
Protoxides	0·348	0·281	0·254	0·294

It is evident from a comparison of Tables I., II., III., with Tables

IV., V., VI., that the soda-granites are not so persistent in their character and composition as the potash-granites of the same district. This result is in accordance with that which I formerly deduced from an examination of the potash- and soda-granites of Leinster, and admits, as I think, of an explanation which I shall presently give.

Assuming that the mica present, as green or black mica, in these granites is the green mica of Mourne, I find the following equations by the method described in Vol. xii. p. 201:

$$Q+4F+5M=1\cdot429$$
$$F+3M=0\cdot367$$
$$F+2M=0\cdot294.$$

From these equations, I find

$$Q=0\cdot472$$
$$F=0\cdot148$$
$$M=0\cdot073.$$

And, using the atomic weights of quartz and green mica already given, I obtain finally—

The Mineralogical Composition of the Soda-Granites of the North-east of Ireland.

Quartz....	21·24
Felspar ..	41·45
Mica	36·50
	99·19

It may here be observed, that the quantity of free silica or quartz in the soda-granites is comparable with that of the potash-granites; but it is much more visible to the eye than in the latter, although from the analyses it appears that the soda-granites are deficient in silica, as compared with the potash-granites, containing, in fact, 7 or 8 *per cent.* less; this is due to the usually large quantity of mica present in the soda-granites, as this mineral requires much less silica than felspar. This example shows how necessary it is to check the impressions of the eye by the severer test of laboratory analysis. A geologist, speculating on the origin of these granites, and not having the resources of chemistry at his command, might pronounce them to be richer in silica than the potash-granites, whereas it appears that, like other soda-granites, they are really more basic, and may have been formed from potash-granites by the addition of iron, magnesia, lime, and soda.

From the analysis of the pink elvan-dikes penetrating the granite of Newry Quarry, it appears that the atomic quotients of silica, peroxides, and protoxides, are as follow:—

Atomic Quotients of Silica, Peroxides, and Protoxides in the Soda-Elvan.

Silica......	1·649
Peroxides ..	0·231
Protoxides ..	0·321

From the fact that the atoms of protoxides exceed the atoms of peroxides, it appears that this elvan cannot be composed of quartz, felspar, and green mica.

If we suppose that hornblende replaces mica in this elvan, and that half the iron is present as protoxide, and that all the alkalies belong to the felspar of the rock, it is easy to calculate the following

Mineralogical Composition of the Soda-Elvan.

Quartz....	=29·52
Felspar ..	=60·15
Hornblende=	8·81
	98·48

From the discussion of the granites of the potash- and soda-type in this district, I feel disposed to draw the following conclusions, which are confirmed in a remarkable manner by some observations I have recently made, in conjunction with Mr. Jukes, in the County Wicklow:—

1st. That both in Leinster and the county Down, the potash-granites are more constant in composition, both mineralogical and chemical, than the corresponding soda-granites.

2ndly. That the potash-granite appears to be the standard type of granite, from which other granites and crystalline rocks are formed by the addition of bases; for example, the anorthite syenite of Carlingford, and the soda-granites of Newry, and in Leinster the outlying patches of granite between the main chain and the sea.

3rdly. That the potash-granite of Leinster is more persistent in external character than the potash-granites of Newry, although the latter are equally constant in chemical composition.

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3. *On the* PALÆOZOIC ROCKS *and* FOSSILS *of the* STATE *of* NEW YORK. Part II. *The Stratigraphy and Classification of the Series.* By J. J. BIGSBY, M.D., F.G.S.

[The publication of this Paper is deferred.]

(Abstract.)

IN the synoptical view of the strata and fossils of the palæozoic basin of New York, read before the Society Nov. 18, 1857, the author desired to arrange the vast stores of information contained in the Official Reports of the State Geologists of New York in a methodical and accessible form; and in this Second Part of the Memoir he treated succinctly of the stratigraphical arrangements hitherto used, and the classification now adopted by himself. This is but little modified from that proposed by De Verneuil; and is mainly characterized by the union of certain sections of the series into natural groups, and by the establishment of a distinct middle Silu-

rian stage, and an equally distinct middle Devonian stage. The lithological and palæontological characters of the several groups of strata were then treated of in succession; their resemblances and differences, in these respects, being carefully noted. From the consideration of the stratigraphical details contained in this and the preceding paper, Dr. Bigsby deduces two main conclusions; namely, 1. That, from the Potsdam sandstone to the summit of the Carboniferous rocks, these strata were laid down in comparative quiet; subject to occasional, vertical, variable, secular oscillations, which led to considerable superficial changes. 2. That their elevation, foldings, fractures, and metamorphism were effected after the deposition of the whole; in a single prolonged transaction, and principally in a N.E. and N.W. direction, along the present Appalachian ridges and their continuation from Labrador to near the Gulf of Mexico. The evidences on which these two propositions rest were next detailed; and the views of the Professors Rogers on these points, and the author's objections, were stated in full.

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PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPERS.

On the Age *of some* Sands *and* Iron-Sandstones *on the* North Downs. By Joseph Prestwich, Esq., F.R.S., Treas. G.S., &c. *With a Note on the* Fossils; by S. V. Wood, Esq., F.G.S.

[Read January 21, 1857*.]

The lower and central tracts of the valley of the Thames, from Reading to the sea, consist of Eocene strata, with a limited covering of Crag on the sea-board of Essex and Suffolk. This mass of Tertiaries is skirted on the south of the Thames by a belt of chalk, which rises by a gradual and continuous slope, broken by numerous small transverse valleys, until it attains an average height of from 500 to 600 feet: it is then abruptly escarped, forming a cliff-like declivity stretching east and west, and at the base of which extend the Lower Cretaceous and Wealden series. This elevated chalk-tract is about ten miles broad at Dover and Canterbury, and ranges westward, with a variable width of six or eight miles, to Guildford, where it contracts to a narrow ridge not half a mile broad. These Downs form a distinct and marked division between the Tertiary strata of the synclinal Thames Valley, and the anticlinal dome-plain of the Weald: they exhibit throughout a chalk-surface, either quite bare or covered on the hill-tops by a thin capping of reddish clay, sand, and flints, with, here and there, an outlier of the Lower Tertiary strata rising above the general level of the chalk-plateau, and forming slightly detached and more conspicuous hills. These outliers are continued at a few places to the very edge of the chalk-escarpment.

Besides the more general drift, and the few local Tertiary outliers, there are, however, scattered commonly on the very summit of the North Downs, from Folkestone to Dorking, a few masses of sand, with subordinate gravel- and ironstone-bands, but generally so much disturbed and so mixed up with the drift, that they appear, and have

* For the other communications read at this Evening Meeting, see Quart. Journ. Geol. Soc. vol. xiii. p. 212.

usually been taken, to form part of it*. They are to be seen on the Chalk Downs above Merstham; I had met with them on the chalk-escarpment near Otford in Kent, at Vigo Hill, again at places near Maidstone, and thence, in increasing importance, to the Downs above Folkestone. At the latter place, on the top of the hill on the Dover road, some of the best sections (small though they are) of these strata are exposed. I have not been able to trace the width of the deposit for more than a mile or two. It seems confined to the higher grounds.

It is the consideration of the age and geological position of these sands and iron-sandstones that forms the subject of the present inquiry. The sands are usually of a light buff-yellow or ochreous colour, though occasionally greenish, siliceous, but mixed with more or less clay commonly red, passing in places into small quartzose grits, and generally containing subordinate seams and bands of coarse iron-sandstone, ironstone grit, and some flint-pebbles. The whole is very irregular in its mode of occurrence, reposing upon a much-worn surface of the chalk, ordinarily without any distinct stratification, or rather the stratification is obliterated, the seams of ironstone being almost invariably broken and fragmentary. There is, however, in all the larger outliers a certain amount of regularity, a certain uniformity of composition, and a distinctiveness of character, which, notwithstanding their rubbly condition, led me to believe that they formed part of some sedimentary deposit *in situ*, and that they were not drift-beds. I was nevertheless unable, in the absence of superposition and of fossils, to come to any satisfactory conclusion with regard to their age; I had, however, satisfied myself that the ironstones at least were not drifted from the Lower Greensand, for on the chalk-hill above Merstham I had found a few blocks of this ironstone† full of *chalk-flint*-pebbles together with some unrolled flints, and again on the Folkestone chalk-cliffs. They are therefore newer than the Chalk. The question then arose, to which of the Tertiary strata these ironstones belonged; and as in East Kent there is found, under the London Clay, a bed of light-yellow siliceous sand, with a subordinate bed of

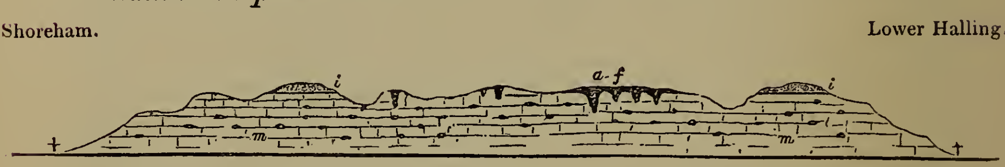
* It has even been a question whether the fragments of iron-sandstone belonging to these beds have not been drifted from the Lower Greensand of the Wealden area. Such ironstone-fragments, or "clinkers," as they are sometimes called, are often found in abundance in the drift-gravel of the transverse valleys of the Chalk Downs and in the Thames Valley. These I believe to be derived from the sands and ironstones of the North Downs, although in mineral character they are difficult to distinguish from the ironstones of the Lower Greensand. At the same time, I would by no means say that all the ironstone-fragments of the Thames-valley drift were derived from the North Downs. In the neighbourhood of Farnham they can in fact be distinctly traced from the Lower Greensand through the valley of the Wey into the Tertiary area; again through the gorge of the Stour, of the Medway, from the Wealden area to the lower levels of the Tertiary area. But I doubt whether the abundant flint- and ironstone-gravel of the deep lateral vales which do not traverse the downs, but commence at or near their summit-ridge, and open into the Tertiary area only, be not local and derived from the adjacent chalk and the superincumbent ferruginous sands, and that they are not transported from the Wealden area.

† There apparently mixed with the drift; but no section is exposed.

coarse and occasionally pebbly iron-sandstone, in some places fossiliferous, at other places without fossils, and often closely resembling in mineral character the ironstones on the Downs, it seemed at first sight most natural to suppose those blocks might be remnants of these beds mixed with the drift.

It might also be a question whether the loamy sands and ironstone were not portions of the Lower Tertiaries *in situ*, but modified in structure and character in consequence of their being nearer the shore of the Old Tertiary sea than the main mass between Faversham and Canterbury. But against this view I found that in all the outliers of Lower Tertiary strata, dotted at intervals over the North Downs even to the very edge of the escarpment, the sands and associated beds retain their clear, undisturbed, more uniform and fresh appearance, and general lighter colour, exhibiting in these isolated masses an exact counterpart in their structure and aspect to the same beds in the central Tertiary mass of the Thames Valley*. I further found that the loamy sands and ironstones formed outliers, often lower, or on a level with those of the Lower Tertiary strata, between which they seem to run as shown in the following section:—

Fig. 1.—*General Section from the Valley of the Medway to the Valley of the Darent, parallel with and near to the edge of the Chalk Escarpment.*



a—f, Loamy yellow sands. *i*, Lower Tertiary sands and pebble-beds. *m*, Chalk.

Above Otford and at Vigo Hill†, the beds consist of fine argillaceous buff-yellow sand. There is a much better exhibition of them at the hamlet of Paddlesworth, about four miles W.N.W. from Folkestone, on the very summit of the Chalk Downs, and at a height of probably about 600 feet above the sea. They there form a slightly detached hill, and consist of 30 to 40 feet of ochreous and ferruginous sands, more or less argillaceous, with subordinate fine quartzose grits and broken beds and seams of iron-sandstone,—some of these forming blocks of 3 to 4 feet wide by 1 foot thick, or even more. These blocks, which are common in and about the hamlet, sometimes contain flint-pebbles and unrolled flints. The fields in the neighbourhood are strewed over with fragments of ironstone, and in a few of these I found on one occasion some pieces of fossil wood pierced by the *Teredo*, together with that which appeared to be the cast of a bivalve shell. Yet on the neighbouring shore at Folkestone, which is covered at

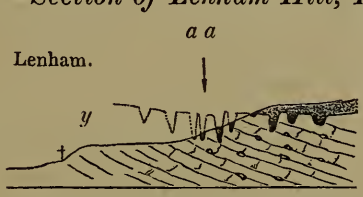
* The Tertiary sands also never present in Kent or Surrey the variable coarse quartzose grits and loamy sands prevailing in the Vigo and Folkestone-hill beds; whilst the flints found in the former are always much more worn.

† Ten years since, a good section of these sands was exposed here, but on a recent visit I found only one small opening preserved in a sand-pipe on the side of the lane descending the escarpment.

places with blocks fallen from the top of the cliff, and presenting therefore very favourable opportunities for examination, I have not found a single fossil.

The question was in this state, when, in the month of December 1854, Mr. Rupert Jones wrote to me from Charing (near Ashford in Kent), to communicate an interesting fact which he and Mr. Harris had noticed in that neighbourhood. He therein stated,—"The sand-pipes along these hills (from Harrietsham to Charing) abound with fragments of the ferruginous rock of the 'basement-bed' (of the London Clay). This is often a conglomerate, and I recognize the pebbles of this conglomerate as being frequent in the 'pipes.' I observe that it abounds with casts of Pecten, Pectunculus, Calyptræa, &c., but there are none of Melania and Cerithium. We find this iron-rock dispersed among the chalk-flints in the 'pipes,' and also sometimes in the sand-cores of the pipes. There are some large ironstone-fragments in which fossils are absent, but, as other pieces retain but faint traces sometimes, I think that all the pieces may be from the basement-bed." This letter was followed by a considerable collection of the specimens alluded to. In some of the pieces of ironstone the fossils were extremely numerous, but they were all in the state of casts and impressions of species difficult to determine, and of genera common in great part to the Lower Tertiaries; and as they in fact looked a good deal like the fossiliferous ironstone of the sands under the London Clay at Boughton, near Faversham, my first impression was rather in favour of such a conclusion. Still there were some fossils which did not belong to that period—there were *Lunulites*, a large *Terebratula*, a species of *Emarginula*, and some peculiar spines of *Echini*, such as I had never met with in our Lower Tertiary strata; not being able, however, to form a decided opinion on the subject or to obtain one from any palæontologist to whom I showed the specimens, I put them on one side waiting further evidence. It was not until Nov. 1855 that I had an opportunity of visiting the spot, and I found Mr. Jones's report quite correct as to these masses of ironstone being in detached blocks in sand-pipes, and mixed up with sandy gravel, clay, and flints. The following is a general section of the hill *:—

Fig. 2.—*Section of Lenham Hill, Kent.*



The dotted line, *y*, shows the probable extension of the fossiliferous beds, on the surface of the Chalk, over the hill, and their former extension in the direction of the Weald.

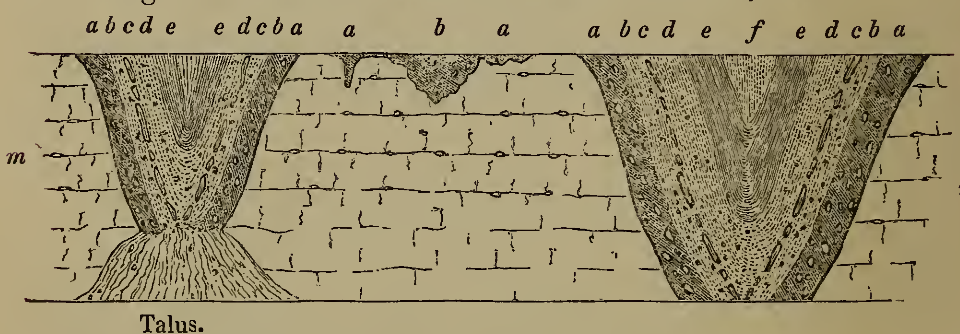
The blocks of ironstone are found irregularly mixed with sand and gravel in the core of the pipes *a, a,* the sides of which are lined

* This section is now much obscured.

with unrolled chalk-flints imbedded in a brown and ferruginous clay. To find similar fossiliferous blocks *in situ*, I re-examined the district between this ridge and the Thames, but without success. I found, however, at another chalk-pit between Lenham Hill and Harrietsham Hill, and distant seven-eighths of a mile W.N.W. from the Lenham pit, some larger sand- and gravel-pipes, in which the more defined structure led me to conclude that the sand- and iron-stone of these pipes were not portions of drift, but were part of a deposit which once spread in regular beds over these hills, and a portion of which had been let down as it were into these pipes, by the gradual dissolution of the chalk at these spots, in the way I have described in a former paper*.

When a subsequent denudation removed the mass of the deposit from that area, these fragmentary portions of the sands and ironstones were protected by their position in the chalk, and remain as evidence of its former wider extension. The Harrietsham pit shows the following interesting section:—

Fig. 3.—*Section on the Hill above Harrietsham, Kent.*

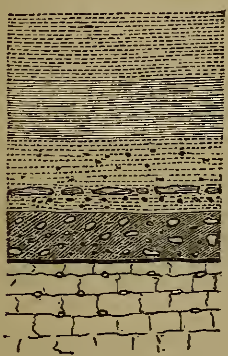


f, *e*, Fine light-red and yellow sands, in parts very argillaceous.
d–b, Greenish sand, more or less argillaceous, with a subordinate bed or seam of ironstone concretions (*c*). In places *c* reposes directly on *a*.
a, Unrolled chalk-flints in brown and black clay. *m*, Chalk.

I found only a few traces of fossils† in this pit, except some doubtful vegetable or spongiform casts on the surface of the ironstone, of the size of fingers, ramified and entirely covering some blocks. Flint-pebbles and a few very small quartz-pebbles occur in the beds *b–d*, and are often encased in the ironstone, which also sometimes contains unrolled flints, as in bed *a*. Now, as these pipes are cylindrical, and as each core of sand is symmetrical, with its several layers following a like order of succession, and retaining a nearly uniform thickness; and further, as the ironstone-band holds in each pipe the same relative position, its separate fragments pitching downwards with the curve assumed by the sand, it is to be inferred that these are let-down portions of strata, of which the original structure was horizontal and formed as in fig. 4.

* Quart. Journ. Geol. Soc. vol. xi. p. 64.
† The cast of a *Cardium* has since been found in the ironstone here.

Fig. 4.—*Diagram-section of the Ironsands in their original horizontal position.*



Apart from the great scarcity of shell-impressions, the ironstones in this pit are precisely similar to those in the Lenham pit; and it is to be observed that there also only portions of the ironstone contain fossils. Amongst the fossils sent me by Mr. Jones was a specimen of a large *Terebratula*; and, when afterwards at Lenham, I was fortunate enough to discover another tolerably perfect cast, and it suddenly struck me, from this and other fossils, that it might be the large Crag species, both from its size and general appearance, and from the absence of any species of that magnitude in our Eocene series. On hastening to compare it with the figures in Mr. Davidson's Monograph, I found that it bore the closest resemblance in figure and size to the *T. grandis*. I again examined the other fossils, but, with the exception of the impression of a *Scalaria*, which resembled the *S. subulata*, I could obtain no satisfactory result. In the summer of 1856 I made another visit to Lenham, and found, in addition to former species, a large Mya-shaped shell †, also different to any of the Lower Tertiary fossils with which I was acquainted, and reminding me of a Crag species. On mentioning these facts to Mr. Searles Wood, he kindly undertook to examine the specimens, and has favoured me with the appended report (see p. 333).

I must confess to hold a stronger opinion on the subject than Mr. Wood, for there are collateral circumstances which greatly strengthen my belief of these beds belonging to the Crag, little as I was prepared to meet with the Crag at such an elevation and such a distance from the main mass. In the first place, I know of no Eocene strata in the London Tertiary area quite like this deposit in its lithological structure. Secondly, no London Clay or Lower Tertiary strata contain any *Terebratula* that can be compared to the *T. grandis*, or a *Lutraria* like the specimen from Lenham; whilst no *Echini* with club-shaped spines, nor *Emarginulæ*, *Mactræ*, nor *Nassæ* have hitherto been met with in the London Clay, or in the beds of sand beneath it; again, *Bryozoa*, which are common at Lenham, are

* These appear in other places to pass upwards into loamy yellow sands with subordinate seams of ironstone and some irregular beds of clay. Some slightly mottled clays above Otford appear to me to belong to this group, although much resembling the mottled clay of the Reading series. It is a question also whether a few sandstone-blocks are not occasionally concreted in these sands.

† Probably the *Lutraria elliptica*.

exceedingly scarce in the London Tertiaries. Thirdly, the structure of the Lower Tertiary sands is much more regular and uniform, and they are not, like these beds, broken up and disturbed in a way which seems to have arisen from the irregularity of the bed of the underlying chalk, both prior to their formation and by an increase in that irregularity at a subsequent period by the action of water wearing pipes. And fourthly, because I find similar beds on the chalk-downs on the opposite side of the Channel, between Calais and Boulogne; and thence, passing across the plain of French Flanders, we again meet with analogous strata,—though more important and with more ironstone,—on the top of Cassell Hill, 515 feet above the sea, and *overlying the Calcaire grossier series.* No fossils are found there; but M. Dumont and Sir C. Lyell refer those beds to the Diestian Sands, which they class with our Crag; for M. Dumont had found near Louvain these same sands overlying the Limburg and Bolderburg strata and containing impressions of shells, of which the following species are mentioned by Sir C. Lyell:—*Terebratula grandis, Solen Ensis,* and *Syndosmya prismatica*; and 13 genera, of which the species could not be determined, are enumerated*.

From the apparent identity of the more important outliers of yellow sands, loams, and iron-sandstones at various places on the North Downs, with the small isolated fragmentary beds at Lenham and Harrietsham, and from the circumstance that, when even such outliers† are wanting, it is common, nevertheless, to find portions of similar sands and pebbles in the core of the pipes dotted over the high chalk-surface, thus showing the former wide extension of the beds, I conclude that they all belong to the same series, and also that they extended formerly for some distance beyond the summit of the Chalk Downs, and that they are all of the same Pliocene age. Hitherto no trace of any Crag has been found south of the Thames‡; the occurrence, therefore, of these beds in Kent, not only so far from the main mass, but also at altitudes so far exceeding any which it attains in Suffolk and Essex, is a matter of considerable interest,—an interest further increased by the circumstance that it gives us a still nearer date whereby to limit the denudation of the Weald; whilst, from this rise in their level, and the fact of their stretching thus far inland, it is probable that they may formerly have ranged over the Wealden area, and even have been connected with the beds of that age in Normandy and Brittany§.

* Quart. Journ. Geol. Soc. vol. viii. p. 295.

† The ironstones which form a marked feature in Belgium and East Kent seem further westward to be of merely local occurrence.

‡ My friend Mr. John Brown, of Stanway, considers some sands at Chislet, between Canterbury and the Reculvers, to belong to the Crag. I cannot agree with him, as I believe them to be identical with the beds *beneath the London Clay* at Herne Bay; but I mention the fact in order to direct the attention of others to the point in dispute, and to state that, in case Mr. Brown's view should prove correct, his observations at Chislet should have the priority over mine at Paddlesworth and Lenham. Amongst the fossils which he has collected in that locality there are some which he considers to be Crag species, whilst others are distinctly Eocene, such as the *Cyprina Morrisii,* and others.

§ It furnishes us also with an important clue to the age of some of the drift-beds on the south of the Thames.

From the greater prevalence of some of the more abundant Coralline Crag forms, I should feel inclined to place these beds in that group rather than in the Red Crag. Thus the *Scalaria subulata, Astarte pygmæa*, and *Mactra triangulata*, as also the genera *Pyrula* and *Avicula*, are peculiar to the Coralline Crag; the *Terebratula grandis, Astarte Omalii*, and *Tellina donacina* are also more particularly abundant in this portion of the Crag, the former shell attaining a larger size than in the Red Crag; and of the genera *Lucina, Kellia*, and *Lepton* there are a considerably greater number of species in the Coralline than in the Red Crag. On the other hand, the *Leda myalis* and *Astarte compressa* are said to occur only in the latter division; but the former is a very doubtful specimen. The remaining species and genera are of about equal value with regard to either division. Still the number of species at all recognizable are so few, that the palæontological argument must be received with reserve.

There are, however, some other points which tend to confirm in some measure this synchronism,—points of physical structure and geographical distribution. Thus, with regard to the latter point, one main feature of the Coralline Crag contrasting with the Red Crag is, that the former contains a considerably larger proportion of species of southern, and the latter of northern affinities*. So in these Lenham beds, the geographical distribution of the 11 recent and 5 extinct species in Mr. Wood's list (p. 334) shows a certain preponderance of southern forms. The following Table exhibits this distribution:—

	Coralline Crag.	Red Crag.	Faluns of Touraine.	Subapennine fossils.	Recent, Mediterranean.	Recent, British Seas.	Recent, Northern Seas.
1. Dentalium costatum	*	*	...	...	*?		
2. Emarginula reticulata	*	*	*	...	...	*	
3. Nassa prismatica	*	*	*	...	*		
4. Scalaria subulata	*						
5. Arca lactea	*	*	*?	*	*	*	
6. Astarte digitaria	*	*	...	...	*		
7. —— compressa	...	*	...	...	...	*	*
8. —— Omalii	*	*					
9. —— pygmæa	*	...	*?				
10. Cytherea rudis	*	*	...	...	*		
11. Leda myalis	...	*	...	...	...	...	*
12. Modiola modiolus	*	*	...	...	*	*	*
13. Mactra triangulata	*						
14. Nucula nucleus	*	*	...	*	*	*	*
15. Tellina donacina	*	...	...	*	*	*	*
16. Terebratula grandis	*	*	*				
	14	12	5	3	8	6	5

* See Mr. S. Wood's Monograph, published by the Palæontographical Society, for much valuable information on this subject.

It thus seems that, with the exception of three extinct species (4, 8, and 13) which are local, and two (7 and 11) recent northern species, the remaining eleven have or have had a southern range,—three as far as Central France, and eight as far as the Mediterranean. The other genera also as a group exhibit more southern than northern affinities.

The connection, before suggested, of an extension of this older Crag eastward and southward over our chalk-downs would account for the introduction of the several more southern forms of Molluscs*. There are even circumstances connected with this inquiry which render it possible that these Lenham beds may be a stage older than the Coralline Crag; for a considerable number of the fossils, so far as such imperfect specimens will allow us to judge, do not apparently belong to either the Coralline or the Red Crag; and are either new species or may be found to agree with some of the older Pliocene, or Upper Miocene, species of France. This can only be determined when we are in possession of better and more specimens, or discover some fresh fossiliferous localities.

I have shown on a former occasion, that the axis of the Weald was probably one of elevation at the commencement of the Cretaceous period,—further, that at the commencement of the Tertiary period the chalk had been so planed down around the Weald, that there could be little doubt that in the centre of the then Wealden area, the Upper and Lower Greensands were exposed, and that their *débris* contributed towards the formation of the Lower London Tertiary beds. Now, again, at this early Crag period it would appear that these Lower Tertiaries, together with the London Clay, which had during a period of subsidence partly, if not entirely, covered up the old Wealden island, were also largely denuded, and that the Crag was deposited in depressions between the remaining outliers of the Tertiary strata, resting in places upon the again bared surface of the Chalk. At the same time it is evident, from the lithological structure of these presumed Crag beds, that they must have derived their origin, not only from the *débris* of the Tertiary strata, but more from that of the Lower Greensand and adjacent strata, for the chief materials of the Lenham and Paddlesworth beds are yellow and ochreous sands more or less mixed with yellow and red clay, quartzose grits, small quartz-pebbles, and green sand—all common and prevailing constituent parts of the Lower Cretaceous series of Kent. Added to this, the prevalence of iron, derived probably from the Lower Greensand, and again concreting a portion of the Crag sands derived from the same older strata†—and giving therefore to this newer iron-sandstone a like appearance to the older,—and of flints derived from the chalk, leads me to believe that another island existed in the Wealden area at the commencement of the Crag period, and that the

* Not that that communication was uninterrupted; it was broken by an old Wealden island.

† Still from the Tertiary strata in part, as the Crag sands often contain the common Lower Tertiary flint-pebbles,—generally scattered, but sometimes in thin seams, and in masses,—together with certain white flint-pebbles.

surface of that island was formed of a larger tract of Lower Greensand and Chalk (with Tertiary cappings) than was exposed in the former island, and that the detritus from this island, worn down by coast- and river-action, contributed the chief supply in forming the encircling deposit of Crag *.

The great denudation of the Weald is thus brought to a still more recent date than this period, these Crag beds extending to the very edge of the chalk-escarpment and having been truncated by the same action that wore down that escarpment. I have previously shown that this operation had taken place at a comparatively recent period, as some beds of drift were cut off in the same way; but I was unable then to assign a date to that drift, some of which now appears however to be older than this Crag. We may conclude, therefore, that the final denudation of the Weald took place subsequently to the Crag period. At the same time, as, in the Suffolk area, a great break takes place between the Coralline and Red Crags, the lower one being a deposit formed in tranquil waters, whereas the Red Crag contains *débris* worn and broken from other beds, and reposes upon a strongly abraded and indented surface of the Coralline Crag, it seems not improbable that another elevation of the Wealden area took place between the Coralline Crag and Red Crag periods, whereby the boundaries of the island † before referred to were so extended as to form a continuous barrier between the French and English Crag areas at or soon after the Red Crag period. This would be in harmony with the fact so often noticed, that at the period of the Red Crag we first find northern shells prevailing to an extent that leads us to believe that the sea of that Crag period was open to and connected with the northern seas, and would show how the communication which at the period of the Coralline Crag existed with more southern seas was then cut off and ceased.

Note.—Since the above paper was read I have again visited all the localities named therein, but without finding any better sections. It is evident that it is on the chalk-downs between Folkestone and Wye that these beds are best developed, and I would especially direct attention to Paddlesworth and to the neighbourhood of Kingmill Down, as well as to the hills above Otford and thence to Vigo Hill. A considerable number of fresh specimens have been obtained from

* On the chalk-hills between Upper Gatton and Great Shabden, and about a mile and a quarter in a direct line N.N.W. from Merstham, there is an outlier of light yellow sand, a small section of which may be seen in a pit in the fir-wood on the east of the road. This sand differs in several respects from the Lower Tertiary sands, and yet is not like any of the presumed Crag beds we have described. Its base is not shown, and only a patch of gravel overlies it, nor could I find any fossils. I am nevertheless inclined to place it with the Lenham group, for it is coarser and not so worn as the Lower Tertiary sands; it contains also a few thin flakes of ironstone, some flint-pebbles (white and not so well worn as the Eocene pebbles), bits of unrolled flints, also some patches of quartzose grit, and a few rare and small fragments apparently of the chert and ragstone of the Lower Greensand. A deeper excavation might possibly expose some of the ironstone-bands and conglomerates, blocks of which are so common at Aldersted Farm on the other side of the valley along which the Brighton road passes.

† Bringing that island into connexion with the continental area.

Lenham, some of which (as well as the beds themselves) have been considered to have a very Eocene look; but I see no cause to alter my opinion, although I admit that it will be very desirable to have that opinion strengthened by better and more positive specimens. I can, however, now add (with doubt) to my former list, *Lutraria elliptica, Tapes perovalis, Pectunculus glycimeris, Leda lanceolata, Cardium edule, Cytherea rudis, Pecten Brueri, Nucula depressa,* Nyst, *Crassatella concentrica,* Duj. (?), *Balanus bisulcatus,* and species of *Phorus, Donax, Venus, Ostrea,* and *Thracia.* I must however mention that Mr. Harris has found on the hills above Charing some blocks of ironstone, which, amongst several undetermined fossils, contain a *Ditrupa* much like the *D. plana* of the London Clay. These may possibly be really blocks from the Lower Tertiary sands which we know often extend in outliers to the edges of the escarpment, and which blocks may have remained when the sands were removed; or they may have been drifted here. The Crag sands are generally so thin, have been so extensively denuded, and are so mixed up in most places with the ordinary drift, which extends so widely over the Chalk Downs, that it is often most difficult to define their extent or even constantly to determine their presence.

Mr. Harris has also been indefatigably at work in tracing the extent of these sands and ironstones above Charing; and we are indebted to him for having had in November last a trench made at Down Wood to a depth of 29 feet, but without, I regret to say, throwing any fresh light on the position of the fossiliferous ironstone. The section was filled up when I was there in February, but from Mr. Harris's description I should infer that it consisted chiefly, if not entirely, of drift. No fossils were found. The following section has been kindly furnished by Mr. Harris:—

Trench in Down Wood, on Charing Hill, about 1¼ *mile N.E. of Charing, Kent*; 15 *feet long,* 4 *feet wide, and* 28 *feet deep.*

	ft.	in.
1. Surface-earth*, small fragments of flint	1	6
2. Reddish sandy loam, sometimes dark-brown, occasionally yellowish, with very few flints and an occasional pebble in its upper half, and with some few flints in its lower portion	25	6
2*a*. Traversing the loam, No. 2, from north to south, is a "run" of whitish loam, with a sectional area of 8 feet square, containing towards its base a few large chalk-flints and some irregularly dispersed masses of unworn flints cemented together with sand and irony matter.		
3. Brownish clay and large chalk-flints, some of them greenish	2	0
4. Chalk-flints, with white coating, supposed to be lying on the chalk†.		

At a distance of a quarter of a mile west of the section above described, another smaller trench was subsequently opened under Mr. Harris's direction; and at the depth of six feet was "found a con-

* The surface of this "grubbed" or displanted woodland is strewed with slags and fragments of ironstone both with and without fossils.

† From the wells or holes dug for getting at the chalk in the vicinity, it is seen that the surface of the chalk is very irregular.

tinuous stratum of fossiliferous iron-sandstone reposing on a bed of very large chalk-flints, externally stained with iron, and a few pieces of iron-sandstone. The sandstone was from 4 to 6 inches in thickness." Mr. Harris considers, that, owing to the rise of the surface from the first to the second section, the sandstone of the latter, if continued eastward, would come out at the surface where the first trench was dug. The beds in the second section, which seem to me to be more like beds *in situ*, would, I think, be cut off before reaching the first section, if I am right in considering the beds there to be drift-beds.

In a chalk-hole in the field west of Warren Street, and now just filled up, I found this small section remaining, of strata which are *in situ* :—

	ft.	in.
Yellow sand	1	0
Mixed red clay and yellow sand	3	0
Seam of compact ironstone, with traces of fossils	0	2
Layer of small flint-pebbles	0	6
Brown sand and clay	1	0

Mr. S. V. Wood's *Remarks on the Fossils from Lenham.*—"Mr. Prestwich has submitted to my examination a series of fossils, on account of their bearing a general aspect to those of the Crag. They consist of casts of shells in sandstone, &c., displaying sometimes the sculpture of the exterior, though oftener the shape only of the interior of the shell; and the majority of the specimens belong to the bivalve division of the Mollusca.

"The cast of a shell is at all times a very unsatisfactory dependence for specific identification; and, unless the same species be exhibited in a bivalve, for example, with the sculpture of the exterior well displayed, while another specimen will equally show the characters of the interior with hinge or dental apparatus, no safe reliance can be placed for a perfect identity with any species; neither is a univalve, if the aperture (upon which the generic character is sometimes dependent) be not also in a perfect condition. In the present case, I am afraid the most that can be said is, that there is a stronger resemblance in these fossils to the shells of the Crag than to those of any other formation, and what may also perhaps assist in the assignment is the apparent absence of any *decided* species exclusively belonging to the Older Tertiaries. There are, however, amongst them two or three forms somewhat resembling species belonging to the Paris Basin, though in these instances there is by no means an identification with any Older Tertiary shell known to me; still, if it be asked whether a perfect reliance can be placed upon any specimens as truly characteristic of the Crag period, I fear an answer must be given in the negative, although the general aspect of the fossils is certainly favourable to the assumption that they belonged to the Upper rather than to the Lower Tertiaries; and, as the locality whence they were obtained is very remote, it is possible the two or three strangers may have existed at the same time with our long- and well-known Crag species; and, if they cannot be identified with any of the Older Tertiaries, which I am unable to do, they will not materially interfere with our determination, and their lithological character will remove all doubt as to the possibility of their being derivative fossils.

"The accompanying list contains the names of those species to which they bear a very close resemblance. I give them as approximations only; and, although there is not one which without a doubt could be satisfactorily determined, I still think that, taken collectively, they are such as to justify a probable assignment to one of the Crag periods, and they appear to have been inhabitants principally of the Coralline zone. In reviewing this list it will be observed that there is a large preponderance of bivalves, and many of the individual specimens belong to the genera *Nucula, Leda,* and *Arca,* with a hinge characterized by a linear series of teeth or denticulations, and of a magnitude approaching what may be called an Arctic Fauna, accompanied with several species of *Astarte,* &c., generally considered also of a Boreal character; and these might perhaps incline us to assign the deposit to the age of the Red Crag:—

Cliona.	Astarte Omalii?
Lunulites. Coronula (?). Balanus(?).	—— compressa?
Diadema? (species of).	Cythera rudis?
Terebratula grandis?	Venus?
Pecten avicula?	Tellina donacina? or Donax.
Modiola modiolus?	Mactra triangulata?
Arca lactea?	Anatina.
Leda myalis?	Panopæa?
Nucula nucleus?	Dentalium costatum?
Cardium (with spines).	Emarginula reticulata?
Cardita.	Trochus.
Lucina or Diplodonta.	Natica.
Kellia or Lepton.	Rissoa?
Isocardia.	Scalaria subulata?
Astarte digitaria?	Nassa prismatica?
—— pygmæa?	Pyrula;

with a few others I have not been able to determine*.

"There is, however, in the Coralline Crag somewhat of an anomalous collection of shells, many of which are peculiar to the Arctic seas of the present day, while some of their associates are found only in the Mediterranean or the South of Britain; and, although there are amongst Mr. Prestwich's fossils many which resemble Red Crag species, there is not one, with the exception of *Leda myalis* (and this is but a doubtful identification, as I have not been able to see the exterior), that might not also be considered as belonging to the Coralline Crag. I believe they may with more propriety be considered as the equivalent of the Older Crag, more especially as there is one specimen which has every appearance of being the cast of a true *Pyrula*; and, although this genus has also been procured from the Red Crag, I believe the specimens so found to be derivative fossils, and not to have belonged to that period. In looking at the list of genera, it will not, I fear, afford much assistance in the determination, as the

* Mr. Searles Wood has since added, with a doubt, a *Phorus*, which he thinks may be related to *Trochus cumularis*, Brongn., and *Pectunculus glycimeris*, although the latter, he says, might be the Vicentin variety of *P. pulvinatus*. See also p. 332.

whole of them have been obtained from the Lower as well as the Upper Tertiaries; and unless any dependence could be placed upon the genus *Astarte* as somewhat characteristic of the Crag, there is not another but has yielded several species throughout the whole of the Tertiary period. There are amongst these fossils several impressions of what appear to have been the spines of a species of *Diadema*; and, although I have never met with this genus, Mr. Woodward tells me he has seen a fragment of a spine from the Coralline Crag, and it is an animal whose presence might be expected in that formation. The shell (or rather the internal cast of it) which most resembles an Eocene or Older Tertiary species is a *Nucula* with a divergent hinge much like *N. deltoidea*, and this at first sight certainly created considerable doubt as to its correct assignment; but our fossil is considerably larger than any specimen or any figure belonging to that species that I have seen, though at the same time it is very different from any Crag species.

"Should these fossils be really the remains of a Crag period, I think their resemblance is greater to the Older portion of the Upper Tertiaries than to the Red Crag; and as we have always been in the habit of considering the Red Crag a deposit formed in a sea open to the northward, with land on the south of it, the presence of the Coralline Crag Formation thus elevated into land, whence these fossils were procured, would not militate against such a supposition.

"In the above list there are 4 species, viz. *Dentalium costatum*, *Nassa prismatica*, *Astarte Omalii*, and *Terebratula grandis*, which, although found in the Red Crag, did not, I think, belong to that period, but were probably introduced into the deposit from destroyed portions of the older bed. This would give to the Coralline Crag a preponderance in number of what I have considered as identifications (or at least strong resemblances), making 14 for that formation, and only 10 for the Red Crag."

On the PALÆOZOIC BASIN *of the* STATE *of* NEW YORK.

Part I. *A Synoptical View of the Mineralogical and Fossil Characters of the Palæozoic Strata of the State of New York.* By J. J. BIGSBY, M.D., F.G.S., Late British Secretary to the Canadian Boundary Commission.

[Read November 18th, 1857.]

Introduction.—It having appeared to others as well as myself that a *résumé*, such as is contemplated by the above heading, is desirable, I have attempted the task in the following pages.

The characteristic geological points have been distributed under a few heads, and then treated with brevity or fulness according to the demands of the occasion;—the heads being those of "mineral character," "mode of transition" (among groups), "place," "position or dip," "thickness," "fossils," in general (typical), "fossils occurrent in Europe," "recurrent in New York."

My hope and intention has been to form a standard of reference with which to confront other palæozoic basins. The materials have been scrupulously selected from the best authorities;—from the able reports of the State Geologists of New York, and from the admirable researches of De Verneuil and Sharpe; introducing also some observations of my own, for it has been my privilege to visit many of the most interesting localities, and very much of the whole region.

The palæontological portion of this Synopsis is not taken from the promiscuous statements of authors, but is based upon a series of elaborate Tables constructed by myself from the writings of James Hall, Vanuxem, Conrad, De Verneuil, Sharpe, Portlock, Salter, Sowerby, Morris, M'Coy, and others. It is true that the fossils of North America still require some revision; but I am encouraged to believe, from the universally admitted competency of the palæontologists spoken of above,—that of James Hall vouched for by Agassiz and De Verneuil after personal examination,—that my Tables contain a great body of truth, to which day after day will only add.

In this Synopsis nothing theoretical has been admitted, as far as I recollect; but valuable facts occurring beyond the limits of the State of New York have been placed at the foot of the page, and only introduced into the general letter-press on unavoidable occasions. At the end of the paper has been appended a short series of inferences, interesting as they appear to me, which result from the facts narrated, and are to be treated on in a few forthcoming papers, mostly ready.

The best notion of the figure, extent, and relations of the State of New York will be obtained by looking at the Geological Map of Middle North-east America now before you*. New York extends from east to west 408 miles, and 310 miles north and south; but in a north-east and south-western direction this State attains the length of 450 miles, in round numbers. It narrows at its west end to nearly 40 miles. Along the south side of Lake Ontario its north and south dimension varies from 90 to 110 miles. Two-thirds of the superficial extent of New York are to the east of Lake Ontario. To treat of the boundaries of New York, political or natural, does not seem to be called for here.

The territory which we have been roughly measuring contains the north-eastern portion of the great central basin or area of the palæozoic rocks of Middle North America.

This is not the place to describe it, further than to say that it occupies the northern, western, and southern parts of the United States, as far west from Lake Champlain as the parallel of longitude 97°, some distance west of the River Missouri; and as far south-west as latitude 33°, about Tuscaloosa in Alabama; each traverse being not far from 1500 miles long, and exhibiting a series of palæozoic rocks of unequalled magnitude, symmetry, and simplicity. Beyond these distant southern and western districts, the central basin sinks under rocks of the cretaceous and tertiary epochs.

* The Map referred to, comprehending Canada and the United States, is a large geological map, constructed by the author, on the scale of 16 miles to an inch, and exhibited to the Meeting when this paper was read.—Edit.

Speaking now of the framework which contains this basin, we find that it is bounded on the east by the metamorphosed rocks of the Appalachian chain of mountains, continued northwards into New York, Massachusetts, Vermont, and Canada, and in reality contemporaneous with the sedimentary strata they encompass.

On the north the central basin or area is sustained unconformably for 2000 miles westward by the Laurentine chain of hill-ridges, which consist of gneiss, syenite, marbles, &c., of a metamorphism more ancient than the eastern framework of the basin, and which stood above the Silurian seas to represent the primal nodus or nucleus of the Western Hemisphere long before, and during, the palæozoic ages which we hope to describe, and when elsewhere all was sea.

An observer starting southwards from the Laurentine chain, as from Kingston on Lake Ontario, would encounter the sedimentary strata in succession from the oldest, until, in Pennsylvania or Ohio, he would stand on wide-spread masses of coal-measures,—each fresh stratum marked by a beach, ridge, or some local feature, and restricted to a narrow band, or outspreading far and wide, according to the accidents of the ground.

Tabular Arrangement of the Palæozoic System of the State of New York.

DEVONIAN.	Upper	Old Red Sandstone	V.	Conglomerate and Sandstone.
	Middle	Chemung Rocks	IV.	Argillaceous Sandstone.
		Portage Sandstone		
		Genesee Slate	III.	Clay and Sandstone.
		Tully Limestone		
		Hamilton Rocks		
		Marcellus Shales		
	Lower	Coniferous Limestone	II.	Limestone.
		Onondaga Limestone		
		Schoharie Grit	I.	Sandstone.
		Cauda-galli Grit		
		Oriskany Limestone		
SILURIAN.	Upper	Upper Pentamerus Limestone	H.	Limestone.
		Delthyris Shaly Limestone		
		Lower Pentamerus Limestone		
		Waterlime Rocks		
		Onondaga Salt Rocks	G.	Sandy Shale.
		Coralline Limestone	F.	Limestone.
		Niagara Shales and Limestone		
	Middle *Transition*	Clinton Rocks	E.	Sandstone.
		Medina Sandstone		
		Oneida Conglomerate	D.	Quartzose Conglomerate.
	Lower	Hudson River Rocks	C.	Clay.
		Utica Slate		
		Trenton Limestone	B.	Limestone.
		Birdseye Limestone		
		Chazy Limestone		
		Calciferous Sandstone	A.	Sandstone.
		Potsdam Sandstone		

If the observer sets out from the banks of the Hudson about Albany, his westward course will give him the same undeviating palæozoic series, and will land him on a grand plateau of carboniferous rocks.

Premising that we must assume for the present the correctness of the palæozoic arrangements of our American brethren, as in the main they are, we proceed at once to describe the successive fossiliferous groups, beginning with Potsdam Sandstone, the earliest, as now considered.

Potsdam Sandstone.

Mineral character.—It is a purely quartzose sandstone, white, grey, red, and green; the colour often in stripes and spots. It is frequently also argillaceous and ferruginous by slow and extensive change.

In some places (Gananoque, St. Lawrence) it assumes the form of a conglomerate of white round pebbles, or of breccia (near Putnam Ferry, Lake Champlain). From its contiguity to igneous rocks, the Potsdam Sandstone sometimes takes on a gneissoid or slaty structure; or its lower layers are in an intermediate state, crystalline, with rounded gravel or sand intermixed (Mount Stessing). At White Hall, Port Kent, &c., it consists, for small spaces, of the debris of granite or gneiss; as, besides quartz, we find both felspar and mica in it*.

Over vast spaces south and west of Lake Superior, Potsdam Sandstone consists of friable light-coloured quartzose sandstone, with intercalations of argillaceous, argillo-calcareous, and earthy deposits.

Mode of Transition.—Potsdam Sandstone rests unconformably on gneiss (Little Falls, &c.) or other crystalline rock along the Laurentine Hills, a continuation of which is the subalpine country of north-west New York, the planes of contact being commonly abrupt and distinct; or it may be separated from the subjacent rock by boulders of the latter (Montmorenci, &c.).

On the eastern borders of the basin, as on the frontiers of Vermont, or in New Jersey, Potsdam Sandstone is gradually delivered from the metamorphic condition in which it is found in those countries, and in proportion as it is continued west.

Place.—This group of strata probably underlies nearly all the central palæozoic basin.

Its northern outcrop runs W.S.W. along the south flank of the Laurentine range of metamorphic hills (creeping in among their valleys), from near Quebec to the River Minnesota or St. Peter's, a distance of about 1600 miles. From thence it gradually turns round

* In Pennsylvania, Prof. H. D. Rogers found this set of strata (the Potsdam) divided into a fourfold group (*Johnson's Atlas*):—

1. Primal, newer slate in Pennsylvania, 700 feet thick.
2. A white sandstone, 300 feet thick.
3. Older slate, felspathic and talcose, 1200 feet thick.
4. Quartzose felspathic conglomerate, with slaty pebbles, 150 feet.

Dale Owen (Geol. Survey of Wisconsin, p. 52) gives an important account of the mineral characters of the Potsdam Sandstone as it occurs on the Upper Mississippi.

east and south, for 400 miles, to Jonesville, on Rock River, near the south boundary of Wisconsin, making the whole northern and western edge 2000 miles long, carefully traced.

Its eastern boundary is projected, in nearly a direct course, about 1600 miles, from the neighbourhood of Montreal to near Tallapoosa in Alabama, through Vermont, Pennsylvania, and the other more southern States.

The principal areas of exposure of Potsdam Sandstone are placed at the eastern and western ends of its northern outcrop; being everywhere else covered up, and a mere selvage left, a few miles broad.

This eastern area, irregular in shape, is very large, and occupies much of the lower parts of the Ottawa Valley (Canada), together with very large portions of the adjacent State, New York (100 m. by 60 m.).

The western mass is still more important, and floors most of middle and western Michigan and of eastern Minnesota.

In these regions, heavy drift covers up this rock for 730 miles east and west, and 500 miles north and south. These immense spaces, occupied by the ancient sandstone and the boulder-drift, may create a feeling of doubt and surprise; but it is to be remembered that we are engaged with a continent great in all its developments.

Position.—Potsdam Sandstone is usually horizontal or undulatory, or with a very small easterly (?) dip, in the State of New York. In the vicinity of intrusive rocks the dip is considerable and various, as to the N.W. at Potsdam, in New York*.

In De Kalb County this rock is much subject both to lateral and vertical pressure, and in some places is quite broken up; and there are many faults and uplifts to be noticed in the north and west of the State. (Hall; Emmons.)

Thickness.—The thickness of the Potsdam Sandstone is 250–300 feet in the N.W. parts of New York, according to Emmons; 400 feet in the S.W. districts, according to Mather; and 5000 feet, in the estimate of Owen, in the south of Lake Superior (but this requires further examination).

Fossils.—The common fossils are Lingulæ, Orbiculæ, Trilobites, and Scolithus linearis: species few, individuals often numerous.

Fossils typical.—Lingula prima, L. antiqua (near Depauville), Scolithus linearis. Dikelocephalus Meniskaensis, D. granulosus (in micaceous sandstone). D. Minnesotensis (Still-water, Mississippi River, in argillo- and magnesio-calcareous beds).

Fossils occurrent in Europe.—Scolithus linearis (Stiper Stones, Salter).

Fossils recurrent in New York.—None.

Calciferous Sandstone.

Mineral Character.—This set of strata is intermediate between sandstone and limestone. It occurs in constantly intermingling varieties.

* For many miles to the south and west of Lake Superior the dip is high, and always to the S.E. (Owen); but on the Mississippi, and near the mouth of the Lacroix River—one of its great eastern tributaries, as well as in Wisconsin generally, the strata are nearly horizontal.

First; from below, it differs little from Potsdam Sandstone.

Secondly; it consists of a fine yellow siliceous sand with carbonate of lime, and fractures with a sparkling grain.

Thirdly; it is a yellowish calciferous material, intercalating with a limestone like that of the Birdseye group.

Near the middle, Calciferous Sandstone is cherty and geodiferous, with *Orthides*. In its upper part it is occasionally oolitic in structure (Ballstone, &c.). It frequently contains drops or buttons of anthracite.

Transition.—Calciferous Sandstone graduates slowly from Potsdam Sandstone, and into either Chazy or Birdseye Limestones, in certain localities.

It rests directly on gneiss at Little Falls, &c., on the River Mohawk; but commonly its substratum is Potsdam Sandstone*.

Place.—The northern and south-western outcrop or edge of Calciferous Sandstone follows closely the corresponding track of Potsdam Sandstone along the skirt of the elder metamorphic rocks of the Laurentine Chain, for a distance of 1756 miles. It is equally as extensive as Potsdam Sandstone, if not more so, sinking with it under the more recent palæozoic strata towards the centre of the basin or area, but reappearing on the impulse of any intrusive rock, as in Texas and elsewhere.

Its direct eastern border from near Montreal runs with some steadiness down the valleys of Lake Champlain and the River Hudson for 550 miles alongside of Potsdam Sandstone, but, in the western parts of the State of New Jersey, becoming both overlaid by younger deposits, and involved in metamorphic influences; it has not, as yet, been seen further south in this vicinity.

In the State of New York it is sometimes unexpectedly absent in patches.

Calciferous Sandstone is in general only seen in long strips, from being covered up. In three places, however, if not in more, it overspreads surfaces several hundred miles long and fifty in breadth. These places are, first, in the north-east of the State of New York, a continuation of the Calciferous Sandstone of the Ottawa Valley; secondly, along the Upper Mississippi and Wisconsin Rivers; and thirdly, on the River Osage, a large western affluent of the River Mississippi.

Position.—There is in general a slight dip toward the south and west; but in the north-west parts of the State it varies much and suddenly, from the abundance there of intrusive rocks. In Jefferson County it undergoes three or four uplifts vertically of 25–35 feet.

In Franklin County the dip is to the N.W., and is slight; in Lawrence County it is to the N.N.E.; and in Jefferson County the dip is to the south.

Thickness.—The thickness varies from 250 to 300 feet in the N.W. of the State (Emmons); but, generally speaking, it is much less in New York.

* On the south-east side of Lake Superior, magnesia enters largely into the composition of this early Silurian rock, according to Whitney and Foster.

Fossils.—See General Table, No. I.

We have here many marine plants—parts of large, succulent, hollow stems. Shells mostly univalves. Fossils apparently few; but they were in reality many, but have been obscured by siliceous infiltration and by physical disturbances (Hall, Pal. i. 9). The upper half is the most fossiliferous. Emmons (Report, p. 114) remarks that, thin as are the subordinate masses of this rock (15–30 ft. only), yet each has its own typical fossils. Also, the species are few, forms peculiar, and individuals numerous.

Fossils typical.—Palæophycus tubulosus; P. irregularis; Buthotrephis antiqua; Lingula acuminata; Euomphalus uniangulatus; Ophileta levata; O. complanata; Maclurea matutina; M. labiata; M. sordida; M. striata; Turbo diluculus; T. obscurus; Pleurotomaria turgida; Bellerophon sulcatus; Orthoceras laqueatum; O. laq. var. *a*; O. primigenium (Vanux.).

Fossils occurrent in Europe.—Orthoceras laqueatum; Bellerophon sulcatinus.

Fossils recurrent in New York.—Scalites angulatus.

Chazy or Black River Limestone.

Mineral Character.—This rock is well defined. It is grey, blue, very compact or subcrystalline, and in layers which are never more than 10 feet thick. There are cherty masses occasionally.

Transition.—This is gradual, below and above. Vanuxem unites Chazy Limestone with the next, the Birdseye Limestone. They are often undistinguishable, especially on the River Madawaska in the Ottawa Valley, U.C.

Place.—Its position is well marked at Chazy Village, on the west side of Lake Champlain. Hall says it is very persistent, and is known almost across North America, but only in patches of moderate size, as in the valleys of the Mohawk and of the Black River, hidden or brought into view by the contours of the country. The latter river has given a name to the rock (Emmons, Report, p. 107). It is plentiful in Canada.

Position.—It has a moderate dip to the west, near Essex, on the west side of Lake Champlain. The inclination is to the south and west, and slight elsewhere, except near dykes and uplifts on Lake Champlain.

Thickness.—This is 130 feet, including Birdseye Limestone, to the west and south of Lake Champlain.

Fossils.—See General Table.

This period was more favourable to animal life than some subsequent ones. Forms here obscure become numerous and prominent at succeeding periods. Swarms arose of crinoids and zoophytes in the earlier parts of the period, with crowds as multitudinous of Brachiopoda and Cephalopoda in other parts, and especially of *Maclurea* (Hall, Pal. i. 15). There are eight (?) species of Trilobites; but individuals are few. Nearly every species perished at the end of this period. Scarcely one of the *Orthocerata* of Chazy Limestone is known to ascend into any subsequent deposition. Of the peculiar forms which began and ended their existence with this mass, we may mention (Hall, Pal. i. 37) the *Maclurea*, *Raphistoma*, and *Scalites*, of which generic analogues are scarcely known higher. The same was the case with the two species of *Bucania* and two of *Orthoceras*.

The organic affinities of this stratum with Trenton Limestone are close. Fragments of crinoidal columns, differing in no respect from the Trenton-Limestone species, are found in this rock at Watertown, New York (Hall, Pal. i. 51).

Fossils typical.—Columnaria alveolata; C. sulcata; Gorgonia? aspera; Streptelasma expansa; Retepora gracilis; R. incepta; Strictopora glomerata; S. fenestrata; Actinocrinus tenuiradiatus; A. sp. ind.; Orbicula deformata; Atrypa acutirostra; A. altilis; A. dubia; A. plena; A. plicifera; Ambonychia mytiloides; Maclurea magna; Raphistoma plenistria; R. var. parva; R. staminæa; R. striata; Capulus auriformis; Murchisonia abbreviata; Pleurotomaria antiquata; P. bi-angulata; P. spec. ind.; Metoptoma dubia; Bucania rotundata; B. sulcatina; Lituites convolvens; Orthoceras, n. s.; O. moniliforme; O. rectangulatum; O. sub-arcuatum; O. tenuiseptum; Ormoceras gracile; O. tenuifilum and var. distans; Endoceras gemelliparum; E. longissimum; E. multitubulatum; E. subcentrale; Gonioceras anceps (Hall and Owen); Asaphus marginalis; A. obtusus; Ceraurus, sp. ind.; Illænus arcturus; I. crassicauda; Isotelus canalis.

Fossils occurrent in Europe.—Columnaria alveolata; C. sulcata; Glyptaster brachiatus; Ambonychia nudata; Maclurea magna; Murchisonia angulata; Pleurotomaria angustata; Raphistoma striata; Scalites angulatus; Orthoceras commune; Bellerophon sulcatinus; a species of Bucania.

Fossils recurrent in New York.—Chætetes lycoperdon; Stromatocerium rugosum; Glyptaster brachiatus; Murchisonia angustata; Orthoceras duplex; O. multiseptum; O. vertebratum; Illænus crassicauda, &c. See Table of Recurrency.

Birdseye Limestone.

Mineral Character.—It is in thick layers, evenly bedded; vertical joints well marked. Its colour is bluish-grey, or light-dove. It is fine-grained or compact; fracture conchoidal. We find it crystalline in patches. It is generally a pure limestone; in places siliceous. (Emmons, p. 108.)

Transition.—From Chazy Limestone to Birdseye the transition is commonly gradual; but on the Mohawk River, and at Essex on Lake Champlain, the transition is abrupt, a part being wanting to connect the two: thus showing, according to Vanuxem, a lapse of time between the completed deposition of the older stratum and the commencement of the newer.

Place.—This deposit is well developed in the counties of Montgomery, Herkimer, Oneida, and Lewis (Vanuxem), and, according to Emmons (Rep. p. 382), "forms an irregular belt through Jefferson County from east to west, with a breadth of at least ten miles. Its northern outcrop, on an east and west line, passes through Depauville and a point two miles south of Evans's Mills, on the great bend of Indian River. From this point it runs to the great bend of the Black River, and thence to a point two miles S.W. of Carthage." Its disappearance at the south under the Trenton Limestone is along a line extending from Champion nearly direct to Watertown. This stratum is in many places altogether wanting, and where it was expected, as at Essex, the village mentioned already.

Position.—It is conformable with its coterminous strata.

Thickness.—Very various; 30 feet on the average, and thinning towards the south.

Fossils.—See General Table. Some of the Orthocerata are ten feet long by one foot broad (Emmons).

Fossils typical.—Fucoides demissus; Phytopsis tubulosa; P. cellulosa; Streptelasma profunda; Strictopora labyrinthica; Leptæna filitexta; L. lævis; Modiolopsis nuculæformis?; Modiola? obtusa; Natica, sp. ind.; Murchisonia varicosa; M. ventricosa; Pleurotomaria nucleolata; P. nodulosa; P. quadricarinata; P. obsoleta; Lituites undatus; Orthoceras fusiforme; O. recticameratum; Cytherina, sp. ind.; Ellipsolites (Emmons, p. 385); Asaphus extans; Calymene multicosta; Ogygia? vetusta.

Fossils occurrent in Europe.—Ampyx; Illænus crassicauda; Murchisonia angulata; Lituites convolvens.

Fossils recurrent in New York.—Chætetes lycoperdon; Stromatocerium rugosum; Murchisonia angustata; M. perangulata; Pleurotomaria umbilicata; Illænus trentonensis, &c. See Table of Recurrency.

Trenton Limestone.

Mineral Character.—This limestone is black or dark-blue below, and thin-bedded. Higher up it is thick-bedded, grey, granular, and subcrystalline. From this point, argillaceous shale, which is always more or less interlaminated, increases by degrees, until it forms the whole mass of the rock.

Transition.—Usually Trenton Limestone graduates from Birdseye by the slow introduction of Trenton fossils (Putnam's Quarry, &c., Vanuxem). It may succeed any of the three preceding groups in shaly layers, or in compact calcareous strata separated by shaly laminæ.

Well-characterized Trenton Limestone rests immediately on Calciferous Sandstone at the Falls, near Straker's Basin, and other places. At Fort Plain and elsewhere it lies upon Birdseye Limestone without admixture. (Vanuxem, p. 48.)

Place.—Trenton Limestone, after occupying the Isles of Mingan in the Gulf of St. Lawrence, skirts the north shore of that great estuary, with moderate interruptions, as might be expected on such a broken forest-clad coast; and then, little more than a selvage visible, it passes along the north side of the river St. Lawrence to Montreal, adhering to the metamorphic cliffs by shreds sometimes. On its way from this point to the remote west, it occupies much of the lower part of the Ottawa Valley, all the eastern two-thirds of the north shore of Lake Ontario, in breadths varying from 40 to 80 miles, embraces Lake Simcoe, passes N.W. from thence into Notawasaga and Gloucester Bays of Lake Huron, and forms many islets in the Georgian Bay, the large one of La Cloche among others. From Ile La Cloche, as a band about ten miles broad, it advances west to the south side of Lake Superior, where it abruptly sweeps round to the south in a broad belt, and constitutes the west shore of the great curvature of Lake Michigan, called "Green Bay."

From hence this vast sheet of Trenton Limestone proceeds southward, at some distance from Lake Michigan, and near Jonesville, Jefferson County, bifurcates,—one branch running off west, to cross the Mississippi, while the other, narrower, after a course of about 150 miles, is lost under the drift of Illinois. The whole length of this northern outcrop is 1700 miles.

To give some idea, however inadequate, of the eastern outcrop of this stratum, we may state, that, due south from Montreal in Canada, Trenton Limestone passes in long strips down both sides of Lake Champlain, and on the east side of the Hudson River, which it crosses near Newburg, to run S.S.W., as a rather broad band, in its proper geological position, to near Centreville in Alabama,—a distance, from Montreal, of about 1130 miles.

Of the broad areas of Trenton Limestone in Tennessee and the south-west, we may not now speak. In the north-west portions of New York in the counties of Jefferson, Lawrence, &c., this limestone occupies much surface, and with very circuitous outlines on account of the unevenness of the country. Together with Chazy Limestone it passes from the Black River to Oneida County, and from thence to Spruce Cradle, Steuben Creek, Beaver Meadow Creek, Stittville, and Holland Patent.

On the north and south sides of Little Falls it appears in patches. Further particulars are here inadmissible.

Position.—Although usually in a kind of wavy horizontality, it is subject to uplifts along the Mohawk Valley, as well as at Baker's Falls and Glenn's Falls in the Hudson Valley.

Thickness.—This is 400 feet at Chazy on Lake Champlain; 300 feet in Lewis County, and much thinner elsewhere, especially attenuating from west to east (Vanuxem).

Fossils.—See General Table. This stratum is very fossiliferous, and contains 256 species, being not very far short of one-third of the whole fossils of the Silurian series.

The numerical Table, No. II., shows us that this rich stratum contains 3 species of Plantæ, 15 of Zoophyta, 10 each of Bryozoa and Echinoderms, 72 of Brachiopoda, 16 of Monomyaria, 19 of Dimyaria, 25 of Trilobites, 37 species of Gasteropoda, chiefly *Pleurotomariæ* and *Murchisoniæ*, 44 of Cephalopoda, chiefly *Orthocerata*.

The Brachiopoda, besides being numerous, are constant and reliable over great areas; but most of them end as species with the group, seventeen only surviving. The *Lingulæ* are the half of the whole genus found in the Silurian system.

"Near the base of Trenton Limestone the *Orthoceras* is very rare, while the few species of *Cyrtoceras* known in this rock seem almost confined to that position. As we ascend in the strata, *Orthocerata* are occasionally found, but never abundantly, in the lower half of the deposit. In the centre of the rock the *Orthoceras* increases in numbers, and in the succeeding beds they are massed together in myriads. In the highest beds of this limestone in many places they have nearly disappeared, though in some portions of the succeeding slate they are again abundant." (Hall, Pal. i. p. 191.)

Six only of invertebrate animals have been transmitted from earlier groups to the Trenton Limestone, which sends on only 45, the great majority perishing.

Fossils typical.—These are 211 in number, leaving thus about one-sixth as either derived from, or transmitted to other groups. All the Echinoderms are typical; 55 Brachiopoda, 31 Gasteropoda, and 42 Cephalopoda. For further detail consult Table II.

Fossils occurrent in Europe.—(See Table of fossils common to both hemispheres.)—Chætetes petropolitanus; Stromatopora concentrica; Ptilodictya acuta; Atrypa protea; Leptæna alternata; L. depressa; L. Stroph. grandis; Lingula attenuata; L. obtusa; Orthis biforata; O. parva; O. rugosa; O. testudinaria; O. Verneuilli; Spirifer biforatus; S. lynx; Terebratula bidentata; T. reticularis; Calymene Fischeri; C. punctata; C. senaria; Ceraurus pleurexanthemus; Illænus crassicauda; Isotelus gigas; Lichas laciniata; Phacops Dalmanni; Trinucleus Caractaci; Modiolopsis modiolaris; Nucula levata; N. poststriata; Subulites elongata; Pleurotomaria lenticularis; P. percarinata; Porcellia ornata; Cyrtoceras multicameratum; Orthoceras arcuoliratum; O. bilineatum; O. commune; O. vertebrale; Bellerophon bilobatus.

The Cystidea occur in the Lower Silurian stage both in America and Europe.

Fossils recurrent in New York.—These are 38 in number, of which 22 only recur once, and that almost always in the next group, or next but one: 15 recur twice. The one remaining passes on into the Devonian system, like *Orbicula lamellosa.* As might be expected, we find among these recurrents four Graptolites, twelve Brachiopoda, nine Trilobites, six Lamellibranchiata, and two Gasteropoda. *Trocholites* is only found here and in the Pulaski Sandstones of the Hudson-River group.

Utica Slate.

Mineral Character.—This subdivision is composed of the same material that separates the dark limestone-layers of the Trenton Limestone. It is a dark, bluish-black, or carbonaceous shale, green in Ohio and the West, weathering brownish and chocolate-coloured. It contains no fragments of other rocks; but in many places there are thin beds of impure limestone. It is metamorphosed into a roofing-slate frequently in the first-named geological district (with Graptolites).

Transition.—This is very gradual, and, as a general rule, from the Trenton Limestone; but near Split Rock, Whallon's Bay, Lake Champlain, as well as in some other places, it lies against and upon Hypogene Rock, overlapping it in wrinkles and curvatures at the line of junction, as we sometimes see Trenton Limestone do in like circumstances.

Place.—Utica Slate is one of the constants, and always interposed between Trenton Limestone and the Hudson-River group throughout the Central Palæozoic area of Middle North America. This is well and abundantly seen on Lake Champlain and in the great valleys of the Hudson, Mohawk, Black, and other rivers. It doubtless underlies, in its place among the fossiliferous strata, the whole of the vast levels in the United States, east of the Mississippi. It is well seen in the great fissures on the Rivers Ohio and Cumberland, and surrounds, in an extensive mass, the Ozark Mountains of Missouri.

One of its most distinct northern outcrops runs from Fonda on the Mohawk, by Mexico Bay and Cobourg on Lake Ontario, Notawasaga Bay, and the Manitoulines Isles in Lake Huron to near Grand Isle, Lake Superior (south shore), about 750 miles. From this point the outcrop of this slate passes south several hundred miles through an imperfectly-explored country, in its proper geological position. From Fonda, north-eastwards, it has been traced to Quebec, a distance of 317 miles.

Position.—Where not disturbed by intrusive rocks, or by post-carboniferous movements, Utica Slate dips slightly to the south-west. The uplift it undergoes at East Canada Creek will be mentioned in another place.

Thickness.—This varies. It is 250 feet in Montgomery County (Vanuxem), and 75 feet in the gorges of Loraine and Rodman, more to the east in this State (Emmons).

Fossils.—Utica Slate only yields 48 species of fossils, as we learn from Table I. Its upper part is not fossiliferous, except in Jefferson County, where it is richer than in the lower portions (Emmons). Most of the Trenton fossils perished; only sixteen Brachiopoda are received here.

Twenty-two fossils first appear here; twenty-six have been received and transmitted (Table II.). Perhaps, from containing too much clay, this series of deposits was unfavourable to animal life.

Fossils typical.—These are strikingly so; but they are only ten; some of the principal orders, the Brachiopoda, Zoophyta, Monomyaria, and Gasteropoda, being unrepresented.

Fossils occurrent in Europe.—No crustacea. Didymograpsus sextans; Diplograpsus mucronatus; D. ramosus; Graptolites sagittarius; Discina crassa; Leptæna alternata; L. depressa; L. Stroph. grandis; Lingula curta; L. quadrata; Orthis parva; O. testudinaria; Spirifer biforatus; Terebratula bidentata; T. reticularis; Clidophorus planulatus; Modiolopsis modiolaris; Nucula poststriata; Porcellia ornata; Bellerophon bilobatus.

Fossils recurrent in New York.—These are almost altogether confined to the Trenton and Hudson-River groups, with an occasional escape into the Clinton group, and, in two species of *Leptæna*, the passage, group by group, into the New York Devonian system. See General Table and Table of Recurrency.

Hudson-River Group.

Mineral character.—This group consists of shale and shaly limestone, with thin courses of limestone and limestone-breccia, the upper portions in many places abounding in fossils. The shales are dark-blue, brown, and black; the gritty sandstones and grits are grey, greenish, and bluish-grey. This rock is so diversified as to have merited the name of "Protean," its mineral characters changing essentially at distant localities.

On the River Hudson, and in many other parts of New York, this rock is a slate with thinly-bedded sandstones, formerly called "argillite" and "greywacke" (Hall). It is often altered in character, deranged in position, and apparently mixed with more ancient schistose rocks (Vanuxem, p. 60). A green or olive colour is very characteristic of this group (Vanuxem). It is often subdivided into the three following portions:—

1. (From below.) Frankfort slate and sandstone.
2. Green slates.
3. Pulaski sandstones or Loraine shales (Emmons, Rep. p. 119).

The first and third portions have received their names from the rock being well characterized at the localities mentioned.

It is a most remarkable fact that the Frankfort Slates give out brine-springs, as at Saltspringville and at Balston. These are the lowest saline springs known.

Transition.—Sometimes this group is distinct from Utica Slate; but in general there is no mineral line of division between them, the change being gradual.

Place.—This is another of the constant groups, and is met with in middle North America wherever there is a sufficiently deep rupture among the sedimentary strata. It occupies much of the middle and eastern parts of New York (valleys of the Hudson, Mohawk, &c.) in broad masses which spread northwards into Canada, and southwards into New Jersey and Pennsylvania, but often in bands attenuated by the accidents of the ground. Westward it crosses from the State of New York, over Lake Ontario, and overspreads much of Upper Canada on its way to the south side of Lake Superior, where it follows the southerly course of the other Silurian groups. The exact outlines of this group have not yet been traced in New York, from the wild and intricate nature of the region it often occupies. It is in great force in Albany, Schenectady, Schoharie, and Saratoga Counties, and may be followed from Saratoga Lake into New Jersey and beyond (Mather, p. 375). One line of east and west outcrop is 1220 miles long—that from the Massachusetts frontier to the south border of Wisconsin near Jonesville,—while its extension from Gaspé of Lower Canada, down the valley of the Hudson, &c., to near Harrisburg, is 1400 miles long.

This group is seen largely in Ohio, Kentucky, Indiana, Missouri, and on the River Mississipi, beyond Dubuque.

Position.—In the vicinity of intrusive or metamorphic rocks, the dip is high, and in various directions; but at some distance from these it is small, and very small generally toward the west and south. The dip in Orange County, New York, is 50°, and south-east. At Albany and at Schenectady, in Ulster and Green Counties, the dip is E.S.E., and very high.

Thickness.—The maximum thickness in Schoharie County is 700 feet. It varies from 500 to 800 feet on the Hudson River in the eastern part of New York (Mather). On the west of Lake Champlain, the thickness is 500 feet; but at Schenectady, the Frankfort Slate alone is 500 feet thick (Mather).

Fossils.—Consult the General Table No. I. and Table No. II.

Frankfort Slate and Sandstone are very poor in fossils, except in *Graptolites*, of which it possesses ten species.

The animal remains are 103 in species, of which 42 have been derived from previous strata, and most of them from the Trenton Group. We here notice especially the effects of sediment on Invertebrate life. Most of the Brachiopoda, Monomyaria, Crustacea, Gasteropoda, and Cephalopoda have disappeared; and there are few Zoophytes, for want of lime.

Several Trenton fossils (*Strophodon semiovalis, Leptæna alternata, Orthis testatus, Calymene senaria*) being continued through Utica Slate into this group, we may almost consider it as a continuation of Trenton Limestone, beginning with a shaly limestone passing through shale and shaly sandstone to the end of the series. Many of the Brachiopoda of Trenton Limestone are characteristic of the upper part of this group (Hall). The *Orthocerata* are sometimes flattened. The Zoophytes here are very few (5), for want of lime.

Fossils typical.—These are numerous (60), because nearly every order has a number of representatives, especially the Dimyaria. *Cyrtolites ornatus* (*Porcellia*) is peculiar to the upper part of the Hudson-River-group. It was at one time supposed that no fossils were transmitted into the newer groups; but Table II. shows that 14 of this group pass upwards beyond the Oneida Conglomerate. They are principally Brachiopoda.

Fossils occurrent in Europe.—Graptolites sagittarius; G. scalaris; G. tenuis; Ptilodictya lanceolata; Glyptaster brachiatus; Leptæna alternata; L. depressa; L. (Stroph.) grandis; Orthis lynx; O. biforata; O. occidentalis, *Lyell*; O. parva; O. testudinaria; Spirifer biforatus; S. lynx; Terebratula bidentata; Atrypa reticularis; Trinucleus Caractaci; Avicula demissa?; Clidophorus planulatus; Lyrodesma plena; Modiolopsis modiolaris; Nucula levata; N. poststriata; Orthonota nasuta; Cyrtolites ornatus; Lituites planorbiformis; Bellerophon bilobatus.

Fossils recurrent in New York.—The received organisms of the Hudson-River-group are principally Brachiopoda (14). The others are scattered, a few of each order. The fossils which this group transmits are *Leptæna depressa, L. sericea, Atrypa didyma ?, Theca triangularis, Calymene Blumenbachii.*

Grey Sandstone.

Mineral Character.—In some parts of this basin a grey sandstone succeeds the Hudson-River-group. It is of a uniform character, and may be described in general as an even-bedded greenish-grey stratum, fine-textured, siliceous, but not vitreous, with a little mica everywhere; often like millstone-grit. It also has beds of breccia, and ends upwards in grey or white unfossiliferous limestone.

The masses belonging to it in Oneida County are thus described by Emmons, p. 124 :—

1. [From below] A greenish, fine-grained, even-bedded sandstone, with thin green slaty layers interposed, and sometimes enclosed also in the rock.

2. A reddish-brown sandstone, the layers 4 to 24 inches thick, alternating with layers of the same colour.

3. White, grey, and reddish limestone, terminating downwards in the preceding rock. Its beds are always thick; and the whole rock is massive and chequered with seams of spar and quartz.

4. A greenish breccia; its fragments not coarse, but very strongly cemented together. Its colouring matter often appears to be chloritic; and, when the mass is fine, it has a trappean appearance.

5. A conglomerate of rounded pebbles of quartz, united apparently without cement. It is confined to Oneida County, and has no fossils.

Now comes the unfossiliferous limestone. It is rarely a homogeneous rock, and is seamed and veined with quartz and spar.

Transition.—We are told by Emmons (p. 406) that the Hudson-River-group is succeeded by this sandstone in Jefferson County; and Hall says "that in Oswego and the adjacent counties the Pulaski shales of the Hudson-River-group slowly change into grey sandstone,—the fossils ceasing, the green matter disappearing, till at length the new stratum is completed. Passing upwards here, the grey sandstone mingles with Medina sandstone,—the latter differing chiefly by its colour, and the grey limestone being often spotted with the colouring matter of Medina sandstone; so that there is here a gradual passage from Hudson-River-group to Medina Sandstone."

The grey sandstone was a sandy beach washed by advancing and retiring waves; for *Lingulæ* are found on it, fixed on little ridges of stony matter. It has also wave-lines like those of our present beaches.

Place.—The Grey sandstone, according to Vanuxem, is found in Oneida, Lewis, and Oswego Counties. It begins a little south of Rome, and covers a large area in the two latter counties. Hall finds it in the west and south, in the townships of Camden, Florence, Mexico, Newhaven, Scriba, Oswego, and Lewis.

Position.—This is an undisturbed rock; but it has a perceptible inclination to the south-west.

Thickness.—In Jefferson County the thickness is about 100 feet, taking in the grey limestone. In other places Emmons makes it 1500 feet, including all the individual masses (Rep. p. 127). I think Prof. Emmons does not here distinguish this rock clearly from the Oneida Conglomerate.

Fossils.—There are very few fossils in the Grey sandstone. They are *Lingula cuneata*, *Avicula demissa*, and *Strophomena nasuta*, the last found by Emmons, near Rome. They are confined to the lower part of the rock. Some fine species of Fucoids have been found (Mather, p. 369) at New Hartford Centre and Hampton Village.

This sandstone, together with some other subordinate strata, are probably the channel of fossil-communication between the Lower and Upper Silurian stages.

Oneida Conglomerate.

This is a group of great importance, from its vast development, especially in length, and from the tokens it bears both of plutonic disturbances, and of certain relations of land and sea at and after the epoch of its deposition.

It is made up of a continued alternation, but irregular in all respects, of three conformable masses:—

1st. A conglomerate of variously-coloured, but chiefly white, quartz-pebbles, usually $\frac{3}{4}$ths of an inch in diameter.

2ndly. Of white, yellowish, or red quartzose sandstone; and

3rdly, and very largely, of red and green shale, highly titaniferous: that is, if the vast formation so named by Sir William Logan be Oneida Conglomerate; for it is considered to be the Hudson-River-group by Professor H. D. Rogers, according to a conversation with me. Many strong reasons may be brought in favour of either view, in the proper place.*

Transition.—The upper portions of the Hudson-River-group either having been removed or never laid down in places, we find that the Oneida Conglomerate may rest on Frankfort Slates (H.-R.-group), as in Herkimer County, or on Pulaski shales (H.-R.-group), as in the west part of Oneida County, the distinction or separation being abrupt (Vanuxem); or, as we have shown, it may succeed the Grey Sandstone just described. This would appear a natural termination of the Hudson-River-group, and would be an easy and gradual introduction of the Oneida Conglomerate. In regular ascending order, this conglomerate may always be taken as succeeding the Hudson-River-group without interpolation and gradually.

Further east, in the State of New York, along the base of the Helderberg Mountains, where the Clinton, Niagara, and Onondaga-salt groups are very thin, the Oneida Conglomerate is absent, and the Hudson-River-group rises to within a few feet of the Tentaculite-,

* Professor Rogers merges Oneida Conglomerate into Medina Sandstone,—both together constituting his "Levant Series" in Pennsylvania.

His brief but clear account of the mineral character of Oneida conglomerate differs little from that given by the New York geologists. It is to the following effect (Johnston's Atlas, 2nd edit., p. 31):—

It is a triple formation. The upper member is a white and light-grey, fine-grained, hard sandstone, alternating near its upper limit with beds of red and greenish shale; the sandstone covered with Fucoids profusely. This is 400 to 500 feet thick in Pennsylvania.

The middle member is a soft, argillaceous, brown sandstone and red shale; thickest (500 feet) in the mountains which cross the Juniata River.

The third or lower member is a hard, greenish-grey, massive sandstone (200 to 400 feet thick), embracing in its eastern outcrop (as in the Kittatinny and Shawangunk Mountains) thick beds of siliceous conglomerate, made up chiefly of the wreck of previously-formed and disturbed older palæozoic rocks.

The upper and middle members constitute the Medina Sandstone of New York.

that is, of the Waterlime-group. In Herkimer and Oneida Counties this conglomerate is closely associated with the Clinton beds which immediately succeed it; and, being there of coarse materials, they would be readily confounded in one group with the conglomerate (Hall, Pal. ii. 1).

It is to be remembered that, extensive as the Oneida Conglomerate is on the Atlantic side of North America, it has no place in the more remote west.

Place.—This rock is in very great mass in Oswego County; and, occupying all the interval between the mouths of Oswego and Salmon Rivers, dips into Lake Ontario, never to be seen more to the westward. From this large exposure in Oswego, it gradually thins off in an E.S.E. direction, and disappears under other rocks a little east of Utica.

Passing to the S.E. and S. by the shores of the Hudson River, and thence into New Jersey, Pennsylvania, and Virginia, this formation becomes very powerful, and forms distinct topographical features. As examples of this, we may instance the Shawangunk Mountains in the south part of New York, and the extension of the same range in the Blue or Kittaling Mountain, which in its southerly prolongation crosses the River Delaware at the Delaware Water-gap, and thence through Pennsylvania and the west part of Maryland into Virginia.

But the northern extension of this conglomerate from the frontiers of New York is perhaps still greater than the southern; for it can be traced, with very few intervals, from the Valley of the Hudson for 700 miles in a north-eastern direction to Gaspé, with a varying but considerable breadth. At Gaspé, the Atlantic stops further search.

Position.—This varies with the locality. In central New York there is perfect conformableness with the Silurian strata in general, and we observe a slight inclination to the south and west. More easterly, and nearer the seat of disturbance and metamorphism, the group becomes highly inclined and displaced, like the surrounding strata. Throughout the great Canadian continuation the dip is high, and to the S.E., with occasional gentle deviations. On the higher parts of the Shawangunk Mountains the Oneida Conglomerate has been thrust up horizontally in thick-bedded cliffs, the flanking rocks having an E.S.E. dip towards the Atlantic, and W.N.W. toward the Mississipi. In a paper on Plutonic Action, in preparation, this subject is further treated.

Thickness.—In this respect we have great differences. In the Shawangunk Mountains (which range from the New Jersey line, near Carpenter's Point, to Ellenville and Warwarsing in Ulster Co.), the maximum is under 500 feet; in the S.E, part of New York it is from 60 to 150 feet (Mather, p. 356); Prof. Rogers makes it about 200 feet.

Fossils.—Very few. Only perhaps a Brachiopod and a few Fucoids have been preserved.

Medina Sandstone.

Mineral Character.—Medina Sandstone is usually a red or variegated, or grey clayey sandstone, both fine and coarse-grained; solid and coherent about the parallel of Lake Cayuga, but becoming friable and marly in the west, with an intercalated mass of grey quartzose sandstone which contains fossils. This sandstone presents beautiful examples of oblique lamination, as at Rochester, Medina, and elsewhere, these lines being in some places more strongly marked than those of the stratification (Hall, p. 40).

Where best developed, as at Medina (Hall, Rep. p. 34, 35), it is in four parts, including the grey band. We begin from above:—

1. Red marl and nearly a shaly sandstone, with green spots and bands,—the bands being horizontal, parallel to the strata, or vertical. It is pebbly, black and red in places (Wolcott).

2. Grey quartzose sandstone, entirely distinct from the mass below.

3. The lower part of this is a mere repetition of No. 1 (red marl, &c.), gradually becoming more sandy west of Genesee River, while in the east this division (No. 3) is more siliceous, the central mass (No. 2) not appearing.

4. The grey or greenish-grey terminal portion of the mass. This is a variable stratum, argillaceous shale, argillaceous or siliceous sandstone by turns (Shawangunk Grit, the "grey band" of Eaton, and the Grey Sandstone spoken of just before Oneida Conglomerate).

There are brine-springs in this group throughout New York (Hall). The mineral character of this group changes gradually, but greatly, as it is traced from east to west.

Place.—Medina Sandstone has not been recognised east of Oneida County, or Little Falls. It is traced from thence towards Oswego, and then goes, as a narrow band, along the south shore of Lake Ontario to its west end, which it wholly embraces, and then takes a somewhat sinuous north-westerly direction to Lake Huron, where, still narrower, it runs along the north side of the Manitouline Islands, and accompanies in its proper situation the other Silurian strata, as they sweep from the south shore of Lake Superior, down the west side of Lake Michigan; a total course of 1100 miles.

Medina Sandstone is a great constant in this basin. We have only mentioned its northern outcrop. The southern extension from Oneida County, our starting-place, in a somewhat irregular course west of the Hudson River, and east of (and among) the Alleghanies, is 750 miles long, giving thus a total outcrop of 1850 miles east, north, and west. On the south it is buried everywhere under newer strata—under the Clinton, about Lake Ontario. M. de Verneuil is under an excusable error in stating (Bullet. Soc. Géol. France, 2 sér. vol. iv. p. 668) that Medina Sandstone ceases westward within the State of New York.

Position.—It dips slightly to the south and west. Further to the south, and beyond this State, it partakes fully of the irregularities of position impressed on its associate strata by the post-carboniferous uplift.

Transition.—Medina Sandstone rests upon the Grey Sandstone, the upper terminal of the Hudson-River-group in Oswego County (Hall, Rep. p. 31). The two intermingle, until the Medina group, always distinguishable by its red colour, is gradually substituted. There is, in truth, in central New York, a slow passage from the Hudson-River-group to the Medina,—a fact which explains the escape of certain fossil species from the lower to the upper Silurian stage by a lateral propagation of life.

Thickness.—I have few materials on this head. At Rochester, more than 100 feet are exposed; and 60–65 miles west, about Queenston, the thickness may be 350 feet (Hall).

Fossils.—This group, throughout the greater part of its thickness, is almost devoid of fossils. Towards the top of the mass (in grey quartzose sandstone No. 2), where it is more arenaceous, in several places (Oswego, Rochester, Medina, Lockport, especially) it contains many fossils, though comprehending few species. Between this point in Medina Sandstone, where fossils appear, and the point in the Hudson-River-group where similar fossils are found, there is a thickness, in some parts, of 1000 feet where no well-defined forms are known to exist. Thus, the grey sandstone ending the Hudson-River-group, the Oneida Conglomerate, and the lower part of the Medina Sandstone, separate the fossiliferous portion of the Hudson-River-group from the point with new organisms, where we are now, by a great thickness of barren strata. It is true that in the east part of the State these groups approach each other within 100 feet by thinning; but there also is no life.

The fossiliferous portion of the Medina Sandstone (the upper) is not thick; but at the west frontier of the State it attains a thickness of 100 feet.

Medina Sandstone only receives four forms of life from previously-existing strata; and it transmits two, perhaps only one.

The Tables II. & IV. show the number of species and the kinds of animal life which escape into and through the disturbed transition-period and past the Oneida Conglomerate. Most of them are recurrents, and some travel great distances.

Fossils typical.—These are seventeen in number, and comprehend neither Zoophyte, Bryozoan, Echinoderm, nor Trilobite.

Fossils occurrent in Europe.—*Cytherina cylindrica** only.

Fossils recurrent in New York—*Bucania trilobata* and *Calymene Blumenbachii.*

The peculiar marine plants of this sandstone are a marked feature (Hall, Pal. ii.). They extend into the Clinton group, and are seen nowhere else. This observation applies equally to New York, Pennsylvania, and Virginia. A belief, however, is gradually arising that many of these supposed plants are in reality *Annelida.*

Clinton Group.

Mineral Character.—The lower part of this set of strata has been well named the Protean Group. It consists of alternating

* *Leperditia cylindrica*, Hall sp., Jones, Annals & Mag. Nat. Hist. 3rd ser. vol. i. p. 253.

shales, sandstones, and conglomerates (counties of Herkimer, Stark, &c.). The shales are the most persistent, being present everywhere, east and west. The last is crowned with a top layer of limestone.

The above statement being true in the general, still this group is continually varying. Its extremities, eastern and western, within the limits of New York, scarcely show a detail in common, mineral or fossil (Hall, Pal. ii.). The easiest way, therefore, of communicating an idea of the true nature of this group will be by a series of sections,—the first exhibiting the Clinton in its most complete form, and the others its diversities from east to west.

Section I.

Above the Lower Falls of the Genessee. (In ascending order.)

1. Green shale, resting on the grey band of the Medina Sandstone.
2. Oolitic iron-ore, with concretions, bits of shells, corals, &c.
3. Pentamerus-limestone, with sandy layers or chert.
4. Green shale, paler than No. 1, with bands of limestone (*Atrypa hemisphærica* and *Graptolites*).
5. A second iron-ore bed.
6. Limestone similar to the more calcareous parts of No. 3. (*Crinoidea.*)

Section II.

James Hall's most easterly section is from the town of Canojoharie, Montgomery County, beyond the eastern limits of the Medina Sandstone and of the Niagara group.

It is as follows (from above):—

1. Drab-coloured layers of the Onondaga-Salt-group.

Clinton Group.

2. Coarse red sandstone, with pebbles, and containing much iron-ore.
3. A space occupied by shales.
4. Greyish sandstone, conglomeratic below; darker coloured and laminated above.

5. Oneida Conglomerate.
7. Shales of the Hudson-River-group.

Section III.

At Vanhornville. (From above.)

1. Onondaga-Salt group.

Clinton Group.

2. Red, coarsely-laminated, friable sandstone, with much iron-ore, and not in distinct beds.
3. Green shale, with fossils.
4. Red, diagonally laminated sandstone.
5. Greyish sandstone and conglomerate, with thin layers of green shale.

6. Oneida Conglomerate.
7. Shales and sandstones of the Hudson-River-group.

Section IV.

In Stark Township, Montgomery County. (From above.)

1. Onondaga-Salt group.
2. Quartzose sandstone and conglomerate, forming the top of the Clinton group.
3. Thin-bedded sandstones, with fucoids, alternating with green shale.
4. Red sandstone, diagonally laminated.
5. White sandstone with pebbles, and green shale.
6. Oneida Conglomerate.
7. Shales of the Hudson-River-group.

Section V.

Three miles south of Utica. It commences below the quartzose sandstone No. 2 of the last section (not seen here), and consequently is 60 to 100 feet below the top of the group.

		Feet.
Clinton Group.	1. Hard siliceous and silico-calcareous layers alternating; with much marine vegetation	15
	2. A slope, probably shaly	20
	3. Shales and shaly sandstones, with *Buthotrephis, Beyrichia*, &c., and iron beds	
	4. Upper portion shaly, and the lower part of thin-bedded sandstones with wave-lines and ripple-marks; *Beyrichia, Nucula*, marine plants	15
	5. A slope, probably shales	25
	6. Alternating layers of shaly sandstones, sandstone, and conglomerate with shale	28
		103

7. Oneida Conglomerate.

We see, then, that in the eastern and central parts of New York, the Clinton group is capped by a thick mass of sandstone, red or grey, accompanied by green shale ; and that, among many minor changes, as we travel westward, limestone in single or more layers, a few feet thick, gradually creeps in from near Lockport, which are in two bands at Rochester, thicken greatly at Medina, and at Lewiston constitute almost the whole group.

The Clinton group in the centre of New York is a powerful and ever-varying formation. Its analogies there are chiefly with the Medina Sandstone ; but in its western extension the Clinton group assimilates to the Niagara group, becoming in mineral and fossil aspects truly Wenlock, and quite distinct from itself in Oneida County*.

Vanuxem, in his Report, p. 83, gives some account of the ore-beds at Sodus ; and which are characteristic of this group as far west as the Genesee River (Hall, Pal. ii. 15). He calls them beds of lenticular clay-iron-ore (like the fossiliferous iron-ore of Pennsylvania),

* Professor H. D. Rogers defines the Clinton group, as it occurs in Pennsylvania, in the following terms:—

It consists of three parts.

1. The upper; variegated red marls or calcareous shales.

2. The middle; an alternation of shales and argillaceous and fossiliferous limestones and calcareous sandstones, with one or two remarkable seams of fossiliferous iron-ore.

3. The lower group, consisting of greenish and yellowish fissile slates, weathering olive- and claret-coloured, including in their central parts beds of red, very ponderous, ferruginous sandstone, usually containing two or three thin layers, rich enough in peroxide of iron to be available as an iron-ore.

The Professor goes on truly to say that the northern outcrop of Clinton, in ranging towards the west, displays what many other formations exhibit—a gradual change from a shore to a mid-sea type,—the shales and sandstones becoming gradually less in volume, and the limestone relatively augmenting. A bed of limestone and another of calcareous shale are all that represent it on the Niagara River; and in Wisconsin it is composed of little more than a thin stratum of fossiliferous limestone, which is there in contact with the Niagara Limestone, and with which it has been confounded.

and says that they lie in the red laminated sandstone, separated from the Oneida Conglomerate only by some shale and white sandstone with pebbles.

There are two ore-beds, 20 feet apart, and each 12 to 15 inches thick. The ore in all its localities is red or brownish-red, very hard, invariably oolitic, or in larger-sized concretions,—the oolitic particles being more abundant in the lower bed, the other in the upper.

In the "fourth geological district" they are separated by the calcareous shale, which contains the *Pentamerus oblongus* abundantly. This fossil, however, is rare in the east of New York (Vanuxem's third district), but is constant, from its first appearance in the east, as far west as beyond Monro County.

Transition.—Everywhere in the eastern and central parts of the State this group rests upon Oneida Conglomerate; for there is no Medina Sandstone in those districts. We have a good superposition east of Saltspringville, where we have, in succession from below—1. Frankfort Slates; 2. Oneida Conglomerate; and 3. The Clinton group. (Hall).

Further west, however, this group rests upon Medina Sandstone, as the sections given above make manifest,—the change being from quartz to clay, and apparently abrupt.

Thickness.—It is thickest in the centre of the State; but how thick exactly, I have not learnt. At Canojoharie it is only 50 feet thick; near Utica it exceeds 100 feet.

Position.—Being usually remote from causes of disturbance, the dip of this group follows that of the adjacent strata, and is almost horizontal, any inclination being toward the west and south.

Fossils.—A great outburst takes place in this group, of both animal and vegetable life; and this certainly from the great variety of mineral habitats which it presents. In the east, in the centre of the State, and on its western frontiers, invertebrate existence differs almost altogether.

One hundred and thirty-one new existences appear. These arise chiefly among the Plantæ, Zoophyta, Bryozoa, Brachiopoda, and Cephalopoda. It receives only 10 forms from the older strata, as may be seen in the Table of Escaped Fossils (IV.). It transmits 28 to the newer strata, 8 of these being Brachiopoda.

In the west the Clinton group loses many of its own characteristic fossils, and becomes charged with the Wenlock types of the Niagara group,—the limits of the two not being always very readily discernible. We have, nevertheless, a good guide as to the real birthplace of the fossils which hover about the limits of these two important and closely-connected groups, in the fact, that on the Clinton side of the probable limit the Clinton fossils are well-formed, while those of Niagara are ill-developed (Hall).

Tracks of molluscs, crustaceans, and other animals are common in this group, but they will be spoken of more conveniently afterwards.

The sandstones of the Clinton give us 13 typical species of plants in Eastern and Central New York especially. Scarcely one is seen further west than the eastern border of Wayne County (Hall, Pal. ii. 11). James Hall hesitates to consider them all Fucoids.

The absence of coral in the east of this group is to be ascribed to the nature of the sediment, and perhaps to agitation in the waters that deposited it.

Individual zoophytes abound in places, as from Wayne County to the head of Lake Ontario; and they resemble those of the Niagara period. Here we find for the first time the *Catenipora escharoides* (*Halysites catenulatus*), a world-wide fossil, together with the Bryozoa *Trematopora tubulosa* and *Retepora Clintoni* (in iron-ore, Vanuxem), and the new and beautiful *Graptolites clintonensis* and *G. venosus*. The Crinoids of this group are only in moderate number. In its lower portions they are very rare, especially in Eastern and Central New York, with the exception of some peculiar ring-like bodies in the ore-beds of Herkimer County; but, after passing to the west of the Genesee River, the upper limestone is often wholly composed of comminuted Crinoids (Hall, Pal. ii. 52).

The eight species of Crinoids are, with one exception, of types distinct from those of the Lower Silurian stage, and resemble more those of the Upper Silurian. It is only the species of the Upper Limestone that are Wenlock; those below are distinct.

Forty-three new Brachiopoda are here introduced, viz. five *Lingulæ*, seven *Leptænæ*, five *Orthides*, three *Spiriferi*, eighteen *Atrypæ*, and three *Pentameri*. Individual *Orthides* are few, and the species are fewer than in the lower stage.

Only three Brachiopoda are derived from older centres of life, and nine are transmitted onwards. Although very plentiful in the west, Brachiopoda are rare east of Wayne County, where the habitats are less suitable.

The species most numerous in individuals are the little *Atrypa hemisphærica* and the *A. congesta*; both of short vertical range.

The *Atrypæ* are more numerous now than the *Leptenæ* or *Orthides*, and contrast in this respect with them strongly. Types come in eminently significant of the middle or transition stage, or which assimilate with Upper Silurian species. In *Atrypa* we have the introduction of the smooth, round, or sub-cylindrical forms, which scarcely occurred in Lower Silurian.

As we see from the Table No. IV., several Brachiopoda from the Hudson-River-group come up here. It was once thought that no lower-stage form had survived the Oneida Conglomerate.

In the Leptænoid type this group is the lowest point at which the *Strophodonta depressa*, *Atrypa affinis*, and the remarkable form *Chonetes cornuta* are seen. The first, with the crenulated hinge-line, reappears in the Coralline limestone of Schoharie.

Lastly, we have the genus *Pentamerus*, unknown below, and marking the middle stage. There are six forms, if not eight (Hall), between the Clinton group and the Onondaga Limestone (Devonian) inclusive, and not seen higher or lower. In New York, it is usually in casts. Of the Monomyaria and Dimyaria, only five of the former have been met with. Far from conspicuous, even these are rare

(Hall, Pal. ii. 83); there is not one of either west of Rochester: the shales below the iron-ore bed on the east side of Wolcott have chiefly furnished them, while one or two species are common further east in the non-calcareous strata. More may be expected, and would probably have been found, but from the low and marshy nature of the country thereabouts. Perhaps *Tellinomya machæriformis* is the most plentiful bivalve in the group.

Trilobites are not prominent, and in many places are wanting. Nine new ones, nevertheless, appear in the west, under Wenlock influences; two have been derived, and four transmitted, leaving six to remain typical. These are mostly very unlike each other (Hall, Pal. ii. 296).

We rarely find entire trilobites east of the Genesee River. From this line westward to Lockport there is a constantly-increasing number of individuals, and a greater perfection in the specimens obtained. From this circumstance, and from the fact that in the west part of the State crinoids flourished in great numbers at the same time, we may infer that many of the fragments (mostly bucklers and caudal shields of trilobites) found in the thinning eastern extension of the shale have been drifted from localities further west.

Of the Gasteropoda eight are original, one received, two transmitted, and seven are left typical (see Table No. II.). The Gasteropoda are confined to that part of the Clinton group (Hall, Pal. ii. 83), which is east of Genesee River; and many of them occur as casts in ferruginous shaly sandstone.

Evidently physical conditions have here had much to do with the number and kind of Cephalopoda. Eleven are original, two received, three transmitted, and eight are typical,—here repeating the lesson often presented by the comparative incapacity of groups of sediments, or successive sea-beds, to receive and nourish each other's population; and this partly perhaps because in New York the floras of the feeding-grounds are respectively restricted always to a single group.

Some interesting Cephalopoda are nearly confined to the lower part of the Clinton group.

The most remarkable genus is the *Ormoceras*, of which a single species, *O. vertebratum*, occurs in great numbers in Chazy Limestone: it is rare in Trenton Limestone, appears again in the Hudson-River-group, and then lastly in the Clinton, having been formerly thought typical of the lower stage. It doubtless owed its strong viability to its free powers of locomotion.

Fossils occurrent in Europe.—Fucoides gracilis; Cornulites serpularius; Halysites catenulatus; Favosites gothlandica; Fenestella prisca; Glyptaster brachiatus; Atrypa hemisphærica; A. reticularis; Leptæna corrugata; L. depressa; L. sericea; Pentamerus oblongus; Spirifer lynx; S. radiatus; Beyrichia lata; Calymene Blumenbachii; C. punctata; Phacops sphærexochus (18).

Fossils recurrent in New York.—Halysites catenulatus; Rhinopora verrucosa; Trematopora tubulosa; Caryocrinites ornatus; Glyptaster brachiatus; Hypanthocrinus decorus; Leptæna crenistria (Devonian also); L. depressa; L. obscura; Orthis elegantula; Spirifer radiatus; Atrypa emacerata (Devonian also); A. neglecta; A. reticularis; Avicula emacerata;

A. rhomboidea; Posidonia (?) alata; Orthonota curta; Acroculia angulata; Platyostoma, n. s.; Orthoceras annulatum; O. virgulatum; Cornulites serpularius; Beyrichia lata; Calymene Blumenbachii; Homalonotus delphinocephalus; Ceraurus (?) insignis; Phacops limulurus.

Of these 28 recurrents, 21 reappear but once, and mostly in the Niagara period; 1 twice; and the rest more frequently.

The curious little crustacean *Beyrichia lata* is in the Clinton, Waterlime, and Pentamerus-limestone groups.

The Niagara Group.

Mineral Character.—This group commences as a dark shale or slate, and passes vertically into a dark-blue or black limestone, by a gradual increase of calcareous matter. When the limestone is in small quantity, it is in the form of hemispherical concretions, made up of successive concentric coats. It is further remarkable for numerous cavities lined with pink calc-spar, sulphate of strontian, selenite, fluor-spar, blende, or iron-pyrites. They are from a very small size to the diameter of two or three feet, and were originally occupied by fossils afterwards removed (Hall, Pal. ii. 3). On the whole, the limestone is as thick as, or thicker than the shale, which, though very thin in the west and far-west, accompanies the limestone everywhere.

This argillaceous limestone (not always so) is the chief or central mass of Upper Silurian Limestone of Middle North America. Many hundred miles west of the State of New York we find the Niagara group just as it is here, mineralogically and palæontologically. At the western end of the Manitouline Islands, in Lake Huron (halfway west), the Niagara Limestone is in great force, but it has become white, hard, and siliceous. Indeed, it may be truly said that in the west this group becomes massive limestone, and contains part of the lead-ores of Iowa, Illinois, and Wisconsin (Hall, Pal. ii. 107).

Transition.—In New York, the terminal or upper limestone of the Clinton group is succeeded by soft argillo-calcareous shale, 80 to 100 feet thick (Hall, Pal. ii. 3), and this gradually, both as to fossil and mineral character. In the lower parts of this shale, small ill-formed fossils, not Clintonian, abound. At Verona (easterly) the Niagara Limestone and Shale, much thinned, may be advantageously seen, resting on the Clinton group; sections exhibiting all this are innumerable.

In Wisconsin and other western regions the assimilation between the Clinton and Niagara groups is so perfect that their fossils are commingled, and they are themselves not to be distinguished.

Place.—The Niagara is one of the great "constant" groups, and always participates in their vast extensions.

In New York it stretches westerly across the State from Roudout on the Hudson River, and on the River Niagara passes into Canada. In its long course it lies between the Clinton and Onondaga-Salt groups,—visible as a belt which, at first narrow, gradually widens, but never in New York exceeding a few miles in breadth.

The Niagara group in its two portions, massive and shaly, is best seen in New York at Rochester, Lockport, and Niagara; but, although so powerful and well-marked in those localities, and even further east in Wayne County, it thins off rapidly east, and appears there quite subordinate to the Clinton, and almost destitute of its proper fossils. In Oneida County this group is in some places a mere thin sheet of shale with some beds of concretionary limestone, and so is scarcely separable from the Clinton beneath.

In the parallel of Little Falls the Niagara group goes no further east.

As before hinted, impoverished and slender as the Niagara has thus become even in the central part of New York, its place is still marked by a thin band of limestone, even as far east as the base of the Helderberg Mountains at Schoharie, and upon the Hudson River at Roudout. This is the Coralline Limestone of Schoharie (4 feet thick), to be spoken of afterwards. Near Schoharie (Hall, Pal. ii. 3) even this thins out as well as the Clinton and Onandago-salt groups, leaving the Hudson-River and Waterlime groups to come into actual contact (De Verneuil, Bullet. Soc. Géol. France, 2 sér. tom. iv. p. 655).

From the centre of the State, westward, the Niagara group, on the contrary, increases in magnitude. At Lockport and on the river Niagara it is 200 to 250 feet thick.

Near the west end of Lake Erie (Hall, Sill. J. xlii. 53), Niagara limestone appears above the surface of the water, from a subterranean uplift. It then, in a S.S.W. direction, forms part of the Cincinnati dome or axis along the borders of Ohio and Indiana.

In the central and western parts of Ohio the Niagara Limestone forms a most important rock, and is called the "Cliff Limestone" by Professor Locke. "We have, therefore, in these regions," says James Hall, "this condition of things: the Niagara limestone, which commences small in the east part of New York, has acquired great thickness, and has become the most prominent limestone, the Lower Helderberg and Onondaga-salt groups having all but thinned out."

Throughout this great extent of country (including North Illinois, Wisconsin, and Iowa), and for many miles west of the Mississipi, the upper beds of the true Niagara Limestone are characterized by, among other things, *Halysites catenulatus*, and often by a *Retepora*, —the former distinctive of Upper Niagara in Western New York.

The Niagara group is scarcely seen in Pennsylvania.

Position.—In New York this is horizontal to common observation; but there is a slight inclination to the south-west, with gentle undulations.

From Scanandea to Verona (New York) the Niagara group is lifted up and fractured (Vanux. p. 92). At Cincinnati on the Ohio, and for some hundred miles S.S.W. and N.N.E., this group, in like manner with others, suffers a prolonged, low, broad uplift, both with and without rupture.

Thickness.—It is four feet thick on the Hudson River, and even in the centre of the State the limestone portion is only a few feet more in thickness; but it enlarges westward to 250 feet at Niagara, and to 1000 feet about the River Mississipi, in the Illinois, &c. (Hall, Sill. Journ. xlv. 158).

Fossils.—A vast concourse of Invertebrates, numbering 180 species in New York, peoples the Niagara group. Among these, 156 new species make their appearance: the orders Monomyaria, Dimyaria, and Gasteropoda are comparatively weak.

Seven lower Silurian species are found surviving here:—

Stromatopora concentrica,	Phacops limulurus,
Trematopora tubulosa,	Bumastus barriensis,
Glyptaster brachiatus,	Calymene punctata,
Platynotus trentonensis.	

The other seventeen received fossils are from its immediate predecessor, and commonly from the calcareous capping.

The Niagara Group transmits but eleven fossils—four Zoophyta and seven Brachiopoda only,—every group being the scene of renewed creations and renewed destruction.

A thick bed of Niagara Limestone near the bottom is almost altogether made up of crinoid-joints, with some bits of zoophytes and shells,—the higher parts of this low-lying limestone becoming little else than zoophytes partly dissolved, and with an occasional mineral druse. The fossils in the shale below are less injured than here.

The Crinoidea and Cystidea develope together, both being more numerous in this limestone than either before or after.

From the Onondaga-Salt group to that of the Devonian Chemung there are not one half as many species as in the Niagara group alone. Thus it is in Europe; and with zoophytes also.

The variety in form, appendages, and ornamentation of Crinoidea is much greater in the upper than in the lower stage. They are confined in the Clinton and Niagara to a small thickness of strata; but they are twice as many as in the lower stage, and the proportion increases upwards. They were gregarious, and are now chiefly found about Lockport.

A large part of the Lower Silurian corals are even of different genera from those of the upper stage.

The Brachiopoda are numerous both in species and individuals. *Lingula* (1), *Leptæna* (5), and *Orthis* (7) are fewer, while *Atrypa* and *Spirifer* have become more plentiful. Of the six species of Monomyaria, only one, *Avicula emacerata*, is common.

Of the five Gasteropoda, *Acroculia* (*Capulus*) *niagarensis* first appears here.

The Cephalopoda are few in the higher parts of the Niagara group, but abound in the lower.

The Crustacea are very important. They characterize the lower shaly beds all over New York; but further westward, limestone, as we know, predominates, with the effect of diminishing the number of trilobites very much, and of proportionately increasing that of zoophyta. The twelve trilobites belong to ten genera,—a fact suggesting that many species yet remain to be discovered.

There is not a single species of the genus *Cyathophyllum* below the Onondaga Limestone, although representatives of this type came into existence at very early periods; still no *Cyathophyllum ceratites* of Goldfuss is known in the Silurian of America, or it is limited to the rocks below the Oriskany Sandstone (Hall). Although in the Niagara of America (=Wenlock) we have the family Cyathophyllidæ represented by *Streptelesma caninia* and three new genera here introduced, we have no true *Cyathophyllum*, nor have we *Cystiphyllum* nor *Heliophyllum* at the same period (Hall, Pal. ii.).

Fossils typical.—The number of fossils peculiar to this group is very great; in part because they belonged principally to animals not migratory, and often fixed to a rocky bottom, such as the Echinodermata, Zoophyta, Bryozoa, and others.

All the Bryozoa are typical except two; so are thirty-two Zoophyta out of thirty-seven; and twenty-five out of twenty-six Echinoderms. So also are all the Crustacea; and, save one, all the Cephalopoda.

This remarkable independence of other groups as to animal life must have arisen from certain conditions of matrix, depth, and temperature, which in the New York basin underwent a violent and sudden change by the advent of the variable sands of the Onondaga-Salt group, often charged with muriatic and sulphuric acids.

Fossils occurrent in Europe.—Sir R. Murchison states that this group contains more European fossils than all Lower Siluria.

Forty-seven European fossils occur in the Niagara group alone. Of these, one (France) is Lower Silurian; one Mid-Silurian (Upper Caradoc); six belong to Wenlock Shale; twenty-one to Wenlock Limestone; three to the Devonian series: of fourteen, the exact place I cannot ascertain, but most of them wear the Wenlock facies. They must be Upper Silurian, together with one or two more not mentioned. (See Table V.)

Forty-seven European fossils out of 180 (just one quarter) is a great number, and especially when we consider that ninety-six of these New York fossils are new species, unknown elsewhere. Twenty-nine are Brachiopoda.

This state of palæozoic life, combined with a close agreement in lithology, almost identifies the Niagara group with the Wenlock of England and Sweden.

Fossils recurrent in New York.—This group possesses thirty-eight recurrents, the life-links which connect it with the other parts of the system. Of these, nineteen come only from the Clinton; six from the lower Silurian; seven originate in the Niagara and pass upwards; and only four use it as a passage into the newer deposits. These are *Catenipora escharoides*, *Stromatopora concentrica*, *Leptæna depressa* and *Atrypa reticularis*. (See Table IX. in Appendix).

Coralline Limestone of Schoharie.

Mineral Character.—This is in reality a mere continuation of the Niagara group of the western limits of New York. See above, p. 360. It scarcely required separation.

It is a dark limestone, with a varying proportion of argillaceous matter, and received its name from the immense number of corals (chiefly *Favosites*) it contains.

Transition.—This takes place gradually, both vertically and horizontally.

Place.—It is only known in the east of the State, and has been most carefully examined by Messrs. Gebhard, of Schoharie. It extends along the base of the Helderberg Mountains, and along the River Hudson. It can also be traced west as far as Herkimer County.

Its place in the upper stage of the Silurian system is well made out. At Schoharie it rests upon the green shale of the Clinton, and continues westward above that group always, and beneath the Onondaga-Salt group (Hall, Pal. ii. 321).

Position.—This is the same as that of the Niagara group.

Thickness.—About four feet.

Fossils.—It is chiefly occupied by broken zoophytes, mostly *Favosites.* Of these but few species have been named—perhaps from their being so comminuted. We find *Columnaria inæqualis*; *Chætetes niagarensis*; *Diplophyllum coralliferum*; *Stromatopora concentrica* and *S. constellata*; *Catenipora escharoides.* The New York geologists do not mention here a single Bryozoan, Echinoderm, Cystidean, or Orthoceratite. There are only two *Leptænæ,* two *Orthides,* three *Spiriferi,* five *Atrypæ,* and one *Strophodonta* (*textilis*).

In the order Monomyaria are met with here four *Aviculæ* and one *Tellinomya,* no Dimyaria, seven Gasteropoda. These fossils show that the thin edge of the Niagara, as we may call the Coralline Limestone placed in the east of the State, sympathizes in the fossil-relations of the arenaceous deposits around. The conditions, we may remark, under which the sediment of the east and west parts of the State was deposited were very different, and the depth of the Silurian sea may have been unequal at that time; therefore we have a varied fauna and the Coralline Limestone of Schoharie.

Fossils typical.—Even in so limited a thickness, this limestone presents us with thirty typical forms, as now known. They are—

Columnaria inæqualis.
Diplophyllum coralliferum.
Stromatopora constellata.
Leptæna bipartita.
—— (Stroph.), n. sp.
Orthis interstriata.
—— orbicularis.
Spiriferi, two new species (*Hall*).
Atrypa limæformis.
—— lamellata.
—— nucleolata.
——, n. sp.
Strophodonta textilis.
Tellinomya æquilateralis.
Murchisonia obtusa.
Murchisonia terebralis.
Avicula limæformis.
—— securiformis.
—— subrecta.
——, n. sp.
Pleurotomaria subdepressa.
Bellerophon auriculatus.
Bucania, sp. indet.
——, n. sp.
Oncoceras expansum.
Trochoceras Gebhardi.
—— turbinata.
Phragmoceras, sp., indet. (near the junction with the Onondaga-Salt group) (29).

Leperditia alta is probably here, and typical (Hall and Mather).

Fossils occurrent in Europe.—Not one in this rock, except as considered a part of the Niagara group.

Fossils recurrent in New York.—Those which this limestone possesses in common with the Niagara group are as follows:—

Catenopora escharoides.	Stromatopora concentrica.
Favosites niagarensis.	Spirifer crispus.
—— gothlandica.	

Four of its fossils appear in newer formations and two in the older, exclusive of the Niagara. (See Table No. IX. in the Appendix).

Onondaga-Salt group.

Mineral Character.—This group consists of successive beds of argillaceous shales, marls, and shaly limestones, with brine-springs, and gypsum in beds and veins.

The prevailing colours are light-ashen and bluish-green; but the lower part of the group is deep red with spots of green, very like the shale of Medina Sandstone.

Vanuxem, in whose geological district this group is well seen, divides it into four parts in the following order, beginning from below:—

1. Red shale with green spots. It is blood-red, fine-grained, earthy in fracture, and without regular lines of division. Although it is of vast extent, and from one to five hundred feet thick, yet nowhere has a fossil been discovered in it, or a pebble, or anything extraneous, except a few thin layers of sandstone, and its different-coloured shales and slate.

2. Alternate beds of red and green shale. This consists of shales and calcareous slate of a light-green and drab colour, well seen near Lenox Turnpike. We have at the top of the series green, then red under it, alternating, downwards, with a little white and greenish sandstone, and finally red shale, as the lowest visible mass.

This second mass or deposit varies in its colours with the locality. Here gypsum occurs in fibrous masses, in reddish or salmon colours, peculiar to this No. 2; but its quantity is small.

This second deposit, as well as the third, are exceedingly permeable to water; so that wells on the hilly parts of the country are useless.

3. The third or Gypseous Deposit.—Two ranges of insulated masses of gypsum, called beds, in thin bands of argillaceous limestone, light and dark green, or drab.

It is only in this deposit No. 3 that we have positive evidence that salt has existed in this group in a solid state.

The great mass consists of rather soft, yellowish, drab, or brownish shale and slate, both argillaceous and calcareous, harder and softer. The whole is usually denominated gypseous marl. Some of the more indurated kind, when weathered, looks as if it had been hacked regularly with a cutting instrument, owing to joints in two directions, giving a rhombic surface.

Dr. Beck found a considerable amount of magnesia in the mass enclosing the lower range of plaster-beds.

The dark colour of the gypsum, and of many of its associates, appears to be owing to carbonaceous matter, as it becomes lighter by long exposure. The gypsum occurs in irregular isolated masses; and these are in two ranges of plaster-beds, as they are called, generally separated by the vermicular rock, with hopper-shaped cavities, and other less characteristic masses.

The "vermicular" rock is dark-grey or blue, and is porous or cellular, like lava, which it greatly resembles. It is full of curvilinear holes and variously-shaped cells, some of them having the forms which are due to common salt, which has afterwards been removed in solution.

There are two masses of this rock, an upper and lower; the former extensive, the latter not so. The upper is four feet thick, the other twenty.

The lower range of gypseous masses are arched over by thin calcareous layers. Just above them are, at intervals, long lines of hopper-shaped cavities. They once contained salt, and are covered in by a bed of the vermicular rock. These curiously-constructed and arranged cavities are each composed of six hoppers, placed with their apices downwards, so as to form the cube. For a more minute description, see Vanuxem's Report, p. 102.

4. The fourth or Magnesian Deposit; so called from presenting needle-formed cavities, caused by the crystallization of the sulphate of magnesia. They are plentiful, as at Troopsville, Springport, &c.

This upper mass is distinguished from those below by certain narrow vertical fissures or gaps, formed by the sulphate of magnesia; by the presence of the peculiar cavities (two or three inches long) first mentioned, and by the calcareous layers being more solid and thick; the softer marls, &c., having terminated with the third deposit.

The Onondaga-Salt group confirms a fact general in Europe, namely, that of the association of saline springs, gypsum, and magnesian limestone (De Verneuil, Bull. S. G. France, iv. p. 656).

The shrinkage-cracks observed in the surface of this rock show that it was, for a time, above water. They are more prominent about Cayuga Lake, and in Middle New York, than further west (Hall, Pal. ii. 147)*.

The presence of so much salt and gypsum, and of some free sulphuric acid, indicates a different origin for this group from that of any other in New York. At Byron, &c., in Genesee County, springs of free sulphuric acid have been met with (Hall, Rep. p. 133).

No valuable brine-springs have been found west of Lake Cayuga (Hall, Rep. p. 133).

Transition.—In New York this group came in at a period when the contemporaneous rocks of England were of the Wenlock age, continuously through several mineral changes, or were part of it; but in the western hemisphere this continuity of deposition was interrupted for a time by the introduction of the salt-group, to be covered here in its turn by Wenlock strata.

* The Onondaga-Salt group, according to Prof. H. D. Rogers, is imperfectly represented in the Appalachian Chain, south-west of the State of New York.

The passage from the Niagara group to the Onondaga is abrupt, without gradation of any kind.

The Niagara strata seem to have sunk down to a great depth, and thus allowed this accumulation of a new sediment 1000 feet thick,—the new sediment brought in perhaps, as James Hall thinks, through the agency of a mud-volcano, which widely spread this vast body of mud over the bed of the existing ocean.

Place.—The group now under consideration occupies the largest territorial surface in Central New York; and about Lake Cayuga and in the county of Onondaga. There the denudation of the newer rocks gives this formation a greater southern extension by several miles than it has further west. It has been, as well as the Niagara group, deeply excavated by ancient agencies throughout the greater part of Western New York. It is often a mere band in passing from the last-mentioned district to the River Niagara, but widens to the breadth of fifty miles in the Canadian counties, south-east of Lake Huron, and is still broader on Lake Michigan.

Its northern and western outcrop can be traced for 1130 miles from Schoharie, in New York, to the west side of Lake Michigan.

The Onondaga rests upon the Niagara group from the middle of Herkimer County westwards, and not only in New York, but whereever visible in its long course across Canada West to Michilimackinac and Lake Michigan, many of the islands of which, with parts of its west side, it occupies.

From where the Niagara group ends eastwards (Little Falls, N. Y.), the Onondaga rests on the Clinton, and still more easterly it reposes on the Frankfort Slate of the Hudson-River-group, and so continues to within a short distance of the Hudson River; but then it thins out to only few feet of thickness, begins to be absent in places, and finally disappears (Mather, Report, 353).

The grey or yellow porous (vermicular) limestone of this group was met with by Vanuxem at Sharon Springs, overlying Frankfort Slates, and underlying the Helderberg series.

Position.—This group displays a series of gentle undulations, like its associate strata. Sometimes they may be, in reality, excavations; but in many places, the layers of this group undeniably dip to the south-west,—at Syracuse, as well as in other situations, at the rate of 25 feet per mile (Vanuxem, p. 108).

Thickness.—This varies from east to west, thinning out in the former direction. It may be estimated at 700–1200 feet.

Fossils.—From the experiments of M. Beudant (Vanux. p. 102), testaceous animals cannot live in water saturated with gypsum; and such was mostly the state of the Onondaga-salt sediment.

Therefore, as Hall says, this group cannot be characterized by its fossils; there being so few, and these so imperfect. The few near the base are a continuation of species from the Niagara; and those near the top of the Onondaga-Salt group appeared after the various salts had ceased to prevail, and during the gradual change which restored the Wenlock epoch. There are few or no fossils in the middle of this group. In one place only, near the road from Jordan to Peru, did

Vanuxem find in the second deposit some *Cytherinæ,* about half the size of those in the next groups above and below. They occur in a thin layer of calciferous slate, which makes a large portion of the third deposit (Vanux. p. 98).

Both the Onondaga and Tentaculite Limestone contain the *Eurypterus remipes,* in clayey limestone with gypsum, in the upper range, third deposit, near Waterville,—at the end, therefore, of muddy saline deposits, on the reappearance of a purer lime.

I am not aware of the presence of a Trilobite in this group. We find in the top and bottom of the Onondaga-Salt group twenty-one new forms, chiefly Gasteropoda,—and these principally in its highest calcareous strata, and having a strong Devonian facies.

Eight species have been received from other Silurian epochs. They are—

Chætetes gothlandica, Stromatopora concentrica, Leptæna obscura, L. subplana, Avicula rhomboidea, Orthoceras æquale, Cornulites serpularius, Tentaculites ornatus.

Two only are transmitted onwards, while twenty-two are typical; almost wholly Gasteropoda and Cephalopoda.

This group has few affinities with any other deposit. The Galt fossils (Upper Canada), which have so added to the fauna of the Onondaga-Salt group, will perhaps prove to be Devonian (Onondaga Limestone, *see* p. 375). The region in which they were found has not been properly examined.

Fossils typical.—Of the twenty-two typical fossils, fourteen were unexpectedly discovered at Galt in Upper Canada, about sixteen miles to the N.W. of Lake Ontario, in a white limestone (Hall, Pal. ii. 147). The typical fossils, by name, are—

Heliolites interstincta, Pentamerus occidentalis (Galt); Megalomus canadensis (Galt); Avicula triquetra; Cyclonema sulcata; Murchisonia bivittata (Galt); M. Boydii (Galt); M. Logani (Galt); M. longispira (Galt); M. macrospira (Galt); M. turritiformis (Galt); Pleurotomaria bispiralis (Galt); P. perlata (Galt); P. sp. ind. (Galt); P. solaroides (Galt); Subulites ventricosa (Galt); Cyrtoceras arcticameratum; Orthoceras læve; Cornulites, sp. ind.; Calymene, sp. ind.; Hypanthocrinites ornatus ?, *De Verneuil.*

Fossils occurrent in Europe.—We only know three—*Tentaculites ornatus* (a Middle and Upper Silurian in both hemispheres), *Favosites gothlandica,* and the *Atrypa didyma,* detected by Daniel Sharpe in Sir Charles Lyell's collection of American fossils.

Fossils recurrent in New York.—These have been already enumerated, and are derived from the two groups nearest below, except the *Orthoceras æquale* (a swimmer), also occurring in the Utica Slate and the Hudson-River group in the E. of New York, where these come in contact with the Onondaga-Salt group.

Waterlime Group.

Mineral Character.—It is composed of two principal members,—Water-limestone and Tentaculite-limestone. Each of these, says Hall, should be subdivided.

The courses of the Waterlime rocks (which are the lower) are thin, and often not more than half an inch thick. They ring under the hammer. The limestone is brownish and geodiferous, impure, from the presence of silex, and often without the power of cementing (Mather, Report, p. 349).

The lowest and middle parts of the Tentaculite-limestone are slaty and black. The upper portion is black and dark grey, compact, and, in some layers, subcrystalline.

Transition.—The plane of separation between the Waterlime group and the Onondaga-Salt is rather well defined on the east side of New York (Mather, p. 348). At the foot of the Helderberg Mountains, the Waterlime group rests on Oneida Conglomerate, there called Shawangunk Grit, having however, but only in places, some pyritous strata, red shales, and grits between them, altogether usually under 30 feet in thickness. The pyrites is sometimes found in the limestone, and sometimes in the conglomerate, but often also only in the intervening shales and grits.

This is an indication of slow transition. The groups Onondaga-Salt, Niagara, Clinton, and Medina do not appear here.

Place.—This group is coexistent with the Lower Helderberg division, and is well seen in Hurley, Kingston, Marbletown, Rochester, Saugerties, Catskill, Athens, Coxsackie, and New Baltimore counties, on the west side of the Hudson River.

Thickness.—30 feet at Schoharie, and 100–150 feet elsewhere.

Position.—In Kingston, Marbletown, Saugerties, and New Baltimore, this group is well exposed by subterranean disturbances which have raised it at various angles and in different directions; but from Coeymans, by Bethlehem, Berne, &c. towards Central New York, the rock dips gently to the west and south, cropping-out towards the Hudson and Mohawk Valleys with a mural escarpment or steep acclivity.

Fossils.—Mather found them to be few; and these few have not yet received proper attention.

The lowest part of the Tentaculite Limestone abounds in *Favosites, Columnaria, Catenipora,* &c. The middle possesses *Tentaculites ornatus, Leperditia alta, Orthis plicata, Avicula rugosa* (all typical, Hall). The upper part furnishes several species of *Asaphus* and *Calymene.*

Prof. H. D. Rogers*, speaking of the Lower Helderberg Limestones of New York, of which Waterlime is the oldest, says that many of their fossils are generically and even specifically identical with the shells, corals, trilobites, and other fossils of the Wenlock of Great Britain, and therefore its nearest equivalent in America; and that it is the uppermost deposit of the Appalachian Sea (*i. e.* the Lower Helderberg group). This is the general conviction of geologists.

In 1854, James Hall, while employed in his great work on the Palæozoic Fossils of New York, said (Sill. Journ. xvii. n. s. p. 312) that, "poor as our lists now are, in the Lower Helderberg group, I

* Johnston's Physical Atlas, new edit.

expect to describe 200 species, exclusive of Corals and Bryozoa, of which I already know fifty species."

Fossils typical.—Until Mr. Hall's anticipations are realized, we find in the Waterlime group five typical fossils; namely,

Atrypa sulcata; Orthis plicata; Avicula rugosa; Euomphalus sulcatus, Littorina antiqua.

Fossils occurrent in Europe.—Tentaculites ornatus (Mid-Silurian); Spirifer plicatus? (Wenlock and Ludlow); Phragmoceras ventricosum (Aymestry and Wenlock).

Fossils recurrent in New York.—Spirifer plicatus; Terebratula hemisphærica; Cornulites serpularius (all Wenlock); Leperditia alta.

Lower Pentamerus Limestone.

Mineral Character.—This rock, according to De Verneuil (Bull. S. G. Fr. iv. 656), in Central New York is distinguished by the thickness of its strata and the compactness of its texture; but according to Mather, p. 347, the Pentamerus Limestone in his (the south-eastern) district is divided into strata and slaty layers by seams and thin partings of fine argillaceous slate or shale. It is in this district a slaty and subcrystalline grey and black limestone. Its upper layers contain here and there courses and flat nodules of hornstone. Vanuxem remarks that the divisional lines of its layers are not straight (p. 118).

Transition.— That this Pentamerus Limestone rests upon the Waterlime group is all I can gather from authors.

Place.—This is a very extensive set of strata in the south-east of the State (Mather, p. 347), running continuously from the west line of Schoharie County, eastward to the Helderberg Mountains in Berne and Bethlehem, whence it extends south-east and south to Kingston, and from thence south-west by Hurley to Rochester.

It then disappears beneath the quaternary beds of the Mamakating Valley, and is rarely seen from that place to Carpenter's Point on the Delaware. It is conspicuous near the village of Schoharie.

Taking up the description from Mather, Vanuxem (p. 118) says that the Pentamerus Limestone enters Central New York (the region allotted to him) from the south-east in considerable force, and continues to the Falls of Oneida Creek. Beyond this it is not distinctly recognized.

It does not exist from the west end of Madison County to Cayuga Lake; for from thence the Waterlime group, the Oriskany Sandstone, and the Onondaga Limestone come together, to the exclusion of all the rocks intermediate to the Waterlime group and the Oriskany Sandstone, which are found to the east.

Position.—Conformable with and parallel to its associate strata.

Thickness.—Vanuxem (p. 119) says that its maximum thickness is in Otsego County, and is not less than 80 feet. It diminishes toward the west, and little exceeds 10 feet on the Oneida Creek. Its limit there is not so well defined as at the east of the State. In the south-east of the State, at Schoharie, Mather (p. 347) found the Pentamerus Limestone to be 12–20 feet thick.

Fossils.—Palæontologically, according to Vanuxem, this rock divides itself into three parts :—

1st (from above). Layers with occasional nodules of hornstone.

2ndly. Similar beds, with *Pentamerus galeatus* (not the Clinton shell, which is *P. oblongus*, p. 356), *Euomphalus profundus*, and other fossils ; having under them a series of layers with *Lepocrinites Gebhardii.*

3rdly. More layers with *Pentamerus galeatus*, separated distinctly from those with the *Lepocrinites Gebhardii.*

At Schoharie we see only two divisions.

Mather finds many fossils in this rock ; but he gives but a slender account of them. Of those we know, six are original, five are derived from other groups, and three are typical. Twelve only are mentioned. Two Brachiopoda extensively distributed in the Lower Silurian stage are met with here.

Fossils recurrent in Europe.—These are two,—*Avicula naviformis* in the Ludlow of Westmoreland (Sharpe) ; and *Spirifer plicatus*, Wenlock of Shropshire and Ludlow of Westmoreland.

Fossils recurrent in New York.—Of eight recurrents, four are intimately connected with the Niagara group, and most of the others are found in the neighbouring strata also closely related to the Niagara ; so that we may consider, with the lamented Sharpe, that the Pentamerus Limestone and its associated limestones form a Western equivalent of the European Wenlock.

Further particulars of considerable interest may be seen by consulting Table VI.

Delthyris (Catskill) Shaly Limestone.

Mineral Character.—According to Hall (Geol. Rep. p. 144), this is an argillaceous shaly mass, or a shale with alternating beds of compact limestone. It was named from the *Delthyris macropleura* of Conrad.

Mather (p. 344) very properly arranges this limestone in three subdivisions :—

a. The upper portion, often called "Scutella-limestone," is a coarse, subcrystalline, grey limestone, full of fossils, with some peculiar to each stratum. The shallow, almost discoidal pelvis of an Encrinite, like a Scutella, is very abundant. It defines and limits this division.

b. The middle subdivision is a slaty limestone containing many genera of Testacea, Corals, Encrinites, with some Trilobites. Some species of the *Pentamerus* are characteristic (Mather, p. 345).

c. The lower subdivision is a mass of slaty argillo-siliceous limestone abounding also in fossil remains, especially in *Strophomena.*

Transition.—Linked together with the previous and subsequent group very closely.

Place.—The upper subdivision (*a*) is well developed from the west frontier-line of Schoharie County, ranging eastward by Schoharie to the east brow of the Helderberg Mountains, and from thence south-east by Clarkville to within two or three miles of the Hudson River. From that place, the outer edge of this Scutella portion runs south near Madison (?) to Kingston. It is well seen north of Cherry Valley and through the townships of Warren and Columbia in the county of Herkimer.

The middle subdivision is coextensive with the upper.

The lower subdivision is only visible eastward on the Helderberg Range and from thence south-east and east to Kingston, and is a prominent and well-characterized rock. It is not seen at Schoharie, nor west of that village (Mather, p. 345).

Position.—The same as the contiguous strata.

Thickness.—It is 30–40 feet in thickness, and is thicker in South-eastern New York than in Central New York.

Fossils.—Fossils are finely formed here and abundant, although they have not yet been fully described.

Of Zoophyta, Bryozoa, Echinodermata, Dimyaria, and Gasteropoda, it is only said by the New York geologists that they abound and belong mostly to the Niagara group.

Out of 71 organic remains, of which we have some particulars, 58 appear to be original, 7 are derived, 6 transmitted, and 53 are typical. But this is only true today.

Upper Pentamerus Limestone.

Mineral Character.—This stratum is distinguished from the last only by greater compactness and some superadded fossils (De Vern. *loc. cit.* p. 657), particularly by a smooth *Pentamerus,* similar in shape to, but distinct from, *P. galeatus.* It contains several forms of *Atrypa,* and according to Mr. Gebhard has a peculiar assemblage of fossils, distinguishing it from the beds below.

This second Pentamerus-limestone, according to Hall (p. 145), rests immediately on the Encrinal or Scutella-limestone. It appears, however, to be represented by Mather's second subdivision, *b,* of the Delthyris shaly limestone.

Transition.—The four subdivisions, Waterlime, Lower Pentamerus limestone, Delthyris shaly limestone, and the Upper Pentamerus limestone, are found together as the result of one epoch by community of fossils and close mineral similarity. They are continuations of the Niagara or Wenlock period, with such modifications as we might expect.

Fossils.—Our information here being limited, we anxiously await the forthcoming volumes of James Hall, treating on the palæontology of the strata above the Onondaga-salt group.

From that able and indefatigable geologist, however, I only expect more abundant illustrations of the equivalency of these four limestones to the Niagara or Wenlock strata.

Of the fossils enumerated as belonging to Lower Helderberg division, eleven are found in the Niagara group of New York, and several others are of the English Wenlock and Ludlow periods. None of them are seen below the Niagara group; some, however, run into the Devonian system, evidently heralding new mineral and vital conditions.

Fossils occurrent in Europe.—These are 18 in number; or more than one-third of the whole. All the 14 marked with an * are English also. They are—

Atrypa tumida* (*S.*†); A. Didyma* (*S.*); Leptæna depressa* (*W.*‡, *S.*), L. (Stroph.) pecten* (*S.*); Orthis hybrida* (*W.*, *S.*), O. orbicularis* (*S.*), O. resupinata* (*S.*); Pentamerus galeatus* (*W.*, *S.*); Spirifer bilobus (*W.*, *De Vern.*), S. plicatus* (*W.*, *S.*); Terebratula borealis* (*De Vern.*, *S.*), T. deflexa (*W.*, *De Vern.*), T. Stricklandi* (*S.*), T. n. s.* (*S.*); Atrypa reticularis* (*W.*, *L.*§, *S.*); Phacops Hausmanni (*De Vern.*), P. macrophthalmus (Eifel, *De Vern.*); Avicula naviformis* (*S.*),=18.

Fossils recurrent in New York.—These are only eleven:—

Leptæna depressa (also Devonian); Orthis resupinata (also Devonian); Spirifer macropleurus; Atrypa reticularis (also Devonian); Terebratula Wilsoni; Pentamerus galeatus; Euomphalus profundus; Avicula naviformis; Theca Forbesii; Lepocrinites Gebhardii; Cornulites serpularius.

They are all from below, except three, which pass upwards.

(Table No. VI. shows the palæontological relations of the four limestones above mentioned.)

The Devonian System of the State of New York.

Oriskany Sandstone.

Mineral Character.—This rock, the Potsdam Sandstone, and the Calciferous Sandstone, are the only strata, at least in and about Central New York, according to Vanuxem (p. 123), which present unaltered the sand of the Crystalline or Hypogene formations, as it appears when pure.

The Oriskany Sandstone is a coarse, rather loosely cemented siliceous sandstone, such as is derived from granite, gneiss, or mica-slate. It is yellowish-white, and contains flat chert-nodules and druses.

In the upper part of the rock are many concretions of dark, compact, and crystalline sandstone, from one to six inches in diameter; and it is full of cavities left by dropped fossils. Hall supposes that much of this rock has once been calcareous, from the number of its pores and holes, and from the abundance of its fossils; and it is now occasionally calcareous in a slight degree (De Verneuil, *loc. cit.* p. 657).

Place.—This sandstone holds a fixed position in the New York series, and is readily traced by its composition and characteristic fossils, which individually are numerous and distinct.

Oriskany Sandstone is confined to Eastern and Central New York, being absent in the west of the State, as well as from the countries westward towards the River Mississipi (De Verneuil).

"It is deposited," says James Hall, "in depressions due either

† S. stands for Daniel Sharpe. ‡ W., Wenlock Limestone.
§ L., Upper Ludlow.

to denudations or to natural inequalities in the surfaces of pre-existing rocks." (De Vern. *loc. cit.*)

Its position (Vanuxem, Rep. p. 123) is best seen in the south-east side of New York, near Salem,—the geographical division "Helderberg" being there complete. It projects from the side of the Helderberg Mountain, and forms a terrace resting upon Delthyris shaly limestone, the Oriskany Sandstone passing under, and covered up by, the Caudagalli Grit. Mather has only seen it in the south-east, on Schoharie Mountain and at Clarkville (p. 340).

It occupies part of the counties of Madison, Onondaga, Genesee, &c. In the eastern and central parts of the State its immediate associates cease entirely (Vanuxem) before reaching the west end of Madison County; and the Oriskany Sandstone rests at Manlius upon the Waterlime group, and is covered by the Onondaga Limestone, as at Perryville,—these three rocks extending, thus connected, to Lake Cayuga.

The localities at which this rock is visible are more numerous on the west side of Central New York than on the east side.

As Daniel Sharpe expresses it, this sandstone, the Caudagalli Grit, and Schoharie Grit are "beds of the same age, locally distributed."

Transition.—Its mode of passage from the subjacent rock is only mentioned twice—at Helderberg and at Oriskany Village. It there rests upon Delthyris shaly limestone, into which it graduates, containing multitudes of the *Atrypa lævis* of the latter rock.

Position.—It is conformable to the strata about it.

Thickness.—This rock in New York varies in thickness from two to seventy feet. It is usually thin in this State, and often in patches. In Pennsylvania, according to Rogers, it is a more constant stratum, and averages 700 feet in thickness.

Fossils.—This is a rock of great geological importance; for on entering it we lose the older fossils, except three *Atrypæ* (*lævis, emacerata* (?), and *reticularis*), *Spirifer niagarensis*, and *S. plicatus.*

As far as is now known, twenty-nine new species are introduced, of which 26 are Brachiopoda—6 *Rhynchonellæ*, 4 *Leptænæ*, 5 *Spiriferi*, 3 *Orthides*, 3 *Atrypæ*, 2 *Chonetes*, 2 *Meganteres*, and 1 *Leptocelia.* It receives and transmits 5 Brachiopoda and 1 Zoophyte into the Corniferous Limestone (Hamilton Group or Chemung), besides the universal *Cornulites serpularius.*

The fossils are mostly at the base of the rock, crowded and very large,—the most common being *Spirifer arenarius, Atrypa elongata,* and *A. unguiformis* of Conrad (Vanuxem, Rep. p. 123). They are all casts, except where the rock is slightly calcareous. The genus *Spirifer*, which has hitherto in the different groups been only of small size, here becomes large, and presents species which, by their dimensions and their numerous plications, approach the Devonian and Carboniferous types.

The plant we find here is a branchless, pipe-like fucoid. It is straight, and stands vertically in the stratum.

In 1854 James Hall wrote that he expected to describe nearly sixty species from this sandstone.

Fossils typical.—Fucoides verticalis; Atrypa elongata; A. peculiaris; Chonetes complanata; Leptæna depressa, var. ventricosa, and L. nucleata (Hall); Orthis unguiformis; O. musculosa; six Rhynchonellæ; Spirifer macropterus; Acroculia crassifrons.

Fossils occurrent in Europe.—Stromatopora concentrica; Cyathocrinites pyriformis (W.); Atrypa unguiformis; Spirifer arenosus; S. cultrijugatus? (Devon.); S. macropterus (Devon.); S. Urii (Devon.); Atrypa reticularis.

Fossils recurrent in New York.—These are eleven in number, most of them being Brachiopoda, and some from all the three stages of the Silurian system, on their way into still higher Devonian strata.

Caudagalli Grit.

Mineral Character.—This is an argillo-calcareous sandstone, passing into green shale. It is merely an upper portion of the Oriskany sandstone.

Transition.—In the State of New York, Vanuxem (p. 129) saw it resting upon the Delthyris shaly limestone, in one of the frequent absences of Oriskany Sandstone proper.

Place.—It generally accompanies Oriskany Sandstone. It extends from the western frontier-line of Schoharie County, eastwards by Schoharie, to the eastern brow of the Helderberg Mountains. From thence its outcrop goes south-east and south to Kingston. It is not seen in the Mamakating Valley further south-west than Marbletown.

This stratum has not been seen in Central New York, westwards, beyond Herkimer County, and not at all in Western New York. It is first visible eastwards in Mather's (S.E.) district, on the north side of Cherry Valley village, some miles from its last western appearance.

Position.—Is conformable to the groups adjacent.

Thickness.—Mather (Rep. p. 341) states this to be about fifty feet.

Fossils.—It presents only one—the elegant fucoid like a cock's tail, which also occurs in the Hamilton and Chemung groups.

Schoharie Grit.

Mineral Character.—This is a calcareous, fine-grained sandstone, —the carbonate of lime disappearing on exposure to weather, without alteration in the form of the rock.

Transition.—This rock and the last described are so thin, that, in De Verneuil's opinion, and in that of most geologists, they ought to be united.

Place.—Schoharie grit is local, and does not extend far west from Schoharie. By Mather it has only been seen near Schoharie and Clarkville, in South-eastern New York. Vanuxem states that this stratum does not exist in Central New York.

Thickness.—Only eight or ten feet at Schoharie.

Position.—This is the same as in the neighbouring strata.

Fossils.—This rock is marked as the lowest point at which in New York we recognize the type of Devonian fish, J. Gebhard having found in it a fragment of the *Asterolepis* (Verneuil, Bull. S. G. Fr. 2 sér. iv. p. 658).

With Schoharie Grit, says James Hall (Pal. i. xvii.), commences a series of fossils as distinct from those of the preceding formations as these from the lower division. We must, indeed, unite all the succeeding strata as Devonian; but the three divisions are only three terms in one system.

This rock contains many fossils, but they have not been registered.

We know of the presence in it of three Brachiopoda—*Atrypa impressa*, Hall, *Chonetes hemisphærica*, Hall, and *Pentamerus aratus*, Hall,—with *Phacops macrophthalmus* and certain *Orthocerata* having cross-rings. There is a *Cyrtoceras* like that of the Eifel on the Rhine. There is also a *Pleurorhynchus* of the size of some Carboniferous species; and numerous Corals occur (De Verneuil, *loc. cit.*).

Onondaga Limestone.

Mineral Character.—It is usually a pure limestone (Vanuxem), of a light-grey colour, and crystalline. Sometimes it is darker and more compact in texture, with its layers separated by green shale in seams.

In some localities it contains numerous nodules of flint in parallel layers (Vanuxem, p. 135). It looks like the Wenlock Limestone of England, but the latter has more intermixed shale. The lower layers of the limestone at Splitrock Quarry frequently hold black pebbles, distinctly waterworn, and identical with the sandstone-nodules, or accretions, of Oriskany Sandstone, south of Paris Hill, near Eastman's Quarry (Vanuxem, p. 137).

Place.—The impure limestone ending the Onondaga-Salt group is succeeded by the Onondaga Limestone, with a few inches of sandstone between them. This takes place throughout all Western New York, where the Waterlime group, Lower Pentamerus limestone, Delthyris shaly limestone, Upper Pentamerus limestone, and the Oriskany Sandstone and its two subordinate grits are wanting.

Onondaga Limestone also rests at Paris Hill and on the west side of Oneida Creek on Oriskany Sandstone. In another place it lies upon the Waterlime group.

This limestone extends from the Helderberg Mountains to near Lake Erie in unbroken continuity (Vanuxem, Rep. p. 132), but remarkably thin in comparison with its extent. Professor Troost found it in the State of Tennessee, marked by its typical Echinoderm, the *Encrinus lævis*.

The range of this limestone, according to another observer (Hall, Rep. p. 151), is in an undulating line, having a general east and west direction, which extends eastwards to the Hudson River, and westwards far beyond the River Niagara into Canada. Its northern outline is everywhere distinct, forming, together with the next succeeding rock, the second great limestone-terrace, which rises to the south of the valley, marking the range of the Onondaga-Salt group.

Transition.—This is abrupt. A pure limestone: this rock has no connexion with the preceding stratum, which may be one of several.

It is parted from the Onondaga-Salt group throughout most of Western New York by a few inches of sandstone, as already stated.

Position.—It is seen at Cherry Valley, &c., to dip south; and it is probable that the dip increases at no great distance from where the rock disappears. This would readily account for higher rocks in the series presenting themselves at the levels where we find them. There are also undulations (Vanux. Rep. p. 134).

Thickness.—This varies from ten to forty feet, and decreases westwards, the stratum being only fourteen inches thick at Black Rock on the River Niagara.

From its varying thickness, the materials of this limestone must have been unequally distributed over the bed of the ocean, lodging in depressions of the previous surface; or these greater developments are only local and due to coral-reefs, but whether circular or straight is not known. There was more than a single line of reef (Vanuxem).

Fossils.—These have not been properly arranged. They are numerous, and mostly zoophytes. This rock presents 39 new or original organisms, most of which are Brachiopoda and Zoophyta. It receives 2 Zoophytes and transmits 1 Monomyarian mollusc (*Avicula pectiniformis*, Hall, Conrad); 33 of its species perished, and are become typical. Hall's researches will alter these figures. In the Upper Helderberg group he expected, in 1854, to describe 100 species, besides Bryozoa and Zoophytes.

This rock is frequently made up entirely of broken corals and crinoids, often tinted pink. It is, in fact, a mere coral-reef for large spaces. An Ichthyodorulite has been found here, and a *Lithodendron.*

Fossils occurrent in Europe.—*Encrinus lævis* is met with in English Wenlock, as well as *Favosites alveolaris* (Hall).

Fossils recurrent in New York.—These are *Catenipora escharoides, Favosites alveolaris*, and *F. gothlandica* from the Upper Silurian stage, together with *Leptæna depressa*, which enters the Corniferous limestone. To these we have only to add the universal *Atrypa reticularis*.

Corniferous Limestone*.

Mineral Character.—Especially at the east end of its range, this is a fine-grained, compact limestone, light greyish-blue, dark-blue, black, or even drab. It contains hornstone in nodules and layers, sometimes to the exclusion of limestone, as is nearly the case at the mouth of the River Niagara (north side), where the layers are black and very rugged. In the higher parts of the rock there is sometimes

* Professor Rogers calls the Upper Helderberg Limestone of New York (that is, the Corniferous and Onondaga) the "Post-meridian Series." He recognizes it as a widely-expanded marine limestone, and as the upper part of the Cliff Limestone of the west. He observes, also, that it contains nodular chert, many fossils, ganoid Devonian fish, Devonian and Carboniferous fossils—*Productus* and *Pentramites*,—showing that even Carboniferous races tenanted the waters of the Appalachian post-meridian sea (Johnston's Atlas, new edit. p. 31).

no hornstone. This rock seems to Hall to be composed of finely-levigated calcareous mud, with much silex introduced.

It is distinguished from Onondaga Limestone by its greater compactness, by its possessing more hornstone, and having no *Crinoidea* nor *Favosites* (Hall); but as this distinction is not always easily made, the two ought to be thrown into one group, which would then be as useful and extensive an horizon as either the Niagara or the Trenton (De Verneuil). The so-called "Seneca Limestone" is the top or terminal portion of the Corniferous (Vanux. Rep. 144).

This is a most persistent stratum, and is more uniform in mineral character and extent than any other. It therefore becomes one of the best planes or levels of reference in the whole New York system (Hall). With this rock terminate all the important limestones of this basin, the calcareous deposits of higher position being thin and local. The subsequent sediments are quite different from that of the Corniferous limestone; and so, for the most part, are the organic remains.

R. C. Taylor (Statistics of Coal) notices the existence of petroleum-ponds in this rock near London, Canada West.

Transition.—It is intimately connected with Onondaga Limestone; they graduate into each other.

Place.—It extends across New York from the Helderberg Mountains to the River Niagara and westwards.

Resting upon Onondaga Limestone, and supporting Marcellus Shale, the Corniferous limestone is co-extensive with them in New York.

It passes into the west from the mouth of the River Niagara, along the north side of Lake Erie, in a broad belt which is projected north-westwardly into Lake Huron and the countries W.S.W. of that body of water, and, bifurcating, is again continued from the S.W. side of Lake Erie southwards into Ohio and Illinois, in both which great States this rock takes its proper place as a Lower Devonian limestone of vast extent.

Like Onondaga Limestone, this rock has been greatly denuded, as about the Rivers Genesee and Niagara. The Lakes Seneca and Cayuga also have been hollowed out of it, the hollow extending dry for many miles north of the first-named lake. Three miles south of the village of Seneca Falls, this limestone is broken by faults, partly from denuding violence, and partly by the removal of subjacent gypseous beds (?) (Hall, Rep. p. 161).

Position.—Corniferous limestone has a general dip to the south-west, and at one place at the rate of 27 feet to the mile (Vanuxem, Rep. p. 141).

Thickness.—The maximum is 80 feet in New York according to one authority, but 71 feet according to Hall; and usually it is much less.

Fossils.—Fossils are few here, and are mostly molluscs (Hall, Rep. p. 163).

The deposition of this limestone was the commencement of a change by which the sea became too deep for corals. Those coral-banks which had been formed in the Onondaga limestone were then buried by calcareous mud derived from other quarters.

Corniferous Limestone gives us forty original forms; and receives only four Brachiopoda (*Leptæna depressa, L. crenistria, Orthis tulliensis,* and *Spirifer cultrijugatus*) and one Trilobite (*Phacops macrophthalmus*). It transmits seven Brachiopoda and four other molluscs.

Thirty-four fossils remain typical, chiefly Brachiopoda and Gasteropoda. Among these are *Odontocephalus selenurus* of Green (at Auburn), and *Calymene crassimarginata*—occurring in the higher parts of the group, where there is no hornstone. There the fossils most prevail.

The organic remains of the Onondaga and Corniferous limestones do not intermingle, but remain quite distinct, as far as is at present known, although those two sets of strata are so closely connected and so similar in composition. For further details the reader is referred to Tables VII. and VIII.

Fossils occurrent in Europe.—There is a *Cyrtoceras* like those of Devonshire (De Verneuil), besides thirteen other invertebrates common to New York and Europe. They are—

Halysites catenulatus	*De V. M'Coy*	Russia, Ireland, &c.
Chonetes nana	*De V.*	Russia (Devonian).
Leptæna depressa	*Sharpe*	Sweden, England.
Orthis crenistria	*De V.*	Europe.
Productus subaculeatus	*De V.*	Russ., France (Dev.).
Spirifer cultrijugatus	*De V.*	Eifel (Dev.).
—— heteroclytus	*De V.*	Russ., Eng. (Dev.).
—— mucronatus	*De V.*	England (Dev.).
Terebratula aspera	*De V.*	France (Dev.).
—— concentrica	*De V.*	Russia, Rhine.
Atrypa reticularis	*De V., Sharpe*	Europe.
Bellerophon striatus	*De V.*	Europe (Dev.).
Lucina proavia	*De V.*	Europe.

Fossils recurrent in New York.—The sympathies of Corniferous limestone are principally with the Hamilton and Chemung groups. The recurrency of Devonian fossils, as affecting this rock, is represented in Tables IX. and X. (the several mineral groups with which it has no palæontological connection are omitted). The relations of this stratum as to fossils, it will be seen by Table X., are all with the upper sections, save in one instance.

Marcellus Shale*.

(The Black Shale of Kentucky, Ohio, and Indiana.)

Mineral Character.—This shale ought to be divided into two parts (Vanuxem, Hall). The lower part is a very black bituminous

* Professor Rogers thus describes the Marcellus Shale of New York, as it is continued into Pennsylvania and further south. It is there, according to him, a black and highly bituminous slate, graduating upwards into a dark-blue argillaceous shale, surmounted occasionally by greenish sandy shales. A thin argillaceous limestone generally occurs at the bottom of the black slate in Pennsylvania, Virginia, and Tennessee.

The fossils of this shale comprise numerous species of mollusca and other marine forms, several of which are identical with the Devonian, and Carboniferous species of Europe, many being found in no other rock. *Goniatites* and other Carboniferous genera characterize Marcellus Shale (Johnston's Atlas, *loc. cit.*).

slate, full of iron-pyrites, with calcareous concretions here and there, and courses of septaria, and has a strong general resemblance to Utica Slate or Genesee Slate. This part ends upwards by a thin band of limestone.

The upper portion above this is a more fissile slate, of an olive- or dark slate-colour. Both these divisions thin off westwards and south-westwards.

At the eastern commencement of this rock, its lithological character is similar throughout the whole mass; but, as we proceed westwards, we perceive a gradual separation of constituents,—the more shaly portions, with some calcareous matter, taking the lower position, while the sandy and slaty parts hold the higher place. This occurs up to near the River Mississippi.

The fine mud composing this rock, together with the nature and delicate state of the fossils, show that this stratum was deposited at a quiescent period.

Transition.—The change from Corniferous limestone is everywhere abrupt. A black argillaceous slate is laid down at once. The fossils of the subjacent limestone are absent.

Place.—It extends, east and west, through New York, with a varying but narrow breadth, from near the River Hudson to Lake Erie. A long strip of it proceeds from Lake Erie, S.S.W. into Tennessee, in its proper stratigraphical position; and it is seen alone (the Hamilton group having thinned out) at Canary Fork and the Harpeth Hills near Nashville in Kentucky, as well as near to and S.W. of Louisville and at New Albany, Indiana. Small portions of coal and much bitumen have been found at some of these places. This shale is seen to rest on Corniferous limestone at Oneida Creek and at Marcellus.

Thickness.—This is 150 feet in Central New York, 30 feet in Western New York, and still less on the north-west frontier of Pennsylvania about Lake Erie. In Pennsylvania, more to the south, the greatest thickness is 300 feet (H. D. Rogers).

Fossils.— In the upper parts of this shale fossils are few; and these principally in the calcareous concretions.

Our accounts of fossils in this and the other Devonian strata are merely provisional, awaiting the appearance of James Hall's new volumes. At present we have to state that Marcellus Shale produces twenty-two original species, chiefly Brachiopoda. It receives but one fossil, a Brachiopod; transmits five; eighteen remaining typical. It contains some remarkable organisms. The characteristic genus *Goniatites* now appears for the first time. Desor (Bull. S. G. France, 2 sér. ix. p. 314) says that in the black schists over the cliff-limestone (equivalent to Marcellus and Genesee Slates) Mr. Christie found many kinds of *Goniatites*, which Mr. Hall thinks identical with those of the Carboniferous limestone of Europe.

One has been named *Goniatites Marcellensis*; but it is from the lower part of the stratum in New York.

The genus *Lingula* reappears here; there are also a *Productus*, a new *Tentaculites*, two *Orthocerata*, and the *Dipleura Dekayi*.

Vanuxem found smooth arborescent fucoids in this group.

Fossils occurrent in Europe.—There is only one, *Productus subaculeatus* (De Vern.). It is both in Russian and Rhenish Devonian.

Fossils recurrent in New York.—Almost its only relations (and they are not close) are with the Genesee Slate, to which, though not near in place, its mineral composition is very similar; *Tentaculites fissurella, Leptæna* (*Stroph.*) *setigera,* and *Avicula fragilis* are the only species common to the two groups.

The highly fossiliferous group (the Hamilton) has only one Marcellus fossil, the *Homalonotus Dekayi*; and according to Hall it is rare.

Hamilton Group*.

Mineral Character.—This group may be called a great development of dull-olive or bluish-grey calcareous shales, weathering grey or brownish. It consists of shale and sandstone in endless mixture, in three distinct mineral masses as to kind, the sandy portions being generally in the middle (Vanuxem). Concretions or septaria are common in every part of this group, in well-defined forms gathered round a nodule of iron-pyrites or some organic body (Hall).

The three portions into which this group has been rightly divided are, beginning from above,—1st, the Moscow Shales; 2nd, Encrinal limestone; and 3rd, the Ludlowville Shales (often called Skeneateles and Olive Shales).

The *Moscow Shales* are dark-blue, finer and more calcareous than the others, and very like the Niagara Shales of Central New York. They terminate upwards in the Tully Limestone, soon to be mentioned; and they contain septaria.

The *Encrinal Limestone* is impure, tough, brown, and full of Echinodermata. It is persistent and always found on the same horizon.

The *Ludlowville Shales* differ from the above in being sandy.

James Hall (Report, p. 165) makes the following useful remarks on this group:—"Although this group is so widely and evenly distributed, and of uniform character over the western part of the State, still at its eastern extremity the lithological character is widely different. The shales are more or less arenaceous; and some parts are well-marked sandstone. The proportion of siliceous and argillaceous earth is nearly reversed from what it is in the same rocks further west. The mass varies from sandy shale to shaly sandstone, and even tolerably pure sandstone. This character gradually changes to the westward,—the sand diminishing, and the clay increasing.

"The features presented by this group at its two extremes and along its whole length offer one of the most instructive exhibitions of the varying character of mechanical deposits. The facts prove the origin of the materials to have been at the east or south-east.

"The force of the current which drifted them into the ocean was

* Professor H. D. Rogers characterizes this group, as he met with it in Pennsylvania, as a bluish-grey, brownish, and olive-coloured sandstone, sometimes calcareous (Atlas, Johnston).

sufficient only to carry on the coarser particles to a certain distance, where they were deposited. The finely levigated mud was carried beyond this point, being floated by less force than the sand.

"Some portion of the clay was deposited with the sand toward the central part of the State; and but little of the latter extended beyond this point. Finally the current became more gentle, and the clay was deposited to a certain extent, beyond which the power of the current was insufficient to carry even this material; and the deposit consequently thinned out in that direction."

Transition.—This is very gradual, and from the Marcellus Shale. In fact, Prof. H. D. Rogers, with the sanction of all American geologists, has included within one and the same series Marcellus Shale, the Hamilton group, and Genesee Slate, and has named them the "Cadent series."

Place.—It is seen to rest on Marcellus Shale in numberless places, among which are Varick and Fayette townships in Seneca County, and on Flint Creek, Ontario County.

If we leave the territory of New York, the extent of the Hamilton group is enormous, and far beyond any profitable details.

Taking our departure from Coeymans, a village on the Hudson River, we trace its eastern outcrop for 244 miles southwards to Orwigsburg.

From Coeymans, again, following the northern outcrop westwards, it stretches across New York, and by Buffalo to South Harbour on Lake Michigan, a distance of 913 miles,—while it forms a belt of 1000 miles in length around the Illinois Coal-field. But this is not all; it takes its proper place among Devonian groups in vast prolonged stripes throughout Ohio, Kentucky, and Tennessee.

In Eastern New York the Hamilton group passes through the counties of Sullivan, Ulster, Greene, Albany, Schoharie, and Otsego. In Central New York it is entirely confined to the counties of Otsego, Madison, Onondaga, Cayuga, Herkimer, Oneida, Courtland, Chenango, and Tompkins. In the first four of these last it covers much surface—one-half of Madison; in the last five, very little. In Western New York it traverses the counties of Ontario, Livingstone, Genesee, and Erie.

Position.—It is conformable with its associate strata; but the hard blue shale of this group about Kidder's Ferry is distinctly seen to rise and fall in undulations (Hall).

Thickness.—In the east of New York it is 1000 feet thick (De Verneuil). In the central and western parts of the State it varies from 700 to 300 feet (Hall and Vanux.); but it always thins westwards, and especially from the River Genesee. On the shore of Lake Erie it is not half as thick as at Lake Seneca (Hall, Report, p. 187). Its greatest thickness in Pennsylvania is 600 feet, according to Rogers. This group has suffered much denudation. The valleys of Seneca and Cayuga Lakes are palæozoic excavations in these shales for more than half their length.

Fossils.—The fossils of the Hamilton group are remarkable for their great numbers and exquisite perfection. We seem to be culling them from the dried ocean-mud, so much do these soft shales resemble the mud-deposits on the bays and shores along the sea-side. It is so rich because its mineral character undergoes constant variation. In the east of New York, many of the fossils of this group enter the Chemung, their lithology being there much the same, which is not the case further west and south-west.

James Hall, in 1854, expected to find in the Hamilton, Portage, and Chemung groups 300 species,—or double that number, if the investigation were pursued in the *Western Counties* as well as in New York. They are at present known to be 155.

In the east of New York, this group abounds with *Avicula* (14 species out of 33, New York Devonian), *Cypricardia* (14 out of the 20, Devonian), and *Nucula* (10 out of 12, Devonian),—while at the west end of the State they are very rare, and are replaced by abundance of *Spiriferi* and *Atrypæ*; and this from change of habitat. Some of the more abundant Corals of Marcellus Shale are here,—new forms, however, being plentiful, and vastly so the Brachiopoda and Dimyaria.

We have here 127 creations or new appearances. Among these are 47 Brachiopoda. There are 22 Monomyaria, 30 Dimyaria, 5 Trilobites, 11 Gasteropoda, and 6 Zoophyta (see Tables VII. and VIII.).

A terrestrial plant has been found in this group, near Cooper's Town; its first appearance in the New York Basin (Hall).

There are marine plants also; but they have not been described, except the singular *Fucoides Caudagalli*. The genera of some of the Corals, Molluscs, and Trilobites are the same as those in the Niagara group: but this would seem to prove little; for the genus *Tellina* appears to run through ten formations, from Upper Silurian to the recent period, and the genus *Cardium* through twenty-two (Morris).

A ridged *Posidonomya* is found on both sides of Lake Otsego. The Acephala are many and fine. *Agelacrinites Hamiltonius* is said to have been found at Hamilton (Vanuxem). In North America there are several species of this curious animal (according to Mr. Billings, the palæontologist of the Canadian Geological Survey), one of which, the *A. Buchii*, was found by me many years ago in Trenton Limestone at Hull, near Ottawa, Upper Canada. We have *Goniatites punctatus*, and the first New York *Inoceramus* (*oviformis*). An *Asterias* from this group is quite different from those of the Lower Silurian stage, or of the present seas, in having the plates perforated by pores, the pores not passing between the plates (Hall).

This group was evidently produced in quiet times. There were no disturbances, uplifts, currents, or high waves. The deposit was made too deep to be reached by surface-waves, except perhaps in particular places (Hall). Its muddy bottom suited the Lamellibranchiata well.

Some beds of limestone in the middle of the Hamilton group are entirely filled, on Lake Skeneateles, with *Cystiphyllum* and *Cyathophyllum* (Hall).

The same group of fossils is often maintained exclusively for many miles, as on the south shore of Lake Erie, where there is a thin stratum made up of *Cypricardia*, *Turbo*, *Bellerophon*, and *Orthocerata*, without any other Mollusc. It is a continuation of a like stratum on the east, but with other shells superadded. Apparently there were distinct periods of formation (Hall).

Fossils typical.—These are 131, and they are principally Brachiopoda and Lamellibranchiata.

Fossils occurrent in Europe.—They are 38 in number in this single and imperfectly-examined group. They represent most of the genera.

Of these 38 species, 21 are members of the Devonian system in their respective countries, 2 belong to the Wenlock Limestone, and 1 to the Upper Ludlow. The remaining 14 have not yet been properly traced. It is easy nevertheless to perceive that the Hamilton group represents the Devonian system in Europe; but the particular stage to which it best refers has yet to be ascertained.

Fossils recurrent in New York.—For particulars, see the Table of Devonian Recurrency in New York.

We observe here, that of the 29 recurrents of this group, none come from its immediate predecessor. Eight are derived from the Corniferous Limestone, although usually the mineral constitutions of the rocks differ.

Eighteen Hamilton fossils, out of 19 which pass upwards, are found again in the Chemung group, mineralogically a very similar set of strata. Only one species proceeds into the Tully Limestone.

The Hamilton maintains more frequent relations with the neighbouring groups than any other, both upwards and downwards; but, unlike the Onondaga and Tully Limestones, &c., none of its fossils are recurrents from the Silurian system.

Tully Limestone.

Mineral Character.—This stratum marks prominently the end of the fossiliferous shales of the Hamilton group; but, being so slender, small, and barren, it scarcely deserves a separate denomination.

It is a thick-bedded deposit, close-grained and compact in parts. It is often a mixture of shaly and calcareous matter,—the latter prevailing, and often sole. The usual colour of this rock is blue or nearly black.

Tully Limestone is the last Devonian stratum in which lime forms an essential part,—the lithological character of the products above being similar throughout, and different from those below.

This contrast of character is more marked toward the west end of New York (Hall) than it is further east; and finally on its eastern extreme there is a greater mineral similarity. Here a few Lower Devonian fossils creep into the uppermost group of Middle Devonian (Hall, p. 213).

Place.—Tully Limestone only occupies a small part of the State; and is particularly well seen on the Cayuga and Seneca Lakes, undulating along their shores in broad low arches. It commences in the east, near Smyrna, Chenango County, and is seen no further west than Lake Canandaigua, about 100 miles distant. Hall (Report, p. 212) found that it thins gradually out, west from the village of Tully, in Onondaga County. In his district, this rock is first observed on the west shores of Lake Cayuga, for many miles, being continuous from the last-named body of water to Lake Seneca, and to the outlet of Crooked Lake.

Transition.—Tully Limestone rests distinctly on the Hamilton group. Besides other instances, this occurs near De Ruyter's Mills, and at the beautiful section on Lake Cayuga given by Hall (Report, p. 211). The transition is abrupt in the west, but more gradual in the east, the two strata assimilating in mineral and fossil character.

Position.—It dips gently to the S.W., with broad undulations, which are very visible on Lake Cayuga, and, more northerly, at Kidder's Ferry, rising and falling with the immediately underlying blue hard shales.

Thickness.—Vanuxem finds it to be 14–20 feet in Central New York; westward of this it becomes less than 10 feet, and, as already said, it dies out near Tully Village.

Fossils.—This rock contains very few fossils, and therefore marks with distinctness the end of the fossiliferous shales of the Hamilton group. A few forms, however, from below make their way into it.

With the end of Moscow Shales (Hamilton), the great mass of the fauna of that group perished; and for a long period the ocean-bed appears to have been without life, save a few creatures in Tully Limestone and Genesee Slate. Living existences only return near the summit of Genesee Slate, and go on increasing, until, in the upper part of the Chemung group, the ocean is crowded with life.

The fossils of the Tully Limestone are—

Strophomena linearis.
Orthis resupinata.
Rhynchonella cuboides?
Atrypa affinis.
—— didyma?
—— lentiformis, var.
Atrypa prisca.
—— reticularis.
Orthis resupinata.
Avicula reticulata.
—— signata?
Calymene marginalis.

Tully Limestone originates 4 Brachiopoda, 1 or 2 *Aviculæ*, and a Trilobite. It neither receives nor transmits, except in Brachiopoda; all of them very recurrent. Of these it receives 6 and transmits 2.

It is not easy to account for this absence of life in Tully Limestone. Further light may be expected from James Hall.

Fossils occurrent in Europe.—It is remarkable that four out of the thirteen fossils of the Tully Limestone (so far as yet known) are European, namely—

Orthis resupinata, *Phill.* (O. Tulliensis): Carbonif.-Lim., England and Ireland.
Rhynchonella cuboides? *Phill.*: Dev. England.
Atrypa didyma?, *Sharpe*: England.
Avicula reticulata, *Conrad*: Europe.

This is a remarkable approximation for localities so very distant, and in so insignificant a stratum.

Fossils recurrent in New York.—These are only three or four. *A. affinis* and *A. reticularis* are both found in the Clinton group of Silurian date, while *A. prisca* is Devonian strictly, as we find it only in the Hamilton and Chemung groups.

Fossils typical.—They are three or four :—*Orthis resupinata* (and perhaps *Rhynchonella cuboides*), *Avicula reticulata,* and *A. signata* (Hall), with *Calymene marginalis.*

Genesee Slate.

Mineral Character.—In New York (Hall, Rep. p. 218), it is a great development of argillaceous fissile black slate, in colour and general character much resembling Marcellus Shale. It contains concretions or septaria in one or more layers. Mineralogically and palæontologically, this rock is everywhere the same, on Lake Cayuga or Lake Erie. From the fineness of its particles and its mineral uniformity, this slate must have been deposited at a quiescent period. Near Ludlow Village, it contains two narrow veins, composed of a mixture of serpentine and limestone, somewhat like a trap-rock : there are two similar veins near the Second Falls at this village (Vanuxem).

Prof. Rogers finds this set of slates to be brownish or bluish-black, and very fissile in Pennsylvania (Johnston's Atlas).

Transition.—This is not mentioned in the New York Reports, as far as I can find.

Position.—Conformable with the surrounding sedimentary strata.

Place.—It is not seen to the east of Smyrna, Chenango County; but it extends westwards through the counties of Seneca, Yates, Ontario, &c., to Lake Erie, in the neighbourhood of which it thins off and disappears.

It rests on Tully Limestone at Kidder's Ferry, Lake Cayuga, and at Crooked Lake, and on the Moscow Shales of the Hamilton group (Hall).

Thickness.—On Seneca Lake and in the county of Ontario, this is 150 feet; but on Lake Erie it is only 27 feet. It is 300 feet thick in Pennsylvania according to Prof. Rogers (Johnston's Atlas).

Fossils.—The fossils found in this State are only ten, according to published statements; and all these occur about the summit. They are—

Tentaculites fissurella.	*Orthis quadricostata.
*Lingula concentrica.	Atrypa quadricostata.
*—— spatulata.	—— reticularis.
*Orbicula Lodensis.	—— didyma?
Leptæna (Stroph.) setigera.	Avicula fragilis.

The fossils marked with an * occur on Lake Cayuga, and are typical.

This stratum has considerable fossil-relations with Marcellus Shale, as may be seen on referring to Tables VIII. and IX.

Genesee Slate gives us six original Invertebrates, four being Brachiopoda, together with a well-defined leaf of grass or sea-weed, with a smooth surface 6 inches long by $\frac{1}{5}$th of an inch broad; Vanuxem also found this grass-like plant in the Portage group.

Prof. Rogers mentions in the Pennsylvanian continuation of this stratum numerous small and delicate Molluscs, chiefly of Devonian, but some of Carboniferous, genera. It also there contains a terrestrial vegetation generically identical with the Coal-measures.

Fossils occurrent in Europe.—We only know of one, the *Orbicula Lodensis*, Hall.

Fossils recurrent in New York.—Five connect this rock with its near relation Marcellus Shale. Two other fossils (*Atrypa didyma* and *A. reticularis*) are received from the Clinton, Onondaga-Salt, and other Silurian groups, assisting therefore to establish the connexion between the different parts of the palæozoic systems.

Fossils typical.—These are four. They are marked with an * in the above list.

Portage Group (or Nunda).

Mineral character.—It is an extensive development of argillaceous and sometimes micaceous shales and flagstones, and, finally, of some thick-bedded sandstones towards its upper part. Like all the mechanical deposits of this system in New York State, it is very variable at different parts.

Shales and sandstones compose the whole. In the lower part, these are more equally intermingled, and the sandstone is finer,—while higher up, the sand is coarser, and there is less shale.

It has been divided into three parts, beginning from below, as follows:—

a. Cashaqua Shale.—This division is worthy of a separate name, and is called after the Creek Cashaqua. It is there a green, soft, argillaceous rock, which crumbles into tenacious clay. It contains calcareous concretions.

b. Gardeau Shale and Flagstones.—These, placed above the Cashaqua Shales, are a great accumulation of green and black slaty and sandy shales, with thin layers of sandstone.

c. Portage Sandstones consist of thick-bedded sandstones with little shale. The lower part is of thinner sandy layers with more shale. Its thick-beddedness and the abundance and variety of its fucoids (some vertical) may perhaps justify the separation of this group from the rocks below: but it is only in the State of New York that the Portage group ends with these thick-bedded sandstones; it is not so in the Western States, Illinois, Indiana, Ohio, &c. Indeed all these palæozoic rocks, as before said, vary greatly with place. In one locality the line of division among its parts is clear, at another obscure, or very gradual*.

The materials of the Portage group (Hall, Rep. p. 254) came from

* Prof. Rogers (Johnston's Atlas) defines the Portage group, as met with in Pennsylvania, to be a rather fine-grained grey sandstone, in thin layers or flags, and parted by thin bands of soft blue shale.

the east of Central New York, and probably from the south-east, as is evident from the thinning of the deposits, and the diminution of the sandy strata, towards the west. The increase of shale westwardly proves the same thing, it being lighter and more transportable. This is a mere repetition of what took place in the sediments of the Hamilton group.

That the sea was alternately shallow and deep is proved (Hall) at every step among these strata.

The ripple-marks and diagonal lamination seen here are not met with in the dark- and light-green argillaceous shales, because they were laid down in deep water. These shales are very homogeneous.

The sands were deposited in shallows; and the occasional diagonal lamination shows that the sand has been pushed over an inclined plane. The shrinkage-cracks are not so large as those in the Medina Sandstone. There are casts of flowing mud at Portage on the banks of the River Genesee, as well as mud-furrows and striæ. Many of the ripple-marks have the appearance of having been caused by a chopped sea, from the current opposing the wind, the ripples being short, interrupted, and irregular.

Place.—The threefold group of Portage is, in truth, the lower portion of the Chemung, the next set of strata. They have been separated, without very good reason, on account of the total absence from the Portage of the Chemung fossils (save *Clymenia complanata* and perhaps *Atrypa reticularis*), the great rarity of Invertebrates of any kind, and the finer grain of its sandstone (Hall). The Portage and Chemung groups always accompany each other, and undergo the same changes. For information, therefore, as to "Place," the reader is referred to the description of the last-mentioned group.

Transition.—Hall says, very accurately, that there is no abrupt mineral change in any of the rocks from the end of Tully Limestone to the top of the Chemung. The Portage group rests upon Genesee Slate, as at Cayuga; and the transition is gradual.

Position.—This rock dips very gently to the south or south-west; —or is horizontal (Hall).

Thickness.—This averages 1000 feet; but the rock thins off to the west, with the rest of its associate strata. It is thickest on the Genesee River.

Fossils.—The fossils of this group present some important peculiarities, induced probably by either depth or temperature.

There are many marine plants; but only two are distinguished (Hall), namely, the *Fucoidea graphica* and *Fucoidea verticalis* (Annelidan?).

Barren of life as is this thick mass of shale and sandstone, still it yields twenty new forms. Among these is the beautiful *Cyathocrinus ornatissimus*, found only, and in great numbers, on a limited part of the south shore of the Lake Erie, at Portland. These animals seem to have all died at once, buried under the sudden accumulation of a new mud.

While the Chemung abounds in Brachiopoda, this group has only five (see Table VIII.). In the Hamilton and Chemung, Brachiopoda are predominating forms.

Three typical *Goniatites* appear in the Portage, the Chemung having only one, and that new. The eminently Devonian Cephalopod, *Clymenia complanata*? (Van. and Hall), shows itself here for the first time, with the *Ungulina suborbicularis* (Hall).

Cashaqua Shale contains, as common (and typical, except *Goniatites sinuosus*), *Avicula speciosa, Ungulina suborbicularis, Bellerophon expansus* (Marc. Shale), *Orthoceras aciculum, Clymenia complanata, Goniatites sinuosus, Pinnopsis acutirostra, P. ornata* (Hall, Rep. p. 243).

The following are in the more central parts of the group :—*Spirifer lævis, Cardium*? *vetustum, Orthis tenuistriata, Lucina*? *retusa, Nucula lineolata, Astarte subtextilis, Bellerophon striatus*?, *Goniatites bicostatus, G. sinuosus, G. retrorsus, Cyathocrinus ornatissimus,*—the principal forms being *Goniatites, Bellerophon, Pterinæa,* and a typical *Avicula* (Hall, Rep. p. 245, and De Vern. *loc. cit.*).

The Portage group only received one Brachiopod and one Gasteropod. It transmits the same bivalve, and a single Cephalopod. Its fossil-connexion with other strata is therefore very slight. We see the same partial distribution of life in the Upper Devonian of England.

Fossils typical.—These are nineteen in number, and are spread through seven orders.

Fossils occurrent in Europe.—Until we hear further from James Hall, we only know of two,—the Devonian *Goniatites retrorsus* of Nassau, and *Atrypa dumosa.*

Fossils recurrent in New York.—These are only four,—*Bellerophon striatus* (Cornif. limest.), *B. expansus, Clymenia complanata* (Chemung), and the almost universal *Atrypa reticularis.*

Chemung Group.

Mineral Character.—This is a highly fossiliferous series of shales and thin-bedded sandstones, sometimes in distinct courses, and in infinite variety both vertically and laterally, from the intermixture of the two ingredients. This thin- or thick-beddedness depends on the purity of the materials, on the proportion of clay, and on rate of deposition.

These rocks may be described as thin-bedded sandstones or flagstones, with intervening shales, and frequently with beds of impure limestone resulting from the aggregation of organic remains (Hall).

The whole series weathers brownish olive. The shales pass from deep black to olive-green. The sandstones vary from brownish grey and light grey to olive. Lines of diagonal lamination and ripple-marks are common.

The upper part of the group tends to be a conglomerate; and here and there it is a true, but very thin, puddingstone, with the usual fossils (Hall).

"It is plain," says Hall (Rep. p. 254), "that the origin of the materials of this deposition was to the east of Central New York, and probably to the south-east, as is evidenced by the thinning of the deposits, and the diminution of the sandy strata, at the west. The increase of shaly strata in the same direction (which finally diminish also) proves the same; for this, being longer suspended, was transported beyond the sand. We have here a corroboration of the same view as presented under the Hamilton Group, viz. a position in Eastern New York near the margin of this ancient sea, while toward the south-west we approach that part of more profound depth and greater distance from shore. The evidence continues through the Hamilton, Portage, and Chemung groups; for in all these, and in the intermediate beds of shale and limestone, we find a constant diminution south-westerly.

"Also in Eastern New York we find, both in the Hamilton and Chemung, specimens of land-plants, or such at least as did not grow beneath an ocean. These are rare in Central New York, one or two fragments only having been found; and at the south-west part of the State and in Ohio I have seen nothing of similar character. The inference naturally follows, that these were derived from land on the eastern margin of this ocean; and that some fragments floated westward, and were deposited with the sand and mud.

"Many of the thin sandy laminæ throughout the district are often almost completely covered with small fragments of carbonaceous matter, apparently derived from terrene vegetation. These seem to have been comminuted fragments of vegetables, brought down by streams from the continent or islands on the east, and, being spread evenly over the surface of the water, were distributed widely," as we see now in lakes and bays.

This indicates an approach to the great coal-measures.

M. de Verneuil (*loc. cit.* p. 662) agrees with these statements. He says that the predominance of sandstones and schists in the eastern parts of New York shows that the continent existed on that side,—from whence the rivers and coasts furnished their elements to the sediments, just as the American geologist observed.

The fucoids and ripple-marks, so abundant in every group from the Potsdam to the Chemung, testify also to the proximity of bottoms and shores; so that, thick as it is, perhaps all the palæozoic deposits were laid down in a shallow sea, whose bottom probably sank, more or less continuously, to receive new sediments.

The Chemung beds are sometimes treated separately, but without good reason. One part is called the Ithaca group. It is a succession of coarse hard shales and sandstones, of a dark colour, and without any limestone. They are about 400 feet thick, and are best seen at Ithaca in the county of Tompkins.

Transition.—Except in a very few places, there is no strongly marked dividing-line between the Portage, Chemung, and Ithaca groups. The distinction is in the presence or absence of certain fossils, and in the sandstone being coarser and more argillaceous than in the rocks below; but its lithology is variable. The same agents were working in the Chemung and the Portage.

Place.—The Chemung group may be termed one of the "constants" of the Central North American palæozoic basin. Throughout its vast extent, embracing a diameter of 1500 miles, speaking roughly, this stratum is brought under human cognizance wherever there is an uplift of sufficient power to remove the superincumbent rocks; and this takes place abundantly in the Western States, especially in Illinois and on the River Mississippi, as will be shown incidentally while treating on another subject.

Together with Marcellus Shale, the Hamilton, and other Devonian groups, the Chemung forms the base and part of the mass of the Catskill Mountains; it likewise occupies the top of a part of the Helderbergs. It ranges, with its usual associates, from the Delaware River, near Carpenter's Point, along the west side of Mamakating Valley, to Kingston; thence, on the west side of the Hudson Valley, nearly north, at the distance of a few miles from the Hudson, to the south frontier-line of Albany County, whence it bears away to the north-west, on the Helderberg Mountains, at a higher level than in other parts of their range, and finally, west, along the southern side of the Mohawk Valley; and it occupies much of the south part of the State between the Erie Canal and Pennsylvania (Mather, Rep. p. 317).

The counties in New York in which the Chemung group prevails are Sullivan, Ulster, Chenango, Courtland, Chemung, Steuben, Alleghany, Cattaraugus, and Chatauque.

In the Western States, it is in narrow bands of enormous length, which follow and underlie Carboniferous Limestone in innumerable windings, and rest upon black slate (Marcellus Slate) or the Hamilton group. It is most conspicuous on the Mississippi, as surrounding the Illinois and Michigan coal-fields; in the Valley of the Cumberland River, besides many other places. On these points we shall soon have further information from Professors Safford and Swallow.

Position.—It exhibits undulations, usually slight; but on the Mississippi River, in two localities of considerable size, the Chemung group is violently subverted by volcanic agency, and in other places it is raised for a short space into flat domes.

Thickness.—It is 1500 feet thick in New York, thinning, however, westwards. In Pennsylvania, Professor H. D. Rogers makes this rock 3200 feet thick. In that district of country, the Chemung displays some most instructive sections.

Fossils.—This group contains 104 species of fossils, many or most of them casts (De Verneuil). They often occur in patches or groups. For instance, we have the following fossils in the green or olive shales and shaly sandstones of Rockville and Phillipsburg on the River Genesee, according to De Verneuil (*loc. cit.* p. 661):—

Pterinæa? suborbicularis; Pecten duplicatus; P. cancellatus; P.? striatus; P. crenulatus; P. convexus; P. dolabriformis; Lima rugostriata; L. glabra; L. obsoleta; Avicula signata.

We find several fossil plants, especially towards the top of the group. Some of them are marine, and some resemble those of the coal-beds. Of these the *Uphantœnia Chemungensis* possesses a beautiful and complex structure; and is therefore indicative, like the genera *Sphenopteris, Sigillaria,* and *Calamites* (which occur here), of a temperature somewhat elevated, and favourable to a fauna of large and ornamented forms, such as we have here. Many of the fossil plants of Chemung have drifted from the east; but others are too well preserved to have travelled far (Hall).

There are here 58 species of Brachiopoda (see Table VII.). There are 57 Brachiopoda in the closely-allied group, the Hamilton. In the same manner, the Monomyaria of the two groups are of nearly the same strength; but the Dimyaria are ten times the most numerous in the older group.

There are here three species of Zoophytes, as far as I can collect, namely *Millepora gracilis*, a *Petraia*, and an undetermined *Cyathophyllum*. There is also one undetermined *Retepora*.

Among the Echinodermata we have only the *Echinus? Drydenensis* and the *Encrinus tricyclas*. While the Echinoderms, Trilobites, and Cephalopoda are disappearing as we ascend in the palæozoic scale, the number of *Aviculæ* and *Pectines* increase. With De Verneuil, we wonder at seeing these two genera, so plentiful in the Devonian and Carboniferous epochs, come down to the recent period without losing their importance, but leaving in every great formation such numerous representatives. The Chemung has one very important Cephalopod, the *Goniatites Chemungensis*. There are three Trilobites, but only in fragments; two of them being derived from the Hamilton group.

The original races in this group present 83 species; 21 have been received from prior strata, 12 of them being Brachiopoda (see Table VII.). We know of no fossil being transmitted to the Catskill Group, the American representative of the Old Red Sandstone of Europe.

At Ithaca the fossils are numerous, but not well preserved. Here is found the *Strophomena Ithacensis*. In the lower part of the mass at Ithaca are three or four species of *Cypricardites*, a shell resembling the *Clymenia* of Phillips, some *Atrypæ*, &c., together with a singular branching nondescript fossil; also, indistinct but long traces of plants of a lanceolate, and sometimes falciform, shape. The *Fucoides Cauda-galli* is seen in De Ruyter, in Smyrna, and in Waverley Sandstone (Dr. Locke). For a general list of the fossils, see the Table of Devonian Fossils.

Fossils occurrent in Europe.—Twenty-six Chemung fossils, or one quarter of the whole, are found in Europe; and most of them, if not all, are Devonian in that hemisphere. Nineteen of them are Brachiopoda, of the genera and species usually found in the Upper Silurian stage and the Devonian system. Many very important families among the Plantæ, Zoophyta, Crustacea, Cephalopoda, &c., are but poorly represented in Europe in these rocks; but still, after all, the number of European fossils met with in Chemung is great, and that, perhaps, partly from its thickness and remarkable extent. In this, it contrasts strongly with the limited fossil-connexion maintained in the old continent by localities not very far removed from each other, as Bohemia and Sweden.

Fossils recurrent in New York.—This group receives from those preceding it twenty-one fossils, principally, as before said, from the Hamilton group, and in the east of New York mostly.

The Chemung is Devonian, says Daniel Sharpe (Géol. Journ. iv. p. 155); and but for its separation from the Hamilton group by the almost unfossiliferous Portage group, the two ought not to be kept separate. Only two Molluscs are derived from the Portage group; and one, *Leptæna crenistria*, from the Clinton of the Silurian system. It has four organic remains in common with Oriskany Sandstone, only one with Caudagalli Grit, namely the singular fucoid giving name to that stratum. It has no relations whatever with Schoharie Grit, Onondaga Limestone, and Marcellus Shale; and with Genesee Slate but one common fossil, *Atrypa reticularis*. The Chemung group receives four species from the Corniferous Limestone, and two from Tully Limestone. We see from all this, that fossil-connexions are not exclusively influenced by the mineral character of the rock.

Fossils typical.—The large number of sixty are peculiar to this group, principally Brachiopoda and Monomyaria, which are inhabitants of mixed sediments. The other ten orders are almost altogether absent, as far as we know at present. To find in any shale or sandstone a Cephalopod, an Echinoderm, or an Annelid, would go far to prove that that shale, &c. did not belong to the Chemung period.

Catskill Group.

Mineral Character.—It consists of light-coloured greenish-grey, or fine-grained red sandstone, interspersed with layers of red or dark-coloured shale and slate, with beds also of grindstone-grit. There is, further, a mass apparently composed of fragments of hard slate cemented by limestone (the "cornstone" of England); but it is only a few feet thick.

We have also conglomerates, more or less coarse, of a greyish, greenish, or red colour.

All these are arranged as follows, from above downwards:—

1. Conglomerates and coarse schists.
2. Red shales, slates, and grits.
3. Grey and greenish-grey slaty grits.
4. Chocolate-coloured grits, with red shales and slates (Mather, Rep. p. 302).

The stratum of brecciated and conglomeratic limestone, marked 129 by Mather, in his detail of layers, as they occur in the Catskill Mountains, and found not far from the base of this group, is met with over a large area, though rarely more than 2 feet thick. It is therefore a good reference-stratum. It often contains carbonates of copper, iron, and zinc, but in very small quantities (Mather, Report, p. 307).

Along the Genesee River, and in Steuben County, the Catskill group exhibits a thin mass of calcareous sandstone, highly charged with iron, and containing the remains of fishes. It rises from beneath the coal-measures of Pennsylvania, extending north, and resting on the rocks of the Chemung group; as in England it does on the Ludlow formation (Hall, Rep. p. 278).

Oblique laminæ of deposition are often strongly marked. The ripple-marks are common and good, the current going from N. 30° E. to S. 30° W. (Mather, Rep. p. 313).

Transition.—There is no well-marked line of demarcation between the Chemung and Catskill groups. The change takes place gradually by the diminution and final disappearance of the fossils found in the former groups, and by the supervention of a harder and more solid rock (Vanux. Rep. p. 187). Neither is there a defined plane of separation between the Chemung rocks and the sandstones of Ohio and Indiana which contain Carboniferous fossils (Hall, Am. Journ. of Science, n. s., vii. p. 45).

The Catskill group is the immediate predecessor, and the base, therefore, of the Coal-formation (Vanux. Rep. p. 189).

From lithological reasons alone, the two deposits Chemung and Catskill are not synchronous. The olive-shales and sandstones of Chemung, full of *Strophomenæ, Spiriferi,* and *Atrypæ,* are succeeded by a red sandstone destitute of the organic remains of the lower rocks. In the higher rocks, shells are few and new, and everywhere there are *Fish.*

Place.—In his district, Vanuxem finds this group in the Counties of Otsego, Chenango, Broome, Steuben, and Tioga. Hall states that it occupies all the County of Delaware, and portions of the Counties of Sullivan, Ulster, Greene, Schoharie, and Albany; but its main body lies in the Catskill Mountains (Hall, Rep. p. 278).

In the five first-named counties, Catskill being the terminal group of the New York series, it holds the highest position relatively to the other rocks, and caps some of the greatest elevations.

Position.—The Catskill group is conformable with the Chemung. Although its strata in the Catskill Mountains seem to the eye to be horizontal when viewed near, they are not so really, but dip at a slight angle to the south-west. From Caterskill Creek the layers emerge in a succession of terraces, with a steep bold escarpment on the east, sloping away gradually to the west (Mather, Rep. p. 306).

The directions of the main axes of elevation and depression are from N.N.E. to S.S.W., and from E.S.E. to W.N.W.; and they have two systems of smooth joints corresponding with and parallel to them.

Thickness.—It varies from 2000 feet in Pennsylvania to 4000 feet in the Catskill Mountains (Mather, p. 306), with a rapid diminution of thickness from the aforesaid mountains westwards (Hall, Rep. p. 278).

Fossils.—Plants very abundant, terrestrial and marine, resembling those of Ithaca and Chemung, but more numerous. There are thin seams of coal, with *Sigillaria simplicita* and Fucoids in the red rocks. Other fossils are few. There are only *Cypricardites Catskillensis* and *C. angustata* at Mount Upton on the River Unadilla, Chenango County. They resemble freshwater shells.

We have here the characteristic fish *Holoptychius nobilissimus* and *Sauripteris Taylori* (Hall), the former being plentiful in Europe on the same horizon.

Inferences.

The following inferences, from the Synoptical View now completed as far as my information extends, are presented to the Society, as marking some of the principal points of interest; but I may be permitted, by way of preface, to make two or three short remarks.

First, I desire to express my high admiration of the learning and ability displayed by the State Geologists of New York, as well as by the able and now famous men engaged in the like arduous pursuits in other portions of the North American Confederation. Upon the results of their toils, dangers, and personal sufferings in the hot and mosquito-haunted forests of the United States, this Synoptical View has been constructed.

Secondly, one very disinterested remark I feel constrained to make before proceeding to my proper work. In my endeavour to understand fully the Silurian system, I read and re-read the works of Sir Roderick Murchison. The impression left on my mind after their perusal, is that they are master-pieces of geological investigation, which a rare combination of talent, perseverance, and opportunity has in all essential points rendered impregnable.

Thirdly, I am entitled thus to speak, because many years ago, standing in North America, on Silurian ground, before it was so denominated, personally and well acquainted with many of the most important geological sections, I clearly foresaw the coming discoveries in their universality and grandeur. Before me was a new and deeply interesting volume of palæozoic story, which my want of field-experience in Europe at that time (together with other duties) prevented my displaying for the instruction and delight of those who find pleasure in the works of creation.

Inferences, Conclusions, or Results.*

1. That, whatever may be the case elsewhere, the Silurian and Devonian systems of New York are parts of one connected and harmonious period—the product of successive and varying Neptunian agencies, operating in waters which deepened westward from the Atlantic, and southwards from the Laurentine chain on the north.

2. That from the Catskill group (Old Red Sandstone) downwards through the whole series, to Potsdam Sandstone, there is perfect and close conformability, and no such unwonted change in fossil life as

* It must be fully understood that these inferences have reference solely and exclusively to the central palæozoic basin or area of Middle North America—not to any similar formation in Europe, nor even to the North-eastern palæozoic basin of Eastern Canada, Gaspé, and the Gulf of St. Lawrence, unless specially mentioned.

to constitute a *systematic* break, except at one place—the Oriskany Sandstone, the base of the Devonian in New York,—there being no break of like importance at the Oneida Conglomerate period, contrary to an opinion towards which able geologists are now inclining,—an opinion which leads them to consider the break at the Oneida Conglomerate as systematic.

3. All the palæozoic groups of New York slowly pass one into the other by gradation of mineral and organic characters, with easily-explained exceptions.

4. The palæozoic strata of New York are comparatively thin. They seem to have lost in thickness what they have gained in extension.

5. De Verneuil rightly divides the New York groups into two great classes,—the "constant" and the "local." Among the former are Potsdam Sandstone, Trenton Limestone, and Niagara. Among the latter are the four lower Helderbergs, and perhaps Oneida Conglomerate, &c. This is a useful division.

6. That it is both convenient and natural to divide the Silurian and Devonian systems of this State each into three stages,—the division being based on change of sediment and their fossil contents.

7. The Middle Silurian stage is a period of especial transition—from the coarseness of some of its sediments, from their innumerable and minute alternations, and from the organic poverty prevailing.

8. That the presence of Oneida Conglomerate in New York does not necessitate a change of name for all the strata below it (of "Cambrian" for instance); because a conglomerate does not always indicate *systematic* change,—not even if there be volcanic intercalation, provided there is conformableness, and some community of fossils.

The Oneida Conglomerate seems to be local, is supernumerary, and only found at present on the east of Middle North America.

9. The hardening and crystallizing effect of metamorphism is seen only in the neighbourhood of hypogene rocks.

10. The New York basin exhibits few uplifts, and those of limited magnitude; no uplifts dividing it into a series of deep basins contained in hypogene beds, as in Bohemia, Wales, &c. Neither has it sheets of alternating volcanic grit (conformable), save in the Potsdam Rock on Lake Superior.

This basin has a "lay" or position of its own, as a number of undulating sheets of sediment, dipping slightly to the south-west, here and there pierced by a peak of crystalline rock, and in certain regions raised into three broad low domes of great length.

11. The sedimentary rocks of this basin have submitted to two kinds of plutonic disturbance, independent of each other, and acting at distant intervals: 1st, that of secular or slow oscillation during deposition; 2nd, that of disturbance arising from paroxysmal uplifts long after their completion.

12. The whole Silurian and Devonian series of strata having, during deposition, sunk to the depth of 13,300 feet, it is submitted as a query whether it does not seem necessary to suppose that they were elevated into their present position by the post-carboniferous

uplift,—such agency being sufficient to produce all the observed phenomena, and the effects diminishing westwards from the central line of disturbance. No other agency is known to me, although hinted at by American geologists.

13. It is a remarkable fact that brine-springs exist in considerable quantity in the Middle stage of the Silurian system, a group or two below the Onondaga-salt-springs of the Upper stage, and three palæozoic systems below any salt-deposits in Europe.

14. That the form and direction of the five great Canadian lakes are not due originally and mainly to the passage of loaded waters over their site, but that they follow the outcrops of their containing sedimentary rocks,—changes in shape and size having, nevertheless, occurred since.

15. The contours of the valley of the St. Lawrence generally (to which much of New York belongs), and its increasing elevation southwestwards, inland from Montreal, are due to the successive altitudes assumed westward, in slopes and plateaux, by the Silurian and Devonian strata, the lowest or most ancient being on the east. This is beautifully evidenced in the rocks forming the basins of the great Canadian lakes.

16. That some of the groups, during and after deposition, were sub-atmospheric, presenting the conditions of dry land and shallow waters for long and varying periods,—and that, together with the marine life they supported, they enjoyed the influences of the sun and other meteorological agencies. This is indicated by animal tracks, sun-cracks on ancient shores, the short ripple-marks of a chopped sea, impressions of reeds waving in running water, and by the presence of bog-iron-ore. This is conformable with what took place in the carboniferous, permian, triassic, liassic, oolitic, wealden, and later periods. Denudations also occurred to most of the groups to a large extent.

17. That in New York, as elsewhere, there is an intimate connexion between fossils and their sediment or habitat. The calcareocolous animals are always found in limestone more or less pure, and the arenicolous in sandstone more or less pure,—with exceptions, such as usually happen with respect to locomotive animals. The calcareocolous are everywhere the most numerous. It is true that molluscs are the principal agents in the deposition of calcareous sea-bottoms; but these latter greatly favour afterwards the multiplication of individuals.

18. That the iron-ore which we so frequently see investing invertebrate remains had access to them after their death and sepulture.

19. Every group, as established by the State Geologists of New York, is a distinct centre of life,—a separate realm or community of animated beings, which may be called epochal, so marked are the differences.

The majority of these existences always perished at the end of the group when certain deposits ceased, because the new sediment, with its new and peculiar flora (and for other reasons), was only able to nourish a few, if any, of the old molluscs.

20. In New York the species of fucoids occupy and are typical of only one group.

21. All the individual existences are perfect at once, from the earliest dawn of life, in their organization and social relations.

22. It is a great thought, that throughout the incalculably long succession of fossiliferous deposits, palæozoic or more modern, all animal and vegetable life was constructed upon the same idea of innervation, organs of sense, supply and waste, fecundation, &c.

23. There is another kind of life-centre—the geographic, belonging to one and the same group. This forms numerous separate provinces linked together by a few common fossils, and displaying extraordinary variety. This principle or regulation is carried out abundantly everywhere. Bohemia and Scandinavia have scarcely a Silurian fossil in common. One-half of the Russian and Irish fossils, and two-thirds of those of New York, are new and peculiar. Even the east and west sides of the small districts in Wales and England investigated by Prof. Phillips differ remarkably in their population. We see this in the American Tertiaries and in the recent seas.

24. Contrary to the opinion of Mr. D. Sharpe, the mollusc having the greatest vertical range has the greatest horizontal extension, being found in the most distant regions.

25. There is no evidence of multiplication of species by transmutation.

26. Fossils may be contemporaneous in geological age, without being contemporaneous *in time* as commonly understood.

Geological age is partly determined by fossil evidence. Now, the presence of living beings (subsequently fossil) depends on mineral and other conditions, such as temperature, depth, currents, &c., which were nowhere the same for large spaces, but were always undergoing changes from plutonic and other causes—changes always more or less local and limited, the deposits being thick or thin in places: so that the universal scheme of palæozoic life was not everywhere worked up to the same point; here preparations were making for Lower Silurian deposits,—there for the Upper, or Devonian, and so on. Thus isochronism was perhaps not common.

27. The principles of recurrency, succession, increment, and relative abundance of fossil species are the same in New York, Wales, and elsewhere, modified by local circumstances.

28. Recurrency, or reappearance in different strata, is at the same time the measure of viability in the species, and of connexion in the groups of strata. It is a kind of living nexus, pointing out that the groups belong to one and the same order of things. It may have been partly caused by migration.

Recurrency is not so common in New York as in Wales,—in other words, vertical range is longer in Wales. Great depth is an obstacle to the existence or transmission of living creatures.

29. Everywhere, on the eastern as well as on the western contitinent, the same fossils, of all orders and kinds, appear in the same succession. A very few Crustacea and a *Lingula* or *Obolus* or two, amid a dense matting of fucoids, appear at what now seems to be the

dawn of life; then some Gasteropoda, a few Cephalopoda, and a few Brachiopoda in the third group from below (Chazy). But in the fifth group from below (Trenton), multitudes of Zoophyta, Bryozoa, Brachiopoda (save *Spiriferi*), Orthocerata, and Trilobites spring forth; but not a Lamellibranchiate. As species, they nearly all perish with the advent of a new deposit; but, as genera, they appear one after another through the successive epochal centres, becoming multiplied in numbers and perfect in form. Then they lessen in numbers, dwindle in size, and finally disappear.

30. There is a close similarity in New York and Wales in the increment and decrement of Zoophyta, Bryozoa, Echinodermata, Brachiopoda, &c.; that is, these fossils are numerous and few at the same points of the Silurian scale.

31. The same genera, species, and amount of individuals abound or are few in the countries just named. Brachiopoda, Crustacea, Orthocerata, are many; Lamellibranchiates few. The extraordinary opulence in fossils of the Rhenish Devonian strata does not obtain in New York. In New York, however, according to our present list, the Lower Silurian stage is the most fossiliferous; in Wales, it is the Upper. Future discoveries may change this condition of things.

32. A remarkable feature in the uppermost four groups of New York Siluria (the Lower Helderberg) is the substitution in them of limestone for the arenaceous mud of the Welsh Ludlows, their contemporaries. It has given them a Wenlock character. But it is to be remembered that the Ludlow and Wenlock groups of Wales are in close fossil-connexion,—74 out of 311 species of organic remains being common to both, or very nearly one quarter.

I shall not proceed at present with these inferences into the American Devonian system, although there is no want of interest. I may just remark that many Silurian Brachiopoda and some other molluscs work themselves up into the Devonian as representatives of a common period. They may even be found in the Carboniferous system, as has been proved by D'Archiac and De Verneuil to be not uncommonly the case in Europe.

The great ruling zoological principles of the Silurian system are continued into the Devonian; but in the latter we have the introduction of Vertebrates in profuse variety, and of new and complex types of Invertebrates in unwonted abundance, the old forms dying out.

EXPLANATION OF THE ABBREVIATIONS USED IN THE FOLLOWING TABLES.

Upper Ludlow	UL.	Devonian	D.
Aymestry Limestone	A.	Hall	H.
Lower Ludlow	LL.	De Verneuil	V.
Wenlock Limestone	WL.	Sharpe	Sh.
Wenlock Shale	WS.	Conrad	C.
Upper Caradoc	UC.	Emmons	E.
Upper Silurian	US.	Vanuxem	Va.
Lower Silurian	LS.		

† New Species, according to James Hall.

TABLE I.—*The Silurian Fossils of the State of New York.*

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
PLANTÆ.																			
Arthrophycus Harlani	...	...	...	...	...	...	...	...	...	H									
sp. ind.	...	...	...	...	...	...	...	...	...	H									
Buthrotrephis antiqua†	...	H																	
flexuosa	...	...	...	...	...	...	E												
gracilis†	...	...	...	...	...	...	...	...	...	...	H								
—— var. crassa	...	...	...	...	...	...	...	...	...	...	H								
—— —— intermedia	...	...	...	...	...	...	...	...	...	...	H								
impudica†	...	...	...	...	...	...	...	...	...	...	H								
palmata†	...	...	...	...	...	...	...	...	...	...	H								
ramosa†	...	...	...	...	...	...	...	...	...	...	H								
subnodosa†	...	...	...	...	...	...	H												
succulea†	...	...	...	...	H														
Dictuolites Beckii	...	...	...	...	...	...	...	...	...	H									
Fucoides demissus	...	...	...	*															
Ichnophycus tridactylus†	...	...	...	...	...	...	...	...	...	...	H								
Palæophycus irregularis†	...	H																	
rugosus†	...	...	...	...	H														
simplex†	...	...	...	...	H														
striatus† ?	...	...	...	...	...	...	...	...	...	...	H								
tortuosus†	...	...	...	...	...	...	...	...	...	H									
tubularis†	...	H																	
virgatus†	...	...	...	...	...	...	H												
sp. ind.	...	...	...	...	...	...	...	...	...	...	H								
sp. ind.	...	...	...	...	...	...	H												

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Rusophycus bilobatus	...	...	...	...	...	...	...	...	...	...	H								
clavatus†	...	...	...	...	...	...	...	...	...	...	H								
pudicus†	...	...	...	...	...	...	...	...	...	...	H								
subangulatus†	...	...	...	...	...	...	...	...	...	...	H								
Sphenothallus angustifolius†	...	...	...	...	...	*													
latifolius†	...	...	...	...	...	...	H												
Incertæ Sedis.																			
Discosorus conoideus†	...	...	...	...	...	...	...	H											
Ellipsolites	...	...	...	E															
Phytopsis tubulosa†	...	...	...	H															
cellulosa†	...	...	...	H															
Receptaculites Neptuni	...	...	...	...	H														
Annelida.																			
Cornulites flexuosus†	...	...	...	...	...	...	...	...	...	...	*								
serpularius	...	...	...	...	...	...	...	...	...	...	*	...	*	H	*	H	H	*	
sp. ind.	...	...	...	...	...	...	...	...	...	...	...	...	...	*					
Nereites Loomisii.																			
Scolithus linearis	H																		
verticalis†	...	...	...	...	...	...	...	...	...	H									
Tentaculites distans†	...	...	...	...	...	...	...	...	...	...	H								
flexuosus†	...	...	...	...	H	...	H												
minutus	...	...	...	...	...	...	...	...	...	...	H								
Niagarensis	...	...	...	...	...	...	...	...	...	...	...	H							
ornatus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	M				
scalaris	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C		
Zoophyta.																			
Aulopora arachnoides	...	...	...	...	H														
Callopora aspera†	...	...	...	...	...	...	...	...	...	...	...	H							
elegantula†	...	...	...	...	...	...	...	...	...	...	...	H							
florida†	...	...	...	...	...	...	...	...	...	...	...	H							
laminata†	...	...	...	...	...	...	...	...	...	...	...	H							
nummiformis†	...	...	...	...	...	...	...	...	...	...	...	H							
Caninia bilateralis†	...	...	...	...	...	...	...	...	...	...	...	H							
Cannapora junciformis	...	...	...	...	...	...	...	...	...	...	H								
Catenipora agglomerata	...	...	...	...	...	...	...	...	...	...	...	H							
escharoides	...	...	...	...	...	...	...	...	...	...	H	H	H						
Chætetes alveolaris	...	...	...	...	...	...	...	...	...	...	...	V							
columnaris†	...	...	...	...	H	...	...	...	...	H									
favosa	...	...	...	...	...	...	...	...	...	...	...	*							
Gothlandica	...	...	...	...	...	...	...	...	...	...	...	*	*	...	V				

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Chætetes lycoperdon	...	...	H	H	H	...	H	...	...	...	H								
Niagarensis†	...	...	...	...	...	...	...	...	...	...	...	*	*						
Petropolitanus	...	...	...	...	V														
rugosus†	...	...	...	...	H														
sp. ind.	...	...	...	...	S	S	S												
Cladopora cervicornis†	...	...	...	...	...	...	...	...	...	...	...	H							
cæspitosa†	...	...	...	...	...	...	...	...	...	...	...	H							
fibrosa†	...	...	...	...	...	...	...	...	...	...	...	H							
macropora†	...	...	...	...	...	...	...	...	...	...	...	H							
multipora†	...	...	...	...	...	...	...	...	...	...	...	H							
reticulata†	...	...	...	...	...	...	...	...	...	...	...	H							
seriata†	...	...	...	...	...	...	...	...	...	...	..	H							
Columnaria alveolata	...	...	H																
inæqualis†	...	...	...	...	...	...	...	...	...	...	...	...	H						
sulcata	...	...	H																
Conophyllum Niagarense	...	...	...	...	...	...	...	...	...	...	...	H							
Cryptolithus tessellatus	...	...	...	...	*														
Cyclolites rotuloides†	...	...	...	...	...	...	...	...	...	...	H								
Dictyonema gracilis†	...	...	...	...	...	...	...	...	...	...	...	H							
retiformis†	...	...	...	...	...	...	...	...	...	...	...	H							
Diplophyllum cæspitosum†	...	...	...	...	...	...	...	...	...	...	...	H							
cæspitosum ?	...	...	...	...	...	...	...	...	...	...	...	H							
coralliferum†	...	...	...	...	...	...	...	...	...	...	...	...	H						
Discophyllum peltatum†	...	...	...	...	...	...	H												
sp. ind.	...	...	...	...	...	...	*												
Favistella favosidea†	...	...	...	...	...	...	...	...	...	...	H								
stellata†	...	...	...	...	...	...	H												
Gorgonia ? aspera†	...	...	H																
perantiqua	...	...	...	...	H														
Heliolites elegans†	...	...	...	...	...	...	...	...	...	...	...	H							
interstincta	...	...	...	...	...	...	...	...	...	...	...	...	...	V					
macrostylus†	...	...	...	...	...	...	...	...	...	...	...	H							
spinipora†	...	...	...	...	...	...	...	...	...	...	...	H							
vetusta†	...	...	...	...	H														
Helopora fragilis†	...	...	...	...	...	...	...	...	...	...	H								
Inocaulis plumosa†	...	...	...	...	...	...	...	...	...	...	...	H							
Limaria fruticosa ?	...	...	...	...	...	...	...	...	...	...	...	H							
enata†	...	...	...	...	...	...	...	...	...	...	...	H							
ramulosa†	...	...	...	...	...	...	...	...	...	...	...	H							
Phænopora constellata†	...	...	...	...	...	...	...	...	...	...	H								
ensiformis†	...	...	...	...	...	...	...	...	...	...	H								
explanata†	...	...	...	...	...	...	...	...	...	...	H								
Pleurodictyum problematicum	...	...	...	...	...	...	...	...	...	...	*								
Polydilasma turbinatum	...	...	...	...	...	...	...	...	...	...	...	H							
Rhinopora angulata	...	...	...	...	...	...	...	...	...	...	*								
tuberculosa	...	...	...	...	...	...	...	...	...	...	...	H							

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Rhinopora tubulosa†	...	...	...	...	...	...	...	...	...	...	H								
verrucosa†	...	...	...	...	...	...	...	...	...	...	H	*							
Stellipora antheloidea	...	...	...	...	H														
Streptolasma caliculum	...	...	...	...	...	...	...	...	...	...	...	H							
Corniculum†	...	...	...	...	H														
crassum†	...	...	...	...	H														
expansum†	...	...	H																
multilamellosum†	...	...	...	...	H														
parvulum†	...	...	...	...	H														
profundum†	...	...	...	H															
Striatopora flexuosa†	...	...	...	...	...	...	...	...	...	...	...	H							
Stromatopora concentrica	...	...	...	...	V	...	...	...	...	...	...	*	*	V					
constellata	...	...	...	...	...	...	...	...	...	...	...	...	H						
Syringopora multicaulis	...	...	...	...	...	...	...	...	...	...	...	H							
Bryozoa.																			
Alecto inflata	...	...	...	...	H														
Astrocerium constrictum†	...	...	...	...	...	...	...	...	...	...	...	H							
parasiticum	...	...	...	...	...	...	...	...	...	...	...	H							
pyriforme†	...	...	...	...	...	...	...	...	...	...	...	H							
venustum	...	...	...	...	...	...	...	...	...	...	...	H							
Ceramopora foliacea†	...	...	...	...	...	...	...	...	...	...	...	H							
imbricata†	...	...	...	...	...	...	...	...	...	...	...	H							
incrustans†	...	...	...	...	...	...	...	...	...	...	...	H							
Clathropora alcicornis	...	...	...	...	...	...	...	...	...	...	...	H							
frondosa†	...	...	...	...	...	...	...	...	...	...	...	H							
Diamesopora dichotoma†	...	...	...	...	...	...	...	...	...	...	...	H							
Escharapora recta	...	...	...	...	H														
var. nodosa	...	...	...	...	H														
Fenestella cribrosa†	...	...	...	...	...	...	...	...	...	...	H								
elegans†	...	...	...	...	...	...	...	...	...	...	H								
prisca	...	...	...	...	...	...	...	...	...	...	H								
tenuis	...	...	...	...	...	...	...	...	...	...	H								
tenuiceps†	...	...	...	...	...	...	...	...	...	...	*	H							
n. sp.†	...	...	...	...	...	...	...	...	...	...	H								
Graptolites amplexicaulis?	...	...	...	...	H														
bicornis†	...	...	...	...	...	H	V												
Clintonensis†	...	...	...	...	...	...	...	...	...	...	*								
furcatus†	...	...	...	...	...	...	H												
gracilis†	...	...	...	...	...	...	H												
lævis†	...	...	...	...	...	H													
mucronatus	...	...	...	...	...	...	H												
pristis	...	...	...	...	...	H	H												
ramosus†	...	...	...	...	...	...	H												
sagittarius	...	...	...	...	H	H													

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Graptolites scalaris	...	...	...	...	H	H													
secalinus	...	...	...	...	...	...	H												
sextans†	...	...	...	...	...	*	V												
serratulus†	...	...	...	...	...	...	H												
tenuis	...	...	...	...	...	H													
venosus†	...	...	...	...	...	...	...	...	...	...	H								
Hornera dichotoma†	...	...	...	...	...	...	...	...	...	...	...	H							
Intricaria? reticulata	...	...	...	...	H														
Lichenalia concentrica†	...	...	...	...	...	...	...	...	...	...	...	H							
Polypora incepta	...	...	...	...	...	...	...	...	...	...	...	H							
Retipora angulata†	...	...	...	...	...	...	...	...	...	...	H								
asperatostriata	...	...	...	...	...	...	...	...	...	...	...	H							
Clintoni	...	...	...	...	...	...	...	...	...	...	V[a]								
diffusa	...	...	...	...	...	...	...	...	...	...	...	H							
foliacea	...	...	...	...	H														
gracilis†	...	...	H																
incepta	...	...	H																
Sagonella membranacea	...	...	...	...	...	...	...	...	...	...	...	H							
Stictopora acuta	...	...	...	...	H														
crassa	...	...	...	...	...	...	...	...	...	...	H								
elegantula	...	...	...	...	H														
fenestrata†	...	...	H																
glomerata	...	...	H																
labyrinthica	...	...	...	H															
lanceolata	...	...	...	...	...	...	*												
punctipora	...	...	...	...	...	...	...	...	...	...	...	H							
ramosa	...	...	...	...	...	...	...	...	...	...	H								
raripora	...	...	...	...	...	...	...	...	...	...	H								
Stromatocerium rugosum	...	...	H	H															
Trematopora aspera†	...	...	...	...	...	...	...	...	...	...	...	H							
coalescens†	...	...	...	...	...	...	...	...	...	...	...	H							
granulifera†	...	...	...	...	...	...	...	...	...	...	...	H							
ostiolata†	...	...	...	...	...	...	...	...	...	...	...	H							
punctata†	...	...	...	...	...	...	...	...	...	...	...	H							
solida†	...	...	...	...	...	...	...	...	...	...	...	H							
sparsa†	...	...	...	...	...	...	...	...	...	...	...	H							
spinulosa†	...	...	...	...	...	...	...	...	...	...	...	H							
striata†	...	...	...	...	...	...	...	...	...	...	...	H							
tuberculosa†	...	...	...	...	...	...	...	...	...	...	...	H							
tubulosa†	...	...	...	...	...	...	...	...	...	...	H	H							
ECHINODERMATA.																			
Actinocrinus tenuiradiatus†	...	...	H																
sp. ind.	...	...	H																
Apiocystites elegans†	...	...	...	...	...	...	...	...	...	...	...	H							

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Asterias matutina†	...	...	...	...	H	...	H												
Astrocrinites pachydactylus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V[a]			
Callicystites Jewettii†, and var.	...	...	...	...	...	...	...	...	...	...	...	H							
Caryocrinus ornatus	...	...	...	...	...	...	...	...	...	...	H	H							
Closterocrinus elongatus†	...	...	...	...	...	...	...	...	...	...	H								
Cyathocrinus pyriformis	...	...	...	...	...	...	...	...	...	...	...	*							
tuberculatus	...	...	...	...	...	...	...	...	...	...	...	*							
Dendrocrinus longidactylus†	...	...	...	..	...	...	...	...	...	...	...	H							
Echinocrinites anatiformis†	...	...	...	...	H	...	H												
sp. ind.	...	...	...	...	...	H													
Eucalyptocrinus cælatus	...	...	...	...	...	...	...	...	...	...	...	H							
decorus	...	...	...	...	...	...	...	..	...	...	H	H							
papulosus†	...	...	...	...	...	...	...	...	...	...	...	H							
Glyptaster brachiatus†	...	...	H	...	...	...	H	...	...	...	H	H							
Glyptocrinus decadactylus	...	...	...	...	...	...	...	...	...	...	H								
plumosus	...	...	...	..	...	...	...	...	...	...	H								
——— ?	...	...	...	.	...	...	...	...	...	...	*								
Hemicystites parasiticus	...	...	...	...	*	...	...	...	...	...	...	*	H						
Heterocrinus gracilis	...	...	...	...	...	...	H												
heterodactylus	...	...	...	...	H														
simplex	...	...	...	...	...	...	H												
Heterocystites armatus†	...	...	...	...	...	...	...	...	...	...	...	H							
Homocrinus cylindricus†	...	...	...	...	...	...	...	...	...	...	...	H							
parvus†	...	...	...	...	...	...	...	...	...	...	...	H							
Hypanthocrinites ornatus	...	...	...	...	...	...	...	...	...	...	...	...	...	*	V				
Ichthyocrinus ? Clintonensis†	...	...	...	...	...	...	...	...	...	...	H								
lævis	...	...	...	...	...	...	...	...	...	...	...	H							
Lecanocrinus caliculus†	...	...	...	...	...	...	...	...	...	...	...	*	H						
macropetalus†	...	...	...	...	...	...	...	...	...	...	...	*	H						
ornatus†	...	...	...	...	...	...	...	...	...	...	...	*	H						
simplex†	...	...	...	...	...	...	...	...	...	...	...	H							
Lepocrinites Gebhardii	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V[a]			
Lyriocrinus dactylus	...	...	...	...	...	...	...	...	...	...	...	H							
Macrostylocrinus ornatus†	...	...	...	...	...	...	...	...	...	...	...	H							
Melocrinites sculptus	...	...	...	...	...	...	...	...	...	...	...	H							
Myelodactylus brachiatus†	...	...	...	...	...	...	...	...	...	...	...	H							
convolutus†	...	...	...	...	...	...	...	...	...	...	...	H							
Nucleocrinus, sp. ind.	...	...	...	...	*														
Palæaster Niagarensis†	...	...	...	...	...	...	...	...	...	...	...	H							
Poteriocrinus alternatus†	...	...	...	...	H														
gracilis	...	...	...	...	H														
Saccocrinus speciosus†	...	...	...	...	...	...	...	...	...	...	...	H							
Schizocrinus nodosus†	...	...	...	...	H														
striatus†	...	...	...	...	H														
sp. ind.	...	...	...	...	H														
Scyphocrinus heterocostatus†	...	...	...	...	H														

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Stephanocrinus angulatus	...	...	...	...	...	...	...	...	...	...	...	H							
gemmiformis†	...	...	...	...	...	...	...	...	...	...	...	*	H						
Thysanocrinus aculeatus†	...	...	...	...	...	...	...	...	...	...	...	H							
caniculatus†	...	...	...	...	...	...	...	...	...	...	...	H							
immaturus†	...	...	...	...	...	...	...	...	...	...	...	H							
liliiformis†	...	...	...	...	...	...	...	...	...	...	...	H							
Brachiopoda.																			
Atrypa acutirostra†	...	...	H																
æquiradiata	...	...	...	...	...	...	...	...	...	...	H								
allitis†	...	...	H																
ambigua†	...	...	...	...	H														
aprina	...	...	...	...	...	...	...	...	...	...	H								
aspera	...	...	...	...	...	...	...	...	...	...	...	*							
bidens†	...	...	...	...	...	...	...	...	...	...	H								
bidentata	...	...	...	...	...	...	...	...	...	...	...	H							
bisulcata	...	...	...	...	*														
brevirostris	...	...	...	...	...	...	...	...	...	...	...	H							
camura†	...	...	...	...	...	...	...	...	...	...	...	H							
circulus†	...	...	...	...	H														
concentrica	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	
congesta	...	...	...	...	...	...	...	...	...	...	H								
corallifera†	...	...	...	...	...	...	...	...	...	...	...	H							
crassirostra†	...	...	...	...	...	...	...	...	...	...	...	H							
cylindrica†	...	...	...	...	...	...	...	...	...	...	H								
cuneata	...	...	...	...	...	...	...	...	...	...	...	H							
cuspidata†	...	...	...	...	H														
deflecta†	...	...	...	...	H														
deflexa	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*		
dentata†	...	...	...	...	H														
didyma	...	...	...	...	...	...	...	...	...	...	S	...	...	...	*				
disparilis†	...	...	...	...	...	...	...	...	...	...	...	H							
dubia†	...	...	H																
emacerata	...	...	...	...	...	...	...	...	...	...	H								
exigua†	...	...	...	...	H														
extans	...	...	...	...	C														
gibbosa†	...	...	...	...	...	...	...	...	...	...	H								
glabella	...	...	...	...	*														
hemiplicata†	...	...	...	...	H														
hemisphærica	...	...	...	...	...	...	...	...	...	...	H	S							
increbrescens†	...	...	...	...	*	H	H												
inflata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V[a]			
intermedia	...	...	...	...	...	...	...	...	...	...	H								
interplicata	...	...	...	...	...	...	...	...	...	...	H								

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Atrypa lacunosa	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Va			
lævis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	M		
limæformis	...	...	...	...	...	...	...	...	...	...	...	...	H						
lamellata	...	...	...	...	...	...	...	...	...	...	...	...	H						
marginalis	...	...	...	...	...	...	...	...	*										
medialis	...	...	...	...	...	...	...	...	...	...	*								
modesta	...	...	...	...	*	*	*												
naviformis	...	...	...	...	...	...	...	...	...	...	H								
neglecta	...	...	...	...	...	...	...	...	...	...	H	H							
nitida	...	...	...	...	...	...	...	...	...	...	...	H							
var. oblata	...	...	...	...	...	...	...	...	...	...	...	H							
nodostriata†	...	...	...	...	...	...	...	...	...	...	...	H							
nucleolata	...	...	...	...	...	...	...	...	...	...	...	...	H						
nucleus	...	...	...	...	H														
oblata†	...	...	...	...	...	...	...	...	...	H									
obtusiplicata†	...	...	...	...	...	...	...	...	H										
planoconvexa†	...	...	...	...	...	...	...	...	...	...	H								
plena†	...	...	H																
plicata†	...	...	...	...	...	...	...	...	...	H									
plicatella	...	...	...	...	...	...	...	...	...	...	...	H							
plicatula	...	...	...	...	...	...	...	...	...	H									
plicifera†	...	...	H																
protea	...	...	...	...	H														
quadricostata†	...	...	...	...	...	...	...	...	...	H									
recurvirostra†	...	...	...	...	H														
reticularis	...	...	...	...	*	*	*	...	...	...	H	H	*	...	*	*	*		
robusta	...	...	...	...	...	...	...	...	...	...	H								
rugosa†	...	...	...	...	...	...	...	...	...	...	...	H							
semiplicata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Va			
singularis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	M		
sordida	...	...	...	...	H														
subtrigonalis†	...	...	...	...	H														
sulcata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*				
tumida	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*		
sp. ind.	...	...	...	...	H	...	...	...	...	...	H	...	H						
n. sp.†	...	...	...	...	...	...	...	...	...	...	...	H							
Chonetes cornuta	...	...	...	...	...	...	...	...	...	...	H								
nana.																			
Cyrtia Dalmanni[1].																			
Eatonia eminens†[1].																			
medialis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Va		
Leptæna[2] alternata	...	...	...	...	S	*	*	...	...	...	H								
alternistriata†	...	...	...	...	H														

[1] (Hall) Lower Helderberg Limestones. [2] Including *Strophomena*.

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Leptæna bipartita†													H						
camerata					H														
concava†																	H		
cornuta											H								
corrugata											*								
crenistria											*								
deflecta					S														
deltoidea					H														
depressa					S	S	S				H	*			V^a	*	H		
elongata																V^a			
fasciata†			H																
filitexta†				H															
grandis					S	S	S					S							
imbrex					S	S	S												
impressa																H			
incrassata			H																
lævis				E															
laticosta†			H																
mucronata											*	?							
nasuta							*	E											
obscura											*			*					
orthodidea			H																
patenta											H								
pecten																S	S		
plano-convexa†					H														
planumbona†					H														
plicifera†			H																
profunda†											H								
pustulosa.																			
punctulifera																	C		
recta					H														
rectilateralis																V^a			
radiata																	V^a		
rugosa																	M		
sericea					S	S	S				H								
semiovalis ?					S	S	S												
striata												H							
subplana												*		V					
subtenta					H														
tenuilineata					C														
tenuistriata					H														
transversalis												H							
varistriata																V^a			
Woolworthana†																	H		
(Strophodonta) Beckii†																	H		
(——) cavumbona																	H		

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Leptæna (Stroph.) Headleyana†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
(——) Leavenworthana†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
n. sp.	...	...	...	...	...	...	...	...	...	...	...	...	H						
sp. ind.†	...	...	...	...	*														
Leptocœlia concava†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
imbricata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
Lingula acuminata	...	C																	
acutirostra	...	...	...	...	...	...	...	...	...	...	H								
æqualis	...	...	...	...	H														
antiqua†	H																		
attenuata ?	...	...	...	...	H														
crassa	...	...	...	...	H														
cuneata†	...	...	...	...	...	...	...	...	...	H									
curta	...	...	...	...	H	C													
elongata†	...	...	...	...	H														
lamellata	...	...	...	...	...	...	...	...	...	...	H	H							
Lodensis.																			
oblata	...	...	...	...	...	...	...	...	...	...	H								
oblonga	...	...	...	...	...	...	...	...	...	...	H								
obtusa†	...	H	...	...	*	V													
ovata	...	...	...	...	*	*													
perovata	...	...	...	...	...	...	...	...	...	...	H								
prima	C																		
quadrata	...	...	...	...	H	H													
riciniformis	...	...	...	...	H														
rectilateralis	...	...	...	...	...	...	E												
Megalomus Canadensis†[1]	...	...	...	...	...	...	...	...	...	...	...	...	...	*					
Meganteris æquiradiata†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H
elliptica†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
lævis†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
mutabilis†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
Merista arcuata†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
bella†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
lævis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
Meeki†[2].																			
princeps†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H
subquadrata†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
Orbicula cælata†	...	...	...	...	...	...	H												
crassa†	...	...	...	...	...	...	H												
deformata†	...	...	H																
filosa†	...	...	...	...	H														
lamellosa†	...	...	...	...	H														
squamiformis†	...	...	...	...	...	...	...	...	...	...	...	H							
subtruncata†	...	...	...	...	...	...	H												

[1] Galt, Canada. [2] Trenton limestone of Tennesee.

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Orbicula tenuilamellata†	...	...	...	...	...	...	...	...	...	...	...	H							
terminalis	...	...	...	...	C														
Orthis æquivalvis†	...	...	...	...	H														
bellarugosa	...	...	...	...	H														
bisulcata	...	...	...	...	E														
centrilineata†	...	...	...	...	...	...	H												
circulus	...	...	...	...	...	...	...	...	...	...	H								
costalis†	...	...	*																
crenistria	...	...	...	...	...	...	...	...	...	...	H								
crispata	...	...	...	...	...	...	E												
deformis†.																			
dichotoma†	...	...	...	...	*														
disparilis	...	...	...	...	C														
elegantula	...	...	...	...	...	...	...	...	...	...	H	H							
eminens[1].																			
erratica†	...	...	...	...	...	...	H												
fasciata†	...	...	...	...	...	...	...	...	...	...	...	H							
fissicosta†	...	...	...	...	H														
Flabellulum	...	...	...	...	...	...	...	...	...	...	...	H							
hybrida	...	...	...	...	...	...	...	...	...	...	...	H	...	...	...	...	H		
insculpta†	...	...	...	...	H														
interstriata†	...	...	...	...	...	...	...	...	...	...	...	...	H						
leptænoides	...	...	...	...	E														
multistriata†[2].																			
oblata†[1].																			
occidentalis†	...	...	...	...	*														
orbicularis	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	S		
parva	...	...	...	...	...	...	S	S	S										
pectinella	...	...	...	...	C														
var. semiovalis	...	...	...	...	H														
perelegans†.																			
perveta	...	...	...	...	C														
pisum	...	...	...	...	...	...	...	...	...	...	...	H							
plicatella†	...	...	...	...	H														
punctostriata	...	...	...	...	...	...	...	...	...	...	...	H							
pyramidalis	...	...	...	...	...	...	...	...	...	...	...	H							
resupinata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*		
rugosa	...	...	...	...	V														
sinuata†	...	...	...	...	H														
strophomenoides†[3].																			
subæquata	...	...	...	...	C														
subcarinata†	H																		
subjugata†	...	...	...	...	H														

[1] Helderberg Mountains.
[2] Like *O. striatula.*
[3] Very like *O. fasciata.*

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Orthis subquadrata†					H														
tenuidens†											H								
testudinaria					*	*	H												
tricenaria					S														
trinucleus†											H								
tubulostriata[1].																			
Tulliensis					*		*												
Verneuilli.																			
sp. ind.		*?																	
Pentamerus fornicatus†											H								
galeatus																H			
oblongus											H								
occidentalis†[2]														H					
ovalis											H								
pseudogaleatus†																			H
Verneuilli†																	H		
Rhynchonella abrupta†																	H		
acutiplicata†																	H		
æquivalvis†																H			
altiplicata†																	H		
bialveata†																	H		
bidentata					*	*	*												
borealis																	S		
Campbellana†																	H		
eminens†																	H		
formosa†																	H		
inutilis†																	H		
mutabilis†																H			
nobilis†																			H
nucleolata†																	H		
planoconvexa†																	H		
pyramidata†																H			
rudis†																	H		
semiplicata†																	H		
Stricklandii																	*		
sulcoplicata†																	H		
transversa†																	H		
tumida												*							
vellicata†																	H		
ventricosa																	H		
Wilsoni												V							
Spirifer bicostatus												H							
biforatus, var. lynx					H	S	*										V[a]		
bilobus												H					H	V[a]	

[1] Helderberg Mountains. [2] Galt, Upper Canada.

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Spirifer concinnus†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H
crispus	...	...	...	...	...	...	...	...	...	...	...	H	H						
cyclopterus†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*			
Cyrtæna	...	...	...	...	...	...	...	...	...	...	...	V							
expansus	...	...	...	...	H														
granulosus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*		
macropleurus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	M		
multistriatus†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
Niagarensis†	...	...	...	...	...	...	...	...	...	...	...	H							
pachyopterus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C		
perforatus†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
perlamellosus†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
pyramidalis†	...	...	...	...	...	...	...	...	...	...	...	H	?						
plicatus	...	...	...	...	...	...	...	...	...	...	...	S	...	...	*	*	*		
radiatus	...	...	...	...	...	...	...	...	...	...	*	*							
sulcatus	...	...	...	...	...	...	...	...	...	...	...	*							
ventricosus†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H	H		
n. sp.†	...	...	...	...	...	...	...	...	...	...	...	...	H						
Strophodonta prisca†	...	...	...	...	...	...	...	...	...	...	H								
textilis†	...	...	...	...	...	...	...	...	...	...	...	...	H						
Waldheimia Deweyi†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
formosa†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
globosa†	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H		
MONOMYARIA.																			
Ambonychia amygdalina†	...	...	...	...	H														
bellastriata†	...	...	...	...	H														
mytiloides	...	...	H																
obtusa†	...	...	...	...	H														
orbicularis	...	...	...	...	C														
radiata[1]	...	...	...	...	...	...	H												
undata	...	...	...	...	C														
sp. ind.	...	...	...	...	*	H													
Avicula demissa[2]	...	...	...	...	...	...	C												
desquamata	...	...	...	...	...	...	H												
elliptica†	...	...	...	...	H														
emacerata	...	...	...	...	...	...	...	...	...	...	H	H							
erecta[3]	...	...	...	...	...	...	C												
insueta	...	...	...	...	...	C													

[1] *carinata.* [2] In Grey sandstone; also Emmons, p. 406.
[3] (*Pterinea retroflexa?*). And in Hamilton group.

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Avicula leptonata [1].																			
limæformis†													H						
monticola																V[a]			
multilineata																*			
naviformis																V[a]	*		
orbiculata†												H							
protexta.																			
rhomboidea†											H			H					
rugosa															H				
securiformis†													H						
subrecta†													H						
subplana†												H							
Trentonensis					H														
triquetra														H					
undata†												H							
sp. ind.†													H						
Posidonia? alata											H	H							
alveata?[2].																			
arcuata?[2].																			
Posidonomya? rhomboidea†												H							
Pterinæa carinata							E												
pleuroptera.																			
retroflexa.																			
undata					E														
Dimyaria.																			
Cardiamorpha vetusta†					H														
Clidophorus planulatus						H	H												
Cypricardia alata										H									
angustata							*												
angustifrons							H												
curta							H												
modiolaris							H												
ovata							H												
sinuata						E													
Edmondia subangulata†					H														
subtruncata†					H														
ventricosa†					H														
Lyrodesma plana							C												
pulchella							H												
Modiolopsis anodontoides					H		H												

[1] In Shale of Woolcot-ore bed. [2] Devonian.

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Modiolopsis arcuatus†	...	...	...	...	H														
aviculoides†	...	...	...	...	H														
carinatus†	...	...	...	...	H														
curtus†	...	...	...	...	...	...	C												
faba	...	...	...	...	...	...	C												
latus†	...	...	...	...	H														
modiolaris	...	...	...	...	C	...	C												
mytiloides†	...	...	...	...	H														
nasutus	...	...	...	...	...	...	C												
nuculiformis†	...	...	...	*?	...	...	H												
orthonota	...	...	...	...	...	...	...	...	...	H									
ovatus†	...	...	...	...	...	...	...	...	...	...	H								
primigenius	...	...	...	...	...	...	...	...	...	H									
parallelus	...	...	...	...	H														
subalatus†	...	...	...	...	...	...	...	...	...	...	H								
subalatus ? †	...	...	...	...	...	...	...	...	...	...	...	H							
subcarinatus†	...	...	...	...	...	...	...	...	...	...	H								
subspatulatus†	...	...	...	...	H														
terminalis†	...	...	...	...	...	...	H												
Trentonensis	...	...	...	...	*														
truncatus†	...	...	...	...	...	...	*												
undulostriatus†	...	...	...	...	...	...	...	...	...	...	...	H							
sp. ind.	...	...	...	...	...	...	H												
Modiola ? obtusa†	...	...	...	H															
squamifera.																			
Myalina mytiliformis	...	...	...	...	...	...	H												
Nucula donaciformis	...	...	...	...	H														
levata	...	...	...	...	H	...	H												
poststriata	...	...	...	...	H	...	H												
Nuculites faba	...	...	...	...	E														
inflata	...	...	...	...	*														
scitula	...	...	...	...	...	E													
Orthonota contracta†	...	...	...	...	...	...	H												
curta	...	...	...	...	...	...	...	...	...	...	H	H							
nasuta	...	...	...	...	...	...	*												
parallela†	...	...	...	...	...	...	H												
pholadis	...	...	...	...	...	...	C												
undulata.																			
Pyrenomæus cuneatus†	...	...	...	...	...	...	...	...	...	...	H								
Tellinomya æquilateralis	...	...	...	...	...	...	...	...	...	...	...	...	H						
anatiformis†	...	...	...	...	H														
curta†	...	...	...	...	...	...	...	...	...	...	H								
dubia†	...	...	...	...	H														
elliptica†	...	...	...	...	...	...	...	...	...	...	H								

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Tellinomya gibbosa†					H														
lata											H								
machæriformis					H														
nasuta†					H														
sanguinolaroidea†					H														
Gasteropoda.																			
Acroculia angulata†											H	H							
auriformis			*																
Niagarensis†												H							
Bellerophon auriculatus													H						
bilobatus					E	E	E				*								
var. acutus					S														
var. corrugatus					H														
cancellatus†							H												
dilatatus												*							
ornatus.																			
profundus					E														
punctifrons					E														
sulcatus		*																	
Bucania bellapuncta†											H								
bidorsata†					H														
expansa†					H														
intexta†					H														
punctifrons†					C														
rotundata			H	*															
stigmosa†											H								
sulcatina				E															
trilobata						H	H			H									
sp. ind.													H						
Carinaropsis carinata†					H														
orbiculata†							H												
patelliformis†							H												
Cyclonema cancellata											H								
obsoleta†											H								
sulcata														H					
ventricosa†											*								
Cyrtolites compressus					C														
filosus					C														
ornatus							C												
Trentonensis					C														
undatus					*														
Euomphalus uniangulatus		H																	

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Euomphalus profundus																H			H
sulcatus†															H				
Holopæa obliqua†					H														
paludiniformis					H														
symmetrica					H														
ventricosa†					H														
Littorina antiqua.																			
Loxonema Boydii														H					
Maclurea labiata		H																	
magna			H																
matutina†		H																	
sordida†		H																	
striata		H																	
Metoptoma ? dubia†			H																
rugosa†							*												
Murchisonia abbreviata			H																
angulata†			*	H															
bellacincta†					H														
bicincta					H														
bivittata†[1]														H					
Boydii[1]														H					
conoidea†										H									
gracilis†					H		H												
Logani†[1]														H					
longispira†[1]														H					
macrospira†[1]														H					
obtusa													*						
orbiculata			H																
perangulata†				*	H														
subfusiformis†					H														
subulata											H								
terebralis†													H						
tricarinata†					H														
turritiformis[1]														H					
uniangulata†					H		H												
var. *α*					*														
var. abbreviata							H												
?varicosa†				H															
ventricosa†				H															
vittata†					H														
Natica ? sp. ind.				H															
Ophileta levata		H																	

[1] Galt, Canada.

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Ophileta complanata	...	H																	
Platyostoma hemisphærica	...	...	...	...	...	...	...	...	...	...	...	H							
Niagarensis†	...	...	...	...	...	...	...	...	...	...	...	H							
sp. ind	...	...	...	...	...	...	...	...	...	...	H	...	H						
Pleurotomaria ambigua†	...	...	...	...	H														
antiquata†	...	...	H																
biangulata†	...	...	H																
bilix	...	...	...	...	...	...	C												
bispiralis†[1]	...	...	...	...	...	...	...	...	...	...	...	...	H						
indenta†	...	...	...	...	H														
lenticularis	...	...	...	...	E														
littorea†	...	...	...	...	...	...	...	...	...	H									
nodulosa†	...	...	...	H															
nucleolata†	...	...	...	H															
obsoleta†	...	...	...	H															
percarinata†	...	...	...	...	H														
perlata†[2]	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H				
pervetusta	...	...	...	...	...	...	...	...	...	H									
quadricarinata†	...	...	...	H															
rotuloides†	...	...	...	...	H														
solarioides†[2]	...	...	...	...	...	...	...	...	...	...	...	...	...	H					
subconica	...	...	...	...	H														
subdepressa†	...	...	...	...	...	...	...	...	...	...	...	...	H						
subtilistriata†	...	...	...	...	H														
turgida†	...	H																	
umbilicata†	...	...	...	*	H														
sp. ind.	...	...	...	...	...	...	...	...	...	...	...	...	...	*					
sp. ind.	...	...	*	...	*	*													
Raphistoma planistria†	...	...	H																
var. parva	...	...	H																
staminea†	...	...	H																
striata[3]	...	...	H																
Scalites angulatus	...	H	H																
Subulites elongata	...	...	...	...	H														
ventricosa†[2]	...	...	...	...	...	...	...	...	...	...	...	...	...	H					
Turbo diluculus†	...	H																	
obscurus†	...	H																	
CEPHALOPODA.																			
Cameroceras Trentoneum	...	...	...	...	H														
Cyrtoceras annulatum†	...	...	...	...	H														

[1] Galt, Canada. [2] Galt.

[3] *Euomphalus gualterius* of Verneuil and Hisinger.

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Cyrtoceras acuticameratum†[1]														H					
arcuatum†					H														
camurum†					H														
cancellatum†												H							
constrictostriatum†					H														
filosum					H														
lamellosum†					H														
macrostomum					*														
multicameratum†					H														
Endoceras angusticameratum†					H														
annulatum†					H														
approximatum†					H														
arctiventrum†					H														
distans†					H														
duplicatum					H														
gemelliparum†			H																
longissimum†			H																
magniventrum† *and* var.				*	H														
multitubulatum†			H																
proteiforme†					H	*?													
var. elongatum					H														
— lineolatum					H														
— strangulatum					H														
— tenuitextum					H														
subcentrale			H																
Gomphoceras ? sp. ind.												H							
Gonioceras anceps			H																
Lituites convolvans			H																
undatus				C															
Oncoceras constrictum†					H														
expansum													H						
gibbosum†										H									
subrectum											H								
Ormoceras crebriseptum							H												
gracile†			H		*?														
moniliforme			H																
tenuifilum			H																
var. distans			H																
vertebratum											H								
Orthoceras abruptum											H								
æquale						*	E												
amplicameratum†					H									*					
annulatum											H	H							

[1] Galt.

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Orthoceras arcuoliratum†	...	...	...	...	H														
articulatum[1].																			
avellum	...	...	...	...	C														
bilineatum *and* var	...	..	...	...	H														
cancellatum†	...	...	...	...	...	...	...	...	...	...	...	H							
clathratum†	...	...	...	...	H														
clavatum†	...		...	...	...	...	...	...	...	...	H								
coralliferum	...	...	...	...	...	H	H												
duplex	...	...	*	...	*														
fusiforme†	...	...	...	H															
imbricatum ?	...	...	...	...	...	...	...	...	...	...	...	H							
junceum†	...	...	...	...	H														
læve	...	...	...	...	...	...	...	...	...	...	...	...	...	*					
lamellosum†	...	...	...	...	...	...	H												
laqueatum† *and* var.	...	H																	
latiannulatum†	...	...	...	...	H														
multicameratum	...	...	...	...	H														
multilineatum	...	...	...	...	H														
multiseptum†	...	...	H	...	...	...	...	...	...	H	H?								
primigenium	...	*																	
rectiannulatum†	..	...	H																
recticameratum	...	...	...	H															
subarcuatum†	...	...	H																
strigatum†	...	...	...	...	H														
tenuiseptum	...	...	H																
teretiforme†	...	...	...	...	H														
textile†	...	...	...	...	H														
Trentonense	...	...	...	...	H														
vertebrale†	...	...	...	...	H														
vertebratum	...	...	*	...	*	...	*	...	...	...	*								
virgatum	...	...	...	...	...	...	...	...	...	...	...	H							
virgulatum†	...	...	...	...	...	...	...	...	...	...	H	H							
undulatum	...	...	...	...	...	...	...	...	...	...	...	H							
undulostriatum	...	...	...	...	H														
n. sp.	...	...	H	...	...	...	...	...	...	*									
sp. ind.	...	...	...	...	H	H	...	...	...	H									
Phragmoceras, sp. ind.	...	...	...	...	...	...	...	...	...	...	...	...	H						
Phragmolites compressus	...	...	...	...	H														
Trochoceras Gebhardi†	...	...	...	...	...	...	...	...	...	...	...	...	H						
turbinatum†	...	...	...	...	...	...	...	...	...	...	...	...	H						
Trocholites ammonius	..	...	...	...	*	E	*												
planorbiformis	...	...	...	...	...	...	*												

[1] Devon.

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Pteropoda.																			
Conularia gracilis†	...	...	...	...	H														
granulata†	...	...	...	...	H														
longa†	...	...	...	...	...	...	H												
Niagarensis†	...	...	...	...	...	...	...	...	...	...	...	H							
papillata†	...	...	...	...	H														
quadrisulcata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C?		
Trentonensis	...	...	...	...	H														
Theca Forbesii	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*			
triangularis	...	...	...	...	...	...	*												
Crustacea.																			
Asaphus extans†	...	...	...	*															
latimarginatus†	...	...	...	...	...	H													
marginalis†	...	...	H																
nodostriatus	...	...	...	...	H														
—— obtusus†	...	...	H																
Acidaspis spinigera†	...	...	...	...	H														
Trentonensis†	...	...	...	...	H														
Agnostus lobatus†	...	...	...	...	...	...	H												
pisiformis	...	...	...	...	...	...	* ?												
Ampyx	...	...	...	...	*														
Arges phlyctænodes†	...	...	...	...	...	...	...	...	...	...	...	*							
Beyrichia lata	...	...	...	...	...	...	...	...	...	...	V	V	...	...	*	*			
symmetrica†	...	...	...	...	...	...	...	...	...	...	...	*							
Bronteus Niagarensis†	...	...	...	...	...	...	...	...	...	...	...	*							
Bumastus Barriensis	...	...	...	...	...	...	...	...	...	...	...	H							
Trentonensis	...	...	...	...	*														
sp. ind.	...	...	...	...	...	...	...	...	...	...	H								
Calymene Beckii	...	...	...	...	H	H	H												
Blumenbachii	...	...	...	...	C	C	C	...	...	...	H	...	*						
var. Niagarensis	...	...	...	...	...	...	...	...	...	...	...	H							
camerata	...	...	...	...	...	...	...	...	...	...	...	...	H						
Clintoni	...	...	...	...	...	...	...	...	...	...	H								
Fischeri	...	...	...	...	V														
multicosta†	...	...	...	H															
punctata	...	...	...	...	V	...	...	...	...	...	...	*							
sp. ind.	...	...	...	...	...	...	...	...	...	...	...	...	...	*					
Ceraurus insignis	...	...	...	...	...	...	...	...	...	...	H	H							
pleurexanthemus	...	...	...	...	H														
pustulosus	...	...	...	...	H														
vigilans	...	...	...	...	H														
sp. ind.	...	...	H																

Table I. (*continued*).

Fossils.	Potsdam Sandstone.	Calciferous Sandstone.	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Grey Sandstone.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Encrinal Limestone.	Upper Pentamerus Limestone.
Cybele punctata											H								
Dikelocephalus Meniskaensis	*																		
granulosus	*																		
Minnesotensis	*																		
Eurypterus remipes														*	*				
Leperditia cylindrica†											H								
alta													H		M				
sp. ind.				H															
Cytherina ? spinosa†												H							
Homalonotus delphinocephalus										*	H	H							
Illænus Arcturus†			H																
crassicauda?			V		H														
latidorsatus†					*														
ovatus					C														
Trentonensis				*	E														
Isotelus canalis			C																
gigas					H	H	H												
planus					*														
Lichas Boltoni†												*							
laciniata					V														
Ogygia ? vetusta				H															
Olenus asaphoides[1]							E												
undulostriatus							H												
Platynotus Trentonensis					C							*							
Phacops callicephalus					H														
laticauda ?					H														
limulurus					H						H	*							
Hausmanni																	C		
Dalmanni												V							
macrophthalmus																	*?		
trisulcatus											H								
Proetus corycæus												C							
Stokesii												H							
Sphærexochus mirus											V								
Trinucleus concentricus					H		H												
PISCES.																			
Oncus Deweii												H							
Ichthyodorulite											H								

[1] Asaphus Buchii.

	other groups.						Typical and extinct.												
	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.	Plantæ.	Zoophyta	Bryozoa.	Annelida.	Echinodermata.	Brachiopoda.	Monomyaria.	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.
Uppe	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	1
Encri	...	...	...	...	1	1	...	...	...	...	...	1	...	...	...	...	...	...	1
Delth	...	...	...	...	...	6	...	...	...	1	...	43	...	...	5	...	1	3	53
Lowe	...	...	1	1	1	11	...	...	...	...	1	5	1	...	...	...	...	...	7
Wate	...	...	...	...	1	3	...	...	...	1	...	1	1	...	...	2	...	...	5
Onon	...	...	...	...	1	2	...	1	...	...	1	2	1	...	1	12	...	4	22
Coral	...	...	...	...	2	5	...	3	...	...	...	11	5	...	1	6	...	4	30
Niaga	...	...	...	...	...	12	...	32	27	1	25	16	4	2	8	4	1	7	127
Clint	...	4	2	...	3	28	13	10	12	...	5	35	3	5	6	6	...	8	103
Medi	...	1	1	...	...	2	5	...	...	...	...	3	...	3	...	3	...	3	17
Oneic	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Huds	...	1	1	...	2	14	5	3	7	...	2	7	2	18	4	7	2	3	60
Utica	1	2	2	...	3	26	1	...	2	...	1	3	...	2	2	...	...	2	13
Trent	4	5	4	...	2	42	4	11	8	...	8	55	15	15	18	31	4	42	211
Birds	...	1	2	...	...	4	3	1	1	...	...	2	...	1	3	7	...	5	23
Chazy	...	...	1	...	2	5	...	4	4	...	2	12	1	...	...	13	...	14	50
Calcif	...	...	1	...	...	1	3	...	...	...	...	1	...	...	...	11	...	...	15
Potsd	...	...	...	...	...	...	1	...	...	...	...	2	...	...	3	...	...	...	6
	5	14	15	1	18	162	35	65	61	3	45	200	33	46	51	102	8	95	744

s have not yet been determined.

k.

					Typical.												
	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.	Plantæ.	Zoophyta.	Bryozoa.	Annelida.	Echinodermata.	Brachiopoda.	Monomyaria.	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.
C	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	2
C	...	...	...	...	...	1	...	...	...	37	18	2	1	1	...	...	60
F	...	...	1	3	1	...	...	...	1	3	3	5	...	4	...	1	18
G	...	...	...	1	...	...	...	...	...	4	...	...	...	...	...	...	4
T	...	...	...	2	...	...	...	...	...	5	1	...	1	...	...	...	7
F	...	...	...	13	1	6	1	...	1	60	20	29	...	9	1	3	131
M	...	...	...	5	1	1	...	...	...	7	3	1	...	2	...	3	18
C	1	...	...	10	...	...	...	1	...	21	1	1	2	5	...	3	34
C	...	...	...	1	...	8	...	...	1	19	...	1	1	3	...	...	33
S	...	...	...	1	...	...	...	...	...	2	...	...	...	...	...	...	2
C	...	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	1
C	...	..	...	6	1	1	...	...	...	22	...	...	...	1	...	...	25
	1	...	1	43	5	17	1	1	3	180	·46	41	5	25	1	10	335

Table II.—*The Group-relations of the Silurian Fossils of the State of New York.*

Fossils first seen in this group. Original.

Groups.	Plantæ.	Zoophyta.	Bryozoa.	Annelida.	Echinodermata.	Brachiopoda.	Monomyaria.	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.
Upper Pentamerus Limestone*	...	...	...	...	...	1	...	...	...	...	...	...	1
Encrinal Limestone	...	...	...	...	...	1	...	...	...	...	...	1	2
Delthyris-Shaly Limestone	...	...	...	1	...	47	...	...	5	...	2	3	58
Lower Pentamerus Limestone	...	...	...	...	1	8	2	...	...	1	1	...	13
Waterlime Group	...	...	...	1	...	1	1	...	...	1	...	...	4
Onondaga-Salt Group	...	1	...	...	1	2	1	...	1	12	...	3	21
Coralline Limestone of Schoharie	...	6	...	...	...	11	5	...	2	6	...	5	35
Niagara Group	...	35	27	1	26	40	4	2	8	4	1	8	156
Clinton Group	13	12	14	2	8	43	6	5	9	8	...	11	131
Medina Sandstone	5	...	...	...	...	3	...	3	...	3	...	3	17
Oneida Conglomerate	3	...	...	...	...	? 1	...	...	...	...	...	...	4?
Hudson-River Group	5	3	7	...	2	5	2	18	4	7	2	3	58
Utica Slate	1	...	5	...	1	3	1	3	2	1	...	5	22
Trenton Limestone	3	14	10	1	10	72	16	19	24	35	4	42	250
Birdseye Limestone	3	1	1	...	...	2	...	2	4	9	...	3	25
Chazy Limestone	...	5	5	...	3	12	1	...	6	14	...	17	63
Calciferous Sandstone	3	...	...	...	...	1	...	...	...	12	...	3	19
Potsdam Sandstone	1	...	...	...	...	2	...	...	3	...	...	...	6
Total	37	77	69	6	52	255	39	52	68	113	10	107	885

Received from previous group.

Groups.	Plantæ.	Zoophyta.	Bryozoa.	Annelida.	Echinodermata.	Brachiopoda.	Monomyaria.	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.
Upper Pentamerus Limestone*	...	...	...	...	...	...	...	...	...	...	...	...	...
Encrinal Limestone	...	...	...	...	...	...	...	...	...	...	...	1	1
Delthyris-Shaly Limestone	...	...	...	...	...	6	1	...	...	...	...	...	7
Lower Pentamerus Limestone	...	1	...	...	...	8	...	...	...	.	...	1	10
Waterlime Group	...	...	...	...	...	3	...	...	...	...	...	2	5
Onondaga-Salt Group	...	1	...	...	...	2	1	...	...	...	...	2	6
Coralline Limestone of Schoharie	...	4	...	...	...	1	...	...	1	1	...	1	8
Niagara Group	...	2	2	...	3	8	2	1	3	1	...	2	24
Clinton Group	...	1	...	...	1	3	...	...	2	1	...	2	10
Medina Sandstone	...	1	...	...	...	...	...	...	1	1	...	1	4
Oneida Conglomerate	...	...	...	...	...	...	...	...	...	...	...	...	...
Hudson-River Group	...	2	3	1	3	14	1	5	5	4	...	4	42
Utica Slate	...	1	2	...	...	14	1	...	3	2	...	1	24
Trenton Limestone	...	1	...	...	...	...	...	...	1	2	...	2	6
Birdseye Limestone	...	1	1	...	...	...	...	...	...	1	...	...	3
Chazy Limestone	...	...	...	...	...	...	...	1	...	1	...	...	2
Calciferous Sandstone	...	...	...	...	...	...	...	...	...	...	...	...	...
Potsdam Sandstone	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	...	15	8	1	7	59	6	7	16	14	...	19	152

Transmitted to other groups.

Groups.	Plantæ.	Zoophyta.	Bryozoa.	Annelida.	Echinodermata.	Brachiopoda.	Monomyaria.	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.
Upper Pentamerus Limestone*	...	...	...	...	...	...	...	...	...	...	...	...	...
Encrinal Limestone	...	...	...	...	...	...	...	...	...	...	...	1	1
Delthyris-Shaly Limestone	...	...	...	...	...	6	...	...	...	...	...	...	6
Lower Pentamerus Limestone	...	...	...	...	...	6	2	...	...	1	1	1	11
Waterlime Group	...	...	...	...	...	2	...	...	...	...	...	1	3
Onondaga-Salt Group	...	1	...	...	...	...	...	...	...	...	...	1	2
Coralline Limestone of Schoharie	...	2	...	...	...	1	...	...	...	...	...	2	5
Niagara Group	...	4	...	...	...	8	...	...	...	...	...	...	12
Clinton Group	...	2	2	...	3	9	3	...	4	2	...	3	28
Medina Sandstone	...	...	...	...	...	...	...	...	1	1	...	...	2
Oneida Conglomerate	...	...	...	...	...	...	...	...	...	...	...	...	...
Hudson-River Group	...	1	...	...	1	6	2	...	1	1	...	2	14
Utica Slate	...	1	3	...	...	13	1	1	2	2	...	3	26
Trenton Limestone	...	4	2	1	2	17	1	4	5	4	...	2	42
Birdseye Limestone	...	1	...	...	...	...	...	...	1	2	...	...	4
Chazy Limestone	...	1	1	...	...	...	...	...	...	1	...	2	5
Calciferous Sandstone	...	...	...	...	...	...	...	...	...	1	...	...	1
Potsdam Sandstone	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	...	17	8	1	6	68	9	5	14	15	1	18	162

Typical and extinct.

Groups.	Plantæ.	Zoophyta.	Bryozoa.	Annelida.	Echinodermata.	Brachiopoda.	Monomyaria.	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.
Upper Pentamerus Limestone*	...	...	...	...	...	1	...	...	...	...	...	...	1
Encrinal Limestone	...	...	...	...	...	1	...	...	...	...	...	...	1
Delthyris-Shaly Limestone	...	...	...	1	...	43	...	...	5	...	1	3	53
Lower Pentamerus Limestone	...	...	...	...	1	5	1	...	...	...	...	...	7
Waterlime Group	...	...	...	1	...	1	1	...	...	2	...	...	5
Onondaga-Salt Group	...	1	...	...	1	2	1	...	1	12	...	4	22
Coralline Limestone of Schoharie	...	3	...	...	...	11	5	...	1	6	...	4	30
Niagara Group	...	32	27	1	25	16	4	2	8	4	1	7	127
Clinton Group	13	10	12	...	5	35	3	5	6	6	...	8	103
Medina Sandstone	5	...	...	...	...	3	...	3	...	3	...	3	17
Oneida Conglomerate	...	...	...	...	...	...	...	...	...	...	...	...	...
Hudson-River Group	5	3	7	...	2	7	2	18	4	7	2	3	60
Utica Slate	1	...	2	...	1	3	...	2	2	...	...	2	13
Trenton Limestone	4	11	8	...	8	55	15	15	18	31	4	42	211
Birdseye Limestone	3	1	1	...	...	2	...	1	3	7	...	5	23
Chazy Limestone	...	4	4	...	2	12	1	...	...	13	...	14	50
Calciferous Sandstone	3	...	...	...	...	1	...	...	...	11	...	...	15
Potsdam Sandstone	1	...	...	...	...	2	...	...	3	...	...	...	6
Total	35	65	61	3	45	200	33	46	51	102	8	95	744

* The upper Pentamerus Limestone and some of its associate beds have many more fossils than are here indicated; but the species have not yet been determined.

Table VII.—*The Group-relations of the Devonian Fossils of the State of New York.*

Taken from an unpublished Table of the Devonian Fossils.

Original.

Groups.	Plantæ.	Zoophyta.	Bryozoa.	Annelida.	Echinodermata.	Brachiopoda.	Monomyaria.	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.
Catskill Group	...	...	...	...	...	...	...	2	...	...	...	...	2
Chemung Group	4	3	1	...	2	46	21	3	1	2	...	...	83
Portage Group	...	...	...	...	1	4	3	5	...	4	...	2	19
Genesee Slate	1	...	...	...	...	4	1	...	...	...	...	...	6
Tully Limestone	...	...	...	...	...	4	...	...	1	...	...	...	4
Hamilton Rocks	...	6	1	...	1	47	22	30	5	11	1	3	127
Marcellus Shale	1	2	...	1	...	8	3	1	...	3	...	3	22
Corniferous Limestone	...	...	...	1	...	24	1	3	2	6	...	3	40
Onondaga Limestone	...	12	...	...	1	20	1	1	1	3	...	...	39
Schoharie Grit	...	...	...	...	...	3	...	...	...	...	...	...	3
Cauda-galli Grit	1	...	...	...	...	...	...	...	...	...	...	...	1
Oriskany Sandstone	1	1	...	...	...	26	...	...	...	1	...	...	29
Total	8	24	2	2	5	186	52	45	10	30	1	11	375

Received.

Groups.	Plantæ.	Zoophyta.	Bryozoa.	Annelida.	Echinodermata.	Brachiopoda.	Monomyaria.	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.
Catskill Group	...	...	...	...	...	...	...	...	...	...	...	...	...
Chemung Group	1	2	...	...	...	12	2	2	2	...	...	1	21
Portage Group	...	...	...	...	...	1	...	...	...	2	...	...	3
Genesee Slate	...	...	...	1	...	2	...	...	...	...	...	...	3
Tully Limestone	...	...	...	...	...	6	...	...	...	...	...	...	6
Hamilton Rocks	1	2	...	...	...	10	...	1	...	1	...	...	15
Marcellus Shale	...	...	...	...	...	1	...	...	...	...	...	...	1
Corniferous Limestone	...	...	...	...	...	4	...	...	1	...	...	...	5
Onondaga Limestone	...	2	...	...	...	1	...	...	...	...	...	...	3
Schoharie Grit	...	...	...	...	...	...	...	...	1	...	...	...	1
Cauda-galli Grit	...	...	...	...	...	...	...	...	...	...	...	...	...
Oriskany Sandstone	...	...	...	...	...	2	...	...	...	...	...	...	2
Total	2	6	...	1	...	39	2	3	4	3	...	1	60

Transmitted.

Groups.	Plantæ.	Zoophyta.	Bryozoa.	Annelida.	Echinodermata.	Brachiopoda.	Monomyaria.	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.
Catskill Group	...	...	...	...	...	...	...	...	...	...	...	...	...
Chemung Group	...	...	...	...	...	...	...	...	...	...	...	...	...
Portage Group	...	...	...	...	...	2	...	...	...	...	...	1	3
Genesee Slate	...	...	...	...	...	1	...	...	...	...	...	...	1
Tully Limestone	...	...	...	...	...	2	...	...	...	...	...	...	2
Hamilton Rocks	1	...	...	...	...	9	1	2	...	...	...	...	13
Marcellus Shale	...	1	...	1	...	2	...	...	1	...	...	...	5
Corniferous Limestone	...	...	...	...	...	7	1	1	...	1	...	...	10
Onondaga Limestone	...	...	...	...	...	...	1	...	...	...	...	...	1
Schoharie Grit	...	...	...	...	...	1	...	...	...	...	...	...	1
Cauda-galli Grit	1	...	...	...	...	...	...	...	...	...	...	...	1
Oriskany Sandstone	...	1	...	...	...	5	..	...	...	...	..	...	6
Total	2	2	...	1	...	29	3	3	1	1	...	1	43

Typical.

Groups.	Plantæ.	Zoophyta.	Bryozoa.	Annelida.	Echinodermata.	Brachiopoda.	Monomyaria.	Dimyaria.	Crustacea.	Gasteropoda.	Pteropoda.	Cephalopoda.	Total.
Catskill Group	...	...	...	...	...	...	...	2	...	...	...	...	2
Chemung Group	...	1	...	...	...	37	18	2	1	1	...	...	60
Portage Group	1	...	...	...	1	3	3	5	...	4	...	1	18
Genesee Slate	...	...	...	...	...	4	...	...	...	...	...	...	4
Tully Limestone	...	...	...	...	...	5	1	...	1	...	...	...	7
Hamilton Rocks	1	6	1	...	1	60	20	29	...	9	1	3	131
Marcellus Shale	1	1	...	...	...	7	3	1	...	2	...	3	18
Corniferous Limestone	...	...	...	1	...	21	1	1	2	5	...	3	34
Onondaga Limestone	...	8	...	...	1	19	...	1	1	3	...	...	33
Schoharie Grit	...	...	...	...	...	2	...	...	...	...	...	...	2
Cauda-galli Grit	1	...	...	...	...	...	...	...	...	...	...	...	1
Oriskany Sandstone	1	1	...	...	...	22	...	...	...	1	...	...	25
Total	5	17	1	1	3	180	46	41	5	25	1	10	335

TABLE III.—*The Recurrent Fossils of Trenton Limestone.*

Fossils.	Trenton Limestone.	Utica Slate.	Hudson-River Group.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limestone of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Upper Pentamerus Limestone.
Graptolites pristis	*	*										
bicornis	*	*										
scalaris	*	*										
sagittarius	*	*										
Chætetes columnaris	*	...	...	*								
sp. ind.	*	*	*									
Stromatopora concentrica	*	...	...	...	...	*	......	*				
Orbicula lamellosa[1]	*											
Leptæna alternata	*	*	*									
depressa	*	*	*									
imbrex	*	*	*									
sericea	*	*	*									
(Stroph.) grandis	*	*	*									
Orthis parva	*	*	*									
testudinaria	*	*	*									
striatula	*	...	*									
Atrypa increbrescens	*	*	*									
modesta	*	*	*									
Terebratula bidentata	*	*	*									
Ambonychia, sp. ind.	*	*										
Tellinomya machæriformis	*	...	...	...	*							
Modiolopsis anodontoides	*	...	*									
modiolaris	*	...	*									
Nucula levata	*	...	*									
poststriata	*	...	*									
Murchisonia uniangulata	*	...	*									
Bellerophon bilobatus	*	*										
Trocholites ammonius	*	...	*									
Orthoceras vertebratum	*	...	*									
Ampyx	*	...	...	...	...	*						
Calymene Beckii	*	*	*									
punctata	*	...	...	...	...	*						
Platynotus Trentonensis	*	...	...	...	...	*						
Isotelus gigas	*	*	*									
Phacops limulurus	*	...	...	...	*	*						
Dalmanni	*	...	...	...	...	...	......	...	...	*	*	
Trinucleus Caractaci	*	...	*									
concentricus	*	...	*									

[1] And in Genesee Slate.

Table IV.—*Fossils escaped from Lower to Upper Silurian, into and across the Middle or Transitional Period.*

Fossils.	Authority.	Chazy Limestone.	Birdseye Limestone.	Trenton Limestone.	Utica Slate.	Hudson River Group.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limestone of Schoharie.	Onondaga-Salt Group.	Waterlime Group.
Chætetes lycoperdon	H.	...	...	...	...	*	...	...	*				
spec.	H.	...	...	*	...	...	...	*					
Stromatopora concentrica	V.	...	...	*	...	...	...	...	...	*	*	*	
Glyptaster brachiatus	H.	*	...	...	...	*	...	...	*	*			
Hemicystites parasiticus	H.	...	...	*	*	*	...	...	...	*			
Leptæna alternata	Sh.	...	...	*	*	*	...	...	*				
depressa	Sh.	...	...	*	*	*	...	...	*	*			
(Stroph.) grandis	Sh.	...	...	*	*	*	...	...	*				
sericea	Sh.	...	...	*	*	*	...	...	*				
Atrypa reticularis	Sh.	...	...	*	*	*	...	...	*				
Bellerophon bilobatus	Sh.	...	...	*	*	*	...	*					
Orthoceras æquale	E.	...	...	...	*	*	...	...	...	...	...	*	
multiseptum	H ?	*	...	...	...	...	...	*	*				
Bucania trilobate	H.	...	...	...	*	*	...	*	*				
Calymene Blumenbachii	C.	...	...	*	*	*	...	...	*	*			
Platynotus Trentonensis	C.	...	...	*	...	...	...	...	...	*			
Phacops limulurus	H.	...	...	*	...	...	...	...	*				

Table V.—*Fossils common to Europe and the Niagara Group of the State of New York.*

Fossil.	European position.	Country.	Authority
Zoophyta.			
Favosites Gothlandica ?	D, US, LS.	Europe, Britain ...	V.
Halysites catenulatus	US, LS.	Europe, Britain ...	V, H.
Heliolites pyriformis ?	D, US, LS.	Europe, Britain ...	V, H.
Stromatopora concentrica	US.	England	V, H.
Eucalyptocrinus decorus	US.	England	V, H.
Atrypa (Rhynchonella) bidentata	WL.	England, Sweden ..	H.
aprina	US.	Russia	V, H.
cuneata ?	WL.	Sweden, England ..	V, H, Sh.
affinis	WL.	Moscow, England ..	H.
didyma ?	Ludlow.	England, Gothland.	Sh.
aspera	D.	France, Rhine, Pennsylvania	V.
marginalis	WS.	England	V.
reticularis	D, US.	Europe, England...	V, Sh.
tumida ?	D.	England, Sweden ..	V.
imbricata	WL.	England	H.

Table V. (*continued.*)

Fossil.	European position.	Country.	Authority
Rhynchonella interplicata	WL.	England, Sweden ..	H.
plicatella ?	WL.	England, Sweden ..	H.
Wilsoni	WL.	Ireland, Sweden ...	V.
brevirostris ?	US.	England	H.
Leptæna depressa	UL, LL, WL.	England, Sweden ..	V, Sh, H.
subplana	D.	France	H.
transversalis	WL.	England, Sweden ..	V. H.
Orthis elegantula	UL, LL, WL.	Russia, England, Sweden, Ireland.	V, H.
flabellulum ?	LS.	Wales	V, H.
hybrida	WL.	England, Ireland...	V, H.
pisum	WS.	Ireland, England...	H.
Spirifer bilobus	US, LS.	Europe, England...	V, H.
crispus	LL, WL.	Sweden, Britain ...	V, Sh, H.
cyrtænus (plicatellus et radiatus)	US.	Europe, Britain ...	V, H.
lynx	US.	Europe................	V.
sinuatus	WL.	England ?............	V.
sulcatus	US.	Sweden	V.
Bumastus Barriensis................	WL.	England	V.
Calymene Blumenbachii	WL.	Ireland, Sweden ...	V.
Cheirurus insignis..................	M. & U. Sil.	Bohemia, &c.	V.
Homalonotus delphinocephalus .	WL.	England	V.
Phacops limulurus..................	L. Silurian.	France	V.
Orthoceras annulatum ?............	US.	Sweden, England ..	H, V.
imbricatum ?	US.	Sweden, England ..	H.
virgatum ?	US.	Sweden, England ..	H.
Bellerophon dilatatus	US, LS.	Britain...............	V.
Conularia Niagarensis	WL.	Dudley, &c	H.

TABLE VI.—*The Group-relations of the Fossils of the four Lower Helderberg Limestones.*

Fossils.	Clinton Group.	Niagara Group.	Coralline Limestone of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limest.	Delthyris-Shaly Limestone.	Upper Pentamerus Limestone.	Authority.	British Strata.
Aulopora repens	...	...	...	...	...	...	*			
Catenipora labyrinthica	...	...	...	...	*	...	...	...	Va.	US,LS.
Calamopora favosa	...	...	...	...	...	...	*	...	C.	
Chætetes Gothlandica	...	*	...	...	*	...	...	...	V, H.	D, US, LS.
Tentaculites ornatus...............	...	...	...	...	*	...	...	...	Va.	US,LS.
scalaris	...	...	...	...	...	...	*	...	C.	LS.

Table VI. (*continued.*)

Fossils.	Clinton Group.	Niagara Group.	Coralline Limestone of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limest.	Delthyris-Shaly Limestone.	Upper Pentamerus Limestone.	Authority.	British Strata.
Cornulites serpularius	...	*	*	*	*	*	*	...	V, &c.	US.
Astrocrinites pachydactylus	...	...	...	...	...	*	...	...	C.	
Lepocrinites Gebhardii	...	...	...	...	...	*	...	...	Va.	
Leptæna depressa[1]	*	*	...	...	...	*	*	...	Sh.	WL.
(Strophom.) impressa	...	...	...	...	...	*	...	...	C.	
(——) indentata	...	...	...	...	...	...	*	...	V.	
(——) elongata	...	...	...	...	...	*	...	...	C.	
(——) pecten	...	...	...	...	...	...	*	...	Sh.	LS.
(——) punctulifera	...	...	...	...	...	...	*	...	C.	
(——) radiata	...	...	...	...	...	...	*	...	C.	
(——) rectilateris	...	...	...	...	...	*	...	...	C.	
(——) rugosa	...	...	...	...	...	...	*	...	C.	
(——) varistriata	...	...	...	...	...	*	...	...	C.	
Orthis hybrida	...	*	...	...	...	...	*	...	Sh.	WL.
occlusa ?	...	...	...	...	...	...	*	...	V.	
orbicularis	...	...	*	...	...	...	*	...	Sh.	WL.
resupinata[2]	...	...	...	...	...	...	*	...	Sh.	WL.
Spirifer (Delthyris) bilobus	*	*	...	...	...	...	*	...	C, V.	
(——) granulosus ?	...	...	...	...	...	...	*	...	C.	
(——) macropleurus	...	...	...	...	...	*	*	...	C.	
(——) pachyopterus	...	...	...	...	...	...	...	...	C.	
(——) plicatus	*	*	...	...	*	*	*	...	Va, Sh.	WL, L
(——) sp. ind.	...	...	...	...	...	...	*	...	Sh.	
Atrypa concentrica[2] ?	...	...	...	...	...	...	*	...	C.	D.
æquiradiata	...	...	...	...	...	...	*	...	V.	
inflata	...	...	...	...	...	*	*	...	C.	
lacunosa	...	...	...	...	...	*	...	...	C.	
lævis	...	...	...	...	...	...	*	...	Va.	
medialis	...	...	...	...	...	...	*	...	Va.	
prisca	...	...	...	...	...	...	*	...	C.	
reticularis	*	*	*	*	*	*	*	...	Sh.	D, US.
semiplicata	...	...	...	...	...	*	...	...	C.	
singularis	...	...	...	...	...	...	*	...	Va.	
sulcata	...	...	...	...	...	...	*	...	Va.	
tumida	...	*	...	...	...	...	*	...	Sh.	WS.
Rhynchonella borealis	...	...	...	...	...	...	*	...	Sh.	WS.
Stricklandi	...	...	...	...	...	...	*	...	Sh.	WL.
Wilsoni	...	*	...	...	...	*	...	...	V.	WL.
Terebratula deflexa ?	...	...	...	...	...	...	*	...	V.	
n. sp.	...	...	...	...	...	...	*	...	Sh.	WS.
Pentamerus galeatus	...	*?	...	...	...	*	*	...	Sh.	WL.
pseudo-galeatus	...	...	...	...	...	...	...	*	H.	
Avicula multilineata	...	...	...	...	...	*	...	...	H.	
monticola	...	...	...	...	...	*	...	...	C.	

[1] Lower Silurian. [2] Devonian.

[*To face p.* 424.

TABLE VIII.—*The Recurrent Fossils of the Devonian System of the State of New York; including the species which enter from the Silurian.*

Fossils.	Lower Silurian.							Middle Silurian.			Upper Silurian.							Lower Devonian.					Middle Devonian.						Upper Devonian.
	Sandstone.	s Sandstone	ıck-River Limestone.	Limestone.	imestone	e.	iver Group.	nglomerate.	ndstone.	roup.	roup.	Limest. of Schoharie.	-Salt Group.	Group.	ntamerus Limestone.	Shaly Limestone.	ntamerus Limestone.	Sandstone.	li Group.	Grit.	Limestone.	s Limestone.	Shale.	Group.	estone.	late.	roup.	Group.	roup.
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	*	
Microdon bellastriata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S	...	...	...	*	
Pleurotomaria pervetusta	...	...	...	...	...	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	*							
Bellerophon striatus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	...	...	...	...	V		
expansus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	*		
Goniatites expansus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Va	...	...	...	*		
Clymenia? complanata	...	...	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H	*	
Cornulites serpularius	...	...	...	...	...	...	...	...	...	V	...	...	...	...	...	...	...	*	...	...	...	*	...	V					
Calymene Blumenbachii	...	...	...	...	*	*	*	...	...	V	V	*	...	...	...	...	...	...	...	V									
Phacops macrophthalmus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V?	...	...	...	V	V	V	...	V					
Pleurodictyum problematicum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	?	V	?				

In this Table the single recurrences are 30; the double 15; the triple 5; the quadruple 3; and the quintuple 5.

TABLE VIII.—*The Recurrent Fossils of the Devonian System of the State of New York; including the species which enter from the Silurian.*

Fossils.	Lower Silurian.							Middle Silurian.			Upper Silurian.							Lower Devonian.					Middle Devonian.						Upper Devonian.
	Potsdam Sandstone.	Calciferous Sandstone	Chazy Black-River Limestone.	Birdseye Limestone.	Trenton Limestone	Utica Slate.	Hudson-River Group.	Oneida Conglomerate.	Medina Sandstone.	Clinton Group.	Niagara Group.	Coralline Limest. of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limestone.	Delthyris-Shaly Limestone.	Upper Pentamerus Limestone.	Oriskany Sandstone.	Cauda-galli Group.	Schoharie Grit.	Onondaga Limestone.	Corniferous Limestone.	Marcellus Shale.	Hamilton Group.	Tully Limestone.	Genesee Slate.	Portage Group.	Chemung Group.	Catskill Group.
Fucoides graphica	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	H		
Cauda-galli	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	*	...	...	...	*	
Tentaculites Fissurella	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	*	...	...	H			
Columnaria, sp. ind.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	*	...	...	*			
Catenipora escharoides	...	...	...	...	...	...	...	...	...	H	H	H	...	...	...	...	...	V	...	...	Va	*	...	*					
Favosites alveolaris	...	...	...	...	...	...	...	...	...	...	V	...	...	...	...	...	...	...	...	...	*								
Gothlandica	...	...	...	...	...	...	...	...	...	...	V	...	*	...	V	...	...	...	...	...	V								
Stromatopora concentrica	...	...	...	...	V	...	...	...	...	...	*	V	V	...	...	...	...	...	...	...	...	...	...	*	...	...	...	*	
Athyris concentrica	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S	...	...	...	S	
Leptæna crenistria	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...	S	...	...	...	S	
depressa	...	...	...	...	S	S	S	...	...	*	S	...	...	...	*	*	...	...	...	...	...	*							
lincaris	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	H				
setigera	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	...	...	*			
Orthis Tulliensis	...	...	...	...	*	...	*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Va	...	...	*				
umbonata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...	V					
Spirifer acanthotus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...	H					
acuminatus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	*	...	...	...	...	...	*	
aperturatus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...	...	*	...	...	...	...	...	*	
cultrijugatus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	...	...	...	V	...	V	...	...	...	*	
heteroclytus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*?	...	...	...	V	...	V					
mucronatus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Va	...	H					
Niagarensis	...	...	...	...	...	...	...	...	...	...	S	...	...	...	...	...	...	*											
plicatus	...	...	...	...	...	...	...	...	...	...	*	...	...	*	*	*	...	*											
Urii	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...	*	...	...	...	*	
Atrypa affinis	...	...	...	...	...	...	...	...	...	*	*	...	...	...	...	...	...	...	...	...	V	...	...	...	*	...	...	H	
didyma	...	...	...	...	...	...	...	...	...	*	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...	*			
emacerata?	...	...	...	...	...	...	...	...	...	*	...	...	...	...	...	...	...	*											
lentiformis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	H				
prisca	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H	*	...	...	H	
reticularis	...	...	...	...	...	...	...	...	...	*	*	...	...	...	...	...	...	*	...	...	*	...	*	...	*	*	*	*	
aspera	...	...	...	...	...	...	...	...	...	...	V	...	...	...	...	...	...	...	...	...	...	V	...	V					
concentrica?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	V	...	...	...	V	
Rhynchonella borealis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S	...	...	...	...	...	...	...	*	...	...	...	S	
Nucula	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	S	
Productus Fragaria?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S	...	...	...	S	
scabriculus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S	...	...	...	S	
Orbicula minuta	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S	S					
Avicula Boydii	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S	...	...	...	S	
fragilis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H	...	...	H	...	*	
multilineata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H	...	...	...	...	...	...	...	...	...	...	...	...	*	
orbiculata	...	...	...	...	...	...	...	...	...	...	H	...	...	...	...	...	...	...	...	...	...	...	...	H					
pectiniformis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S	...	...	...	...	S	
Pterinæa fasciculata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	V					
Lucina rugosa	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	...	V					
Posidonia lirata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S	...	...	...	*	
Chemnitzia nexilis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	...	V					
Modiola concentrica	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	*	
Microdon bellastriata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	S	...	...	...	*	
Pleurotomaria pervetusta	...	...	...	...	...	...	...	...	*	...	...	...	...	...	...	...	...	...	...	...	...	*							
Bellerophon striatus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	...	...	...	...	V		
expansus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	...	...	...	*		
Goniatites expansus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Va	...	...	...	*		
Clymenia? complanata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H	*	
Cornulites serpularius	...	...	...	...	...	...	...	...	...	V	...	...	...	...	...	...	...	*	...	...	...	*	...	V					
Calymene Blumenbachii	...	...	...	...	*	*	*	...	...	V	V	*	...	...	...	...	...	...	...	V									
Phacops macrophthalmus	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V?	...	...	...	V	V	V	...	V					
Pleurodictyum problematicum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*	?	V	?				

In this Table the single recurrences are 30; the double 15; the triple 5; the quadruple 3; and the quintuple 5.

Table VI. (*continued*).

Fossils.	Clinton Group.	Niagara Group.	Coralline Limestone of Schoharie.	Onondaga-Salt Group.	Waterlime Group.	Lower Pentamerus Limest.	Delthyris-Shaly Limestone.	Upper Pentamerus Limestone.	Authority.	British Strata.
Avicula naviformis	...	...	...	...	...	*	*	...	C, Sh.	UL.
rugosa	...	...	...	...	*	...	...	...	Va.	
Euomphalus profundus	...	...	...	...	...	*	...	...	C.	
sulcatus	...	...	...	...	*					
Littorina antiqua	...	...	...	...	*	...	...	...	Va.	
Platyceras Gebhardii	...	...	...	...	...	...	*	...	C.	
ventricosum	...	...	...	...	...	...	*	...	C.	
Calceola plicata ?	...	...	...	...	...	...	*	...	C.	
Phragmoceras ventricosum	...	...	...	...	*					
Theca Forbesii	...	...	...	...	...	*	*			
Conularia quadrisulcata ?	...	...	...	...	...	...	*	...	C, H.	
Leperditia alta	...	...	*	...	...	*	...	...	Va.	
Phacops Hausmanni	...	...	...	...	...	...	*	...	V.	
macrophthalmica	...	...	...	...	...	...	*	...	V.	
Asaphus pleuroptyx	...	...	...	...	...	...	*	...	C.	
nasutus	...	...	...	...	...	...	*	...	C.	
?Acidaspis tuberculata	...	...	...	...	...	...	*	...	C.	
Acantholoma, sp. ind.	...	...	...	...	...	...	*	...	C.	
Dicranurus, sp. ind.	...	...	...	...	...	...	*	...	C.	

Table IX.—*The Recurrency of the Fossils of the Corniferous Limestone.*

Fossils.	Oriskany Shale.	Corniferous Limestone.	Hamilton Group.	Tully Limestone.	Portage Group.	Chemung Group.
Spirifer cultrijugatus	*	*	*			
heteroclytus	...	*	*			
mucronatus	...	*	*	...	...	*
Atrypa prisca	...	*	*			
lentiformis	...	*	...	*		
aspera	...	*				
Terebratula concentrica	...	*	*	...	...	*
Rhynchonella borealis	...	*	...	...	...	*
Avicula pectiniformis	...	*	...	...	...	*
Lucina rugosa	...	*	*			
Bellerophon striatus	...	*	...	...	*	

TABLE X.—*Hamilton Fossils common to the State of New York and Europe.*

Authority.	Fossils.	Country.	Palæozoic position.
Hall	Aulopora tubæformis	England	Upper Sil.
Hall, De Vern	Cystiphyllum cylindricum	Ireland, England	Upper Sil.
Hall	Strombodes helianthoides	Europe............	Devonian.
Sharpe	Athyris concentrica.........	England	Carbon. and Dev.
Sharpe	lamellosa..............	Europe, England	Carboniferous.
Hall	Atrypa affinis	Russia, England.	Upper Sil.
De Vern., Sharpe .	Leptæna Dutertrii	France	Devonian.
De Verneuil	(Stroph.) laticosta ...	Eifel...............	Devonian.
Sharpe	(——) Sharpei	Westmoreland...	Carboniferous.
Sharpe	Orthis eximia...............	Russia	Carboniferous.
De Verneuil	Michelini...............	Russ. Belg. Swed.	Carboniferous.
Sharpe	opercularis	Russia	Devonian.
De Verneuil	umbonata	Brittany	Devonian.
Sharpe	Productus Fragaria ?	Devonshire	Devonian.
Sharpe	scabriculus	Europe, England	Carb. & Up. Dev.
De Verneuil	subaculeatus	Russ., Rhine, &c.	Upper Devonian.
De Verneuil	Spirifer cultrijugatus	Eifel...............	Devonian.
De Verneuil	heteroclytus	Russia, Engl.,&c.	Devonian.
De Verneuil	mucronatus............	Europe............	Devonian.
Sharpe	Urii........................	Scotland, Devon.	Carb. & Up. Dev.
De Verneuil	Atrypa aspera	France, Rhine ...	Devonian.
De Verneuil	concentrica	Europe, England	Devonian.
De Verneuil	cuboides	Europe............	Devonian.
De Verneuil	reticularis	Europe............	Devon. and Sil.
Sharpe	Terebratula Nucula.........	Europe, England	Upper Silurian.
Sharpe	Avicula Boydii	Westmoreland...	Upper Silurian.
Sharpe	quadrula	Westmoreland...	Upper Silurian.
De Verneuil	Pterinæa fasciculata	Nassau...........	Devonian.
De Verneuil	Cardium loricatum	Eifel...............	Devonian.
De Verneuil	Grammysia Hamiltonensis	Eifel, France ...	Devonian.
De Verneuil	Lucina proavia	Eifel...............	Devonian.
De Verneuil	Sanguinolaria dorsata......	Eifel, England...	Devonian.
Hall	Nucula lineata...............	England	Devonian.
Sharpe	Orthoceras articulatum ...	Wales	Upper Ludlow.
Hall, De Vern. ...	Chemnitzia nexilis	France, England.	Devonian.

TABLE XI.—*European Fossils in the Chemung Group of the State of New York.*

Author.	Fossil.	Country.	System.
Sharpe, De V...	Athyris concentrica.	Europe, Engl..	Carbonif., Dev.
Hall	Leptæna (Stroph.) interstrialis ...	Engl., France..	Devonian.
Sharpe	Umbraculum ?..................	England, Eifel	Devonian.
Vanuxem	membranacea	England	Devonian.
De Verneuil ...	Orthis crenistria.....................	Europe	Carbonif., Dev.
Hall	interlineata.....................	England	Devonian.
Hall	Unguiculus	Eifel, England	Devonian.
Sharpe	Productus Fragaria ?	England	Devonian.
Sharpe	plicatilis ?	Europe, Engl..	Carboniferous.
De Verneuil ...	subaculeatus	France, Rhine	Upper Devonian.

Table XI. (*continued*).

Authority.	Fossils.	Country.	System.
Sharpe	Spirifer aperturatus	Eifel............	Devonian.
Hall	disjunctus	Engl., Europe.	Devonian.
De Vernueil ...	mucronatus	Eifel............	Devonian.
Sharpe	Urii	Europe, Engl..	Carbonif., Dev.
De Vernueil ...	Verneuilli = disjunctus	Belgium, &c.	
Sharpe	Atrypa aspera	Europe, Engl..	Dev., Up. Sil.
De V., Sharpe ..	reticularis	Europe, Engl..	Carbonif., Dev.
Sharpe	Rhynchonella Nucula	Europe, Engl..	Upper Silurian.
Sharpe	borealis	Europe, Engl..	Dev., Up. Sil.
Sharpe	Avicula Boydii	Westmoreland	Upper Silurian.
Sh., De V., Hall	Damnoniensis	England	Devonian.
De Verneuil ...	Inoceramus Chemungensis.........	Eifel, Usk ...	Dev., Up. Sil.

On the Palæozoic Basin *of the* State *of* New York.

Part II. *Classification of the Palæozoic Strata of the State of New York.* By J. J. Bigsby, M.D., F.G.S., late British Secretary to the Canadian Boundary Commission.

[Read January 28, 1858.]

The task of distributing the palæozoic sedimentary rocks of New York into natural divisions became easy after the publication of the 'Silurian System' of Sir Roderick Murchison.

This State is peculiarly favourable to such studies, from the directions, lofty sides, and other features of its principal lakes and rivers. Many of the latter, such as the Genesee, Black, and Onondaga Rivers, rise in the south, and, running north, cross and lay bare successive strata in the most satisfactory manner. Other streams, like the Mohawk, in the eastern part of New York, rise in the west, and also traverse nearly the whole series.

Glacial and other natural erosions, as well as some prolonged artificial excavations, disclose the outcrops of the strata in a succession of exposures unparalleled in number and extent. In the counties of Herkimer and Otsego the cliffs often attain an elevation of a thousand feet, followed closely by others surmounting them.

No country in the world, says De Verneuil, presents so complete and uninterrupted a development of the Silurian and Devonian systems, if we except Sweden, where it is on a small scale. In these regions, therefore, our investigations are far simpler and more decisive than amid the disturbances of many parts of Europe. We are in the position of the anatomist who examines a perfect animal instead of a mass of dismembered fragments.

As types of comparison, the palæozoic rocks of this State are to be preferred to any other, as a whole.

In the following observations we shall first consider the sedimentary strata of this Central Basin under the aspect of groups, as established by the official geologists of New York—this appearing to be the natural mode of proceeding. We shall then endeavour to show the grounds on which these groups have been combined into stages and systems.

I am aware that, by not including the Carboniferous system within the scope of these inquiries, except incidentally, some useful lights are lost; but the subject is so extensive that my hands are already full—not to mention that there is no coal in New York State.

I was induced to draw up a Synoptical View of the treasures buried, as it were, in the official Reports of the State Geologists of New York by a desire to see them in a more methodical and accessible form; and now a similar feeling prompts me to explain the stratigraphical treatment they have received.

I venture to suggest the subjoined Table as exhibiting the natural arrangement of the palæozoic sedimentary strata of New York.

This Table, which is mainly that used by the State Geologists of New York, and which, like every other part of this paper, has reference to that tract of country only, I adopt and hope to justify, having, however, presumed to introduce the two following modifications:—

1. I have united into natural groups, A, B, C, and others, such allied strata as seemed to me needlessly separated. These strata are named "sections" in the Table.

2. I have established a distinct middle stage in the Silurian and Devonian systems, respectively, of New York,—a division suggested by others, but never effected, and this partly on account of the difficulty of finding a satisfactory summit.

It must not be forgotten that all such arrangements are imperfect, and that they are made to facilitate reference and for other uses—to give brief expression to ascertained facts, and to aid in the construction and use of extensive tables of fossils for particular purposes.

Of the separation, by American observers, of the groups into the four divisions, Champlain, Ontario, Helderberg, and Erie, very little will be said, as it is merely geographical, and was proposed before the almost universal prevalence of these strata was known. It also involves some false classification, in uniting the upper and lower Helderberg groups, for they include rocks which do not even belong to the same system.

The arrangement of the palæozoic sedimentary rocks of this State, after some few mistakes committed and corrected, was early agreed upon, and the twenty-nine groups (sections) of our Table erected by common consent. Granting that the official Geologists have in some instances been too minute in their distinctions (a pardonable error in new territory, where a broad base was required), they are fully justified in the groups they have set up. Their distinctions might have been advantageously carried still further, but for the limited faculties of man; for a single New York group of moderate thickness may contain several "*formations*" in Deshayes' sense of the word. According to Deshayes, a formation "is a space of time represented by a certain number of beds, laid down under the influence of the same phenomena;" or, in other words, a formation is cha-

Stratigraphical Table.

DEVONIAN.				SILURIAN.			
Stage.	Sections.	Group.	Prevailing Mineral.	Stage.	Sections.	Group.	Prevailing Mineral.
Upper	Catskill Sandstone	V.	Siliceous Conglomerate and Sandstone.	Upper	Upper Pentamerus Limestone; Delthyris-Shaly Limestone; Lower Pentamerus Limest.; Waterlime Rocks	H.	Limestone.
Middle	Chemung Rocks; Portage Sandstone	IV.	Argillaceous Sandstone.		Onondaga Salt Rock	G.	Sandy Shale.
	Genesee Slate; Tully Limestone; Hamilton Rocks; Marcellus Shales	III.	Clay and Sandstone.		Coralline Limestone, Schoharie; Niagara Shale and Limestone	F.	Limestone.
Lower	Corniferous Limestone; Onondaga Limestone	II.	Limestone.	Middle	Clinton Rocks; Medina Sandstone	E.	Sandstone.
	Schoharie Grit; Cauda-galli Grit; Oriskany Sandstone	I.	Calcareous Sandstone.		Oneida Conglomerate	D.	Siliceous Conglomerate.
				Lower	Hudson River Rocks; Utica Slate	C.	Clay.
					Trenton Limestone; Birdseye Limestone; Chazy Limestone	B.	Limestone.
					Calciferous Sandstone; Potsdam Sandstone	A.	Sandstone.

racterized by the constancy of its fossils. (Ami Boué, Mémoires, &c., pp. 140–144.)

Our American friends have only brought together such contiguous strata as agree in mineral condition, fossil contents, and position, three great tests of synchronism and common origin to which the various sections perfectly respond. These divisions are important as well as distinct, and are applicable satisfactorily over large areas, always occupying the same geological horizon, but perhaps under considerable lithological variations. Nearly every one of these groups has its own mineral character, which usually softens or melts into that of its coterminous stratum, their constituent earths not only alternating in the mass, but in their minuter commixtures also, and becoming more and more seldom repeated as each stratum is penetrated. In proof of this, reference may be made to the Synoptical View generally.

Further, each group is a natural and not an artificial division, because it is a new zoological province, a true centre of organic life, with a fauna principally typical, meaning by that term the part which appears with the group and perishes. Examples of this are universal.

Their claims, therefore, each to its separate place in the great series cannot be doubted; and they are more readily ascertained in New York than in Wales, from the rarer admixture there of fossils of different epochs.

On the separate Groups as arranged in the Table.

Potsdam Sandstone and Calciferous Sandstone, or Group A.—The three lower natural aggregates, marked A, B, C, form, as we shall afterwards see, the lower stage of the Silurian system.

The first, or lowest, consists of Potsdam Sandstone and Calciferous Sandstone. These strata undergo innumerable slight or limited lithological changes, and graduate one into the other with conformableness. All their fossils are typical save one. In general, Potsdam Sandstone contains few animal remains. In New York, Potsdam Sandstone only yields a *Scolithus* (*linearis*), two species of *Lingula*, and a few Trilobites, the latter met with very recently.

On the Upper Mississipi, *Lingulæ*, *Orbiculæ*, and some highly organized and typical Trilobites have been found by David Owen.

Calciferous Sandstone possesses a larger fauna, chiefly consisting of Gasteropoda (11 out of its 19 fossils), and three typical Orthoceratites. The only fossil connecting these enormous sheets of arenaceous matter with the system to which they belong is the *Scalites angulatus* of Chazy Limestone. Group A, in its lithology and fossil contents, then, is sufficiently distinct. The second group, B, is established upon equally solid grounds. It is a series of limestones with frequent argillaceous impurities and shaly alternations, especially in Trenton Limestone.

Trenton Limestone is the predominant member. It is three times as thick as Chazy and Birdseye Limestone taken together, and it is by far the most fossiliferous. But these last (Chazy and Birdseye Limestones) retain their relative positions over considerable spaces, and are the products of the same natural causes; they are also bound together by a common organic facies (Sharpe), and by sixteen important species (in nine genera) of Silurian life, common to some two, at least, of the members of this group.

Fossils common to the Three Members of Group B.

Fossils.	Chazy L.	Birdseye L.	Trenton L.	Fossils.	Chazy L.	Birdseye L.	Trenton L.
Stromatocerium rugosum ...	*	*		Pleurotomaria umbilicata ...	...	*	*
Chætetes Lycoperdon	*	*	*	Orthoceras duplex	*	...	*
Lingula obtusa	...	*	*	—— vertebrale	*	...	*
—— (Crania) quadrata......	...	*	*	Ormoceras gracile	*	...	*
—— ovata	...	*	*	Illænus Arcturus	*	...	*
Leptæna alternata	...	*	*	—— crassicauda	*	...	*
Murchisonia angustata	*	*		—— Trentonensis............	...	*	*
—— perangulata	...	*	*	Bellerophon bilobatus	...	*	*

The peculiar Cephalopod, *Ormoceras gracile,* is one of these. The Chazy Limestone is remarkable for containing another species, together with a variety; they are both typical. Its Zoophytes and Bryozoa have only five species each; but individuals so abound that the rock is often a mere coral-reef.

On the rocky floor of some shallows near the mouth of the Madawaska, a tributary of the River Ottawa in Canada, Sir W. Logan met with a profusion of finely-developed fossils of these three limestones—existing therefore in common. Thus it is in Silurian rocks as in the secondary and tertiary. The Lias, for instance, of Yorkshire is divided into zones, each distinguished by its own fossils; but in following the same strata to considerable distances (as in the Silurian case), the organisms typical of one member are seen to become common to several formations, and thus to combine all into one group, the Liassic (Murchison).

Group C consists of the two very wide-spread sections, Utica Slate and Hudson-River group. It is the uppermost aggregate of the lower stage. Utica Slate has been deposited in quiet waters, as we learn from its homogeneous character and the smoothness of its grain; while the Hudson-River strata were laid down in varying depths, and often among conflicting currents; for we find in them numerous beds of conglomerates and breccias, both quartzose and calcareous, the latter laden with Trenton fossils.

In fact, a definition of the Hudson-River group in some localities would describe the Oneida Conglomerate, the stratum next succeeding. This vast deposit prevails over such wide spaces, and resembles, as just mentioned, the last section so closely, that Professor Rogers and

Sir William Logan are at issue as to the real position of the mass of slate and conglomerate which extends from Gaspé to the Shawangunk Range, a distance of 800 miles,—whether these strata are of the Hudson-River or Oneida Conglomerate.

The distinction between this Group C and its predecessor B is broad in its mineral conditions, in the sudden diminution (in Utica Slate) of the abounding Trentonian life, and in the accession throughout Group C of new and interesting invertebrates, the majority of them being typical. Utica Slate, comparatively unfossiliferous, has only ten typical species; but the Hudson-River group has sixty, although the whole population of the latter is only three-tenths of that of Trenton Limestone. Their *Graptolites* are numerous, and usually typical.

This Group C, then, is a distinct epochal centre; but it is not without its affinities to Group B, and through their Brachiopoda principally,—this, however, not being so great as once thought; for the fossils common to both groups are only one-fourteenth of the whole.

Oneida Conglomerate, Group D of the Middle Stage.—The separation of this stratum from every other (save one, perhaps) is justified by its mineral structure and constitution, and by the nearly total absence of life.

It consists of an alternation of three kinds of material: 1st, a conglomerate of quartz-pebbles; 2nd, a siliceous sandstone; and, 3rd, of a hard red and green shale. When the thin limestones of the Hudson-River section are wanting, and when conglomerates of white and black quartz-pebbles become frequent, that section can scarcely be distinguished from the Oneida Conglomerate.

Medina Sandstone and Clinton Rocks, Group E.—This is entitled, for useful purposes, to be treated as an independent formation, as will be seen from the following remarks. Firmly as the Clinton strata are linked to the Niagara group, they are still more intimately and extensively united with the Medina, and especially in Pennsylvania (H. D. Rogers). We are speaking with sufficient precision for our present object, when we say that Group E stands apart from all its neighbours in its lithological aspect,—an aspect which is perpetually changing, and which becomes calcareous in the west. These two sections contain large and beautiful Fucoids in great quantities (which are exclusively their own), together with several animal organisms in common, and typical of this group.

Niagara Group and Schoharie Coralline Limestone, Group F, like its kindred group H (Lower Helderberg), consists of limestones and shales, which vary in purity over the large spaces they occupy,—constantly returning, however, to their normal composition.

The main distinction of the Group F resides in its characteristic forms of animal life; and this is amply sufficient to vindicate its independence. The fossils of the Niagara section are mostly new, are extremely abundant in certain spots, and comprehend 145 typical forms out of 180. There are here three times as many species of Zoophyta, Bryozoa, and Echinodermata as there are even in the rich domain of the Trenton section. Their delicacy of organization has rendered them intolerant of mineral change, and therefore typical.

The Niagara fossils exhibit much greater variety in form, appendage, and ornament than those of the lower stage. The Brachiopoda of this section are less in number by one-third than those of Trenton; 40 of them are new, out of 48; and they are very prolific of individuals.

The genus *Lingula* has but one representative here. *Orthis* and *Leptæna* are each one-third of the Trenton number, while *Atrypa* remains numerous, and *Spirifer* has multiplied fivefold. 9 out of 13 Trilobites, and 7 out of 10 Cephalopoda are typical. These are striking facts.

The Coralline Limestone of Schoharie is admitted by all to be a part of the Niagara section. Although it has 30 fossils peculiar to itself, principally Brachiopoda, Monomyaria, and Gasteropoda, it has 7 important molluscs in common with the Niagara section; viz. *Catenipora escharoides, Chætetes Niagarensis, Stromatopora concentrica, Spirifer crispus, Atrypa reticularis, Cornulites serpularius,* and *Asaphus Blumenbachii.*

We must speak of the four Lower Helderberg formations in connexion with the Group F, on account of their intimate relations with it, although separated by 1000 feet of argillo-arenaceous strata (Onondaga-Salt group).

Group H has been divided into Waterlime Rock (lowest), Lower Pentamerus Limestone, Delthyris-Shaly Limestone, and Upper Pentamerus Limestone. In the Synoptical View, these beds have been shown to be of one epoch by their mineral and fossil characters, and by conformableness.

Though a local, and in some sense a supplementary group, confined to the State of New York, these strata are distinct as a series, overspreading considerable space, and nearly allied to the English Wenlock, but possessing typical fossils, of which Delthyris-Shaly Limestone alone has 30; the others show fewer, owing probably to imperfect examination.

The Onondaga-Salt Group, G.—The strongly-marked peculiarities of this group, with its deposits of gypsum and its brine-springs, &c., with its barrenness of fossils except about its calcareous capping, are so clearly explained in the Synoptical View, and so conclusive of its being a separate and unique series of sediments, that no further remark upon them is required.

The Silurian Stages of the New York Basin.

These are three—the Lower, the Middle, and the Upper. We shall speak of them in order.

The Lower Stage.—In this part of the Central Palæozoic Basin, the lower stage does not rest upon beds which can in any sense be considered as the North American representatives of the Longmynd rocks of Wales. In the east of New York its beds issue, and proceed westwards, from the metamorphic sheets of mineral matter which floor most of New England, and which are in truth contemporaneous with them. On the north, along the great Laurentine ridge, they rest unconformably on a series of metamorphic rocks, older than those just spoken of, and consisting of syenitic gneiss, white marble, hornblende-rocks, chloritic and other slates, largely intermixed with phosphate of lime.

But there is, on the north shore of Lake Huron, and on both sides of Lake Superior, 600–1000 miles to the west of central New York, an extensive suite of rocks, which stand in the same relation to the Silurian beds as do the Longmynd of Wales. This suite has been carefully examined by Sir William Logan*, Messrs. Murray, Whitney, and Foster. The quasi-Longmynd of Lake Huron is at the same time unconformable to the Silurians above them and the old metamorphic rocks below; its total thickness is about 10,000 feet; and it extends about 80 miles along the shore of the Lake.

This formation is lithologically different from the Longmynd of Wales,—being of white, often vitreous sandstone, with many beds of quartz-conglomerate; and it alternates with great masses of greenstone-slate, and of conglomerate with pebbles of syenite and granite in a matrix of greenstone. A persistent band of limestone, 150 feet thick, with thin layers of chert, is found in the middle of the series. Greenstone-dykes, large and small, everywhere traverse the strike in considerable numbers.

The rocks upon which the Huron Longmynd rest are micaceous and chloritic schists, gneiss, and granites,—a continuation almost certainly of the older metamorphic rocks in more eastern Canada.

It will be convenient for the sake of brevity simply to refer to Foster and Whitney's Report for information respecting these oldest rocks on the south side of Lake Superior, and to Silliman's Journal (n. s. vol. xiv. p. 227) for the N.E. portion of that Lake.

The lower stage of the Silurian system is distinguished from the others by the four following important features, besides a multitude of minor details, as discovered by a comparison, section by section.

1. The groups of the lower stage are the most extensive. They are in sheets 1000 and 1400 miles in diameter. We have Calciferous Sandstone and Trenton Limestone in the Gulf of St. Lawrence, and stretching westwards and southwards through the Canadas, New York, into Michigan, Wisconsin, Minnesota, Texas, &c. Neither are the other groups very inferior in extent.

2. It is remarkable for the comparative uniformity of mineral condition of the same section in very distant countries. Variations occur frequently, but there is a constant recurrence to the normal mineral type. The Potsdam Sandstone of the Mississipi or of Lake Superior is described in nearly the same terms as that from eastern New York. The difference consists in the proportion of clay or oxide of iron contained. The same may be said of the other strata. The steady, regulated mineral change westward, observed in the middle and upper Silurians from east to west, has not commenced,—a very noticeable fact.

* Sill. Journ., n. s. vol. xiv. p. 225.

3. The same species of fossils are, as a consequence, more widely disseminated in this stage.

4. Species of fossils are few, and individuals are many in the early part of the lower stage; but after the discontinuity of life at the close of Calciferous Sandstone, which was much more complete than that at the close of the Hudson-River Rocks, animated beings peopled the Lower Silurian seas in greater numbers perhaps than in the upper stage; but upon the whole (for there are exceptions) their forms are plainer and simpler.

The Middle Stage.—Many practical advantages are obtained by admitting the existence of a middle stage, although there may be difference of opinion as to its upper termination and other points.

In this place I simply express my belief that the change of conditions, or break, which created this middle or transitional stage, did not proceed from a great crust-rupture in the region now called the United States, nor from any disturbance at all comparable to the post-carboniferous uplift, but perhaps from violent currents carrying westwards the products of distant catastrophes, such currents being impelled by a crust-undulation. The further discussion of this subject I postpone to a more convenient part of this paper.

The middle stage commences with the Oneida Conglomerate of eastern New York and Lower Canada, and it may be made to end with the Clinton Rocks.

The fact is, that in eastern and central New York the Clinton Rocks have intimate and extensive relations with Medina Sandstone* (still closer in Pennsylvania according to H. D. Rogers), while in the western portion of the State and in its upper beds it has slowly graduated into the Niagara section, the great mass, however, for some hundred square-miles, being arenaceous, and in all respects having a transitional character.

The middle stage of the Silurian system in the State of New York is firmly based upon the great and frequent changes of mineral character which it presents, and upon the notable disappearance of Lower Silurian races, accompanied by the introduction of a few important and new forms of animal and vegetable life.

It is remarkable for the great predominance, first, of conglomerate and grit, and, secondly, of sandstones, in the higher and western beds, diversified almost *ad infinitum* by intermixtures of clay, lime, and iron—no stratum remaining the same even for a moderate breadth of country. Further, everywhere in this stage a gradual change was always going on in a westerly direction, from coarseness to fineness—from quartz-shingle through clay to limestone, with all the usually concomitant succession of new organisms which takes place in existing sea-beds.

* Hall (Palæontology, &c. ii. p. 2) says that, in the western portion of the State, the limit between the Medina Sandstone and the Clinton group is well defined, and the materials distinct; but in the central part of the State, the Clinton (like the Medina Sandstone) begins by a shaly deposit, succeeded by alternations of sandstone, in character like those of Medina Sandstone.

We have in the middle stage (Clinton section) probably the first considerable aggregation of iron-ore in sedimentary rocks.

As might have been anticipated, the middle stage does not abound in traces of life. For 1000 feet above the Hudson-River Rocks, west of the Oneida Conglomerate, we have a homogeneous argillaceous sandstone totally barren of fossils; but at about 100 feet from the top of Medina Sandstone they begin to appear.

The supposed marine plants, *Palæophyci*, &c., become, by their vast assemblages, and sometimes by the beauty of their forms, a prominent feature of this stage.

The Brachiopoda here (Hall, Rep. p. 53) contrast with those of the lower stage, and species are introduced eminently significant of a new phase.

Species of *Orthides* are much fewer, and even individuals are rare.

In the Leptænoid type we have now for the first time the crenulate-hinged *Strophodonta* and the remarkable mollusc *Chonetes*. *Atrypæ* are more numerous here than *Leptæna* or *Orthis*, compared with the lower stage; and they have the smooth, round, or subcylindrical forms which rarely occur in the lower beds. Lastly, we have the genus *Pentamerus*, which is wholly unknown in the stage below. Three species, *P. oblongus*, *P. fornicatus*, and *P. ovalis* (Hall), are restricted to the Clinton section, but others mount up into Upper Silurian.

There are no Trilobites in Medina Sandstone, but we meet with twelve in the Clinton group; of these, seven are typical. One species of the genus *Beyrichia* appears here, imbedded in iron-ore.

The Upper Stage.—The upper stage of this system is constituted best by placing the Niagara section at its base, and by including all the superincumbent strata up to Oriskany Sandstone. All these rocks have comparatively permanent mineral characters. The numerous changes of the middle stage have either moderated or ceased altogether.

The Niagara and its four kindred limestones (Lower Helderberg) consist wholly of argillaceous shales and limestones, the latter in Niagara being sometimes pure in the west, or mixed with magnesia, or white and sparkling with siliceous drops.

The fossils of the upper stage are, except in parts, abundant, various, elegant, in great measure typical, and gregarious. Upon this subject we refer to the observations on Group F in page 432.

The Devonian System.

The establishment of a new system seems to be called for on the completion of the Upper Pentamerus Limestone. The call has been obeyed, and the new system has been named "The Devonian." It extends from Oriskany Sandstone to the summit of the Catskill group, or the Old Red Sandstone.

The Devonian system is established in New York on the following grounds, among others:—

1. It is introduced by gritty calcareous sandstones, composed

discernibly of fragments of hypogene rocks, such as mica?, felspar, and quartz,—indications of some disturbance.

2. There is here a sudden and almost total change of fossil life. Not only are nearly all the Silurian fossils extinguished, but we witness the accession of many new genera of invertebrates, and the first appearance of fish and reptiles in North America.

3. Small but certain indications of terrestrial vegetation are here met with.

The Devonian system covers about one-third of the State of New York, and especially its central and southern districts. It was probably De Verneuil that first announced its true palæozoic limits, from having discovered the remains of fish, the Goniatite of Nassau, *Murchisonia bilineata*, *Productus subaculeatus*, *Athyris concentrica*, large *Spiriferi*, and many other characteristic fossils in the strata beginning with Oriskany Sandstone and ending in Coal-measures.

The Devonian fossils of this basin, even with the most sanguine expectations of James Hall as to the result of future research, are much fewer than those of the Rhenish provinces and other parts of Europe.

In Eastern Canada (Gaspé) the Devonian is 7000 feet thick, according to Sir William Logan; but in New York the greatest thickness of the Devonian is 4000 feet; and it thins out west, disappearing entirely beyond the Mississipi, where the carboniferous rocks repose on Silurian strata. In Arkansas, more to the south, however, the Devonian (Chemung, Rogers) is in great force again, as well as in Nova Scotia (Dawson), and in Massachusetts, near Boston, as detected by Professor Agassiz.

The five groups into which I have compressed the twelve sections of the American geologists will now be noticed *seriatim*, and then the three stages into which, for convenience, I have divided them.

See Table VII. in the 'Synoptical View,' for the group-relations of the Devonian fossils of New York.

Groups.

Oriskany Sandstone, Caudagalli Grit, Schoharie Grit. Group I. —These three beds being, in truth, one deposit, we treat them as such (see 'Synoptical View'). We observe that the Lower Devonian stage begins, like the Lower Silurian and the Upper Devonian, with a sandstone, containing so much disseminated calcareous matter, as, first, to be a calciferous sandstone, terminating upwards abruptly in a limestone, which has received the name of the Onondaga Limestone. Lithologically, therefore, the Oriskany Sandstone, with its small subordinates, is clearly separate from all other Devonian deposits.

The facies of the fossils of this group is Devonian, and they are often of large size,—a Devonian characteristic; thirteen are original and six typical. It contains two Silurian Brachiopoda. Its five *Spiriferi* are distinctly Devonian, as are its *Cyrtoceras* (Eifel) and the *Pleurorhynchus* (?). Schoharie Grit has yielded more than one indisputable specimen of fish-remains (*Asterolepis*). All this taken together, according to Hall and De Verneuil (Sill. Journ. vii. 320, n. s.), permits us to place Oriskany Sandstone on the same horizon with the Rhenish Spirifer-Sandstein of Sandberger,—that is, at the base of the Devonian system (Murchison, Siluria, p. 373).

Onondaga and Corniferous Limestones. Group II.—These closely-connected strata are severed abruptly from the subjacent grits. Their lithology requires no further notice than to state, that the latter is marked by the great quantity of silica it contains, both infiltrated and in layers.

Onondaga Limestone presents us with twenty-seven original and twenty-two typical fossils. This includes twelve species of zoophytes; four of them having ascended from the Niagara section. It is often a true coral-reef.

The Corniferous Limestone has but one zoophyte, but has nineteen original brachiopods and twenty-two typical fossils in seven genera. Group II. therefore comprehends two independent epochal centres of life.

Marcellus Shale, Hamilton Rocks, Tully Limestone, and Genesee Slate. Group III.—Marcellus Shale acquires a distinct position by holding the earliest American *Goniatites* (*G. expansus, G. Marcellensis*), as well as by its eighteen typical fossils. But in the 'Synoptical View' this shale has been shown to be simply the lower part of the richly fossiliferous Hamilton section.

This last-named formation has 119 original organisms, and its typical forms amount to the great number of 106; they are principally Brachiopoda and Lamellibranchiata. It gives us the characteristic fossil, *Goniatites punctatus*, and the first *Inoceramus* (*oviformis*). Tully Limestone is a thin stratum, which must have been noticed for industrial purposes, as it is only a slender aggregation of the calcareous matters which often pervade the Hamilton section.

Genesee Slate is poor in fossils, with but four typical Brachiopoda. There are reasons indeed why it should be rather united to the next succeeding group.

Portage and Chemung Rocks. Group IV.—These sandstones and shales are the product of the same epoch, and, according to H. D. Rogers, ought never to have been separated. In their fossil contents, however, they are distinct. Of the nineteen original Portage species, only two enter the Chemung—one of these being *Clymenia complanata?* With the older groups just reviewed, the Portage has very slight connexion.

The Chemung assemblage of strata are placed apart from all others by the presence of sixty typical fossils, having, at the same time, sixty-eight which are original. They are almost wholly Brachiopoda and Monomyaria, as in the Hamilton section, with which the affinities of the Chemung rocks, both lithological and vital, are very strong, although separated by three sections of strata.

The Catskill Strata. Group V.—This is distinguished at once from its predecessors by the instant arrest of molluscan life, and the presence of *Holoptychius nobilissimus* and other Old Red Sandstone fishes. The tranquillity in which the middle stage of the New York Devonian system was deposited ceases, to be succeeded by the moderate disturbance indicated by the alternating conglomerates, grits, and sandstones which are henceforth continuous into the Carboniferous era. The Catskill group, therefore, has in North America both place and period of its own.

The Stages of the New York Devonian System.

We are now to treat of the three stages into which it is proposed to divide this system—the Lower, Middle, and Upper.

The Lower stage begins with Oriskany Sandstone, the Middle with Marcellus Shale, and the Upper with Catskill Sandstone—the representative of the Old Red Sandstone of Europe.

The Lower Stage.—This stage is not without its difficulties. The sandstone at its base, with its two attendant grits, though truly Devonian, is local, but not found largely in New York, and only found largely in Pennsylvania. It does not exist in Canada, Ohio, and the West; and thus becomes of limited use as a permanent horizon. Seeing this, the lower stage might be made to consist of the Corniferous Limestone and Onondaga Limestone, its smaller associate (subjacent), when we should have, as in nature, a vast and constant plane of reference in the western countries (Hall) based directly upon the Niagara beds,—thus forming over the face of these regions a calcareous mantle of surpassing extent and thickness; because it will be remembered that the Onondaga Salt-group and the four (Wenlock) Limestones above it, which in New York help to fill up the interval between Onondaga Limestone and Niagara, besides being very thin in parts of New York itself (Hall, Rep. p. 151), disappear in the W.S.W. (Hall).

De Verneuil (Bull. Soc. Géol. Fr. 2 sér. iv. 670, &c.) begins the lower stage with Oriskany Sandstone; for, according to Hall, its deposition was preceded by a violent movement of the waters, which denuded and hollowed out the ground*; and its fossils are analogous to those of the Devonian era, such as the great Spirifers, which are quite unknown in true Silurian. H. D. Rogers (Rep. Assoc. Adv. Science, 1856, p. 178) also finds a distinct plane of discontinuity in Pennsylvania on this horizon, dividing the Lower Helderbergs from Oriskany Sandstone.

The lower stage consists of a calcareous sandstone succeeded by limestone, all the principal sediments having fossils exclusively their own. It therefore has a well-defined existence.

The Middle Stage.—Marcellus Shale is selected as the base of this large and highly fossiliferous stage; 1st, because of its abrupt separation from the Corniferous Limestone; 2ndly, from its being the first of a long succession of shales and sandstones; and 3rdly, because it is almost completely independent, as to animal life, of all previous deposits.

* In certain cases this may have occurred, but not in others; for Oriskany Sandstone *graduates* from Delthyris Shaly Limestone. In a few feet, the change is effected; and Silurian life is extinguished, or nearly so.

This stage embraces the two groups III. and IV. Both of them are mainly alternating depositions from quiet waters of argillaceous and arenaceous mud; group No. III. occasionally possessing more or less of limestone, either minutely disseminated or in seams. It has been shown elsewhere that the fossil-relations of the different parts of this stage are nowhere unfrequent, but are remarkably close between the Hamilton and Chemung Rocks. This is, therefore, a natural stage.

Upper Stage.—This stage includes the numerous and varied strata, of great thickness, in the southern districts of New York, which have been associated together under the name of the Catskill Sandstones.

This is a safely-designated horizon. With perfect conformableness, there is here a sudden change of lithological constitution. Instead of an impalpable mud, we find boulders, pebbles, grit, and red sandstone, with occasional shales. The fossils of the middle stage have all disappeared, and two new Dimyaria (*Cypricardites angustata* and *C. Catskillensis*, Vanuxem) are the only representatives of the molluscan type remaining; while some of the fish and plants belonging to the Old Red Sandstone of Europe are present in moderate numbers.

Inferential Propositions.

In possession of the stratigraphical details contained in the 'Synoptical View' and in the preceding pages, it seems desirable to bestow some attention on historical geology, and to pronounce, if possible, on some of the influences which have resulted in the present aspect and condition of the palæozoic sedimentary beds of the State of New York.

Of these influences or conditions, two, which are not the least important, according to the views of many geologists, may be summed up in the following short propositions:—

1. That from the Potsdam Sandstone to the summit of the Carboniferous rocks, these strata were laid down in comparative quiet; subject to secular oscillations—vertical, variable, perhaps constant, and which led to considerable superficial changes.

2. That their elevation, foldings, fracture, and metamorphism were effected after the deposition of the whole, in a single prolonged transaction, and principally in a N.E. and S.W. direction along the present Appalachian ridges and their continuation from Labrador to the Gulf of Mexico.

From these statements the Professors Rogers dissent; but principally as regards the period at which the great crust-movement spoken of in the second proposition took place.

I shall first endeavour to support the propositions just laid down, and shall afterwards address myself to the views of our able American brethren.

I. With regard to the first proposition—

1. This is made very probable, if not proved, by an examination of the uniting planes of coterminous sections or sets of beds. With rare exceptions, they are all undisturbed and conformable in New York, as may be seen through the whole ample series of palæozoic

rocks in that State. These strata are, therefore, the offspring of quiet times, not excepting Oneida Conglomerate, when out of a certain disturbed district, and when acted on by currents only. To this conformability in the several important sections with which I am acquainted, I offer personal testimony.

2. This rest from plutonic interference is indicated by the usual, and often extreme, fineness of the deposit, and by the small proportion of conglomerate or breccia in these ever-varying strata; coarse materials, indeed, are often due to surf-action, or to currents urged on by winds.

3. It is indicated by the very gradual mineral passage from one stratum to another during the palæozoic age.

4. It is indicated by the fact that fossils are in common, in many coterminous strata, for certain thicknesses.

This proposition is adopted by many leading geologists in America. James Hall, in his Official Report, p. 20, says, "From the absence of all extensive disturbances of the strata, we are enabled to trace an uninterrupted series from the Potsdam Sandstone to the Old Red."

In his 'Palæontology' (vol. i. p. xv.), the same author regards "the entire succession as forming a series intimately linked together by the nature of its organic contents, and showing no important changes till we arrive at the Old Red Sandstone." Again (Sill. Journ. n. s. vii. 49), James Hall makes the decisive statement, "During all the time of its deposition [the palæozoic formation in North America], the surface was free from great disturbances."

Prof. Emmons, one of the State-geologists (Rep. p. 99), remarks that, "In the whole space, such is the order and regularity in the succession [of the New York palæozoic rocks], that we meet with no unconformable masses, nor sudden and abrupt passages from one group or series of rocks to another. There is a gradual sequence or transition from one mass to another."

Sir William Logan (Canad. Journ. 1854, p. 1), speaking of the New York strata continued into Canada, writes: "These various formations are a set of close-fitting, conformable sheets, intersected by the general surface of the country."

De Verneuil (Bull. Soc. Géol. de France, 2 sér. iv. 684) says: "During the whole period in which the palæozoic 'terrain' was being deposited in North America, the earth was free from great perturbations."

Dr. Fitton has informed me that, after careful personal examination of the palæozoic rocks of Wales, in company with our late President, Daniel Sharpe, he is of opinion that the whole belong to the same grand epoch, and may be called Cambrian or Silurian at pleasure, according as the observer begins at the bottom or at the top of the series.

Sir Roderick Murchison, in his 'Silurian System,' gives proof upon proof of the gradual passage of nearly all the Welsh deposits into each other, together with five distinct instances (and perhaps more) of the Lower Silurian being continuous into the Longmynd rocks (pp. 256, 352).

The oscillations referred to in the first proposition did not disturb the conformableness of the strata, because they operated on the whole equally and simultaneously.

II. The second proposition, namely, that the only *great* plutonic disturbance in the palæozoic series we are now concerned with took place after the deposition of the coal-measures, rests on the following considerations, among some others which will appear in the sequel:—

1st. Because the disturbed country (the Appalachian Ridge) on the Atlantic side of North America is gathered up and compacted into one mass, and exhibits the working of a single cause, most powerfully in the centre, less and less laterally, but nevertheless extending sideways, in deep-seated throes, to great distances, and there showing itself in broad undulations or low-arched domes, or in minor fractures.

2ndly. Because the axes or lines of uplift, both principal and subordinate, are continuous in nearly the same direction for the great distance of 1500 miles, with the usual great transverse fissures, according to the State-geologists employed in these regions. These axes are sometimes in straight lines for 100 miles together, and in one instance for more than 200 miles.

3rdly. Because, in like manner, the dips and foldings, so close, highly inclined, and sharp along the central line of disturbance, gradually open wider and wider, become undulatory, and finally horizontal continuously from stratum to stratum, as they depart westwards, and floor the flat countries there.

4thly. Because the whole series of the palæozoic formations of Middle North-east America, from the oldest to the newest, was equally affected over the tract of country just referred to; the coal-measures (the newest) fully partaking of the great and general disturbance, becoming anthracitic, and then slowly returning to the bituminous state, and to horizontality, as they pass into the Western plains, away from the seat of elevatory action. This is universally admitted, and has been beautifully explained by Professors W. B. and H. D. Rogers.

5thly. Because, as would occur in singleness of action, in most of the other strata, the return westward to their original position and mineral state is gradual—as is seen in the natural sections of the Mohawk Valley, and about the head of Lake Champlain. The proximity of the Atlantic Ocean, together with certain overlying Tertiaries, prevents our observing this on the east of the Appalachian Ridge.

6thly. Because, as J. D. Dana (Address, Sill. Journ. n. s. xxii. p. 311) expresses himself, "simplicity of structure is *the* feature of American geology." Hence the lessened probability of oft-repeated revolutions; which revolutions on the western continent are remarkable for completeness, and for their clear exhibition of geological principles. All this is in strong contrast with the complex and mangled condition of European palæozoic formations.

7thly. Because the upheavals, fractures, and inversions hinted at, but not pointed out, by that highly esteemed State-geologist, Mather, as having occurred before and near the period of the Shawangunk Grit or Oneida Conglomerate, are situated among the wrecks of the post-carboniferous catastrophe, and are therefore obnoxious to the gravest doubts as to their real origin. Neither is a disturbance so timed necessary to explain appearances.

The localities referred to are on the River Rondout, a tributary of the Hudson River, and Mount Becraft, near the city of Hudson, on a spur of which eminence Professor H. D. Rogers met with an important section, which I have not seen.

8thly. Because, if the great Canadian assemblage of strata, called Oneida Conglomerate by Sir William Logan, but Hudson-River group by Professor H. D. Rogers in conversation with me, should be the latter, we have evidence, in its numerous alternations of varying breccias and conglomerates, that the disturbances (if any) commenced with the end of Utica Slate, and therefore at another and earlier period than when the Oneida Conglomerate was thrown down.

J. D. Dana, the learned naturalist, who in extensive travel and philosophical spirit is the Charles Darwin of America, I was very lately gratified in no common degree to find, absolutely affirms my two propositions in the following forcible words :—"All the various oscillations that were in slow movement through the Silurian, Devonian, and Carboniferous ages, and which were increasing their frequency throughout the last, were premonitions of the great period of revolution when the Atlantic border, from Labrador to Alabama, was at last folded up into mountains, and the Silurian, Devonian, and Carboniferous rocks were baked or crystallized. No such event had happened since the revolution closing the Azoic period. From that time on, all the various beds of succeeding ages, up to the top of the Carboniferous, had been laid down in horizontal or nearly horizontal layers, over New England, as well as in the West: for the continent, from New England westwards, we have reason to believe, was then nearly a plain. *There had been no disturbances, except some minor uplifts.* The deposits, with some small exceptions, were a single unbroken record until this Appalachian revolution." This was one of the most general periods of catastrophe and metamorphism in the world's history.

In speaking of parts of Wales and districts adjacent, Professor Phillips (Memoirs Geol. Surv. ii. p. 207) might be the historian of the palæozoic deposits of New York.

He uses the following language :—"All these districts, after having been part of a sea-bed subject to continual or interrupted subsidence, were displaced by one great system of mechanical forces operating through one period of time." This is a close definition of my views.

Objections discussed.—As has been mentioned already, the two propositions, which I have thus been endeavouring to maintain, are not fully acquiesced in by the Professors Rogers and other eminent geologists. We shall now enter upon the delicate task of both stating and testing the opinions of the gifted brothers we have just named, who have most successfully devoted their great intellects in life-long labours to the study of physical geology, and under the most favourable circumstances.

As some apology for differing with geologists of the first order, some of them perhaps less familiar with quiet than with disturbed districts, I may be permitted to say, that it is unfaithful to scientific progress, and to the sacredness of truth itself, to rest too exclusively on authority,—not, after unbiased study and inquiry, to write modestly what we think honestly. Neither do I stand alone.

In our examination of the different groups of the Lower Silurian stage, we have seen a greater or less connexion between them, and commonly both as to fossils and mineral character; but on the complete deposition of the Hudson-River rocks new conditions supervene; and all observers are agreed that here is placed a dismemberment—a cessation, *in degree*, of palæozoic sequences, and therefore a new starting-point.

So far all opinions coincide; but opposite sides are taken, and maintained with honourable pertinacity, as to whether this stop or break is a break of system or of stage; in other words, whether or not all below the Oneida Conglomerate of Middle North-east America should be denominated *Cambrian*, and all above it *Silurian*.

If the two propositions stated in page 38 be true, as I believe they are, the limited change, physical and vital, which they admit, at this period, is reduced to the inferior significance and value of a break of stage only. If, however, with Professors Rogers, Sedgwick, and other eminent men, we see a wide extending crust-rupture of almost unparalleled force and range, at the period of the Oneida Conglomerate, by which utter destruction fell upon existing surfaces, followed by a totally new series of deposits and their inhabitants, then this break is to be deemed *systematic*.

Before exhibiting more fully the views of these gentlemen, I beg to observe that they appear to have formed too low an estimate of the change of all conditions implied in the establishment of a system.

A new system at any epoch is not necessarily created by a moderate change of levels, by the presence of conglomerates, or by the extinction of a fauna. Were this the case, systems would almost equal in number the Silurian sections themselves.

Much more is required. If we pass from one system to another, as from the Silurian to the Devonian (which is a mild instance), we find a new phase, new actions, and new animal forms in the latter, and these of great import. Little physical disturbance has taken place. Dry land has increased in quantity; and we have a terrestrial vegetation for the first time. The molluscs have a new facies, are very much larger, more ornamented, and rather more numerous than in Silurian sediments. Few of the old forms are left; many new and singular animals come forth; and, what in scientific value exceeds all other considerations, a novel and completely different type of life is introduced—the vertebrate (in the forms of fishes and reptiles)—a type which, after many and constantly ascending modifications, through countless ages, has become the tabernacle of the highest order of existences.

If we leave the Devonian for the Carboniferous system, the scene is totally changed. In the latter we are presented with buried jungle in layer upon layer, spreading over enormous spaces (1,000,000 square-miles in one body), distinctly of terrestrial origin, and intermingled for the first time with freshwater deposits—unless Austen is right in regarding some of the Devonian rocks as freshwater (Journ. of Proc. Geol. Soc. xii. p. 51). Marine life is new, various, and prolific.

And thus we might advance along the whole series of sedimentary rocks; but this may suffice to show that systems exhibit differences which are profound and universal, in comparison with which those introduced with the Oneida Conglomerate were small indeed.

The following paragraphs contain such a summary, however imperfect, of the opinions on this subject of Professors Rogers as is compatible with the limits of this paper; and they are an abstract from the memoir by the younger brother, "On the Correlation of the North American and British Palæozoic Strata" (see Report Assoc. Adv. Science, 1856). I shall endeavour to show my sincere admiration of this valuable memoir by all the clearness and fidelity I can command.

Professor H. D. Rogers (*loc. cit.* p. 178) states that—

1st. "The break or plane of discontinuity terminating the Matinal series, or Hudson-River group, exceeds all the others in the Appalachian basin for the abruptness of the transition which it implies in the organic remains, and in the magnitude of the crust-movement*."

2nd. (p. 186.) This Matinal break "revolutionized alike the entire extent of the American and European areas, both in their inhabitants and in their physical geography." It was a "stupendous movement," "tremendous and nearly universal," p. 181.

Evidence of the Physical Break.—1. "From the Gulf of St. Lawrence to the River Hudson (nearly 800 miles) this break is marked by *an unconformable interrupted sequence*†, the Matinal rocks [Hudson River group], highly inclined and folded, generally supporting less inclined strata of the Levant [Medina Sandstone], or some other middle palæozoic formation." (p. 178.)

* "The Appalachian palæozoic strata contain several important planes of discontinuity. These are of very unequal magnitude, both geographically and stratigraphically. ...The two most conspicuous of all are, that at the end of the Matinal or Hudson-River period, and that at the beginning of the Vespertine or first Carboniferous age. Another, although materially less extensive, divides the Premeridian or Lower Helderberg period from the Meridian or Oriskany Sandstone age." *Loc. cit.* p. 178. (Post-carboniferous crust-movement is not adverted to.)

† "Two sets of strata resting in contact," says H. D. Rogers, "may present not only an absence of parallelism, but an omission of one or more intermediate formations elsewhere existing. This state of things implies not only an inclining of the inferior beds, but a lifting of them into dry land, with a lapse of time before their immersion for the reception of the overlying deposits. Such a condition, familiar as the commonest species of unconformity, may fitly be entitled *an unconformable interrupted sequence*." (p. 178.)

2. The Niagara group lies discordantly on the Hudson-River group in Gaspé, the Eastern townships, and Vermont. (p. 178.)

3. "Undulated Matinal rocks support horizontal Niagara or Scalent strata, with a lapse of two intermediate formations for some distance from the Hudson, westward along the base of the Helderberg range." (p. 178.)

4. Unconformity extends west of the River Hudson as far as the Oneida Lake, a distance of about 120 miles, with and without interruption of sequence in the strata. (p. 178.)

5. The Levant beds (Medina Sandstone and Clinton Rocks) evidence this crust-movement in every feature of their composition. The lower bed is a conglomerate of Cambrian pebbles and sand. (p. 179.)

6. "Over half the width of the [Western] Continent there exists, notwithstanding an almost absolute horizontality and parallelism of the two sets of strata, or the lower and middle palæozoic series, a true discontinuity in the sequence of the formations. In New York there is a conformable interrupted sequence* from the Hudson to Oneida County: from Oneida to Lake Ontario, the Levant Conglomerate or Lowest Silurian stratum enters the gap and makes the sequence complete."

7. The Professor goes on to say that there is a similar and contemporaneous break at Cincinnati in Ohio. The lower palæozoic strata coming to day there, the Niagara Limestone rests upon the Hudson-River group direct, there being no Medina Sandstone there, and little of the Clinton rock. (p. 180.) This break is repeated in a still more striking manner in Tennessee, as well as in Southern Wisconsin and Eastern Missouri. In this last region, and further west, "there is a chain of broad anticlinals, exposing ancient plutonic and gneissic rocks, but chiefly the older palæozoic strata near their axes. Around every one of these, either the middle, that is Silurian and Devonian, or upper, namely Carboniferous deposits, rest in discordant superposition (with or without parallelism) upon the Primal, Auroral, and Matinal members [Potsdam, Chazy, and Hudson-River groups] of the older palæozoic division." (p. 180.)

The Palæontological Break.—This is more remarkable than the physical, according to Mr. Rogers (p. 181), who states that only three dilapidated fossils escape from below the break into the strata above, namely *Bellerophon trilobatus, Delthyris Lynx, Leptæna alternata,* with a few dubious fragments of other fossils which appear to be forms belonging to Lower Silurian strata (p. 183). "This horizon of the upper limit of the Matinal rocks is incontestably the sharpest, palæontologically, within the whole palæontological system

* "One set of strata may rest immediately on another with perfect parallelism, and yet their plane of contact represent a long interval of time and a total change of sedimentary conditions and of the physical geography; for certain beds, or even whole formations interposed between them in other districts, may be altogether absent. This relationship is entitled *a conformable interrupted sequence.* It proves not merely a lift of the watery floor into dry land, and its subsequent re-immersion, but a movement unaccompanied by any tilting or undulation of the lower deposit." (*Loc. cit.* p. 178.)

of the Appalachian basin, whether we measure it by the smallness in the proportion of the species which bridge the gulf, or by the alteration in their types of structure." (*Loc. cit.* p. 182.)

Remarks on the above Evidences.—In remarking upon the physical evidences first, it may be stated that, excepting Becraft's Mountain, occupying only an area of a few square miles, no sites are pointed out where the "tremendous" destroying forces of the Oneida period have been exerted, no line is drawn between them and those which affected also the post-carboniferous period.

In reference to Evidence No. 1 (the discordant position of the Hudson-River and Medina Sandstone), the answer may be this:—these rocks, being here within the range of the post-carboniferous movement, as I hope to show, owe their discordancy to its agency.

In reference to the second Evidence (the Niagara limestone lying discordantly on the Hudson-River rocks in Gaspé, &c.), the same reply may be safely made, with this addition as concerns Gaspé:—That region is 200 or 300 miles distant from the central basin of New York, and is in the middle of another and wholly independent palæozoic area, which I thought was my own discovery until I found it in Professor Emmons's Report; he names it "the north-eastern basin." Its base rests upon the ancient metamorphic rocks of the north shore of the Gulf of St. Lawrence. From thence it sends an ascending series of Silurian and other palæozoic strata eastward across Lower Canada, Gaspé, New Brunswick, Nova Scotia, and so onward into the Atlantic Ocean.

With regard to No. 3, I perhaps may be permitted to suggest another cause for one portion of the statements. May not the lapse of the two intermediate formations be attributed to exhaustion of materials, as in the case of Oriskany Sandstone, which only spots certain parts of New York? The undulations may be claimed as post-carboniferous, as in the case of Evidence No. 4.

With regard to Evidence No. 5, stating that the Levant beds (Medina Sandstone, &c.) are full of evidence of this Oneida movement in its conglomerates and sands, I repeat that it is granted throughout this discussion that there has been change of level, capable, in particular modes, of producing conglomerates—recollecting at the same time that subterranean disturbance is not always necessary to their formation. Land-floods, violent tides, or winds, a surf battering down a line of cliffs—any of these superficial agencies may give us all the forms of rock-comminution.

The prolonged and slightly curving outline of the Oneida Conglomerate and the Shawangunk Grit (its southward continuation) greatly favours the old and well-established idea that it was the eastern border of a great sea gradually and curiously filled up, and occupying the site of the present middle north-east America.

The following are additional reasons (most of them derived from personal observations in the field, by the Professors Rogers themselves) for believing the physical derangements of the Appalachian chain (1200 miles long in the United States only) took place after the Carboniferous period, and not at the close of the Hudson-River group. They certainly appear to prove unity of time and action throughout this great length of country,—the time being that of the post-carboniferous uplift. I have collected them together for that purpose.

1st. The general conformation of the disturbed region across its whole breadth is the same. The Appalachian ridges are long, narrow, and steep, with even summits and remarkable parallelism. Many of them are almost perfectly straight for more than fifty miles. Some of their groups are curved; but the outlines of all are marked by gentle transitions and an astonishing degree of regularity (H. D. Rogers, Trans. Assoc. Am. Geol. 1842, p. 475).

2nd. The movement of elevation, folding, fracture, and metamorphism affected the Coal-measures equally with all the other strata in and about the Appalachian ridges. The strikes and dips of all the gneiss, slates, and marbles, and of all the unchanged fossiliferous rocks, are clearly continuous into or from the coal, according to the end of the series at which we begin. Professor Rogers (Trans. p. 522) says, "Excepting in one or two localities, the Appalachian formations constitute one unbroken succession of *conforming strata*, from the lowest members of the system, which repose immediately on the primary or metamorphic rocks, to the highest of the carboniferous strata; we must therefore conclude that the *elevatory action could not have begun, at least with any degree of intensity, until the completion* of the carboniferous formation," but immediately afterwards.

In proof of this I appeal to the most beautiful exhibition of geological arrangement on record, that of Pennsylvania, laid down by the brothers Rogers, and, by their generous permission, placed on the map before you little more than a year ago.

It has been the enviable privilege of these distinguished observers to indicate to their fellow-men the grand conceptions and exquisite order that have hitherto lain hid in these mountain-recesses.

The map shows that every individual stratum, throughout the long palæozoic succession, stands in its proper stratigraphical relation, with its strike running north-east, or varying with the great central axes of the crust-ruptures from Alabama to Canada: imperfectly represented on my map by a broad white line.

On a branch of the River Juniata, fifteen miles south of Huntingdon, Pennsylvania, the high contours of the country expose a solitary oblong mass of coal-measures (ten to twelve miles long), thirty miles to the east of any of its carbonaceous contemporaries. It is curious to remark its near parallelism to the central axes (thirty miles east), and to notice how it is based upon, and surrounded by, the usual suite of sedimentary rocks downwards.

3rd. According to Rogers (Trans. p. 490), "Every section of the Appalachian chain, whatever its direction or curvature, offers the same remarkable and beautiful features and gradations in its axes; implying that the cause of these phænomena was *some grand and simple energy* co-extensive with the whole margin of the Appalachian Sea from Canada to Alabama."

4th. Further, he observes (*l. c.* p. 480), "While the general direction of the Appalachian chain is north-east and south-west, there is a remarkable predominance of south-eastern dips throughout its entire length. This is particularly the case along the south-east, or most disturbed, side of the belt.... But as we proceed toward the north-west, or from the region of greatest disturbance, the opposite or north-west dips, which previously were of rare occurrence, and always very steep, become progressively more numerous, and, as a general rule, more gentle." From hence we deduce singleness of action.

5th. We find also (*l. c.* p. 507) that a gradually increasing interval between the axes takes place as we advance north-westwards from the south-east side,—another proof of the oneness of this movement.

6th. The geological features of the northern and southern extremities of this great uplift are mainly the same; that is, along and around the axes of Vermont in the north, and Holston in the south. Much stress is laid by Messrs. Rogers on the fact that, in the great crust-rupture at Cincinnati, the Niagara group comes in direct contact with the Hudson-River group (there very calcareous), the Medina Sandstone and Clinton Rocks being absent from their proper place. The movement itself probably belongs to the post-carboniferous period; or, anyhow, it is so moderate as, with other considerations, only to create a break of stage. The absence (or dying out) of the arenaceous Group E. at this place may be accounted for by its position—in the centre of the Upper Silurian Sea. Cincinnati is 320 miles west from the centre of the Appalachian chain, and much further from the eastern borders of the sea just alluded to.

In places innumerable along the course of the middle and upper Mississipi, considerably to the west of Cincinnati, the absence of middle and upper Silurian and of many Devonian groups becomes quite common,—and from simple exhaustion of force and materials, as is generally supposed—not from plutonic disturbance. In this direction we seem to reach the western limits of the central palæozoic basin; for the prevailing rocks are arenaceous.

I shall only specify three instances of the deficiencies just mentioned.

On the Mississipi, just above Grand Glaize Creek, and in Salt Creek, near St. Genevieve, Trenton Limestone is only separated by a little sandstone or shale from the Chemung group,—the Chemung supporting Carboniferous Limestone (Shumard, Rep. on Missouri, 1855). Dr. Shumard reports a like fact in Lewis County. The same rocks meet, and all the groups which usually intervene are wanting. Professor Swallow, the State Geologist, testifies to the same extensive deficiencies in the middle palæozoic strata throughout Missouri.

It is to be remarked upon this, that at the distance of 800 to 1000 miles from the great uplift traversing Vermont, New York, Pennsylvania, Ohio, &c., we may well suppose the existence of new conditions, quite independent of crust-movements*. James Hall (Sill. Journ. n.s. xxiii. p. 194), in some degree confirming this opinion, says, "It would appear that at a period long preceding the commencement of the Carboniferous-limestone deposits, the ancient ocean began to contract its area:" and then (p. 195) makes the following remarkable statement—that "The coal-measures [of the Mississipi Valley] extend much further to the north than the northern limits of the Carboniferous limestones, and are spread out over the thinning and slightly inclined edges of these beds, and over the more disturbed and highly elevated edges of the rocks of the preceding periods; so that the coal-measures rest respectively *upon all the formations* from Lower Silurian to the Carboniferous Limestones."

By these observations it is intended to show that probably the strata of this basin near the Mississipi gradually died out, and were not much disturbed: but at present so little is known of the geological structure of the Western States that, no general conclusions can as yet be safely drawn.

Palæontological Break.—The palæontological break, according to the Professors Rogers, is "more remarkable than the physical," only three dilapidated fossils with a few indistinct fragments having escaped the general wreck†.

But the non-transmission of animal or vegetable life into the upper strata is by no means the unerring indication of a break of stage—much less of system,—or of any extraordinary and radical discontinuance of action; were it so, we should be afflicted with a chaotic multiplication of stages in palæozoic times.

Potsdam Sandstone neither receives nor transmits life. Calciferous Sandstone transmits only one species upwards. Medina Sandstone only one (*Orthoceras multiseptum*); Chazy Limestone, five; Birdseye Limestone, four; while from other Silurian strata many forms of life pass upwards.

In the same way, in the Devonian system, Onondaga Limestone transmits doubtfully a single brachiopod (*Atrypa reticularis*); Marcellus Shale, only four; Portage group, two; and the Chemung, none whatever. From Oriskany Sandstone seven fossils escape upwards; and from Corniferous Limestone and the Hamilton section, thirteen each.

The palæozoic law of life is, that the vast majority of every epochal fauna, if not the whole, live and perish together. Agassiz‡ insists upon the existence of this law with very great rigour—with a rigour which is excessive, according to our present knowledge.

This great naturalist says, "As fossil remains are studied more

* From Niagara to the Mississipi, about	690	miles.
,, middle of Appalachian chain to Cincinnati	320	,,
,, New York to River Mississipi	950	,,
,, Albany to Utica	120	,,

† Professor Hall states that he is in possession of other fossils, but so broken up and abraded that they are indeterminable.

‡ Contributions to American Natural History, vol. i. pp. 96, 104.

carefully in a zoological point of view, the supposed identity of species in different geological formations vanishes gradually more and more." . . . . "Facts do not exhibit a gradual disappearance of a limited number of species, and an equally gradual introduction of an equally limited number of new ones, but, on the contrary, the simultaneous creation and the simultaneous destruction of entire faunæ." In another place (p. 96), Agassiz observes, "There was, during each great geological era, an assemblage of animals and plants differing essentially for each period : and by '*period*' I mean those minor subdivisions in the successive sets of strata of rocks which constitute the crust of our globe, the number of which is increasing daily, as our investigations become more extensive and more precise."

We may therefore conclude that the proximate extinction of the fauna of the Hudson-River section does not necessarily announce the advent of a new palæozoic system. But, as was shown by a table in the Synoptical View, more fossils survived the Oneida break than has been generally supposed.

List of New York Fossils which have escaped, past the Oneida Conglomerate, from the Lower to the Upper Silurian Stage.

Fossils.	Chazy Limestone.	Trenton Limestone.	Utica Slate.	Hudson River Rocks.	Oneida Conglomerate.	Medina Sandstone.	Clinton Rocks.	Niagara Rocks.	Coralline Limestone of Schoharie.	Onondaga-Salt Rocks.	Waterlime Rocks.
Chætetes Lycoperdon	...	...	...	* H	...	...	* H				
—— columnaris	...	* H	...	...	...	* H					
Stromatopora concentrica	...	* V	...	...	...	...	...	*	*	*V	
Glyptaster brachiatus	*H	...	...	* H	...	...	* H	* H			
Hemicystites parasiticus	?	*	...	...	...	...	...	* H			
Leptæna alternata	...	*	*	* S	...	...	*				
—— depressa	.,.	*	*	* S	...	...	*	* S			
—— (Stroph.) grandis	...	* S	*	* S	...	...	* S				
—— (Stroph.) sericea	...	*	*	* S	...	...	* H				
Atrypa reticularis	...	*	*	*	...	...	* S				
Bellerophon bilobatus	...	*	*	*	...	* S					
Calymene Blumenbachii	...	* C	* C	* C	...	...	* H				
Platynotus Trentonensis	...	* C	...	...	...	...	...	*			
Phacops limulurus	...	* H	...	...	...	...	* H				
Orthoceras æquale	...	...	*	*	...	...	...	...	...	* E	

H. signifies Hall as authority ; V, De Verneuil ; S, Daniel Sharpe ; C, Conrad ; E, Emmons.

Of the fifteen escaped fossils, two are doubtful, but worth notice —*Hemicystites parasiticus* (Trenton Limestone and Niagara Limestone, Hall), *Bucania trilobata* (Utica Slate, Hudson River group, Medina Sandstone, Hall).

Five of the fossils thus common to Lower and Upper Silurian strata are vouched for by James Hall, six by Daniel Sharpe, one by De Verneuil, two by Conrad, and one by Emmons. I am incapable of believing, as yet, that these pains-taking and experienced palæontologists have erred in their identifications; and I feel fully entitled to reason upon them as faithful interpretations of nature.

I shall conclude these observations by stating that if we look at the whole palæozoic scheme, and the presence of recurrent fossils at all periods of this vast epoch and in every known part of the globe, we shall perhaps be of opinion that a way of escape from the Lower to the Middle and Upper Silurian Stage in New York would be provided. And so it seems to be. In four localities these stages are either in contact or approach each other closely, so as to admit of the possible transmission upwards of the species of the Lower Stage —not that molluscs have been seen in actual transition, where the strata are close together. Doubtless in these shattered forest- and swamp-covered wildernesses many similar facts will come to light as they are progressively cultivated by man.

In the State of New York, along the base of the Helderberg Mountains, where the Clinton and Niagara sections and the Onondaga-Salt group are very thin, the Oneida Conglomerate is absent, and the Hudson-River rocks rise to within a few feet of Tentaculite (Waterlime) Limestone. In the south part of Herkimer County (central New York) the shales of the Hudson-River rocks are separated from the sandstones and ore-beds of the Clinton group only by some thin strata of Oneida Conglomerate (Hall, Pal. ii.).

From where the Niagara group ends eastwards (at Little Falls) the Onondaga Salt group rests on the Clinton beds; and still more easterly it reposes on the Frankfort Slate of the Hudson-River rocks, and so continues to within a short distance of the River Hudson. This is an important and extensive example of actual contact of Lower and Upper Silurian, having of course its palæontological consequences.

The grey or yellow porous limestone of the same Onondaga-Salt group was met with by Vanuxem at Sharon Springs, overlying Frankfort Slate and underlying the Helderberg series. With these facts before us, we need not be surprised at fourteen fossils having been recognized by some of the ablest palæontologists of any period as belonging to both Upper and Lower Silurian.

On the Microscopical Structure *of* Crystals, *indicating the* Origin *of* Minerals *and* Rocks.

By H. C. Sorby, Esq., F.R.S., F.G.S., Corresponding Member of the Lyceum of Natural History of New York, and of the Academy of Natural Sciences of Philadelphia, &c.

[Read December 2, 1857.]

[Plates XVI.–XIX.]

CONTENTS.

In this paper I shall attempt to prove that artificial and natural crystalline substances possess sufficiently characteristic structures to point out whether they were deposited from solution in water or crystallized from a mass in the state of igneous fusion; and also that in some cases an approximation may be made to the rate at, and the temperature and pressure under which they were formed.

History of the Subject.—The existence of cavities in quartz, topaz, and fluor-spar, containing fluid, has long been known. Mr. Sivright found them also in calcite, barytes, and selenite. Sir David Brewster discovered them in emerald, beryl, cymophane, peridot, felspar, and rock-salt, as well as in a number of crystals formed artificially. In his admirable paper in the 'Transactions of the Royal Society of Edinburgh' (1824, vol. x. pt. 1. p. 1), he remarks that, being persuaded that water thus mechanically enclosed will be found in every crystal deposited from solution, he was next desirous of finding it in crystals formed by heat or sublimation; but, in no case having been able to discover the slightest trace of its existence, he considered, in the absence of all other information on the subject, the result highly favourable to the supposition of the aqueous origin of all minerals in which cavities containing water had been discovered. No distinction, however, was made by the author between minerals occurring in veins, and those forming the constituents of rock-masses; so that this paper, and others published subsequently (Trans. of Geol. Soc. vol. iii. p. 455, and of Roy. Soc. of Edinburgh, vol. x. pt. 2. p. 407, Ed. New Phil. Journ. April 1845, p. 386, Phil. Mag. vol. xxxi. Aug. 1847, p. 101, and vol. xxxiii. Jan. 1849, p. 489), though of the highest interest optically and physically, can scarcely be considered applications of the subject to pure geology.

In the 'Philosophical Transactions of the Royal Society' (1822, p. 367), Sir H. Davy described the experiments which he made to determine the nature of the fluid contained in the larger cavities of rock-crystal. He found that it was nearly pure water, and that the bubble along with it was either azote or a vacuum. In some cavities he found a kind of mineral oil or naphtha.

In his 'Note sur les émanations volcaniques et métallifères' (Bulletin de la Société Géologique de France, 2e série, t. iv. p. 1249), M. Elie de Beaumont alludes to the presence of cavities, with fluid, in quartz, as an argument in support of his views respecting the origin of granite. Similar remarks are also made by Bischoff (Chemical and Physical Geology, Cavendish Society's Translation, vol. ii. pp. 16 and 477) and by Scheerer (Discussion sur la nature plutonique du granite, Bull. Soc. Géol. de France, 2e sér. t. iv. p. 468); but they all treat the subject as if these cavities were comparatively rare. Such as are large enough to be distinctly visible to the naked eye are, indeed, rare; but when a high magnifying power is employed, it is easy to see that the proportion of many millions to a cubic inch is very common in some minerals.

Such, so far as I am aware, was the state of this subject when my attention was directed to it by examining the excellent collection of "fluid-cavities" in the possession of Mr. Alexander Bryson of Edinburgh, who told me he had found some in the granite of Aberdeen. I immediately perceived that the subject could not fail to lead to valuable results when applied to geological inquiries, and soon proved that my supposition was well founded. In my paper on the microscopical structure of mica-schist, read before the British Association at Cheltenham, I argued that "the vast number of fluid-cavities containing water indicates that the metamorphic changes have been due to an aqueous process and an elevated temperature, and not to heat alone and a simple partial fusion." (Report for 1856, Trans. Sect. p. 78.)

I. Structure of Artificial Crystals.

§ 1. *Crystals formed from solution in water.*

a. Mode of preparation and examination; general and special characters.

Great and small are relative terms; and therefore it will be well to adopt a scale, so that the actual size of the cavities described by such terms may be known. Since a very common size is about $\frac{1}{1000}$th of an inch in diameter, I shall adopt the following scale, and call

Cavities above $\frac{1}{100}$th of an inch in diameter, very large.
,, from $\frac{1}{100}$th to $\frac{1}{1000}$th, moderately large.
,, from $\frac{1}{1000}$th to $\frac{1}{10000}$th, moderately small.
,, less than $\frac{1}{10000}$th, very small.

In some respects it is best to mount crystals formed in the wet way, in as shallow glass cells as will hold them, in a concentrated cold solution of the salt itself; for then, never being dried, none of the cavities can lose their fluid, which is not the case if they are mounted in varnish or Canada balsam. Independent of that, some facts are seen to greater advantage when crystals are mounted in clear varnish in cells which may be made out of cardboard with a wadding-punch ; and I therefore usually adopt both methods. The magnifying powers generally required are from 50 to 400 linear; and when the crystals possess strong double refraction, a polarizer or analyser should be used, so adjusted that only one image of the cavities is visible; or else they appear indistinct.

I have in nearly all cases lithographed the accompanying figures (Pls. XVI.–XIX.) as seen with one adjustment of the focus, but have slightly shaded the enclosed crystals, although they are sometimes quite colourless, in order to distinguish them from irregularities on the surface of the cavities. The figures with a dotted outline represent portions of crystals, whereas all the rest are entire crystals or detached cavities, as if the surrounding paper were the clear substance of the larger crystals in which they occur.

Few substances could be more suitable, as characteristic types, than the chlorides of sodium and potassium, sulphate and bichromate of potash, alum, and sulphate of zinc.

When a solution of chloride of potassium is allowed to evaporate spontaneously, the character and form of the crystals vary most remarkably, according as the weather is cold or warm, moist or dry. In cool damp weather, when evaporation goes on slowly, sometimes all the crystals are similar to fig. 1, having a square patch towards the centre, which is white by reflected, but black by transmitted light, whilst the rest of the crystal is clear and transparent. When much more highly magnified, it is seen that the opacity of the central portion is due to vast numbers of minute cavities, the amount of which varies in bands parallel to the sides of the crystal, and also in such a manner as to give rise to the peculiar cross seen in the figure. These cavities are full of the liquid from which the crystals were deposited; and this having a smaller power of refraction than the substance of the crystal, the contents reflect and strongly refract the light, and, like the bubbles of air in the water of a cataract, give a white appearance as seen by reflexion, or darkness and opacity when viewed by transmitted light.

The manner in which these cavities are formed is well illustrated by fig. 2, where the unshaded portion represents part of the extreme edge of a crystal of common salt, and the shaded the concentrated solution from which it crystallized, entering into a deep notch formed by the irregular growth of the crystal. If, on the further growth of the crystal, more salt were to be deposited at the upper part of the notch than at the bottom, as shown by the dotted line, a portion of the liquid would be enclosed in the crystal, and form a fluid-cavity like that seen on the right-hand side; whereas, if the crystal grew so as to enclose the projecting portion of fluid by a plane parallel to the face of the crystal, a fluid-cavity like that on the left side would be produced. These two cavities, as well as figs. 3, 4, and 5, illustrate the usual character of those in common salt or chloride of potassium. When deep, they have a broad dark outline, like fig. 4; but when flat and very shallow, they are bounded by a narrow black line, as in fig. 5. Often they are much longer in one direction than in any other, so as to be tubes, like fig. 3; and this is especially the case in the long prismatic crystals of chloride of potassium sometimes formed on the cooling of a warm solution.

The manner in which the cavities are produced necessarily causes them to be *full of fluid* at the time of their formation. If this takes place at the ordinary temperature, and they are kept in fluid, they remain quite full, and none of the cavities contain bubbles. When, however, they are formed at a higher temperature, the fluid of course contracts on cooling, and, just as happens on the cooling of a glass-tube filled with hot water, a vacuity like a bubble makes its appearance, as shown in fig. 7. In order to obtain crystals slowly deposited at the heat of boiling water, I employ a flat-bottomed flask, over the mouth of which I tie a piece of blotting-paper, and keep it in a bath of boiling water, with the long neck projecting through a hole in a metal plate covering the bath.

For these experiments no substance is more convenient than common salt, because it is so very little more soluble in hot than in cold water. Having, then, a concentrated solution in the flask, it evaporates through the blotting-paper, and crystals are slowly deposited at the heat of boiling water. When a number of about $\frac{1}{30}$th of an inch in diameter are formed, the hot solution is quickly poured off, and a small quantity of a concentrated cold solution added, so as to prevent the deposition of salt when the remaining solution becomes cold; and then, separating the larger and very small by means of sieves, the crystals of about $\frac{1}{20}$th to $\frac{1}{50}$th of an inch in diameter are mounted in glass cells in a concentrated solution of the salt. On examining them with the microscope, it is seen that the greater part of the cavities contain small bubbles, produced by the contraction of the fluid. Adopting the same method with chloride of potassium, in some cases most excellent thin flat crystals are formed, containing many very interesting cavities. A portion of one of these crystals is drawn in fig. 6, which serves to show the great number and peculiar form of the cavities, and how they occur in bands parallel to the edges of the crystal. Unlike when formed at the ordinary temperature, many of the cavities are of very complicated forms, as shown in figs. 8 and 10.

In order to ascertain the relative size of the fluid and bubbles in the cavities, it is best to measure with the micrometer such long regular tubes as figs. 9 and 50. It may also be determined with sufficient accuracy from cavities like figs. 101 and 113, which are equally deep throughout, and have a flattened vacuity, so that the proportion between their *areas* is that between their *volumes*. If, however, neither of these kinds can be found, the best approximation that can be made is to be derived from such cavities as are nearly equiaxed, so that the relative magnitude of the cavity and vacuity equals the cube of the ratio of their diameters.

In the very excellent tubular cavity (fig. 9) in chloride of potassium formed at a heat not much below that of boiling water, the vacuity is about ·025 of the fluid; but, if the cohesion of the sides produced no effect, it should have been about ·030. Hence I think we must conclude that the cohesion of the liquid to the sides of so small a cavity slightly diminishes the size of the vacuity, either by stretching the fluid or the substance of the crystal. That very minute cavities do produce such an effect, is proved by the fact that they often contain no bubbles, as though the cohesive force entirely counteracted the contraction of the fluid, and operated like the reverse of a very great pressure; and M. Berthelot has also shown (Annales de Chimie, 3e sér. t. xxx. p. 232) that this occurs to a certain extent, even in glass-tubes.

When fluid-cavities are large, the bubbles move about, if the crystal be turned, like those in spirit-levels; but when small, this test is not easily applied. We can readily see, with a high magnifying power, that the constant tremor of the ground causes the bubble in a level to be in constant motion; but no such movement can be seen in the larger fluid-cavities. In the very small, however, the bubbles move in a most striking manner, as if they were minute animalcules swimming about and exploring every part of the cavities. The true physical cause of this movement still remains to be determined; for hitherto I have not been able to form any theory that was not apparently upset by facts subsequently discovered. Whatever be the cause, the fact of the movement is of very great value in these inquiries, since, when a bubble moves about, the substance in the cavity must of course be a liquid.

The peculiarities of fluid-cavities formed when crystals are deposited from a solution containing some other salt, can be studied to great advantage by crystallizing common salt from a solution of bichromate of potash. If the solution be saturated with the bichromate at the ordinary temperature, it is of a deep yellow colour, and the fluid-cavities in the crystals of common salt deposited from it are seen to be filled with this yellow liquid; and the crystals are thus rendered yellow, and remain so when mounted in a colourless solution of common salt. If, however, the crystals be formed at the temperature of boiling water in a solution containing more of the bichromate than can remain dissolved at the ordinary temperature, small crystals of the deep red colour of that salt are deposited inside the fluid-cavities, as shown by figs. 11 and 12. When the solution is saturated at 100° C. with both common salt and the bichromate, so that, on slow evaporation at that temperature, crystals of both salts are deposited, the common salt encloses some small crystals of the bichromate, like fig. 14. Occasionally these so interfere with the crystallization, that they give rise to small attached fluid-cavities, as seen on the right-hand side of fig. 15 ; or there may be more than one crystal and a larger fluid-cavity, like fig. 16. These fluid-cavities differ from those just described, in containing no small crystals of the bichromate, that which could not be retained in solution having been deposited on the larger preexisting crystals. Moreover, as shown by fig. 16, these enclosed crystals project beyond the general boundary-line of the fluid-cavities, whereas in the other case they are merely deposited on the surface of the cavities. Great numbers of that kind do also occur; and often so many crystals are deposited, that the cavity appears to be quite full of them, as shown by fig. 17. It is, however, well worthy of remark, that many of the smaller cavities remain for months full of a deep yellow liquid, which I have supposed to be represented by the shading in fig. 13, containing far more of the bichromate in solution than can be retained when in large quantities, as if these minute cavities exercised the same influence in preventing the deposition of crystals, that, according to Dr. Percy's and my own observations (Dec. 1857), minute tubes exercise in preventing the freezing of water until the temperature is much lower than that at which it freezes at once in larger tubes.

When, instead of bichromate of potash, chloride of potassium is employed, small cubic or rectangular crystals are deposited in the fluid-cavities of the common salt, as shown in figs. 18 and 19 ; and in every case that I have seen, their edges are all parallel to the rectangular planes of the cavities. If a concentrated solution of hydrochlorate of ammonia be used, the fluid-cavities in the common salt contain crystals of the salt of ammonia of a very rounded character, as shown by fig. 20, so as to appear like enclosed globules of a dense liquid.

These experiments (March 1858) therefore show that, when crystals are formed at an elevated temperature, evidence of it is afforded by the contraction of the fluid enclosed in the cavities giving rise to a vacuity, and the reduction of its solvent power causing the deposition of crystals. Since, of course, the amount of the contraction of the fluid depends upon the height of the temperature from which it has cooled, the relative size of the vacuity must indicate how much the temperature at which the crystals were formed was above that at which they are examined, in the same manner as the sinking of the mercury in a self-registering-maximum thermometer shows the difference in the temperature.

Figs. 21 & 22 in nitrate of potash, 23 in binoxalate of ammonia, 24 and 25 in sulphate of zinc, represent fluid-cavities of rather striking forms,—the shading in figs. 24 and 25 being like the appearance produced by planes inclined to the line of vision. In many substances the fluid-cavities are commonly in the form of tubes, which are often of irregular width, and, as it were, pass into rows of smaller, shorter cavities, as shown by fig. 26, representing a portion of alum. Some of the cavities in this salt are as shown in fig. 27 ;

but the more common forms are like figs. 28, 30, and 31. When deposited at a heat of 50° C. (122° F.), the cohesion of the sides is sufficient to entirely counteract the small amount of contraction, and prevents the formation of vacuities. Besides fluid-cavities, a few most interesting larger cavities full of air were formed, which appear as if they had been bubbles, given off from the solution, that were enclosed in the growing crystal. Small quantities of this air are also in some cases caught up in the fluid-cavities; so that a few contain bubbles of considerable size in proportion to that of the cavity. The difference between the cavities full of fluid and those full of air is most striking. The refractive power of the fluid being nearly the same as that of the crystal, the cavities containing it are almost invisible by reflected light, and give only a narrow outline by transmitted, whilst, the refractive power of the air being so much less, the cavities containing it shine brilliantly by reflected light, and by transmitted light have a very broad and dark outline, as shown by fig. 29.

Hitherto all my descriptions refer to crystals that were mounted in liquid and never dried. When, however, exposed for some time to dry air, it is as if some of the cavities were not so completely closed as to prevent the slow passage of liquid from them; and therefore bubbles make their appearance, gradually increasing in size, and becoming quite large, as shown by figs. 30 and 31, which are cavities in alum, originally quite full of fluid at the ordinary temperature. In the case of some crystals, especially those like alum, containing chemically combined water, perhaps the fluid may actually pass off through their solid substance; but this is apparently confined to cavities near the surface. In many crystals, however, and especially in the more solid parts, where the fluid has been completely shut up, it appears to remain nearly or quite permanently—at all events for many years—even when they have been kept quite dry. These facts must be carefully borne in mind when attempting to deduce the temperature at which crystals were formed; and care must be taken not to confound cavities that have lost some fluid by drying, with those in a normal state enclosing bubbles that have been produced by the contraction of the liquid on cooling. They may often be distinguished without much difficulty, because when fluid is lost there is a great inequality in the relative size of the bubbles in different cavities, whereas in the other case it is nearly uniform.

If the planes of a fluid-cavity are inclined at certain angles to the line of vision, they may totally reflect the transmitted light, and the cavity appear like a fragment of some black and opake substance enclosed in the crystal. This is often the case in sulphate of potash; and an example from that salt is represented by fig. 33.

When a solution of common salt is evaporated at 100° C. in an open-mouthed flask, a crust is formed on the sides, above the level of the solution. In this case, during the growth, the crystalline crust is alternately exposed to the solution and the air; and when a portion is mounted in fluid and examined with the microscope, it is seen to have a peculiar and very interesting structure. Some of the cavities are precisely like those formed below the level of the solution, whilst others are as if it had been partially evaporated in the cavities before they were finally enclosed in solid crystal; and therefore they contain much solid matter, as shown by fig. 37. Minute crystals of sulphate of lime are also enclosed in the solid crystal; and some have been deposited inside the fluid-cavities before they were finally shut up, as shown in fig. 36. Other cavities have caught up air as well as fluid, so that they contain very large bubbles, as shown in fig. 34; whilst in others, like fig. 35, there is no fluid;—these various kinds gradually passing into one another. In a similar manner when the solution of salt contains less bichromate of potash than can be held in solution at the ordinary temperature, there occur, in the crystalline crust, cavities like those in crystals formed below the level of the liquid when a dilute solution is employed, as well as like those when a saturated hot solution is used, on account of its becoming variously concentrated by drying on the surface of the crust.

b. Number, size, form, and arrangement of cavities.

There is generally a most intimate relation between the number of cavities in a crystal and the rate at which it was formed. This is well illustrated by the chlorides of sodium and potassium; for when very slowly deposited, they are transparent, and contain but few, whereas, when deposited more quickly, they are so full of cavities as to be very white and opake. In some cases the deposition proceeds rapidly at first, and white opake nuclei are formed; and afterwards it proceeds more slowly, and the exterior of the crystals is clear and transparent, as shown by fig. 1,—the change from opake to transparent being either sudden or gradual, according to circumstances. This also usually happens when substances are crystallized by the cooling of a strong hot solution; for then deposition proceeds rapidly at first, but slowly towards the close of the process. Sulphate of potash, however, contains nearly as many cavities when formed slowly as when deposited quickly. There is also a considerable difference in the number of cavities in different salts, though formed under similar conditions. Thus, if solutions of alum and chloride of potassium be evaporated moderately quickly side by side at the ordinary temperature, the chloride of potassium contains so many cavities as to be perfectly white and opake, whereas the alum contains very few, and is perfectly transparent. The same is the case when a mixed solution of common salt and alum is evaporated.

In general the size of the cavities varies inversely as their number; for when the crystals are slowly formed, they are larger, though less numerous, as shown to great advantage by the different parts of fig. 1. If the rate of growth be the same, crystals formed at a high temperature contain fewer and larger cavities than those formed at a lower.

When the sides of the cavities are definite and straight, they are planes of the crystal; and therefore there is a connexion between the form of the crystal and that of the cavities. For example, in the cubic crystals of the chlorides of sodium and potassium they are rectangular, as seen in figs. 4, 17, & 19; and in the octahedral crystals of alum they are often equilateral triangles, like figs. 28 & 30: but, from forms thus essentially related to the planes of the crystals, they pass into all kinds of irregular shapes only slightly related, as shown in a remarkable manner by the cavities in chloride of potassium formed at 100° C. (figs. 8 & 10).

The arrangement of the cavities is also sometimes related to the form of the crystal, as shown in fig. 1; and bands parallel to the bounding edges are very common, being in fact lines of growth, probably indicating variations in the rate of deposition. In some cases they occur as bands of single cavities, twisting and curving about without any very definite connexion, as shown by fig. 32; or they are scattered promiscuously through the entire crystal.

c. *Expansion of fluids by heat.*

By the experiments described above, I have shown that, at the temperature at which they are formed, the fluid-cavities in crystals are full of the fluid, and that, if they be examined at a lower temperature, they contain vacuities, owing to the contraction of the fluid on cooling. Hence I think it is only reasonable to conclude that, provided the temperature were not known, it might be ascertained approximately by determining what increase of heat would be required to expand the fluid so as to fill the cavities. In some cases this can be learned by direct experiment; but generally it cannot, and we must have recourse to calculation. From the nature of the case the temperature is that required to cause the liquid to expand so much that the increase in volume is equal to the size of the vacuity. Taking, then, the volume of liquid for unity, and representing the relative sizes of the vacuity by V, it is easy to perceive that, if the law of the expansion of the liquid were known, and the value of V had been ascertained by observation, the temperature could be calculated.

In order to be able to do this, I have (June 1858) made an extensive series of experiments to ascertain the law of the expansion of water and saline solutions up to a temperature of 200° C. (392° F.). This I did by hermetically enclosing the liquid in strong glass tubes about 2 inches long and $\frac{1}{30}$th of an inch internal diameter, and heating them in a bath of paraffine, with such arrangements that the increase in volume could be measured, by means of a micrometer microscope, to within the $\frac{1}{1000}$th of an inch. This, however, is not the place for anything but the general conclusions. By appropriate experiments and calculations, I find that the increase in volume may be represented very accurately by an expression of the form $V = Bt + Ct^2$, where t is the temperature in degrees Centigrade, and B and C constants, the value of which depends upon the nature of the aqueous solution. Perhaps, indeed, in reality there may be terms involving higher powers of t than t^2; but if so, they are so nearly compensated for by the unequal expansion of the mercury of the thermometer itself, by the expansion of the glass tube, or the compression of the liquid by the rapidly increasing tension of the vapour, that their value up to 200° C. is so small that they do not produce any clearly marked effect in the results. The action of water on glass at temperatures above 200° C. is so powerful that I was unable to determine the volume at a greater heat; but from 25° to 200° there is such a very close agreement between calculation and experiment that I think the formula would give sufficiently accurate approximations to the truth up to at least 300°. The law does not hold good near the freezing-point; but that is of no consequence in the present inquiry. The following are the actual values for water and various saline solutions, the volume at 0° C. being taken for unity:—

1.	Water	$V = \cdot0001344t + \cdot000003245t^2$
2.	,, with 10 p. c. of chloride of potassium	$V = \cdot0001868t + \cdot000002524t^2$
3.	,, ,, 25 p. c. of chloride of potassium	$V = \cdot0003006t + \cdot000001410t^2$
4.	,, ,, $12\frac{1}{2}$ p. c. of chloride of potassium + $12\frac{1}{2}$ p. c. of chloride of sodium	$V = \cdot0003280t + \cdot000001422t^2$
5.	,, ,, 25 p. c. of chloride of sodium	$V = \cdot0003520t + \cdot000001370t^2$
6.	,, ,, 25 p. c. of sulphate of soda	$V = \cdot0003077t + \cdot000001644t^2$
7.	,, ,, 25 p. c. of mixed salts, being the mean of 3, 4, 5, & 6	$V = \cdot0003221t + \cdot000001461t^2$

On examining this table, it will be seen that the addition of salts to the water increases the value of the coefficient of t, but decreases that of t^2; thus causing the expansion to be more uniform, by making it greater at low, and at the same time considerably less at high, temperatures. As far as I have been able to ascertain, the most trustworthy experiments indicate that the product of these coefficients is nearly constant, and that the increase in the value of the coefficient of t varies in simple proportion to the quantity of salt in the solution, the amount of water being taken as constant. Probably these laws are not strictly correct, but still sufficiently so to enable us to determine the effect of variation in the strength of the solution as accurately as is requisite for the purpose of the present paper.

d. Effects of pressure.

These conclusions of course apply to those cases where the pressure to which the liquid is exposed is only equal to the elastic force of the vapour; but since, in nature's laboratory, crystals have no doubt often been formed under very great pressure, it will be necessary to take into account the compression of the fluid. The amount of this has been determined with great accuracy by a number of observers (Gmelin's Handbook of Chemistry, Cavendish Society's Translation, vol. ii. p. 62); but I would particularly refer to the paper of M. Grassi (Annales de Chimie, t. xxxi. p. 437). He there shows that the amount of compression of pure water, for a pressure equal to one atmosphere, is ·0000502, but decreases as the temperature increases. It is less for saline solutions, but increases as the temperature increases; being, for a concentrated solution of common salt, ·0000379. In the case of both pure water and saline solutions, the diminution of the volume is in simple and direct proportion to the pressure. Since, then, the amount of the compression of pure water decreases as the heat increases, but that of saline solutions increases, I think it extremely probable that, at very high temperatures, both would converge toward a similar amount; and, since it would be extremely difficult, or even perhaps impossible, to ascertain the fact by experiment at a very high temperature, we may adopt provisionally the mean of the two, as being probably not very far from the truth, especially in the case of moderately strong saline solutions. From this, however, must be deducted the amount of the compression of the crystal itself; and if it be the same as that of glass, we should have an apparent compression of ·0000358 for the pressure of each atmosphere, or ·00000271 for that of each foot of rock of sp. gr. 2·5, which I adopt as a unit because it seems more congenial with the subject before us. In accordance with this and other principles already described, the fluid about to be caught up in a fluid-cavity being expanded by the heat to $1+V$, would have its volume reduced $(1+V)\cdot00000271$ for the pressure of each foot of rock. Therefore, when crystals are formed at a high temperature, under a pressure equal to p feet of rock, the real volume of the highly heated but compressed liquid, caught up so as to fill a cavity, would be $1+V-(1+V)\cdot00000271\,p$; and when cold and the pressure removed, as it must be when a vacuity has been formed, the size of the vacuity would be the difference between this and the volume of the fluid taken as unity, viz. $V-(1+V)\cdot00000271\,p$.

e. The elastic force of the vapour of water.

This has been determined in a very satisfactory manner by Dulong and Arago (Quart. Journal of Science, Jan. to June 1830, p. 191); and they give an empirical formula, which they say is particularly applicable to high temperatures. Adopting this, and modifying it so that t represents single degrees above 0° C., and e the elastic force expressed in feet of rock, we have $e=13\cdot2\{1+\cdot007153\,(t-100)\}^5$.

From the various facts described above, I deduce the following equations.

Adopting as units, for the temperature, degrees Centrigade; for the pressure, feet of rock of sp. gr. 2·5, so that 13·2 feet equal one atmosphere; and for the volume of the vacuities, that of the fluid in the cavities at 0°,—

If t = the temperature,
p = the pressure beyond that equal to the elastic force of the vapour at t,
V = the relative size of the vacuity at 0° C., corresponding to t, when $p=0$,
v = the relative size of the vacuity as *actually observed* liable to the influence of the pressure p,
e = the elastic force of the vapour of water at t.

B and C = two constants, whose values depend on the nature and strength of the saline solution in the cavity,

Then we have

$$V = Bt + Ct^2 \ldots\ldots\ldots\ldots \text{equation (1)}$$

$$= \frac{v + \cdot 00000271p}{1 - \cdot 00000271p} \ldots\ldots\ldots\ldots (2)$$

$$t = \frac{\sqrt{4CV + B^2} - B}{2C} \ldots\ldots\ldots\ldots (3)$$

$$= \frac{\sqrt{4C\frac{v + \cdot 00000271p}{1 - \cdot 00000271p} + B^2} - B}{2C} \ldots\ldots\ldots\ldots (4)$$

$$v = (Bt + Ct^2)(1 - \cdot 00000271p) - \cdot 00000271p \ldots\ldots (5)$$

$$p = 369{,}000\frac{V - v}{1 + V} \ldots\ldots\ldots\ldots (6)$$

$$e = 13\cdot 2\{1 + \cdot 007153(t - 100)\}^5 \ldots\ldots\ldots\ldots (7)$$

If $p = 0$, $v = V$.

These equations can be considered strictly accurate only for moderate values of t and p; but for greater there must certainly be a limit past which they would cease to give accurate results. At present, however, it is impossible to say what that limit is; and therefore I think we cannot do better than adopt them provisionally.

It will be seen from (5) that the actual relative size of the vacuities depends on both the temperature and the pressure at which the cavities were formed. Therefore we have single equations involving two unknown quantities; so that, unless the value of one be known, that of the other cannot be determined. If the pressure were known, the temperature could be calculated from (4), and thus the fluid-cavities be made use of as self-registering thermometers, whilst, if the temperature or the value of V were known, the pressure could be calculated from (6), and thus the fluid-cavities be employed as spring-balances. They are, in fact, in this respect analogous to air-thermometers, which may be used as thermometers or barometers, according as the real pressure or temperature is known. If the *actual* pressure be known only approximately, but must have been the same for any two or more crystals having v different, the *difference* in the temperature could be calculated from (4); or, if the temperature were the same, and an approximation to the value of V known, the *difference* in the pressure could be ascertained from (6). I do not think there is any reason to believe that the actual size of the fluid-cavities can invalidate these general principles. Is not the proportion between the diameter and circumference of a circle the same, whether it is visible to the naked eye or cannot be seen without a high magnifying power? Similarly, since there appears to be no connexion between the actual quantity of fluid and the proportionate increase in the volume by heat or decrease by pressure, we may, I think, as fully rely on the *ratios* deduced from the minute tubes enclosed in solid crystal, as from the larger tubes employed in our experiments. Sometimes, indeed, it is difficult to determine that ratio accurately; but very often a close approximation can be made by means of the microscope-micrometer, as already described.

§ 2. *Crystals formed by sublimation.*

In this case, if no fluid be present, of course no fluid-cavities can be formed; but irregularities in the growth of the crystals cause them to catch up gas or vapour, so as to form what may be conveniently distinguished by the names *gas-* or *vapour-cavities*. Such cavities are well seen in hydrochlorate of ammonia, as shown by fig. 38, or in corrosive sublimate, fig. 39. They are, in fact, like bubbles of more or less regular form, enclosed in the solid crystal, and differ from full fluid-cavities in having a broader and darker margin. If formed at a high temperature and under great pressure, since the enclosed highly compressed vapour might be condensed on cooling, the cavities might be covered with small crystals, or contain some liquid, according to the nature of the enclosed vapour.

§ 3. *Crystals formed by fusion.*

The formation of crystals from a state of igneous fusion is in every respect analogous to what takes place when crystals are formed in water. It is simply the deposition of crystals from solution in a liquid that becomes solid at a high temperature, or the crystallization of that liquid itself, in the same manner as when crystals are deposited from solution in water, or the water itself freezes. Nevertheless the temperature at which water and melted rocks become solid are so very different, that the two processes may be conveniently classed under different heads. It is quite inaccurate to suppose that the presence of water is essential in the formation of crystals; for, as every chemist well knows, many can be formed without a trace of water being present.

A glass is a liquid which, on cooling, becomes more and more viscous, and at length solidifies without undergoing any sudden and definite change in physical structure. If, however, the liquid, after cooling to a certain temperature, crystallize, it undergoes a sudden and entire physical change, and the structure becomes stony. In most cases the crystals thus formed possess double refraction, and therefore depolarize polarized light; whereas the uncrystalline glass has no more influence on it than such a liquid as stiff Canada balsam.

The best illustration I have met with of the characteristic structure of crystals formed artificially by the cooling of a heterogeneous mass in the state of igneous fusion, are the thin flat crystals of basic silicate of protoxide of iron, so common in the slags of copper- and nickel-ores. Their surfaces are covered with deep striæ; and when crystals sufficiently thin to be partially transparent are mounted in Canada balsam and examined with a microscope, it is seen that many such striæ have been covered up, so as to form tubular cavities enclosing the material of the slag surrounding the crystals, as shown by fig. 40. In one part is a long, straight, open depression on the face of the crystal; and in another is a tubular cavity of varying width, enclosed in the solid crystal; whilst in other parts are smaller and shorter cavities, related to the larger in precisely the same manner as those occurring in alum, shown in fig. 26. When more highly magnified, some are seen to be as shown by figs. 41 and 42, which, in containing bubbles, closely resemble fluid-cavities. They were indeed *fluid-cavities* when first formed; but it was a fluid that did not remain *liquid* at the ordinary temperature, being in fact a *glass*. It of course appears more natural to call a space inside a crystal, containing only a gas or liquid, a *cavity*; but if it thus contain a solid glassy substance, since some convenient name is requisite, it appears to me that we cannot do better than adopt a term analogous to that so generally adopted for fluid-filled cavities, and call these glass-filled cavities *glass-cavities*.

The most characteristic difference between fluid-cavities and glass-cavities is the movement of the bubbles in the fluid-cavities; for of course bubbles cannot move in solid glass. However, since many of the bubbles in fluid-cavities do not move, we are sometimes compelled to have recourse to other tests. Strongly heating the crystal expels the fluid from fluid-cavities, but produces no effect on glass-cavities unless the heat be sufficient to melt the enclosed glass. They may also often be distinguished, without spoiling the object, by the difference in the relation between the dark exterior and transparent centre of the bubbles. The dark exterior is of course due to the refraction and total reflection of the light in passing through the bubble, which vary as the refractive power of the substance. Therefore, since that of the glass is considerably greater than that of the aqueous solutions in the fluid-cavities, the dark zone is considerably wider; and if the bubbles be spheres, the bright central spot, seen with a particular adjustment of the focus of the microscope, is relatively nearly twice as large in fluid-cavities as in glass-cavities.

Sometimes the glass-cavities in the basic silicate of iron contain crystals of a dark colour, that have been deposited from the glass on cooling, as shown by figs. 44 and 45, and are thus analogous to the fluid-cavities in crystals deposited from a strong hot solution of another salt. Others, like fig. 43, are analogous to those in which contemporaneously formed crystals were caught up along with the fluid, and project beyond the general outline of the cavity. In other cases they are entirely filled with the dark substance that became crystalline on cooling, as shown by fig. 46; and these, being stone-filled cavities, may be distinguished by the name of *stone-cavities*, in order to carry out the same general nomenclature. These are analogous to what cavities containing water would be if the ordinary temperature of the atmosphere was so low that the fluid froze, and the whole cavity was filled with minute crystals of ice and of any salt previously in solution in the water.

A few good glass-cavities occur in the crystals of Humboldtilite, so common in many slags of iron-furnaces, as shown by fig. 48; and in some crystals of pyroxene in the slag of the blast-furnaces at Masborough, good examples of stone-cavities are found, one of which is represented in fig. 47.

The connexion between the form of the crystals and that of the cavities is precisely the same in the case of glass- and stone-cavities as of fluid-cavities. Thus, in fig. 45, four, and in figs. 41 and 46 two straight sides are directly connected with planes of the crystals, whilst in figs. 42, 44, 47, and 48 they are curved and scarcely in any way related. There is thus a most perfect analogy between glass- and stone-cavities and fluid-cavities, in every respect except the nature of the included substances. These, however, differ from one another as much as the fusing-points of the liquids from which the crystals were deposited, and as the two processes of igneous fusion and aqueous solution; and are so essentially connected with those processes as to point out most clearly how the crystals were formed.

When a perfectly pure homogeneous substance crystallizes on cooling from a state of fusion, of course no cavities like those just described can be formed; but some substances in passing from the liquid to the solid state give off gas that was soluble in them when liquid, but cannot be dissolved by them when solid. This fact is well illustrated by the freezing of water, the bubbles enclosed in ice being gas-cavities produced in this manner by the cooling and solidification of a substance fusing at a low temperature. When heated to the melting-point, the ice thaws round about these cavities, as described by Dr. Tyndall (Proceedings of the Royal Society, vol. ix. p. 76); and they then contain both water and a bubble, like the fluid-cavities in crystals deposited from solution in water at an elevated temperature. It is, however, merely a deceptive *analogy*, without any true *affinity*. The real relationship is to what would in all probability occur if crystals formed by the cooling of a substance that becomes solid at a high temperature were heated to the point of fusion, when probably it would fuse first round about the few gas-cavities which such crystals often contain.

The most important result that could be produced by the operation of great pressure, in the formation of crystals by igneous fusion, is what might occur if it were so great as entirely to counteract the elastic force of the vapour of water, and permit it to be present in a liquid state along with the melted stony matter. It would be extremely difficult to prove by actual experiment what is the structure of crystals formed under such conditions; but I think the general principles derived from the experiments already described enable us to form a very satisfactory conclusion on the subject. Some crystals might be deposited from solution in the highly heated water, and catch up small portions of the fused stone, whilst others might be formed by the crystallization of the melted stone, and catch up small portions of the liquid water. In both cases the characteristic structure would be the presence in the same crystal of the peculiarities of crystals formed from a state of igneous fusion, combined with the peculiarities of those deposited from solution in water; and it might be difficult, or even impossible, to decide which process was essential, or whether their combination was requisite for the production of any particular kind of crystal. When, therefore, formed under great pressure by the combined influence of liquid water and melted stone, we may, I think, conclude that the crystals would contain glass- or stone-cavities, and perhaps gas- and vapour-cavities, as well as fluid-cavities, the relative size of the vacuities depending on the temperature and pressure,—whilst both the fluid- and vapour-cavities might contain small crystals, deposited on cooling.

§ 4. *General Conclusions.*

The various facts described above will, I think, warrant the following general conclusions :—

1. Crystals possessing only cavities containing water more or less saturated with various salts were formed by being deposited from solution in water.

2. The relative size of the vacuities in normal fluid-cavities depends on the temperature and pressure at which the crystals were formed, and may in some cases be employed to determine the actual or relative temperature and pressure.

3. Crystals containing only glass- or stone-cavities were formed by being deposited from a substance in the state of igneous fusion.

4. Crystals containing only gas- or vapour-cavities were formed by sublimation or by the solidification of a fused homogeneous substance, unless they are fluid-cavities that have lost all their fluid.

5. Other circumstances being the same, crystals containing few cavities were formed more slowly than those containing more.

6. Crystals possessing fluid-cavities containing a variable amount of crystals, and gradually passing into gas-cavities, were formed under the alternate presence of the liquid and a gas.

7. Crystals in which are found both cavities containing water and cavities containing glass or stone were formed, under great pressure, by the combined action of igneous fusion and water.

8. Crystals having the characters of 6 and 7 combined were formed, under great pressure, by the united action of igneous fusion and water alternating with vapour or a gas, so as to include all the conditions of igneous fusion, aqueous solution, and gaseous sublimation.

Such then are the general principles I purpose to apply in investigating the origin of minerals and rocks. It will be perceived at once that, in one way or other, they may be brought to bear on almost every branch of physical and chemical geology. In this communication I shall illustrate the subject by applying them to some of the leading branches of inquiry, without attempting to treat each in a complete manner.

II. Structure of Natural Crystals.

§ 1. *Methods employed in examining minerals and rocks.*

In examining the microscopical structure of rocks and minerals, I have in many cases prepared sections sufficiently thin to admit of the use of transmitted light with very high magnifying powers, for which purpose they should be from about $\frac{1}{100}$th to $\frac{1}{1000}$th of an inch thick. I here particularly draw attention to the necessity of not using any *polishing powder*, because it enters into, and fills up, cavities and flaws, and would easily give rise to factitious appearances that might mislead most fatally. This must be carefully borne in mind when the manner in which a section has been prepared is not known; for otherwise it might be worse than useless. The surfaces of the rock or mineral should be dressed extremely fine, with water, on a perfectly flat piece of very hard and smooth Water-of-Ayr stone, when they usually become quite sufficiently polished. One side of the section is of course fixed on glass with Canada balsam before it is rubbed down very thin; and when finished, thin glass should be mounted over the upper surface with the same substance. This not only preserves the object from injury, but has the most important effect of rendering it far more clear and transparent. In many cases, however, it is unnecessary to prepare such sections. Portions of the mineral can be broken off sufficiently thin, and when mounted under glass in Canada balsam can be most readily examined with high magnifying powers. This method has not only the advantage of saving much time, but, there being no necessity for a strong heat, the risk of expelling the fluid from the fluid-cavities is obviated. For some purposes, however, thin sections are quite indispensable; and in mounting them care should be taken not to employ a higher temperature than is absolutely necessary.

For the examination of mounted fragments, I have found Messrs. Smith and Beck's $\frac{1}{5}$th-inch object-glass of very great value on account of not approaching the object too closely; and by using along with this their second eye-piece with a micrometer, the size of anything can be measured at once. This is the power I have chiefly employed, and is about 400 linear; the divisions of the micrometer are $\frac{1}{8000}$th of an inch; and thus cavities much less than that are quite distinct, their contents are easily seen, and their dimensions and that of the vacuity can be measured to within $\frac{1}{50000}$th of an inch.

§ 2. *Water contained in crystals.*

The difference between the water *mechanically enclosed* in the fluid-cavities of a crystal, and that *chemically combined* with the substance of which it is composed, is of course most complete. That chemically combined is one of the essential constituents of the mineral, cannot be seen with any kind of magnifying power, and is probably not in the state of liquid water; whereas that in the fluid-cavities is altogether unessential to the existence of the substance, and is in the form of a visible liquid, merely enclosed mechanically.

When a mineral contains fluid-cavities, of course it does not necessarily follow that the fluid is *water*; and it is often difficult to ascertain what it is when *in* the cavities. If, however, the mineral contains no chemically combined water, it is easy to prove what it is when *out* of the cavities. On applying a strong heat, the expansion of the fluid, or the elastic force of the vapour, bursts the cavity and often causes the crystal to fly to pieces with great violence. When subsequently examined with the microscope, it is seen that the fluid has been expelled; and in order to ascertain whether or not the fluid thus given off is water, I adopt the following method. I have a glass tube 8 inches long and with a $\frac{1}{4}$-inch bore, closed at one end; and, having placed in it fragments of the mineral dried at 100° C., I fill the tube with air dried by passing over chloride of calcium. The open end is then closed with a well-dried cork, and the other passed through two holes in the opposite sides of a small box containing a mixture of pounded ice or snow and salt, so as to project about a couple of inches. A sufficiently strong heat is then applied to the closed end, containing the fragments, to expel the fluid from the cavities. If they contained water, it is condensed as small crystals of ice on the cold part of the tube; and when the whole has cooled, it is withdrawn from the box and placed in a strong solution of common salt, at a temperature several degrees below the freezing-point of water, and the form of the enclosed crystals examined with a magnifying glass. By carefully noticing the rise of a thermometer as the solution of salt becomes warmer, the temperature at which they cease to be solid and pass into a liquid is easily ascertained; and if it be found that the crystalline form and melting-point of the liquid thus given off from the fluid-cavities are the same as those of water, I think we may safely conclude that the liquid seen in the cavities is *water* or some *aqueous* solution.

§ 3. *Minerals contained in Secondary Rocks.*

a. Rock-Salt, Calcite, &c.

In proceeding now to apply the above general conclusions to the investigation of the circumstances under which natural crystals were formed, it will be best to commence with rock-salt, since its peculiar structure can be imitated artificially with perfect accuracy. It often contains excellent fluid-cavities, which, besides a fluid, sometimes enclose a variable, and often a considerable, quantity of mud. On the whole, the specimens I have examined do not contain much of this substance; and in the solid parts of the crystals the cavities are full of liquid. Hence the salt must have been deposited very slowly from solution in more or less muddy water, at a heat not very considerably, if at all, higher than the ordinary temperature of the atmosphere, unless it was formed under a very great pressure. Much the same conclusions apply to the selenite in gypseous marls; but most of the cavities have lost fluid by drying,—which need not surprise us, since it contains combined water and has a very laminar structure.

When pure calcite containing no fluid-cavities is heated, it does not decrepitate, and gives off no water; but when it contains fluid-cavities, the crystals fly to pieces and give off water, and I therefore conclude that the fluid in the cavities is water. I have found many excellent fluid-cavities in the calcite of modern tufaceous deposits, in that of the veins in limestone, and in many trappean rocks; also in fluor spar, in the sulphates of baryta and strontia, and in several other minerals found in ordinary veins, as if they had been deposited from solution in water. In most of the cases I have examined, the vacuities in the normal fluid-cavities are very small; and, unless they were formed under great pressure, the temperature must have varied from that of the atmosphere up to about that of boiling water. Much, however, remains to be determined; and the variations in temperature have too local a connexion to be considered in this paper.

b. Quartz-veins.

Since the facts to be learned from the study of the fluid-cavities in quartz are extremely interesting, I must describe them in some detail. As is well known, they are occasionally of considerable size, so as to be perfectly visible to the naked eye, and contain bubbles that move about like those in spirit-levels. The fluid contained in them was proved by Sir H. Davy (Philosophical Transactions, 1822, p. 367) to be nearly pure water; and my own experiments confirm that conclusion. I froze the fluid in a cavity about $\frac{1}{5}$th of an inch in diameter in a transparent crystal, and found that it thawed exactly at the thawing-point of ice. When clear quartz containing no fluid-cavities is heated in a tube, no water is given off; but that with fluid-cavities gives off a fluid condensing, at a low temperature, into crystals whose form and thawing-point are the same as those of ice. Besides this water, there is often another substance given off, which condenses as a solid nearer to the hot end of the tube than where the water is deposited. I have ascertained that this is chloride of potassium or sodium. The water also often has a strong acid-reaction, due to hydrochloric acid, either derived from the decomposition of the above-named salts by the heated quartz, or, as is certainly the case in some instances, existing in a free state in the fluid-cavities.

In order to ascertain the nature of the salts dissolved in the fluid in the cavities, I reduce the carefully-washed crystals to powder, so as to break open the cavities, and then dissolve out the soluble salts with distilled water. When rendered quite clear by filtering and standing for some days, on evaporating this solution to dryness, the nature of the salts can be ascertained by the microscope and appropriate chemical tests. In this manner I have found (July, 1858) that the fluid in the cavities often contains a very considerable quantity of the chlorides of potassium and sodium, the sulphates of potash, soda, and lime, and sometimes free acids. This explains why I was not able to freeze the fluid in some rock-crystal from Ceylon, containing very excellent fluid-cavities of about $\frac{1}{100}$th of an inch in diameter, at a temperature of about $-20°$ C. ($-4°$ F.); for though, according to my own observations, pure water in tubes less than $\frac{1}{200}$th of an inch in diameter does not freeze till the temperature is reduced to about $-15°$ C. ($3°$ F.), it freezes at once at that temperature in those of the diameter of these fluid-cavities. It also serves to explain the amount of expansion by heat. I had ascertained from most excellent data, that the vacuities were uniformly very nearly ·141 of the enclosed liquid at 0° C.; and therefore, calculating from the results of my experiments, if the fluid had been pure water, it would have expanded so as to fill the cavities at 189° C. However, on heating a portion of the quartz in a bath of paraffine, so arranged that it could be examined with the microscope, I found that at 217° C. very minute bubbles were still visible in the fluid-cavities; but at 220° they had most certainly disappeared. We may therefore conclude that the fluid expands so as to fill the cavities at a temperature of from 218° to 219°. On reducing some of the crystal to powder, I obtained so much of alkaline chlorides and sulphates that I do not think they could amount to less than 15 per cent. of the fluid in the cavities. They could not amount to above 30 per cent.; or else crystals would have been deposited in the cavities. If in equation (3) we substitute the values of B and C, previously determined for a solution containing 25 per cent. of mixed alkaline chlorides and sulphates, we obtain

$$t=\sqrt{684462V+12144}-110 \ldots\ldots\ldots \text{equation (8)}$$

and substituting in this the value, V=·141, we find $t=219°·4$. Calculating from the laws of the variation due to a difference in the amount of salt in solution, if less or more than 25 per cent., the value of t would be reduced; so that, if 20 or 30 per cent., it would be 218°. If therefore, as is probable, the fluid in the cavities is a strong solution, the temperature determined by calculation almost exactly agrees with that previously ascertained by actual experiment. It is seldom that the size of the cavities is sufficiently large to enable me to verify my calculations in this manner; for the experiment cannot be made when very high magnifying powers are requisite; but the agreement in this case is so remarkable as to cause me to have very considerable confidence in those that cannot thus be verified.

Equation (8) of course gives the temperature requisite to expand the fluid so as to fill the cavity, and does not indicate the temperature at which the crystal was formed, unless the pressure was only equal to the elastic force of the vapour. This true temperature is expressed by substituting the value of V given by equation (2), in (8), when we obtain

$$t=\sqrt{684462\frac{v+{\cdot}00000271p}{1-{\cdot}00000271p}+12144}-110 \ldots \text{equation (9)}$$

which, of course, becomes (8) when $p=0$.

Some quartz contains cavities enclosing two immiscible fluids, like those occurring in Brazilian topaz, described by Sir David Brewster (Transactions of the Royal Society of Edinburgh, vol. x. pp. 1 and 407). Since, however, their peculiarities have been so well explained by him, and they occur so rarely in quartz as to be quite an exception to the general rule, I need not do more than refer to fig. 52 as an illustration of their general character. They appear as if they contained two bubbles, one inside the other, owing to the fluid which has a less refractive power containing a bubble, and collecting itself into a globular form. Since the bubble moves about in the central fluid, and this also moves in the exterior fluid, both must be liquids; and I very strongly suspect that further research will prove that one is water and the other a condensed gas.

In determining the relative size of the vacuities in fluid-cavities, of course, care must be taken not to make use of such as have caught up bubbles of gas along with the fluid, which is more likely to happen with large cavities than with small. There is also a greater risk of the large coming across flaws in the crystal, so as to lose fluid. The very minute should, however, be avoided, as being too much affected by the cohesion of the liquid to the sides. It is therefore best to select those of moderate size, which have vacuities of very uniform relative magnitude, in parts where vapour- or gas- cavities do not occur and the crystal is very solid. Sometimes we may distinctly see that the quartz has been cracked, and the cracks afterwards filled up with quartz. This, like the formation of the large veins described below, appears in some cases to have taken place at a lower temperature, and explains why bands of cavities occasionally occur with vacuities relatively less than those in the fluid-cavities of the general mass. As already mentioned, whenever it is possible, such tubular cavities should be chosen as that represented by fig. 50.

In the trachyte of Ponza there occur veins of quartz, as described by Scrope (Transactions of the Geol. Soc. 2nd ser. vol. ii. p. 208). These contain many fluid-cavities with water holding in solution the chlorides of potassium and sodium, the sulphates of potash, soda, and lime, and free hydrochloric acid. In this case we may, I think, conclude that the pressure was not very great, so that $v=V$, and the relative size of the vacuities would indicate the temperature at which the crystals were deposited from the aqueous solution. The mean of many good observations is $v=\cdot 143$, which, when substituted in equation (8), gives $t=$ about 220° C. (428° F.). At this temperature the elastic force of the vapour of water is, from (7), equal to 292 feet of rock.

The quartz of the veins in Cornwall has precisely the same structure as the above in every respect; the fluid-cavities contain the same salts in solution; and at a great distance from the granite, making no allowance for pressure, the relative size of the vacuities indicates the same temperature, but if the pressure was great, a still higher. On approaching the granite, the temperature and pressure appear to have been much greater; for the relative size of the vacuities in the fluid-cavities in the quartz of the veins is nearly the same as in those in that of the granite itself. Thus, the mean of the means for the quartz of the granite at St. Michael's Mount and Mousehole is $v=\cdot 148$, and for the quartz of the associated quartz-veins, also containing mica, tin-ore, wolfram, and other minerals, $v=\cdot 133$. In cases like this, I think we may consider the pressure equal for both, so that the *difference* of the temperature may be calculated by means of equation (9). If the pressure was no greater than the elastic force of the vapour, these facts indicate that the quartz of the veins crystallized at a temperature not more than

16° C. lower than that at which the quartz of the granite itself crystallized; but, as I shall show below, it is far more probable that the pressure was very great, and the temperature a dull red heat visible in the dark, and, if so, substituting in (9) the value, $p=43,100$, deduced from equation (10), given further on, I calculate by equation (9) that the difference in the temperature must have been about 13°. These results clearly show that a great variation in the actual temperature and pressure produces only a small variation in the calculated *difference* in temperature. Perhaps some may think such calculations an impossible refinement; but the facts appear sufficiently distinct to warrant them. In a similar manner I find that the quartz first deposited in a vein in granite at Camborne indicates a temperature quite equal to that at which the granite crystallized; but in the quartz deposited towards the close of the process the relative size of the vacuities is so much less that the temperature must have fallen fully 30° or 40° C., which is quite probable.

The number of the fluid-cavities in the quartz of veins is often very great, as if it had been deposited rapidly. They are frequently on an average less than $\frac{1}{1000}$th of an inch apart, which corresponds to upwards of a thousand millions in a cubic inch; and they are the chief cause of the very usual whiteness of the mineral. As an illustration of their forms, I refer to figs. 49, 50, and 51. Fig. 49 is of very irregular shape, whilst fig. 50 is a tube extremely well fitted for determining the relative size of the vacuity with great accuracy. Clear and transparent crystals contain few or none, as if deposited far more slowly; and very often crystals, which at their base are white and opaque on account of the number of cavities, are clear and transparent at their extremities from containing very few, as though, like what so very commonly happens in making artificial crystals, deposition proceeded rapidly at first, but much more slowly towards the close of the process. The form and arrangement of the fluid-cavities are also in every respect analogous to those in crystals prepared artificially; and every peculiarity in the structure of the quartz of veins, and their relation to the granite, can be most completely explained by supposing that it was deposited from water holding various salts and acids in solution, at a temperature varying from about 200° C. to a dull red heat visible in the dark. In those cases where we must suppose a very high temperature and a great pressure in order to explain the relation between the fluid-cavities in the quartz of the veins and in that of the granite itself, such other minerals as mica, felspar, and tin-ore were often deposited, especially towards the commencement of the process, as if water at a very high temperature were the effective cause of their production. Tin-ore contains many excellent fluid-cavities, though they are usually very small *.

Of course these conclusions do not apply to all quartz, for, as I have shown, some must have been deposited from nearly pure water;

* These deductions are strongly confirmed by the fact, that several of the above-named minerals have been formed artificially by the action of water at temperatures similar to those just described.—Senarmont, Ann. de Chimie, 3e sér. t. xxxii. p. 129; Daubrée, Ann. des Mines, 5e sér. t. xii. p. 289.—Oct. 1858.

and that associated with chalcedony in veins or in cavities contains very few fluid-cavities with relatively small vacuities, indicating a slow deposition from water at a much lower temperature.

§ 4. *Metamorphic Rocks.*

In some portions of the granite containing large crystals of felspar at Trevalgan, near St. Ives, Cornwall, the felspar has been more or less completely removed, and its place filled with quartz, mica, or schorl, either alone or variously mixed. These most interesting and important pseudomorphs appear to have been almost entirely overlooked; though I have found them in so many other localities in Cornwall that they cannot be very rare. The removal of the felspar from the centre of the surrounding, fine-grained granite, and the introduction of the quartz, mica, and schorl, cannot I think be explained except by the action of water. In this quartz are many very interesting fluid-cavities, and in some parts nearly all contain small cubic crystals, as shown by fig. 53. In other cases, besides such cubes, there occur prismatic crystals, like in fig. 55, or more rarely rhombic, as fig. 54. Occasionally the angles of the cubic crystals are corroded and rounded, as shown by fig. 55; and some cavities, as fig. 56, are so full of crystals that their form cannot be determined. The quartz also contains gas- or vapour-cavities, and every connecting link between them and the other cavities. In all respects therefore the structure of this quartz is analogous to those crystals that are formed artificially above the surface of a hot liquid, and exposed alternately to water and air. When reduced to powder, water dissolves out much chloride of sodium, and a good deal of sulphate of lime, and hence the cubic crystals in the fluid-cavities are no doubt chloride of sodium, and perhaps some of the prisms may be selenite. Even if the effects of pressure are supposed to have been not material, the relative size of the vacuities indicates a heat of 220° C.; but, since the relative size of those in the fluid-cavities in the granite is nearly the same, in accordance with the principles described below, the pressure was probably very great, and the temperature nearly or quite equal to a dull red heat, visible in the dark.

It therefore appears, that to the action of water at a very high temperature, holding various salts in solution, must be ascribed the removal of the felspar, and the production of the mica, quartz, and schorl. In a paper read at the British Association (Report, 1857, p. 92), I showed that the material of the quartz and mica might be derived from felspar, decomposed by the removal of part of the alkaline bases; and we thus have a key to those cases of metamorphosis where deposits of decomposed felspar-clays have been converted into crystallized mica and quartz, so as to constitute mica-schist. In the bands of quartz in mica-schist and gneiss, which are as it were irregular concretions passing along the foliation, and in the carbonate of lime and iron sometimes associated with the quartz, occur vast numbers of fluid-cavities containing water. The quartz mixed up with the mica, forming the chief constituent of the schist, also abounds with fluid-cavities; and I have even found them in some of the garnets. These facts led me to argue, in my paper on mica-schist already referred to (Report of British Association, 1856, p. 78), that the alteration of deposits of decomposed felspar into crystallized mica and quartz was not the effect of dry heat and a partial fusion, but was due to highly heated water disseminated through the rock. If so, it is no wonder that ordinary shales have never been converted into mica-schist artificially, by the mere heat of furnaces, since the conditions are not those met with in nature—water is absent.

The mean relative size of the vacuities in the fluid-cavities in the quartz of the slightly metamorphosed schists in Cornwall, at a considerable distance from the granite, is ·125, which corresponds to a heat of at least 200° C. (392° F.); and therefore a considerable thickness of rock must have been raised to a high temperature. If the pressure was great, the temperature must have been still higher; and on approaching the granite, the relative size of the vacuities indicates nearly as high a temperature as that at which the granite itself was consolidated, which agrees with the gradual passage from gneiss to granite, and might be used as a strong argument by those who contend that some granites are only thoroughly metamorphosed stratified rocks. The vacuities in the fluid-cavities in the mica-schist of the southern border of the Highlands of Scotland are relatively so small ($v = {\cdot}05$) that, if they were formed under no great pressure, they indicate a temperature of only 105° C. (221° F.). It, however, appears to me far more probable that the heat was really as high as in the case of analogous rocks in Cornwall, but the pressure greater. If so, from equation (6) we deduce that the Highland rocks were metamorphosed under a pressure equal to about 23,700 feet of rock more than those in Cornwall, or probably when at a much greater depth from the surface; a result which is confirmed in a most remarkable manner by a comparison of the fluid-cavities in the elvans and granites. These conclusions only apply to when the quartz crystallized: it does not follow that the rock was never heated to a still higher temperature.

§ 5. *Minerals and rocks formed by cooling from a state of igneous fusion.*

The most instructive glass-cavities that I have met with in natural minerals are those in the crystals of clear, transparent felspar contained in some of the pitchstone of Arran. Pitchstone, like obsidian and some artificial slags, consists of a glassy base, having no action on polarized light, in which are scattered small crystals that decompose it and show colours. The basis of the pitchstone surrounding the crystals of felspar is transparent, and nearly colourless, but contains vast numbers of minute, green, prismatic crystals, probably some variety of pyroxene, often arranged in radiate groups, which impart a deep green colour to the rock. These may be seen to great advantage in thin splinters, but the glass-cavities in the felspar can be studied to far greater advantage in thin sections of the rock. The surfaces of the crystals of felspar are in some cases irregular, and portions of the surrounding pitchstone project right into them. Such projecting portions of the glassy basis have often become enclosed in the solid crystal, in precisely the same manner as the fluid-cavities in crystals formed from solution in water, as shown by fig. 2. Fig. 57 is a very good example of one of the larger of these glass-cavities. The centre is full of glass, precisely like the general basis of the pitchstone, except that the groups of green crystals are not so large and well developed, whilst somewhat larger prisms than those in the centre are attached to the sides, as if deposited during the cooling of the glassy solvent. The accompanying bubble is no doubt the effect of the contraction of the glass before it became solid. Fig. 58 is an example of a smaller cavity, having all the green crystals attached to the sides. It also contains several bubbles, which is a fact very characteristic of glass-cavities, since it never occurs in fluid-cavities, except under very peculiar circumstances, seldom met with. A common kind of cavity is shown by fig. 62; but the very smallest of all contain no green crystals, like fig. 60, corresponding therefore to those very small fluid-cavities in which crystals have not been deposited from a supersaturated solution. Fig. 61 is a case where the bubble has been much distorted, and crystals project from the sides quite into it, proving that the crystals were deposited before the glass became solid. Besides these glass cavities, the felspar has caught up small, colourless, contemporaneously-formed, prismatic crystals, to which in some cases glass-cavities are attached. A very excellent example of these is shown by fig. 59; and it is a striking fact, that very nearly all the green, prismatic crystals have been deposited on the included large crystal. The felspar also contains bands of vapour-cavities, and it is near to them that cavities with several bubbles occur; but, at a distance from them, the glass-cavities almost always, if not invariably, contain a bubble from $\frac{1}{4}$th to $\frac{1}{6}$th the diameter of the cavity. In some cases, however, there are cavities like fig. 63, which do not contain the prismatic crystals or a bubble, being more like stone-cavities.

In the pitchstone are also some dark crystals, not visible except in sections, which look extremely like augite. The glass-cavities in these do not contain the green crystals; and if the two minerals are the same substance, this fact agrees with what takes place in crystals formed from solution in water, the material being merely deposited on the sides, and not as independent crystals. They, however, contain bubbles, relatively of a smaller size than those in the felspar; whilst the glass-cavities in another mineral, the exact nature of which I have not been able to determine, contain many green crystals, but no bubble, as shown by fig. 64, probably owing to these minerals contracting more than felspar in cooling from a high temperature.

The analogy between these glass-cavities and fluid-cavities is therefore in many respects very striking; and, as will be seen, their peculiar characters can be most perfectly explained, if we suppose that the glassy base, when in a state of fusion, acted like a solvent liquid and dissolved various mineral substances, which were deposited on cooling in precisely the same manner as crystals are deposited on the cooling of a saturated, aqueous solution. There is therefore, in my opinion, no more necessary connexion between the temperature at which the crystals were deposited from this glassy solvent and their own fusing-point, when heated alone, than between the temperature at which crystals are deposited from solution in water and their own fusing-point, even if they be fusible. In both cases, the only necessary connexion is, that the crystals could not be deposited in a *solid* form, except at a lower temperature than that at which they become *liquid*; but it might be any heat less than that high enough to cause the glossy solvent to be sufficiently fluid. These facts are of very great importance in the study of igneous rocks, and serve to explain several peculiarities in their structure. Such glass-cavities, however, differ essentially from fluid-cavities, in containing bubbles that never move, and do not change their place or disappear when the fragment containing them is heated, unless the heat is strong enough to melt the enclosed glass, which is more fusible than the felspar.

The best examples of glass-cavities that I have met with in the erupted lavas of Vesuvius occur in the augite. One very excellent case is shown by fig. 65. They contain, at least, two kinds of crystals, which sometimes project beyond the general outline of the cavities, as shown in the figure, as if they were formed at the same time as the augite, and were caught up in it along with the fused material of the glass-cavity, which on cooling deposited other crystals, and by contracting gave rise to a small bubble. In some cases long prismatic crystals have been caught up in the augite, as shown by fig. 66, having two glass-cavities attached to them, one with a bubble and the other without, which is not unfrequently the case in detached cavities, as if, like in some fluid-cavities, the cohesion of the sides had overcome the contraction of the melted glass.

The leucite in the lava of Vesuvius often contains many cavities, the material in which has to a great extent become crystalline, and therefore they are very commonly stone-cavities. An example of one, partially stone and partially glass, is shown by fig. 68, which is somewhat analogous to those in the felspar of the pitchstone, represented by fig. 63. Another form is shown by fig. 70, and a very curious, almost circular, flat cavity is seen in fig. 69, containing three different kinds of crystals; whilst fig. 67 represents a crystal enclosed in the solid leucite, with a small stone-cavity attached to it. In no case have I seen decided bubbles in the cavities in leucite; but their absence from cavities containing many crystals is easily explained, because many substances expand in crystallizing to such an extent as would compensate for the previous contraction from a high temperature. In the felspar of the trachyte of Ponza the cavities are all filled with stony matter, as shown by fig. 71. A very long tubular cavity is represented by fig. 72.

The general arrangement of these various glass- and stone-cavities is precisely analogous to that of those in crystals formed artificially; and, independent of the fact that, in all their essential characters, they are identical with the cavities in the crystals in artificial furnace slags, their very nature proves the igneous origin of the minerals containing them. This is especially the case with glass-cavities; for nothing but igneous fusion could so liquefy the enclosed glass that perfectly spherical bubbles could be produced.

Besides stone- and glass-cavities, the minerals of erupted lavas contain gas- or vapour-cavities, as if they had caught up small quantities of gases and vapours that were in contact with them; but I have never found any fluid-cavities, and hence the purely igneous origin of the characteristic minerals of erupted lavas appears to be completely proved. The zeolites, however, occurring in the cavities of lava that has been exposed to the action of water since it was erupted, contain no glass- or stone-cavities, but a few fluid-cavities, as if deposited very slowly from solution in water. The best examples I have met with are in the Arragonite in the lava of Vesuvius, which have the vacuities equal to about $\frac{1}{10}$th of the fluid, corresponding to a temperature of 160° C. (320° F.).

Precisely the same conclusions apply to far more ancient trappean rocks. The augite in some of the basaltic rocks of Scotland has the same characteristic structure as that in the modern lavas of Vesuvius. A very good example of a glass-cavity is shown by fig. 73, containing a bubble and many small crystals deposited on the sides of the cavity. In the case shown by fig. 74, many most distinct crystals have been formed on the sides, but it contains no bubble, whilst sometimes, as fig. 75, there is a bubble but no crystals. In the felspar of a porphyritic greenstone from Arthur's Seat near Edinburgh, there occur many stone-cavities; but, like the felspar itself, they have undergone a great amount of alteration by the subsequent action of water. Fig. 76 is much like some of the cavities in leucite, whilst that shown by fig. 77 evidently contained a bubble like a glass-cavity, but it has been filled with the chloritic mineral that has been introduced by water into nearly all parts of the rock. In fact the microscope clearly shows that the amount of alteration effected by the action of water on these ancient volcanic rocks is very much more than is generally supposed; and rocks, which to the naked eye appear to contain only two or three minerals, are seen to be made up of ten or twelve. Some of these are the igneous minerals containing glass- or stone-cavities, and others are zeolitic minerals containing fluid-cavities, which indicate that they have been deposited from more or less heated water. The characteristic structure of the minerals of which ancient trappean rocks are composed is, therefore, so analogous to, or even identical with, that of the constituents of modern lavas, that the purely igneous origin of these ancient lavas appears to me to be completely established; but, at the same time, their present aspect is often to a very great extent due to the subsequent action of water. In fact they have frequently been as much metamorphosed by water as some stratified rocks have been by heat. The production of zeolites, by the action of the thermal springs at Plombières on the ancient masonry, strongly confirms these deductions. (Daubrée, Annales des Mines, 5e série, t. xii. p. 289, and xiii. p. 227.)

§ 6. *Minerals and Rocks formed by the combined operation of water and igneous fusion.*

a. *Minerals in the blocks ejected from Vesuvius.*

As is well known, in the blocks ejected from Vesuvius during eruption, a large series of minerals occurs, which do not exist in the erupted lava. Many of these are found in the limestone blocks in the Conglomerate of Somma, and, as pointed out by Delesse (Bulletin de la Société Géologique de France, 1852, t. ix. p. 136), in their number and character they differ so much from erupted lava, that it is little probable that the rock was ever in a state of simple igneous fusion. This conclusion is completely borne out by the microscopical structure of the minerals, for they contain many fluid-cavities, as well as glass- and stone-cavities, indicating that they were formed by the combined action of water and igneous fusion.

In the calcite associated with light green mica, I have found many very excellent fluid-cavities, as shown by fig. 78. When heated they give off *water*, and on reducing the spar to powder, water extracts the chlorides of potassium, sodium, and magnesium, and the sulphates of potash, soda, and lime. Hence I think there can be no doubt that the cubic crystals seen in the cavities are chloride of potassium or sodium, and the fluid a concentrated aqueous solution of those salts. I have not been able to ascertain the relative size of the vacuities with great accuracy, but it is nearly $\frac{1}{4}$th of the volume of the fluid. Similar cavities occur in the nepheline of ejected blocks, and they all contain one or more cubic crystals of chloride of potassium or sodium, as shown by figs. 79, 80, and 83, no doubt deposited from the fluid on cooling, like those seen in the cavities formed artificially (figs. 18 and 19). Occasionally there are crystals of some other substance, as in fig. 79. I have very carefully determined the relative size of the vacuities, and find that it is about ·28 of the fluid; and it is so uniform as to forbid us from supposing that the vacuities are owing to a loss of fluid. In calculating the temperature in this and the other cases given below, I shall assume that the pressure was not much greater than sufficient to counteract the elastic force of the vapour, so that we may consider $v = V$, and make use of equation (8). Judging from the change in the amount of expansion produced by an increase in the amount of salt in the experiments already described, the temperature indicated by relatively large vacuities would be nearly the same when there was more salt than can be retained in solution at the ordinary temperature, as when there was only 25 per cent.; the small difference being singularly enough almost exactly compensated for by the increase in the bulk of the salt on crystallizing. This is a fortunate circumstance in this inquiry; since, when, as in the case of the fluid-cavities in many modern volcanic minerals, the vacuities and included crystals are relatively large, it is unnecessary to take anything into account but the relative size of the vacuities, and substitute their values in equation (8). In this manner I deduce that this nepheline and calcite must have been formed at a temperature of about 340° C. (644° F.). Of course, if the pressure was greater than supposed, the temperature must have been still higher. Since then (Gmelin's Handbook of Chemistry, Cavendish Society's Translation, vol. i. p. 167) solid bodies begin to be dull red in the dark at 335° C., and bright red at 400°, this temperature would be that of a very dull red heat only just visible in the dark, at which, from equation (7), the elastic force of the vapour would be equal to a pressure of 1954 feet of rock.

On heating the fragment containing the cavity shown by fig. 80 to a very dull red heat visible in the dark, it became as fig. 81. The small crystals had disappeared, and the vacuity and crystal had changed their places; thus proving that the cavity contained a liquid, and that the crystals were soluble in it. On heating to a very decided red heat, the cavity became as fig. 82; the fluid had disappeared, and the nepheline had partially fused and collapsed over the altered crystal. When another fragment containing the cavity, fig. 83, was heated to a dull red heat, the cavity lost its fluid, and the crystal melted into a globule, as shown in fig. 84. All these results agree perfectly with the supposition, that the fluid is an aqueous solution, and the crystals chloride of potassium or sodium; and it will be seen that the expansion of the liquid is not sufficient to burst the cavities until the heat is that of redness, which agrees perfectly well with calculation, if we consider that the enclosed crystal was not all dissolved on account of being exposed to a high temperature for only a short time. All, or nearly all, the fluid-cavities contain the crystals, which are on an average equal to about $\frac{1}{3}$rd of the bulk of the liquid, or about four times as much as is deposited from a solution of chloride of potassium saturated at the heat of boiling water, and many times more than from a solution of chloride of sodium. This entirely confirms the conclusion derived from the size of the vacuity, since, to dissolve so large an additional quantity, a very high temperature would certainly be requisite. Some cavities, as shown by fig. 85, are as though many minute crystals had been deposited over their whole surface, except where prevented by the attached cube.

Most excellent gas-cavities also occur in the same nepheline, as shown by figs. 86 and 87, being like bubbles of gas enclosed during the growth of the crystal, in the same manner as in some of the artificial crystals already described. Others, like fig. 88, are as if some highly compressed, heated vapour had been enclosed, and on cooling had condensed into small crystals. Such cavities can be distinguished from stone-cavities by the fact of being partially transparent in the centre. The same fragment of nepheline also contains excellent glass-cavities, figs. 89 and 90, in all respects analogous to those in crystals formed when melted stony matter is present. As will be seen, the outline is very obscure, and quite different from that of the fluid-cavities, and is rendered apparent chiefly by the small crystals. The difference is also strongly marked by the presence of several bubbles, as shown by fig. 90. This glass-cavity was in the same fragment as the fluid-cavity, fig. 80, and when heated to a very dull red heat, it remained nearly as drawn. When, however, heated a little higher, the minute crystals disappeared, and the bubbles changed their places; whilst at the same temperature the fluid-cavity still retained its fluid. At the temperature at which the fluid was expelled, it became as fig. 91, where all the crystals had disappeared, and the bubbles not only had changed their places, but two had coalesced. It is therefore clearly proved by experiment (April 1858) that, at a heat not sufficient to expand the fluid in the cavities so much as to burst them, the substance in the glass-cavities is melted, so as to dissolve the small crystals it had previously deposited on cooling more slowly, and permit a change in the position of the bubbles, all which results agree most perfectly with the supposition that the crystals were formed at a red heat visible in the dark, when melted stony matter, gases, vapours, and liquid water saturated with soluble alkaline salts, were all present and alternately in contact with the growing crystals, so that the conditions of fusion, sublimation, and solution were all united.

In the idocrase forming along with calcite the general mass of a block ejected from Vesuvius, many fluid-cavities occur, which often contain so many crystals that it is difficult to determine their form. A very good example is given in fig. 92, with crystals like those in the fluid-cavities in nepheline. Fig. 93 shows clearly that the relative size of the vacuities is very great. On an average, they are equal to one-third of the fluid, and therefore indicate a temperature of 380° C. (716° F.), or a decided red heat; at which temperature the elastic force of the vapour of water is, from equation (7), equal to the pressure of 3222 feet of rock. Similar cavities occur in hornblende, indicating a heat of 360° C. There are also very good fluid-cavities in the crystals of felspar found in the ejected masses of ice-spar. These contain many crystals of two or three kinds (as shown by fig. 94). On reducing the felspar to powder, I found the usual chlorides and sulphates, but besides these a very considerable quantity of the carbonates of potash and soda, and, therefore, probably the presence of these carbonates is the reason why the crystals in the cavities differ so much from those previously described, though in other specimens they are quite similar, all being cubes. As shown by fig. 95, the vacuities are very large, and of about the same relative size as those in idocrase, indicating a temperature of 380° C. Other cavities, like fig. 96, have caught up vapour or gas along with the fluid, in the same manner as sometimes occurs in artificial crystals; whilst others are quite full of the gas or vapour, which in some cases has been condensed into crystals on cooling, so as to cover the surface, as shown by fig. 97, seen out of focus in the centre. The same crystal also contains most decided and excellent glass-cavities, like fig. 98, and others, as fig. 99, that have become to a great extent crystalline, and contain no bubbles; both of which are very analogous to cavities in the felspar of the pitchstone of Arran.

We are thus led to conclude that the peculiar minerals characteristic of the blocks ejected from Vesuvius were formed at a dull red heat, under a pressure equal to several thousand feet of rock, when water containing a large quantity of alkaline salts in solution was present, along with melted rock and various gases and vapours. Whether or no the presence of this water was instrumental, or even essentially requisite, in producing some of the minerals, still remains to be proved; but I think no one could compare the drusy cavities in the ejected blocks with the crystalline cavities in the slags of furnaces, without perceiving that the occurrence of various minerals, placed one over the other in regular order, is a most striking difference, which could be accounted for most completely by the action of water. It would also probably serve to explain why, according to Daubeny (Treatise on Volcanos, 2nd edition, p. 236), the minerals most characteristic of the ejected blocks are never found in the erupted lavas, the crystalline minerals of which were apparently formed when no *liquid* water was present. I therefore think we must conclude provisionally, that at a great depth from the surface, at the foci of volcanic activity, liquid water is present along with the melted rock, and that it produces results that would not otherwise occur.

It may perhaps be thought that the spheroidal condition assumed by water in contact with highly heated substances, would explain why it might be present at a less depth, and under less pressures, than those I have described; but it appears to me that water could not remain in the spheroidal state, unless the vapour could escape, and that the temperature it remains at is essentially connected with the boiling-point at the pressure to which it is exposed, and therefore the permanent presence of water at such a high temperature necessitates a great pressure, even if it was in the spheroidal state. But I think no one who has made experiments on the subject, would think it possible for water in that state to enter into tubes less than $\frac{1}{1000}$th of an inch in diameter. This, however, has constantly occurred in the minerals of the ejected blocks, and hence it appears to me almost demonstrated that it was not in the spheroidal state, separated by a layer of vapour, but in actual contact with the crystals at a high temperature, and under great pressure.

The presence of genuine gas- and vapour-cavities side by side with the fluid-cavities, and the existence of so large an amount of salts in solution in the fluid, prove that the water was caught up in a *liquid* state, and not as *vapour* so highly compressed as to condense into an equal bulk of water (see Cagniard de La Tour's paper, Annales de Chemie, 1822, t. xxi. p. 127); for in that case, since in the nepheline there is no gradual passage from fluid-cavities to vapour-cavities, we should have to conclude that the two gaseous bodies were not mutually diffusible, and that a very large amount of various alkaline salts was present as *vapour* along with the vapour of water; both of which suppositions are I think quite inadmissible.

Perhaps some may suppose that possibly the water penetrated into the cavities long after the minerals were formed. This, however, would necessitate percolation through the solid substance of the crystals, a fact differing as much from percolation through a rock, or amongst the minute crystals of which such substances as agate are composed, or even through the pores existing in imperfectly solidified metals, as the passage of water through solid glass would differ from its passage amongst closely-packed fragments of glass. Not only does this appear to me most improbable, but actually opposed by facts. In the first place, the proportion between the amount of fluid and the size of the cavities in the nepheline is so uniform that I cannot believe it to be the result of accident, as we should have to suppose if they were not all filled full at the same temperature. If, to overcome this difficulty, it be supposed that the fluid penetrated into the cavities when in a highly heated state, it would require it to have been at the same temperature as that at which I have supposed it entered in the same legitimate way that it enters into the fluid-cavities in artificial crystals. But, even then, the facts are against the supposition; for, besides fluid-cavities, there occur gas-cavities like figs. 86 and 87; and though there is no absolute line of division between their form and that of the fluid-cavities, their general characteristic shape is very different, because, as in artificial crystals, in one case the crystal is moulded to the bubble of gas, whereas in the other the irregular growth of the crystal determines the form of the cavity. Moreover, besides these gas-cavities, there are the bubbles in the glass-cavities, which never contain a fluid. If then we suppose that the fluid percolated through the solid crystal into the fluid-cavities, we are led to conclude that it selected these cavities like artificial fluid-cavities, but avoided those resembling artificial gas-cavities, and the vacuities in the glass-cavities, a conclusion which is so extremely unreasonable that we must reject the proposition that leads to it.

b. Granitic Rocks.

In some of the trachyte of Ponza of solid character, as if it had been formed under considerable pressure, there occur a few small crystals of quartz, forming one of the genuine constituents of the igneous rock, in every respect like those in many elvans and some granites that contain but little quartz. They can scarcely be distinguished in the rock in its natural state, but are readily seen in a thin section. When I examined this (April 1858), I found that the quartz contains very excellent fluid-cavities, as shown by figs. 100, 101, and 102. There is no doubt that they contain a liquid, for the bubbles move about in it. They are usually very flat, like fig. 101, and, when inclined in particular positions, the transmitted light is totally reflected from the bubble, which therefore appears like a black opaque substance, as shown by fig. 102. By careful measurements, I find that the relative size of the vacuities is very nearly ·30. Assuming then, that, like in the fluid-cavities in the minerals of ejected blocks, and in the quartz of the veins in the self-same trachyte, as well as in those in the quartz of elvans and granite, the enclosed fluid is a strong aqueous solution of alkaline chlorides and sulphates, I deduce, from equation (8), that the temperature at which the crystals of quartz in the trachyte were formed was at least 356° C., which closely corresponds with the mean deduced from the fluid-cavities in the blocks ejected from Vesuvius. At this temperature the elactic force of the vapour of water is equal to about 2400 feet of rock, and therefore the quartz must have crystallized under that pressure, at least. Considering the nature of the rock, the pressure cannot, I think, have been very much more than that, though it must have been somewhat more, and then of course the calculated temperature would be higher; but it would require a pressure equal to upwards of 19,000 feet of rock to alter it to 400°C. If it was equal to about 4000 feet, the calculated temperature would be 360° C. (680° F.). This is a very dull red heat visible in the dark, and the elactic force of the vapour of water would be equal to 2500 feet of rock. It does not necessarily follow that the rock was finally consolidated under such a pressure, or at such a depth, since the strength of quartz is such, that, if the crystals had been formed at a considerable depth, they might be carried to a much less without the elastic force of the fluid bursting the cavities. To completely fuse such a rock, a white heat is necessary; but I find that, when in a glassy state, thin fragments become soft enough to bend at a very moderate red heat, so that the temperature at which it became *quite solid* probably could not differ very materially from the dull red heat deduced from the fluid-cavities, the two independent facts strongly confirming each other.

Along with these fluid-cavities occur most excellent stone-cavities, as shown by fig. 103, in every respect analogous to those in the crystals in slags, and especially like some in leucite; and it may easily be seen that they are small portions of the surrounding felspathic material of the trachyte, that have been enclosed in the growing crystals of quartz. That they were caught up when their substance was in a fused, or at all events in a soft state, is proved by the fact, that their form is related to, and they are moulded upon, the crystalline planes of the quartz; whereas, if they had been solid fragments, the quartz would have been moulded to their own form. It therefore appears to me to be completely proved, that these crystals of quartz were generated under similar physical conditions to those concerned in the development of the minerals of the ejected blocks, by the combined influence of a dull red heat, liquid water, and partially melted rock.

The structure of the quartz of many elvans and some granites is in every respect analogous to that in the trachyte just described. The only sensible difference is that the fluid-cavities are seldom so flat, and gas- or vapour-cavities more numerous. The proof of the igneous origin of elvans is complete, for the stone-cavities are very well developed. Examples of these are shown by figs. 104, 105, 106, and 107, from the elvans near Penrhyn and Gwennap. As will be seen, fig. 104 is extremely like those in the trachyte, differing only in being of rather coarser grain, and in containing a long prism of schorl. Very often long hair-like crystals of that mineral occur in the quartz itself, sometimes attached to stone-cavities, as shown by fig. 106; like the crystals with attached stone-cavities in leucite, fig. 67. Fig. 105 represents a cavity of more irregular shape, and fig. 107 is from an elvan of much coarser grain, and has a gas- or vapour-cavity attached to it. These gas- or vapour-cavities often occur in distinct bands, like those in augite and other volcanic minerals; but sometimes they are mixed up with fluid-cavities, which in that case have bubbles of variable relative size, caused by the irregular combination of fluid and vapour in the same cavity; whilst in other parts fluid-cavities occur alone, with vacuities of very uniform relative size. As in the case of artificial crystals, the form of the fluid-cavities is often related to the crystalline planes of the quartz, as shown by fig. 108. Fig. 109 is a fluid-cavity containing prismatic crystals, which in some cases must certainly have been caught up during the growth of the quartz, and not deposited from the solution on cooling, for they often pass through the cavities, as shown by fig. 110, and appear to be schorl.

The passage from elvans to granite is quite gradual, and this is also the case with the peculiarities in the microscopical structure of their constituent minerals. The quartz of granite often abounds with most excellent fluid-cavities, and as an illustration of this fact, I have in fig. 111 represented a portion of the quartz of the granite of St. Austel, which occurs as distinct crystals, precisely like that in the trachyte described above, and not as a residue of crystallization. In many granites the fluid-cavities are so numerous in the quartz, that on an average they are not above $\frac{1}{1000}$th of an inch apart. This agrees with the proportion of a thousand millions in a cubic inch; and in some cases there must be more than ten times as many. They also really constitute a most important part of the whole bulk of the quartz, for sometimes they make up at least 5 per cent. of the volume; and I have found that the loss of water on heating the quartz of the granite of Cornwall to redness is on an average about 0·4 per cent. of its weight, which is equivalent to about 1 p. c. of its bulk. These fluid-cavities are not confined to veins of granite, or to that part near the junction with the stratified rocks, but are quite as numerous in the most solid rock, far away from the junctions; as though the fluid was not an *accidental* ingredient, due to the percolation of water to a fused mass naturally containing none, but as if it was a *genuine* constituent of the rock when melted. Their number varies very much in different granites, but hitherto I have found them in all specimens I have examined; and, though there are exceptions to the rule, yet on the whole they are more numerous in granites than in elvans, and in coarse-grained, than in fine-grained granites*.

The felspar of the Cornish granites is usually so opaque, on account of partial decomposition, that it is difficult to see the fluid-cavities.

* This is especially the case near Aberdeen; for in the quartz of the coarse-grained veins, having crystals of mica, felspar, and schorl several inches long, the fluid-cavities are so numerous, large, and distinct, that even with only a moderately high magnifying power they may be seen to greater advantage than in any other granite I have hitherto examined; whereas in the rather fine-grained stone used in building, they are few, small, and obscure.—Oct. 1858.

Fig. 112 is one in this mineral, but they are undoubtedly very rare. Few also occur in this mica, but they are certainly sometimes met with, as shown by fig. 113, which is very flat and shallow. The presence of so many in the quartz, and of so few in the felspar and mica, is analogous to what occurs when a mixed solution of common salt and alum is evaporated, as already described; and, when solutions of alum and chloride of potassium are evaporated side by side, the crystals of chloride of potassium are even more loaded with fluid-cavities than the quartz in granite, whilst some of the crystals of alum contain none.

By many experiments, I have proved most conclusively that the fluid in the cavities in the quartz of granites and elvans is *water*, holding in solution the chlorides of potassium and sodium, the sulphates of potash, soda, and lime, sometimes one, and sometimes the other salt predominating. Since the solution has often a most decided acid reaction before, or even after, having been evaporated to dryness, there must be an excess of the acids present. This occurrence of *free* hydrochloric and sulphuric acid is, I think, a very interesting fact, when we bear in mind how very characteristic they are of modern volcanic activity. Sometimes the amount of salts dissolved in the heated water was greater than could be retained in solution at the ordinary temperature, and cubic crystals of the chlorides have been deposited, as shown by fig. 114. Near the granite, this is also sometimes the case with the fluid-cavities in the quartz of metamorphic schists and quartz-veins, which cavities contain the same saline solution as those in the quartz of the granite itself, as if in all these cases the quartz had been deposited from the same liquid, which, at a greater distance from the granite, became more dilute, on account of being mixed with pure water. Besides the cubic crystals, the fluid-cavities in the quartz of granite occasionally also contain prismatic crystals, as seen in fig. 115, and therefore agree very closely with those in the blocks ejected from Vesuvius. There is often a considerable variation in the amount of crystals contained in the fluid-cavities in the same portion of quartz, as if the strength of the solution had varied during the consolidation of the rock; and there is also sometimes a passage from fluid- to vapour-cavities, as if there had been an alternation of liquid and vapour or gases; both of which circumstances would be likely to occur.

The stone-cavities are not well developed, except in granites whose structure approximates somewhat to that of elvans. The most distinct I have yet found are in the quartz of the granite of St. Austel, containing the fluid-cavities, fig. 111. They are entirely similar to those in the quartz of the trachyte of Ponza or of elvans, as will be seen on comparing fig. 117 with figs. 103 and 104. As I have already remarked, when some substances pass into the crystalline state they occupy more space than when melted, and therefore, if entirely enclosed in a solid substance, they might expand so much as to crack it, like we all know often happens when water freezes. This appears to have occurred in the cavity fig. 119, there being three cracks radiating from it, as drawn. This increase in the bulk of the included stone, explains why there are no vacuities in the stone-cavities of granites and elvans. In the quartz of very coarse-grained granites the stone-cavities are generally obscure and of irregular shape, as shown by fig. 118. Those in the felspar are often so much obscured by the partial decomposition of that mineral, that it is difficult to distinguish them from small decomposed patches; but in some very clear from the granite of Lamorna they are sufficiently distinct, and, as shown by fig. 120, are very analogous to those in the felspar of the trachyte of Ponza, figs. 71 and 72.

Besides fluid- and stone-cavities, the quartz of granite often contains vapour-cavities, like those in minerals from modern volcanos. Some are almost perfect spheres, and exactly like enclosed bubbles of gas; but others are of more irregular shape, and gradually interfere with and pass into fluid-cavities, in the same manner as occurs in some of the minerals of ejected blocks, and in crystals formed artificially by alternate exposure to liquid and the air. Some of these empty cavities may be fluid-cavities that have lost their fluid, but I have found them in specimens obtained on the sea-coast below low-water mark, which were afterwards kept under water and never dried, and therefore some must certainly be genuine gas- or vapour-cavities.

On the whole, then, the microscopical structure of the constituent minerals of granite is in every respect analogous to that of those formed at great depths and ejected from modern volcanos, or that of the quartz in the trachyte of Ponza, as though granite had been formed under similar physical conditions, combining at once both igneous fusion, aqueous solution, and gaseous sublimation. The proof of the operation of water is quite as strong as of that of heat; and, in fact, I must admit, that in the case of coarse-grained, highly quartzose granites there is so very little evidence of igneous fusion, and such overwhelming proof of the action of water, that it is impossible to draw a line between them and those veins where, in all probability, mica, felspar, and quartz have been deposited from solution in water, without there being any definite genuine igneous fusion like that in the case of furnace slags or erupted lavas. There is, therefore, in the microscopical structure a most complete and gradual passage from granite to simple quartz-veins; and my own observations in the field cause me to entirely agree with M. Elie de Beaumont (Note sur les émanations volcaniques et métallifères, Bulletin de la Société Géologique de France, 2 série, t. iv. p. 1249) in concluding that there is also the same gradual passage on a large scale.

My remarks respecting the possibility of the water having passed into the fluid-cavities in nepheline after they were formed, will, to a considerable extent, apply to the fluid-cavities in the quartz of elvans and granites. If they had contained *nearly pure* water, and were quite full, and easily lost it on drying, such a supposition would have been sufficiently probable. It is, however, not mere water, but various *saline solutions*, with *free acids*, precisely like the fluid in the cavities of some modern volcanic minerals. Moreover, that a very great pressure will not cause water to pass through solid crystal, except by cracking it, is proved by the fact, that when the quartz from Ceylon, in which the fluid expands so as to fill the cavities at about 218° C., was heated to at least 350°, some of the fluid-cavities still retained their fluid, though, judging from the force calculated to be necessary to counteract the expansion of the fluid, they must have resisted a pressure equal to about 40,000 feet of rock. Also in my experiments in treating fragments of nepheline to a red heat, a thickness of only $\frac{1}{100}$th of an inch must in some cases have resisted a pressure of several thousand feet. Since water has not penetrated into the vapour-cavities, or into the vacuities in the glass-cavities, in ancient trappean rocks, it should appear that a considerable pressure for a very long time will not cause it to pass through the solid substance of crystals. In my opinion this could only happen by the formation of *actual cracks*, which, as sometimes happens with cracked glass, were healed up by the adhesion of the sides, after the fluid had entered. This, however, would differ as much from the escape of the fluid when the crystal is strongly heated, as the breaking of an arch by a symmetrical pressure from above would differ from a fracture produced by a pressure from the inside; and, therefore, if fluid-cavities can resist so great a pressure from within, it appears to me that none at all probable could burst them from without. That the fluid remains permanently in many of the cavities in quartz, is, I think, proved by the fact that, when specimens are obtained below low-water mark on the sea-coast, and afterwards kept in water, the cavities are in no respect different from those in very thin fragments which have been kept dry for years. On the whole, in the absence of any proof of the contrary, I think these reasons are sufficient to warrant the conclusion that the aqueous solutions enclosed in the fluid-cavities in the quartz of granitic rocks, were caught up during the formation of the crystals, and have remained ever since, hermetically sealed up in their solid substance, without any increase or diminution of the fluid ; and that therefore we may determine from their present condition the circumstances under which the rock was originally formed.

In my opinion, the water associated with thoroughly melted igneous rocks at great depths does not dissolve the rock, but the rock dissolves the water, either chemically as a hydrate, or physically as a gas. In the case of those obsidians and pitchstones which, when heated to redness, give off water having a strong acid reaction, it may probably be in the form of a hydrate, retaining its water when heated under pressure. It is also sufficiently probable that, as suggested by M. Angelot (Bulletin de la Société Géologique de France, 1 sér. t. xiii. p. 178), fused rock, under great pressure, may dissolve a considerable amount of the vapour of water, in the same manner as liquids dissolve gases. In either case, if the fused rock passed by gradual cooling into anhydrous crystalline compounds, the water would necessarily be set free ; and, if the pressure was so great that it could not escape as vapour, an intimate mixture of partially melted rock and liquid water would be the result. It is difficult to form any very definite opinion as to the actual amount of this water, and to decide whether or no it exercised an important influence over the crystalline processes that took place during the consolidation of such rocks as granite. The comparatively large quantity of alkaline chlorides and sulphates, dissolved in those portions caught up in the growing crystals, indicates that the amount cannot have been *unlimited*; but, bearing in mind the facts I alluded to when describing the fluid-cavities in the blocks ejected from modern volcanos, and knowing, as we do, that the action of highly heated water is so very energetic, I cannot think that its influence was unimportant. On the contrary, seeing that the fluid-cavities in the quartz of quartz-veins contain the selfsame salts and acids as those in the granite, as though it had been deposited from portions of the liquid which had passed from the granite up fissures, I think the amount, though limited, must nevertheless have been *considerable*, and that its presence will serve to account for the connexion between granite and quartz-veins, and the very intimate relation of both to the metamorphic rocks, and explain many peculiarities in the arrangement of the minerals in the cavities in granite or in the solid rock, even if it was not the effective cause of their elimination and crystallization. These analytical deductions have been confirmed in a most striking manner by the admirable experiments of M. Daubrée (Observations sur le métamorphisme, &c., Annales des Mines, 5[e] sér. t. xii. p. 289), who, in having produced felspar and quartz artificially, by the action of water at a similar temperature to that I have deduced from the fluid-cavities, has removed some of the principal objections that might have been urged against my conclusions. I therefore must confess myself to be a very strong adherent to the views of Scrope (Treatise on Volcanos; and on the nature of the liquidity of lava, Quarterly Journal of the Geological Society, vol. xii. p. 338), Elie de Beaumont (Note sur les émanations volcaniques, *ut supra*), and Scheerer (Discussion sur la nature plutonique du granite, &c., Bulletin de la Société Géologique de France, 2 sér. vol. iv. p. 468, and vol. vi. p. 644), though, as will be perceived, I by no means agree with them in every particular.

c. Temperature and pressure under which granitic rocks have been formed.

In studying the fluid-cavities in elvans and granite, it is particularly necessary to bear in mind the influence of pressure. As already shown, the temperature requisite to expand the fluid so as to fill the cavities is that at which the crystal was formed only when the pressure was not greater than the elastic force of the vapour, and when in equation (9) $p=0$; but if the pressure was very great, that temperature would necessarily be far short of the actual heat. Therefore, as already described, the true heat can only be determined when the approximate value of the pressure is known; and the pressure cannot be deduced unless we can in some way or other approximate to the temperature. The trachyte of Ponza was probably formed under so small a pressure that it scarcely need be taken into account; but, in the case of granites, such a supposition would lead to the conclusion that sometimes they did not solidify from a state of fusion until the temperature was as low as that of boiling water. In the present state of the inquiry (July 1858), it therefore appears to me that the best course is to suppose that the quartz of the various igneous rocks crystallized at about the same temperature, and that the greatest value of v yet observed, viz. in the trachyte of Ponza, was when p was not so great as to prevent the value ·3 being a sufficiently accurate approximation to V to be substituted in equation (6), so as to enable us to calculate the value of p from the observed value of v by the equation

$$p=369{,}000\ \frac{\cdot 3-v}{1+\cdot 3}\ \ldots\ldots\ldots \text{ equation (10).}$$

Considering the very strong analogy between the structure of this trachyte and that of elvans and granites, this supposition appears to me quite admissible as an approximation until a more correct is known. Of course the results deduced from the equation are the amounts of *pressure* in feet of rock, and not the actual *depth*. In some cases the pressure was probably much greater than that of the superincumbent rocks, for otherwise they could not have been fractured and elevated; whereas in other cases it may have been much less, if the internal pressures had been in any way relieved. Fortunately, a considerable variation in the strength of the saline solutions in the fluid-cavities would be to a great extent compensated for, because, though a more dilute solution would expand more by heat, it would be more compressed by pressure. Moreover, according to the principles described by Mr. James Thompson (Transactions of the Royal Society of Edinburgh, vol. xvi. p. 575), which have been strikingly verified by the experiments of Professor Wm. Thompson on the thawing of ice (Philosophical Magazine, 3rd ser. vol. xxxvii. p. 123), by those of Bunsen on spermaceti and paraffine (Poggendorff's Annalen der Physik und Chemie, 1850, vol. lxxxi. p. 562), and by those of Hopkins and Fairbairn on spermaceti, paraffine, sulphur, and stearine (Report of the British Association for 1854, p. 57),—if a substance expands in solidifying, it would become solid at a lower temperature when under a greater pressure; whereas if it contracts, it would solidify at a higher temperature. Therefore if, as I have already shown, the stone-cavities in the quartz of granite indicate that the general fused mass from which the quartz crystallized expanded in the act of solidification, it would probably become solid at a lower temperature when under greater pressure. We may, however, be nearly certain, that at very great pressures the compression of water would be relatively less than at moderate; for, if not, a finite pressure would compress it into nothing; and therefore, since the force required to produce this relatively less compression of the liquid, which was not so much expanded by the lower temperature, might be nearly the same as would produce the greater compression of the more heated and expanded liquid assumed in the above equation, it is obvious that these two sources of error have a tendency to counteract one another, and therefore perhaps the equation would give a tolerably accurate approximation to the truth when the pressure was very great, as well as when only small. Even if the real amount of the compression of the highly heated liquid differed from that supposed to be the most probable, the difference would affect all the results in similar proportion, and therefore, though not *actually* correct, they would be sufficiently accurate *as compared with each other*. The chief point about which there may be some doubt is whether, when the rock contains much quartz, it became crystalline at a higher temperature than when it contains less. I have, indeed, found cases where there was evidence of the first-formed quartz having crystallized at a higher temperature than the last, but the facts were scarcely sufficiently decided to be fully relied on, and in the present state of the inquiry this cannot be accurately taken into account; nor, indeed, if mean results are employed, do any other facts seem to require that it should. That even highly quartzose elvans and granites did not become finally solid at a temperature much higher than a dull-red heat, is, I think, clearly proved by the great number of hair-like crystals of schorl enclosed in the quartz; for schorl readily melts at a bright-red heat, and therefore must have crystallized at a lower temperature than that. The properties of the pyrognomic minerals described by Scheerer (Discussion sur la nature plutonique du granite, &c., *ut supra*) indicate a temperature not higher than a brown-red heat. It therefore appears to me in the highest degree probable that granites and elvans became finally solid at about the dull-red heat calculated from the fluid-cavities in the quartz of the trachyte of Ponza. Still, however, taking everything into consideration, the following deductions must only be looked upon as the best approximations that can be made at present, for so many data are only imperfectly known.

From the nature of the case, equation (10) gives the *excess* of pressure over and above that under which the quartz of the trachyte of Ponza crystallized, whatever, within moderate limits, the *real* temperature and pressure might be. If then we consider these to have been 360° C., and 4000 feet of rock, that amount would have to be added to the calculated value of p, in order to obtain the *total* pressure.

The greatest value of v that I have yet found for any elvan is for one at Gwennap, in which it is very nearly ·25. This, from equation (8), indicates a minimum temperature of about 320° C. (608° F.), or very little lower than a dull-red heat visible in the dark. Substituting this value of v in equation (10) we obtain $p=14,100$ feet, to which, as explained above, must be added 4000 feet to arrive at the total pressure, which was therefore about 18,100 feet. The least value of v for any elvan in Cornwall is ·125, for that at Swanpool, near Falmouth, which corresponds to a pressure of 53,900 feet. The mean of my observations in the elvans of Cornwall gives a pressure of 40,300 feet; but, for the analogous quartzose porphyry-dykes in the Highlands of Scotland, 69,000 feet.

I have never yet found any granite in which v is greater than ·2, which is the relative size of the vacuities in that of St. Austel. This indicates a minimum temperature of 256° C. (493° F.), and a pressure equal to about 32,400 feet of rock, or considerably less than some of the elvans. In the Cornish granite I have never found v less than ·09, in that from the Ding Dong mine near Penzance, which corresponds to a pressure of 63,600 feet; and the mean of all my observations gives 50,000 feet, or 9700 feet more than the mean for the elvans. This, I think, is a very satisfactory result, since the association of those rocks clearly proves that granite must have been consolidated at a considerably greater depth than elvans.

The conclusions derived from my examination of the various granites in the neighbourhood of Aberdeen are very striking. In the main mass, at a considerable distance from the stratified rocks, v=about ·04 ; and the great difference between vacuities of that size and those in the fluid-cavities in the quartz of the trachyte of Ponza will be seen on comparing fig. 116 with fig. 100, both magnified to the same extent. If the pressure were not taken into account, this would indicate a temperature lower than that of boiling water; but if the temperature was the same as that at which the quartz of the trachyte of Ponza crystallized, the pressure must have been equal to about 78,000 feet of rock. If the temperature was higher, the pressure must have been still greater. In the exterior part close to the stratified rocks v=·071, which indicates a pressure of 69,000 feet. This is the same as for the porphyries, but 9000 feet less than for the centre of the granite, which appears to me a very reasonable result, since it is extremely probable that the pressure on the outside would be considerably less than in the interior. In some more recent veins of very coarse-grained granite intersecting the other, v=·166, which corresponds to a pressure of only 42,000 feet, as though the conditions under which it was consolidated differed materially from the other case, either on account of the elevation of the rocks, or some other physical change. The general mean of all my measurements in the main masses of granite in the south border of the Highlands from Aberdeen to Ben Cruachan indicates a pressure of about 76,000 feet, or 7000 feet more than the quartzose porphyry-dykes. The number of cavities is also much less than in those granites formed under a less pressure, as if the crystallization had taken place more slowly, on account of a more gradual cooling, which would probably be the case, if the thickness of the superincumbent rocks was greater.

Comparing these conclusions and that derived from a comparison of the metamorphic rocks, we have as under :—

The granites of the Highlands indicate a pressure of 26,000 feet of rock more than those of Cornwall.

The elvans of the Highlands indicate a pressure of 28,700 feet of rock more than those of Cornwall.

The metamorphic rocks indicate a pressure of 23,700 feet of rock more than those of Cornwall.

This remarkable agreement cannot be the result of mere accident, but I think clearly points out that the consolidation of the granites and elvans, and the metamorphosis of the stratified rocks, took place in the Highlands at a very much greater depth than in Cornwall,—

a conclusion which appears to me to agree extremely well with the general association of facts on a large scale.

Of course all the pressures deduced as above involve any error there may be in the amount of compression supposed to be the most probable for highly heated water, and would be materially altered by variations in the temperature; but, considering all the circumstances of the case, it appears to me as likely that they are too little as too great, and, therefore, at present we cannot do better than adopt them provisionally.

In order that the various results may be compared more conveniently, I subjoin the following Table. The first column gives the temperature in degrees Centigrade requisite to expand the fluid so as to fill the cavities, if the pressure was not greater than the elastic force of the vapour, which, of course, is the lowest temperature at which the rock can have been consolidated, since the excess of pressure could not be less than nothing. In the other column is given the pressure in feet of rock requisite to compress the fluid so much that it would just fill the cavities at 360°, being, therefore, the actual pressure, if in each case the rock was consolidated at that temperature.

	Temperature.	Pressure.
Trachyte of Ponza	356°	4,000
Elvan at Gwennap	320	18,100
Granite at St. Austel	256	32,400
Mean of the Cornish elvans	250	40,300
More recent veins of granite at Aberdeen	245	42,000
Mean of Cornish granites	216	50,000
Elvan at Swanpool, near Falmouth	203	53,900
Granite from the Ding Dong Mine, near Penzance	162	63,600
Mean of the Highland porphyry-dykes	135	69,000
Exterior of the main mass of the granite at Aberdeen	135	69,000
Mean of the Highland granites	99	76,000
Centre of the main mass of the granite at Aberdeen	89	78,000

It will thus easily be seen that, if pressure is not taken into account, there is a gradual decrease in temperature on passing from trachyte to granite; whilst if, as is far more probable, the temperature was nearly the same, the pressure increases in passing from trachyte through elvans to granite; and I think all geologists will agree with me in thinking that this is a very satisfactory result.

It therefore appears that the fluid-cavities indicate that all the elvans and granites I have hitherto examined were consolidated under pressures varying from about 18,000 to 78,000 feet of rock. These are certainly very great pressures; but, bearing in mind that they probably represent the forces concerned in the elevation of mountains, I think they are sufficiently reasonable. They also correspond very well with the pressure under which, in many cases, the lava at the foci of modern volcanic activity must become solid, as is well illustrated by the Peak of Teneriffe. It is upwards of 12,000 feet high, and the bottom of the ocean from which the volcanic district of the Canary Islands rises is 12,000 feet deep, and at no great distance westward it is 16,800 feet (Lieut. Maury's Physical Geography of the Sea, 1st edition, plate xi.). If, as is sufficiently probable, the lava at a great depth extends some distance westward of the exhibition of volcanic activity at the surface, there must be a considerable thickness of rock between it and the bottom of the ocean, or else it could not, as it does, resist the pressure of a column of lava at least 20,000 feet high, when an eruption takes place from the Peak. If a few thousand feet is sufficient for that purpose, when the internal forces are relieved by an eruption of lava near the summit of the Peak, there would be a pressure of an actual column of at least 30,000 feet of melted rock on the lava at the base. Probably, however, part of the lava is at a greater depth than a few thousand feet below the general bed of the ocean, and the pressure may be more when not relieved by an eruption, and therefore it appears to me reasonable to suppose it might in some cases be solidified under double that pressure. At all events the best conclusions we can deduce from this modern volcano agree so well with the amounts calculated from the fluid-cavities in granitic rocks, that I cannot but conclude that the pressure under which granites and elvans were consolidated was of the same *order of magnitude* as the pressure under which the lava of modern volcanos must be solidified at the foci of their activity, as though these rocks were the unerupted lavas of ancient volcanos, variously protruded amongst the superincumbent strata.

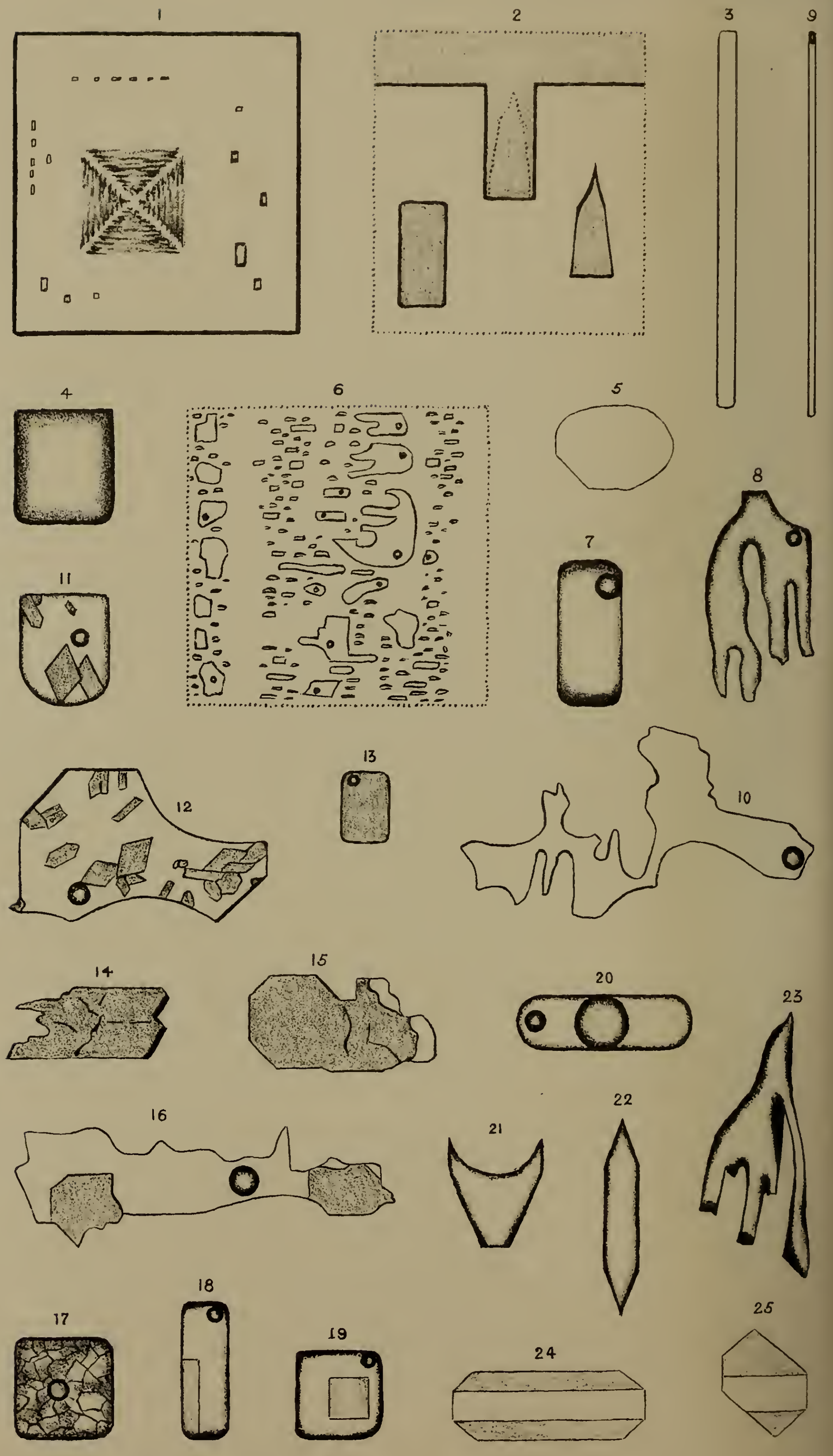
As is well known, the temperature of rocks increases with the depth; and it becomes an interesting question to determine whether the rate of increase might give the temperature deduced from the fluid-cavities in the quartz of the trachyte of Ponza, at a depth which would correspond with the amount of pressure deduced from a comparison with those in the quartz of granite. According to M. Cordier (Edinburgh New Philosophical Journal, 1828, vol. iv. p. 273), the rate of increase is not uniform in all countries, being in some as rapid as 1° F. for each 24 feet, and in others not more than 1° for each 104 feet, as if owing to an irregular distribution of the subterranean heat. If the increase was the same for great depths, there would be a temperature of 680° F. at a depth varying from 15,100 to 65,500 feet. According to Mr. R. W. Fox (British Association Report for 1857, p. 96), the rate of increase in various mines in Cornwall is by no means uniform, but varies from 1° for each 32 feet to 1° for 71 feet, being on an average 1° for 49 feet, which would give a temperature of 680° at a depth of 30,900 feet. However, he states expressly that the increase is more rapid in shallow than in deep mines; and, according to information kindly furnished to me by Mr. Robert Hunt, the rate is 1° for every 50 feet in penetrating through the first 100 fathoms; for the next 100 fathoms 1° for 70 feet; whilst, when the depth exceeds 200 fathoms, it is only 1° for each 85 feet of depth. If this be the true rate of increase far below the surface, there would be a temperature of 680° F. at a depth of about 53,500 feet. These results will be best compared with the pressures under which granites were most probably formed, by means of the following Table:—

	Depth in Feet.		*Pressure in feet of Rock.*
Cordier's results	15,100 to 65,500	Various granites	32,400 to 78,000
Fox's mean	30,900	Cornish granites	32,400 ,, 63,600
Hunt's results	53,500	Mean of ditto	50,000

It will thus be seen that, if the rate of increase to a very great depth is the same as near the surface, the calculated temperature would occur at a less depth than corresponds with the calculated pressure, although the general order of magnitude of the two quantities is very similar; whilst, if the rate of increase to a very great depth is the same as below 200 fathoms, it would occur in Cornwall at a depth which corresponds remarkably well with the calculated mean pressure for the granites in that district. Very variable elements enter into the calculations; there are many possible sources of error; the number of feet of rock expressing the pressure might differ very considerably from the actual depth, and the distribution of heat in the earth's crust, when the granite was consolidated, might not be the same as now. Still, however, we must admit that the rate of increase in the heat of the rocks indicates that the temperature at which the quartz of granite probably crystallized would in all probability occur at a depth agreeing very well with the pressure to which it appears to have been exposed. Since, then, as I have already shown, the metamorphic rocks near the granite crystallized at about the same temperature as the granite itself, I think, even if we do not give our entire assent, we must acknowledge that the above fact is a strong argument in favour of the supposition that the temperature concerned in the normal metamorphosis of gneissoid rocks was due to their having been at a sufficiently great depth beneath superincumbent strata.

It will, therefore, be seen that the application of the principles I have described leads to many very striking and remarkable results, which agree so extremely well amongst themselves and with other general circumstances, that I cannot for one moment believe them to be the effect of accident. On the contrary, they clearly point to definite laws; and though, in the infancy of such a wide subject, involving many very difficult physical questions, considerable errors cannot be avoided, yet the character of the results indicates that the general principles are correct.

With respect, then, to minerals and rocks formed at a high temperature, my chief conclusions are as follows. At one end of the chain are erupted lavas, indicating as perfect and complete fusion as the slags of furnaces, and at the other end are simple quartz veins, having a structure precisely analogous to that of crystals deposited from water. Between these there is every connecting link, and the central link is granite. When the water intimately associated with the melted rock at great depths was given off as vapour whilst the rock remained fused, the structure is analogous to that of furnace slags. If, however, the pressure was so great that the water could not escape as vapour, it passed as a highly heated liquid holding different materials in solution up the fissures in the superincumbent rocks, and deposited various crystalline substances to form mineral



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veins. It also penetrated into the stratified rocks, heated, sometimes for a great thickness, to a high temperature, and assisted in changing their physical and chemical characters, whilst that remaining amongst the partially-melted igneous rock served to modify the crystalline processes which took place during its consolidation. These results are all derived from the study of the microscopical structure of the crystals; but my own observations in the field lead me to conclude that they agree equally well with the general structure of the mountains themselves, and serve to account for facts that could not have been satisfactorily explained without the aid of the microscope. And here I cannot but make a few remarks in conclusion on the value of that instrument, and of the most accurate physics in the study of physical geology. Although with a first-rate microscope, having an achromatic condenser, the structure of such crystals and sections of rocks and minerals as I have prepared for myself with very great care can be seen by good day-light as distinctly as if visible to the naked eye, still some geologists, only accustomed to examine large masses in the field, may perhaps be disposed to question the value of the facts I have described, and to think the objects so minute as to be quite beneath their notice, and that all attempts at accurate calculations from such small data are quite inadmissible. What other science, however, has prospered by adopting such a creed? What physiologist would think of ignoring all the invaluable discoveries that have been made in his science with the microscope, merely because the objects are minute? What would become of astronomy if everything was stripped from it that could not be deduced by rough calculation from observations made without telescopes? With such striking examples before us, shall we physical geologists maintain that only rough and imperfect methods of research are applicable to our own science? Against such an opinion I certainly must protest; and I argue that there is no necessary connexion between the size of an object and the value of a fact, and that, though the objects I have described are minute, the conclusions to be derived from the facts are great.

DESCRIPTION OF PLATES XVI. TO XIX.

The number of times that the objects are magnified in linear dimensions is expressed by the sign ×. The figures with a dotted outline are portions of crystals, and the rest are entire separate cavities and crystals.

PLATE XVI.

CAVITIES IN CRYSTALS FORMED ARTIFICIALLY.

§ 1. *From solution in Water.*

Fig. 1. A single crystal of chloride of potassium deposited on slow evaporation in winter. ×60.

Fig. 2. A portion of the edge of a crystal of chloride of sodium, ×200, showing how the fluid-cavities are formed.

Fig. 3. A fluid-cavity in chloride of potassium formed at the ordinary temperature. ×800.

Figs. 4, 5. Fluid-cavities in chloride of sodium formed at the ordinary temperature. 4, ×800; 5, ×1000.

Fig. 6. A portion of a crystal of chloride of potassium formed at 100° C. ×150.
Fig. 7. A fluid-cavity in chloride of sodium formed at 100° C. ×400.
Figs. 8, 9, 10. Fluid-cavities in chloride of potassium formed at 100° C. 8, ×300; 9, ×400; 10, ×200.
Figs. 11, 12, 13. Fluid-cavities in chloride of sodium formed at 100° C., in a strong solution of bichromate of potash. 11, 13, ×1000; 12, ×600.
Figs. 14, 15, 16. Crystals of bichromate of potash and attached fluid-cavities, in chloride of sodium formed at 100° C., in a concentrated solution of the bichromate. 14, 15, ×100; 16, ×70.
Fig. 17. A fluid-cavity in chloride of sodium formed at 100° C., in a concentrated solution of bichromate of potash. ×800.
Figs. 18, 19. Fluid-cavities in chloride of sodium formed at 100° C., in a strong solution of chloride of potassium. 18, ×800; 19, ×1200.
Fig. 20. A fluid-cavity in chloride of sodium formed at 100° C., in a strong solution of hydrochloride of ammonia. ×800.
Figs. 21, 22. Fluid-cavities in nitrate of potash formed at the ordinary temperature. 21, ×400; 22, ×200.
Fig. 23. A fluid-cavity in binoxalate of ammonia formed at the ordinary temperature. ×150.
Figs. 24, 25. Fluid-cavities in sulphate of zinc formed at the ordinary temperature. ×130.

Plate XVII.

Fig. 26. A portion of a crystal of alum formed at 50° C. ×100.
Figs. 27, 28. Fluid-cavities in alum formed at 50° C. 27, ×100; 28, ×400.
Fig. 29. A gas-cavity in a portion of a crystal of alum formed at 50° C. ×50.
Figs. 30, 31. Fluid-cavities in alum that have lost water by drying. 30, ×800; 31, ×400.
Fig. 32. A portion of a crystal of bichromate of potash, with bands of fluid-cavities. ×200.
Fig. 33. A fluid-cavity in bisulphate of potash, which totally reflects the transmitted light. ×200.
Figs. 34, 36, 37. Fluid-cavities in chloride of sodium formed above the level of the liquid at 100° C. 34, ×800; 36, 37, ×1000.
Fig. 35. A gas-cavity in chloride of sodium formed above the level of the liquid at 100° C. ×600.

§ 2. *Formed by Sublimation.*

Fig. 38. A gas-cavity in hydrochlorate of ammonia. ×600.
Fig. 39. A gas-cavity in corrosive sublimate. ×400.

§ 3. *Formed from a state of Igneous Fusion.*

Fig. 40. A portion of a crystal of basic silicate of protoxide of iron, from a copper slag. ×200.
Figs. 41, 42, 43. Glass-cavities in a portion of a crystal of basic silicate of protoxide of iron, from a copper slag. 41, ×1600; 42, ×400; 43, ×600.
Figs. 44, 45. Part glass-, part stone-cavities in a portion of a crystal of basic silicate of protoxide of iron, from a copper slag. 44, ×1200; 45, ×1600.
Fig. 46. A stone-cavity in a portion of a crystal of basic silicate of protoxide of iron, from a copper slag. ×1600.
Fig. 47. A stone-cavity in pyroxene, from a blast-furnace slag. ×800.
Fig. 48. A glass-cavity in Humboldtilite, from a blast-furnace slag. ×400.

Fluid-Cavities in Natural Minerals.

Figs. 49, 50, 51. In quartz of a vein at Mousehole, near Penzance. ×800.
Fig. 52. A fluid-cavity containing two fluids, in the quartz of a porphyry at Cove, near Aberdeen. ×2000.

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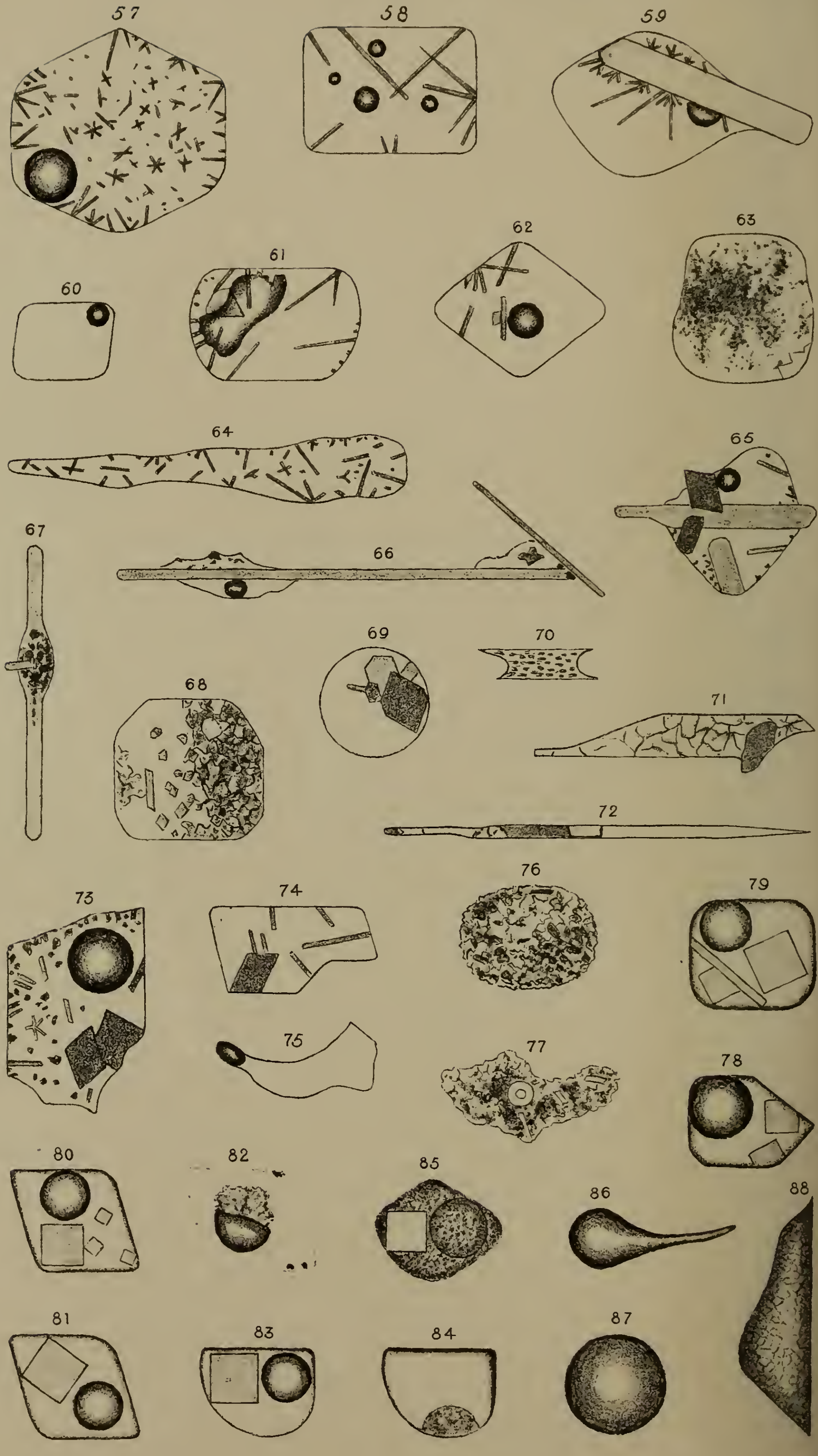

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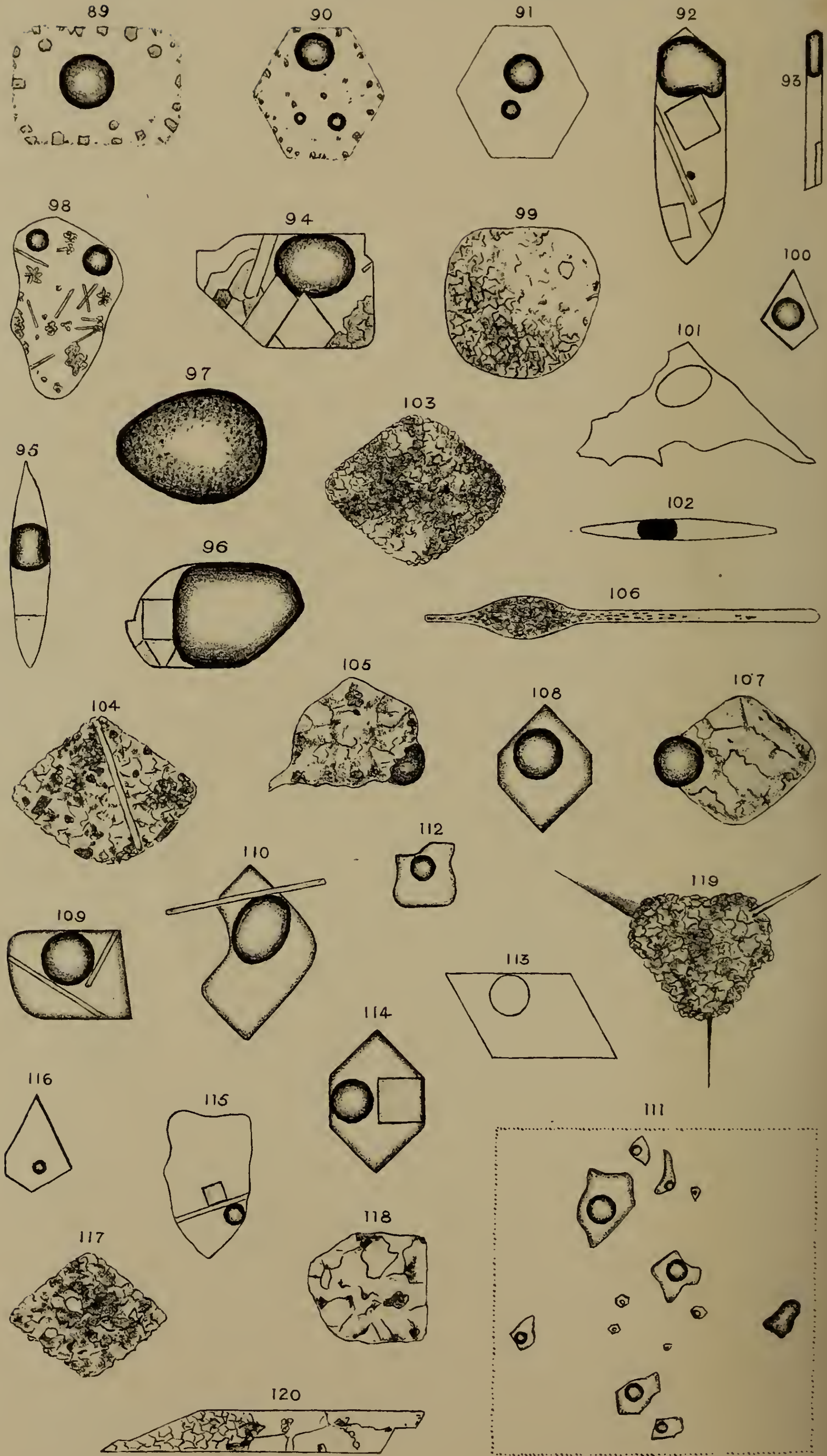

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Figs. 53, 54, 55, 56. Fluid-cavities containing various crystals, in quartz replacing felspar, at Trevalgan, near St. Ives, Cornwall. 53, ×1600; 54, 55, 56, ×800.

Plate XVIII.

Glass- and Stone-cavities in the Minerals of Erupted Lavas, &c.

Figs. 57, 58, 59, 60, 61, 62. Glass-cavities in the felspar of a porphyritic pitchstone in Arran. 57, ×300; 58, ×330; 59, ×360; 60, ×1600; 61, ×600; 62, ×400.

Fig. 63. A cavity of a different character in the felspar of a porphyritic pitchstone in Arran. ×600.

Fig. 64. A glass-cavity in a prismatic crystal in a porphyritic pitchstone in Arran. ×300.

Figs. 65, 66. Glass-cavities attached to crystals in the augite of the lava of Vesuvius. 65, ×500; 66, ×400.

Fig. 67. A stone-cavity attached to a crystal in the leucite of the lava of Vesuvius. ×300.

Figs. 68, 69, 70. Stone- and glass-cavities in the leucite of the lava of Vesuvius. 68, ×600; 69, 70, ×800.

Figs. 71, 72. Stone-cavities in the felspar of the trachyte of Ponza. ×800.

Figs. 73, 74. Glass-cavities in the augite of a trappean rock at Balloch, Dumbarton. 73, ×450; 74, ×600.

Fig. 75. A glass-cavity in the augite of a trappean rock near Glasgow. ×600.

Figs. 76, 77. Altered glass- or stone-cavities in the felspar of a porphyritic greenstone at Arthur's Seat, near Edinburgh. 76, ×400; 77, ×200.

Fluid-, Gas-, Vapour-, Stone- and Glass-cavities in Minerals formed by the combined action of Water and Igneous Fusion.

Fig. 78. A fluid-cavity in the calcite of a block ejected from Vesuvius. ×300.

Figs. 79, 80, 83, 85. Fluid-cavities in the nepheline of a block ejected from Vesuvius. ×1000.

Figs. 81, 82, 84. Fluid-cavities in the nepheline of a block ejected from Vesuvius, after having been heated to a more or less bright red heat.

Figs. 86, 87. Gas-cavities in the nepheline of a block ejected from Vesuvius, in a natural state. 86, ×1000; 87, ×400.

Fig. 88. A vapour-cavity in the nepheline of a block ejected from Vesuvius. ×800.

Plate XIX.

Figs. 89, 90. Glass-cavities in the nepheline of a block ejected from Vesuvius. 89, ×400; 90, ×1200.

Fig. 91. The cavity, fig. 90, after having been heated to bright redness.

Figs. 92, 93. Fluid-cavities in the idocrase of a block ejected from Vesuvius. ×1200.

Figs. 94, 95. Fluid-cavities in the felspar of a block ejected from Vesuvius. 94, ×800; 95, ×1600.

Fig. 96. A fluid-cavity in the felspar of a block ejected from Vesuvius, with much enclosed vapour. ×500.

Fig. 97. A vapour-cavity in the felspar of a block ejected from Vesuvius, out of focus in the centre. ×500.

Fig. 98. A glass-cavity in the felspar of a block ejected from Vesuvius, out of focus in the centre. ×400.

Fig. 99. A stone-cavity in the felspar of a block ejected from Vesuvius, out of focus in the centre. ×500.

Figs. 100, 101. Fluid-cavities in the quartz of a trachyte from Ponza. 100, ×2000; 101, ×800.

Fig. 102. A fluid-cavity in the quartz of a trachyte from Ponza, ×1600, so placed that the bubble totally reflects the transmitted light.

Fig. 103. A stone-cavity in the quartz of a trachyte from Ponza. ×400.

Figs. 104, 105. Stone-cavities in the quartz of an elvan near Penrhyn, Cornwall. 104, ×250; 105, ×800.

Fig. 106. A stone-cavity attached to a crystal of schorl in the quartz of an elvan near Penrhyn, Cornwall. ×400.

Fig. 107. A stone-cavity attached to a vapour- or gas-cavity in the quartz of an elvan near Gwennap, Cornwall. ×800.

Fig. 108. A fluid-cavity in the quartz of an elvan near Gwennap. ×2000.

Figs. 109, 110. Fluid-cavities in the quartz of an elvan near Gwennap, enclosing or attached to crystals of schorl. ×1200.

Fig. 111. A portion of the quartz of the granite at St. Austel, Cornwall, ×200, with many fluid-cavities, and one vapour- or gas-cavity.

Fig. 112. A fluid-cavity in the felspar of the granite at Penrhyn, Cornwall. ×1600.

Fig. 113. A fluid-cavity in the mica of a granite-vein at Polmear Cove, Cornwall. ×1600.

Figs. 114, 115. Fluid-cavities in the quartz of the granite from the Ding Dong Mine, near Penzance. 114, ×2000; 115, ×800.

Fig. 116. A fluid-cavity in the quartz of the main mass of granite at Aberdeen. ×2000.

Fig. 117. A stone-cavity in the quartz of the granite at St. Austel. ×1000.

Fig. 118. A stone-cavity in the quartz of a rather coarse-grained granite near Cape Cornwall. ×800.

Fig. 119. A stone-cavity in the quartz of the granite at St. Austel, with radiating cracks. ×600.

Fig. 120. A stone-cavity in the felspar of the granite at Lamorna, near Penzance. ×800

THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

February 3, 1858.

Viscount Dufferin, Dufferin Lodge, Highgate, and Clandeboye, Co. Down, the Rev. Fred. Smithe, M.A., Churchdown, Gloucestershire, and the Rev. W. A. Jones, M.A., Taunton, were elected Fellows.

The following communication was read:—

On the Succession *of* Rocks *in the* Northern Highlands, *from the oldest* Gneiss, *through* strata *of* Cambrian *and* Lower Silurian age, *to the* Old Red Sandstone *inclusive.* By Sir R. I. Murchison, F.R.S., V.P.G.S., &c.

[Abstract.]

[The publication of this Memoir is postponed.]

This memoir comprised a general sketch of the succession of the stratified rock-masses occupying the northernmost counties of Scotland (Sutherland, Caithness, and Ross), as determined by former observations of Prof. Sedgwick and the author, and of Macculloch, Jameson, Cunningham, Miller, and Nicol, and by the recent discoveries of Mr. C. Peach. In the commencement, Sir Roderick, having referred to the long-held opinion that the great mountainous masses of red conglomerate and sandstone of the west coast were detached portions of the Old Red Sandstone, alluded to Mr. C. Peach's discovery (in 1854) of organic remains in the limestone of Durness, which led the author to revisit the Highlands (accompanied by Prof. Nicol), when having found still more fossils, he expressed his conviction (at the British Association, Glasgow Meeting, 1854) that the quartzites of Sutherland and their subordinate limestones were of Lower Silurian age; and was strengthened in the opinion (which he had already published) that large portions of the crystalline rocks of the Highlands would prove to be the equivalents of the Lower Silurian deposits in the South of Scotland. In 1856 Colonel James and Prof. Nicol separately observed the unconformable overlap of the great conglomerates by the quartzite series; and the latter geologist greatly extended all previous observations, and communicated to the Society a memoir, showing that the old gneiss and its superposed conglomerate, as seen along a very extensive region of the western coast, formed the buttresses upon which all the crystalline quartz-rock and limestone of the western parts of Ross-shire and Sutherland reposed. At the same time Prof. Nicol hypothetically suggested, that, until the evidence of fossils was more complete, the quartzite and limestone might be considered as the equivalent of the Carboniferous series of the South of Scotland. Another hypothesis, which had been propounded by the late Mr. Hugh Miller, regarded the quartz-rocks and hard limestones of Sutherland merely as the metamorphosed representatives of the Old Red and Caithness series of the Eastern Coast.

Both of these hypotheses, however, seemed to the author to be incompatible with the physical order of the rock-masses in question; for, according to the observations made long ago by Prof. Sedgwick and himself, the above-mentioned crystalline rocks, in the lower part of which the Durness fossils have recently been found, are the inferior members of the great undulating mass of micaceous and schistose rocks, which, rolling over to Caithness on the east, there constitute the basis out of which the bottom strata of the Old Red Sandstone are chiefly formed.

Of late, Mr. Peach has, by his untiring perseverance, obtained a still larger collection of fossils from Durness, and in better preservation than those found in 1854, and Mr. Salter finds that this collection of well-defined forms comprises genera belonging only to the Lower Silurian of North America. Hence all doubt is now dispelled; and the author, following up the suggestions which he offered at the Glasgow Meeting of the British Association, describes in the present paper these rocks and their fossils; defining the great unfossiliferous conglomerate-masses of Sutherland as of Cambrian age, the quartzites and limestones as Lower Silurian, and the overlying micaceous and gneissose schists and flagstones as also of Silurian age.

In the body of the memoir, Sir Roderick, after a brief notice of the "fundamental gneiss," described the "Cambrian red sandstone and conglomerate," alluding to the faithful descriptions of it by Hugh Miller and Nicol. He also detailed certain subsequent observations of Colonel James and Mr. Peach on the unconformity of these rocks to the overlying quartzites, and on the great dislocations exhibited in these masses; and he also noticed the discovery of a porphyry between the gneiss and the conglomerate by the latter observer.

The "Lower Silurian rocks, in the form of quartz-rock, crystalline limestone, chloritic and micaceous schists, and younger gneiss," were then described. The fossils from the quartz-rock consist of small annelide-tubes, now named *Serpulites Maccullochii,* and traces of fucoids. These fossils were long ago noticed, but of late they have been traced in beds for great distances by Mr. Peach. The strong band of limestone between two quartz-rocks is estimated by Colonel James to lie about 800 feet above the base of the series, and is of great extent. The fossils * detected in it have been determined by Mr. Salter to be *Maclurea Peachii,* spec. nov. (and its curious twisted operculum), *Ophileta compacta,* well known in Canada, *Oncoceras,* spec., and *Orthoceras,* a smooth species with a compressed siphuncle. They all closely resemble fossils of the Lower Silurian rocks of North America, which range from the Calciferous rock up to the Trenton Limestone, both inclusive,—a group especially to be found in the limestones of the Ottawa River in Canada.

Passing across Ross-shire in a more southern parallel, from Loch Duich in Kintail, on the west, to the frontier of the Old Red Sandstone on the east, the general succession of rocks was described to be much the same as that in North-west Sutherland, though there are considerable changes of lithological character when the same rocks are followed southwards or south-south-west upon their strike; and the author stated his belief, that not only may the regularly bedded limestones which are intercalated in the chloritic and quartzose rocks of Dumbartonshire be classed with some of the oldest of those stratified masses which, like the limestones of Sutherland, are unquestionably of Lower Silurian age, but that the vast and evidently overlying masses of mica-schist and quartzose-gneissic flag-rocks of the Breadalbane district may be some day found to be simply the prolongations of the micaceous flagstones of the North-western Highlands above alluded to, as overlying the quartz-rock and fossiliferous limestone: further, that in the still higher limestones and schists seen on the banks of Loch Tay, we may speculate on the existence of the equivalents of younger and higher strata than any which are observed in the Northern Counties.

After some observations on the truly stratified condition of these micaceous and gneissose schists (younger gneiss) of the Highlands, Sir Roderick proceeded to the consideration of the "Old Red Sandstone of the North-east of Scotland,"—defining the tripartite division of this great series, and demonstrating that the beds with *Cephalaspis Lyellii* and *Pterygotus Anglicus* of Forfarshire really lie at the base of the series, and are certainly of greater antiquity than the bituminous fossil-bearing schists of Caithness. This division is in accordance with the relations of the deposits of the Devonian period, as seen in Devonshire and Germany, though the lowest member of the Old Red of Scotland has no representative in the Devonian rocks of Russia. The Caithness flagstones were described as being in the middle of the series; whilst the underlying conglomerates and sand-

* Twenty-three in all, 11 of which are identical with American forms.—Oct. 1858.

stones were shown to be the true equivalents of the Cephalaspis-beds of Forfarshire, and of the lower cornstone-strata of Herefordshire, which there graduate downwards, through the tilestones, into the uppermost Silurian rocks of Ludlow.

The Old Red rocks of the North Highlands were described in some detail by the author, who showed that the group, as seen in Caithness and the Orkney Islands, is composed of—1st, lower red conglomerate and sandstones; 2nd, grey and dark-coloured flagstones and schists, both bituminous and calcareous (this portion being in Elginshire and Murrayshire represented by Cornstones); and 3rd, upper red sandstones. The North Scottish Old Red contains one great inferior portion which has no representative in the Devonian rocks of some foreign countries, though it is completely represented in all its parts in other tracts both of Britain and the Continent.

Having next described the conditions under which many of the species of fish (at least twenty-one) found fossil in Caithness, Cromarty, and Morayshire, occur in Russia commingled with the middle Devonian mollusks of Devon, the Boulonnais, and the Rhine, and having pointed out that the lowest member of the Devonian series, with its *Cephalaspides*, is wanting in Russia, Sir Roderick insisted on the importance of the Devonian series in the scale of formations, and on the fact that the Old Red conglomerates, ichthyolitic schists, and cornstones, with the overlying sandstones, of Scotland and Herefordshire fully represent in time the Devonian rocks of the South of England and the Continent, so full of corals, crinoids, and marine mollusks.

Some brief observations on the Newer Red Sandstone of the West Coast of Ross-shire, and the Lias and Oolitic deposits of the North of Scotland and the Western Isles, concluded this paper.

February 10, 1858.

ANNUAL GENERAL MEETING.

[For Reports and Address see the beginning of this volume.]

February 24, 1858.

T. Ashford Sanford, Esq., Nynehead Court, Somerset; C. E. Austen, Esq., C.E., Grove House, Croydon; and Thomas R. Polwhele, Esq., Geol. Surv. Great Britain, were elected Fellows.

The following communications were read:—

1. *On the* Gradual Elevation *of the* Coast *of* Sicily *from the mouth of the* Simeto *to the* Onobola. By Gaetano Giorgio Gemmellaro. Communicated by Sir C. Lyell, F.R.S., F.G.S.

A recent alluvial soil which forms the plain of Catania is composed of rolled blocks (*ciottoli*) of sandstone, limestone, and basalt, with clay and sand. Volcanic currents from Etna more or less recent, all augitic,—basalt, for the most part spheroidal and prismatic, a pleistocene formation which has succeeded to that of the Terre Forte of Catania, ancient prismatic and compact currents from Etna, recent alluvium from San Tecla to Mascali, formed of volcanic felspathic and augitic rocks—these elements constitute the topography of the coast of Sicily from the mouth of the Simeto to the Onobola.

From the Simeto to the Sciarra del Principe it is difficult to find characteristic features in the recent alluvium, such as may mark the lapse of time. The Sciarra del Principe, a volcanic current of 1669; the shore at Catania, in which are seen pebbles of sandstone, recent lavas, and fragmentary matter; the Sciarra dell' Armisi; that of the Crocifisso of Lognina; the current of 1361,—these form the coast to the neighbourhood of Lognina, and have been much changed from their primitive aspect, these materials being daily used in the construction of the mole at Catania.

In the Scala di Lognina, from 4 decimetres to 1 metre above the level of the sea, among great blocks of lava which form the shore, one may observe a marine breccia, formed of small blocks of sandstone, augitic lava, and fragmentary matter, cemented together by a calcareo-siliceous cement.

From Lognina to Aci Castello, the volcanic currents which form the shore present nothing of interest. Here begins the basaltic current which came to the surface of the earth before the pleistocene formation; and as far as the Capo de' Molini, the study of the coast is interesting in every respect.

From the Pietra delle Sarpe, passing by the *cotello* to the *cannito* of S. Giuseppe, the front of the volcanic current of 1169 has a very compact structure, and forms a perpendicular cliff, showing in several points, and for several metres in height, a zone of corrosion, depending on the chemico-mechanical action of the sea-water. The lava, from the upper part of which the blocks come that are seen along the shore, shows itself with a very scoriaceous and irregular surface at the height of from 8 decimetres to 1 metre above the level of the sea, which makes one suppose that the igneous current must once have touched the waters of the sea. Besides this, which is observed in all lavas which are in contact with the waters, it appears that we may also add the presence of many *Serpulæ*, which indicate that the current formerly touched the sea-water, and that it still preserves its primitive configuration.

From the west of the Cannito of S. Giuseppe to the basaltic rock on which the ancient castle is built, one may see the same volcanic current, which covers the spheroidal basalt, metamorphosed for 3 decimetres from its surface of contact. The south side of the rock, formed entirely of spheroidal basalt and piperino, being in a state of decomposition, falls continually, and presents nothing that is interesting for examination.

To the north of the rock the same lava of 1169 is excavated and corroded at different heights; and at 2 metres above the level of the sea, we find adhering a coarse shelly sand, in which may be distinguished, almost in a normal position, *Cypræa lurida*, Lamk., *Turbo rugosus*, L., *Patella cærulea*, Lamk.(?), *Patella scutellaris*, Lamk., and *Balanus balanoides*, Rang.

Along the shore from the Pietra degli Uccelli northwards there are a great quantity of blocks of prismatic lava, some of the size of 4 to 7 decimetres, perfectly rolled, and others subangular, masses of 1 and 3 cubic metres, to which adheres a shelly calcareo-marine deposit of the recent epoch.

These blocks, thus rolled and subangular, are generally corroded on the surface by the chemical action of the chloride of sodium of the sea-water; and this condition extends for many metres above the sea-level to the northern side of the provincial road, in the farm of Signor Zappola and of Barone Sisto. Here these blocks rest on the pleistocene formation, which succeeds to that of the Terre Forte of Catania, and which is seen at Cefali, Leucatia, S. Paolo, and Catira; they are generally 2 or 3 metres in thickness, usually corroded like a wasp's nest on the surface.

At the height of about 14 metres above the level of the sea is an oval block, well rolled, 8 decimetres long and 4 wide, encrusted by *Serpulæ*. At a few paces from it is seen another block of prismatic lava of the enormous size of 7 cubic metres, about 13 metres above the level of the sea, also corroded on the surface by sea-salt, to the northern face of which *Serpulæ* are adhering; and in a crack was found a shell, which I believe to be *Cardita calyculata*, Brug., which is living on our shores. On the surface of the soil have been found many shells in a sub-fossil state, among which the most prevailing are *Trochus fragraoides*, Lamk., *Trochus articulatus*, Lamk., *Donax trunculus*, L., and *Patella scutellaris*, Lamk., which, although they have been generally referred to the pleistocene fauna, must be rather considered, as Sir C. Lyell pointed out to me on the spot, as shells of the more modern epoch or raised coast.

To the south of Aci Trezza, a group of basalts raise their crests above the sea, and are commonly called the Faraglioni, or Cyclopean rocks, the largest of which is called the Island, or Faraglione grande, and on their surface they have clay more or less altered by the intrusion of basalt.

Beginning an examination of them from west to east, we first see the so-called Faraglionelli di Passaggio, which are, in my opinion, the most important in the researches in which I am occupied. On their sides we find attached large pieces of a calcareo-siliceous shelly marine deposit of the actual epoch, of which the highest is 5 metres 6 decimetres above the level of the sea. It is everywhere bored horizontally by the *Modiola lithophaga*, Lamk., which is sometimes found entire, and sometimes in various states of alteration. Besides this, I have also found adhering the *Lima squarrosa*, *Arca Noæ*, *Cardita calyculata*, *Spondylus gæderopus*, *Murex truncatus*, *Dentalium entale*, *Ostrea plicatula*, *Vermetus gigas*, *Vermetus triqueter*, and many *Serpulæ* identical with those which live on the corresponding coast.

The Faraglione of the Birds (degli Uccelli) presents also on its sides fragments of the same calcareo-siliceous deposit, but less extensive. On the east side there is one patch entirely isolated, which, after great labour, I reached, up the perpendicular ascent of the decomposed rock. I measured the height, which is 11 metres 1 decimetre above the water. This fragment (*lembo*), which marks one of the greatest heights in our coast above the sea in the present epoch, is isolated on the side of the basalt; perhaps because the rock, having fallen into fragments, may have carried with it the lower part, which was its base. The basalt presents no lithophagous shells in its structure; but corrosion is seen at some points, which depends, in my opinion, on the action of external agents, and chiefly those of the salts of sea-water, which continually tend to bring it down.

The Pialsagia and the Faraglione del Mezio have also on their weathered sides patches and fragments of the same nature; and to the west of this last such patches are at considerable heights, and in the zone of the *Modiola lithophaga*, Lamk.; here we see adhering a very large *Spondylus gæderopus*.

The Faraglione grande at a certain height, in consequence of the continual giving way of its prisms, presents nothing of interest to the observer; whilst in the lower part we find patches of the usual calcareous deposit 4 to 6 metres above the sea.

In the island we find interesting phenomena. On its sides are many fragments of the calcareo-siliceous shelly deposit more or less high above the level of the sea; here the argillolite and there the basalt show a zone of irregular corrosion some metres from the water. The island has large clefts, almost all directed from north to south. In the most western of these, on the sides, are great quantities of patches of calcareo-siliceous deposits, similar to those which are seen on the flanks of the other basaltic rocks, extending from the level of the sea to the height of 7 metres 8 decimetres, the maximum. These patches are horizontally bored by the *Modiola lithophaga*, Lamk., which is found in all periods of its organic development; and we also find great part of the littoral shells now living on the coast. The argillolite, which forms the sides of this cleft above the before-mentioned patches, is also bored for about 5 more metres by the *Modiola lithophaga*, Lamk.; so that we have at this point one side bored by lithophagous shells, as high as almost 13 metres above the sea.

In the great *eastern cleft* we find a marine breccia, formed of blocks of augitic lava, basalt, and argillolite, at the height of from 4 to 6 metres. In it there are great quantities of shells, which are in a fine state of preservation; among these many are adhering to the breccia in a normal position.

Of these, the following species are identical with those now living on our shores:—*Arca Noæ*, L., *Cardita calyculata*, Lamk., *Patella cærulea*, Lamk., *Fissurella gibba*, Phil., *Monodonta corallina*, L., *Buccinum variabile*, Phil., *Rissoa calathisca*, *Trochus cingulatus*, Brocchi, *T. Adansonii*, Payr., *Mitra lutescens*, Lamk., *Colombella rustica*, L., *Turbo neritoides*, L., *Cypræa lurida*, L., *Vermetus gigas*, Biv., and others.

The lateral walls of these clefts are bored by *Modiola lithophaga* regularly and horizontally, which holes are seen at the height of about 9 metres above the sea-level.

Along the shore from Aci Trezza to Capo de' Molini we may continually observe, at the height of from 3 to 5 metres, large blocks of prismatic lava and basalt, rolled and blunted, the calcareo-siliceous shelly deposit, and marine breccia, formed of pebbles (*ciottoli*) of augitic lava, of basalt, and sandstone, and of gasteropodous and lamellibranchiate shells.

From this place to Aci Reale, the recent volcanic currents do not present any phenomena of interest. On the shore of the cliff of the Scalazza of Aci Reale, we find large blocks of compact augitic lava more or less rolled and rounded, which have generally the surface corroded by the action of chloride of sodium and other salts of the sea-water. We likewise find in this place, among the blocks, the calcareo-siliceous deposit, which extends upon them from 2 to 4 metres in height; and the immense current, which forms the wonderful Grotto delle Colombe, shows a zone of erosion several metres in height.

The shore of S. Tecla is almost entirely formed of recent alluvium, the materials of which are pebbles of felspathic and augitic lava of various sizes. Then come volcanic (augitic) currents from Etna, more or less recent; and lastly, from Prajola to the Onobola a great alluvial deposit extends along the shore.

Now from these observations we may discern—

1st. That from the shores of the Simeto to the Onobola we find from place to place undeniable characters of the ancient levels of the sea in the recent epoch.

2nd. That the great blocks with blunted angles, rolled, and corroded on the surface, the calcareo-siliceous shelly deposit, and the marine breccia, which are seen at different heights above the level of the sea, are the effect of the continued and daily action of the waves of the sea.

3rd. That the existence and disposition of the holes of the *Modiola lithophaga*, Lamk., in the calcareo-siliceous shelly deposit, and the normal position of the shells, both gasteropod and lamellibranchiate, make one suppose a slow and gradual elevation of the coast.

4th. Lastly, that the *Lithophagæ* and the calcareo-siliceous deposit being found on several islands and on the Faraglione of the Birds up to the height of almost 13 metres, and on the shore of the Pietra degli Uccelli there being large blocks of lava, blunted, rolled, and invested with *Serpulæ* to the height of 14 metres, we may establish the mean height to be 13 metres and 5 decimetres,—the greatest height of the now undeniable gradual elevation of the coast of Sicily from the Simeto to the Onobola during the present period.

2. *On* Fossil Shells *and* Striated Boulders *at* High Levels *in* Scotland. By Thomas F. Jamieson, Esq. In Letters addressed to Sir R. I. Murchison, V.P.G.S., &c.

[As the notices read before the Meeting from these letters are fully detailed by Mr. Jamieson in a Paper received shortly afterwards, the latter is here printed in full.]

On the Pleistocene Deposits *of* Aberdeenshire. By T. F. Jamieson, Esq. Communicated by James Smith, Esq., F.G.S.

In the lower districts of Aberdeenshire, all along the coast, we find the rocks almost entirely hidden by a clothing of superficial matter, varying in quality from fine clay to stony earth, loose shingly gravel, and sand. In some places this covering is of great depth, exceeding even 100 feet in thickness, and is most developed in wide basin-shaped tracts, where the rock sits low. Much of it seems to have been gradually accumulated under the waters of a former sea, and, when now exposed to the light of day, presents a series of stratified layers of silt, sand, and clay, occasionally disposed in laminæ as thin as paper.

A careful search now and then discloses traces of marine shells scantily dispersed, either in the shape of broken fragments or, more rarely, in a perfect condition—bivalves entire and shut, with the delicate skin or epidermis in complete preservation, apparently in the spot where the animals had lived and died. In other places, however, we find large boulders, and blocks sometimes of gigantic size, together with deposits the character of which cannot be accounted for by the causes at present operating on our coast.

Commencing at the southern boundary of the shire, I shall proceed north, sketching the features of the coast as I go along.

At the mouth of the River Dee the denuded remains of these beds are found on both sides of the stream; and at the Torry brickwork on the southern side, the succession of strata is as follows:—

1. Shingle, or coarse water-worn gravel, irregularly bedded . . . . 7 feet.
2. Finely-laminated clay, varying in colour from yellowish-brown to red and bluish-grey. Contains some thin seams of fine sand . . . . 22 feet.
3. Gravel; depth unascertained.

No organic remains appear to have been got in this excavation, the base of which is probably rather below the present sea-level. At the bottom of the uppermost gravel-bed, and resting between it and the subjacent clay, I saw an angular boulder of quartzose gneiss, between two and three feet in length. None were seen by me in the clay itself; but the manager of the work told me that they are occasionally found in all the beds. I suspect they must be of small size, for I saw no large blocks lying about the place.

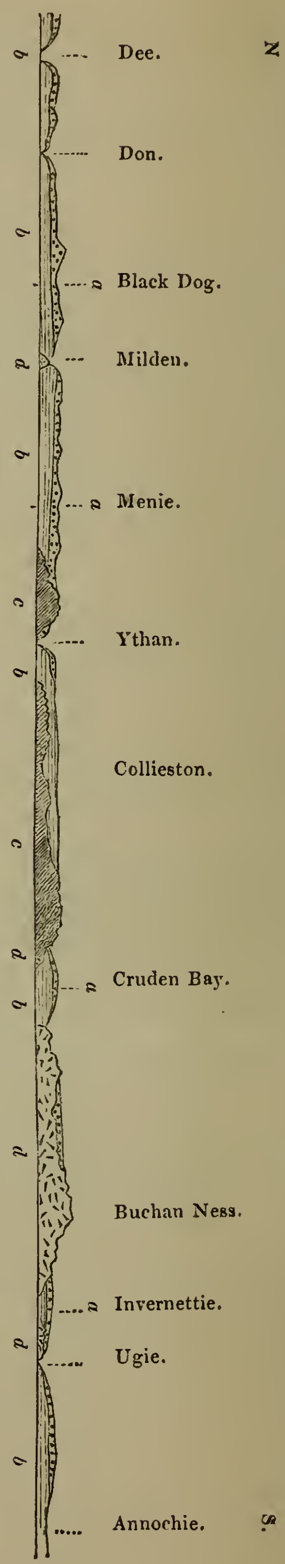
At another brickwork, on the opposite side of the river, the series of beds, commencing also at the surface, is—

		Feet.
1.	Water-worn gravel and sand, stratified	12
2.	Alternating seams of fine sand and brownish clay, the layers very numerous and somewhat undulating	20
	The clay gets redder towards the lower part, and passes down into	
3.	A mass of fine brick-red clay	17
4.	Fine light-greyish clay, with thin seams of sand	10
5.	Sand and gravel irregularly disposed..............	10
6.	Strata of fine pale-greyish clay, laminated and containing seams of small sand	20
7.	Fine sand; depth unascertained.	

In the mass of red clay the skeleton of a bird was obtained about twelve years ago. It is now in the museum of the Marischal College, Aberdeen, where it is ticketed as the bones of a duck. I have not seen any shells or other organic remains from this excavation; but the workmen told me that, a few years ago, they had found in the lowermost clay-strata the remains or impression of what they thought were fossils, but nothing that would bear removal. No boulders or large stones were seen by me in any part of this excavation; the clay-strata are, indeed, remarkably devoid of stones and pebbles of every kind.

The bottom of the cutting is a little below the present high-water mark.

The greater part of the city of Aberdeen appears to stand on this gravel-covered clay; and some borings for Artesian wells, attempted in different parts of the town, reveal its connection with the sub jacent rock.



d. Granite. c. Gneiss and mica-schist. b. Stratified clay and sand. a. Gravel and boulder-clay.

Fig. 1.—*Section along the Coast of Aberdeenshire.* Length about 35 miles.

I have obtained the following account of the most interesting of these bores. One sunk at the Woolman Hill pierced through—

	Feet.
1. Vegetable mould	6
2. Grey or bluish clay	18
3. Sand and shingle	20
4. Light blue clay	6
5. Rough sand and shingle	3
6. Old Red Sandstone conglomerate	115
7. Alternating strata of compact red sandstone and clay	74
8. Mica slate	9

Another, executed by Messrs. Richards and Co., disclosed the following beds:—

	Feet.
1. Moss and black earth	18
2. Gravel and small stones	14
3. Reddish clay	5
4. Loose sand and clay	6
5. Rock, mostly granitic	132

To the north of Aberdeen the coast is low, with a sandy beach all the way to the River Ythan.

Between the mouths of the Dee and Don the surface is generally occupied by coarse water-rolled gravel and shingle, which frequently assumes the form of large irregular mounds and hillocks, such as the Broad Hill, the Powder-magazine Hill, and others. This gravel, so far as my observation goes, is found to rest upon fine strata of clay and sand, occasionally exposed in cuttings at the outskirts of the town. For instance, at the Seaton Brickwork, near the River Don, the following section is got:—

	Feet.
Gravel	3
Fine clay of a yellowish-brown or bluish-brown hue; contains some thin seams of sand	16
Sand and gravel; depth unascertained.	

The bottom of this section is also about the sea-level. No shells appear to have been found here. These brickworks are generally established at a spot where the gravel-covering is thin, in order to avoid the expense of reaching the clay.

Keeping still close to the sea, we find another excavation for clay about 2½ miles to the north of the River Don, at a place known by the name of the Black Dog. Here the cutting discloses—

	Feet.
Coarse gravel and shingle, water-rolled	4
Fine strata of clay and sand, disposed in undulating layers; contain broken shells	11
Sand; depth unknown.	

The clay varies in colour from brick-red to a dull-greenish tint, and predominates over the sand, which is of fine quality and brownish colour. The shells that occur in some of the seams, although apparently all in a broken or comminuted state, yet often retain their glossy surface. Those which I found were in very small fragments; amongst them, however, I could recognize the *Cyprina Islandica*, *Tellina solidula*, *Saxicava rugosa*, *Cardium echinatum*, and a species of *Astarte*; and doubtless others occur. No boulders were seen in these beds of sand and clay. The meeting of the upper bed of gravel with the clay forms a distinct horizontal line, the two masses not mingling where they join. The section here is also not much above the sea-level, although somewhat higher than the last.

Large irregular mounds and straggling narrow ridges of coarse gravel abound in this locality, known by the name of the Hills of Fife. I have not met with any shells in this gravel, the base of which seems to rest on the stratified beds.

A little further on, and we come to the Burn of Millden, along the banks of which we again find the stratified clay and sand cropping out. A section, the base of which is probably not more than three feet above high-water mark, shows some 16 feet of alternating layers of pure red clay and fine greyish sand, quite devoid of all stones. These strata are arranged horizontally, and terminate somewhat abruptly towards the sea. Their surface indicates considerable denudation; and on the top of one of the banks, lodged amongst the bent-covered sand which drifts off the adjoining beach, I found two or three boulders of gneiss, granite, and syenitic greenstone,—the largest not exceeding 3½ feet in diameter. Some boulders of granite and trap occur also in the bed of the stream. These may have been left by the agency which denuded the clay.

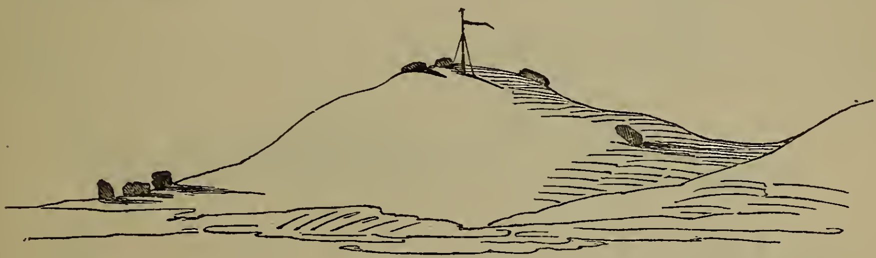
A short distance further up the stream, and at a height of probably not more than nine or ten feet above the sea, there is a very small patch of what appears to be the Old Red Sandstone conglomerate, but quite smothered beneath a heavy mass of the stratified sand and clay.

Mounds and ridges of coarse ferruginous shingle and gravel, all water-rolled, come nearly close up to the top of these banks, as if superimposed abruptly on the stratified beds,—while, a little further north, some small cuttings occasionally show the gravel overlying fine red clay.

The great mass of shingle, however, retreats inland a short distance here, returning towards the beach at Menie, from whence it may be traced, with hardly any interruption, to the mouth of the Ythan.

In the neighbourhood of Hopeshill the fields abound with large boulders, mostly of syenitic greenstone and other varieties of trap, similar in quality to rock *in situ* a few miles to the west. Near the Menie Coast-guard Station I found these large boulders of trap, granite, and gneiss resting on the top and surface of the gravel-ridges (fig. 2), some of them measuring six feet in length, and more or less rounded in form: I traced them also amongst the low hillocks of blown sand overgrown with bents, which margin the beach, occurring sometimes singly, sometimes in clusters, and of various sizes up to 11 or 12 feet in length. Their surfaces are either rounded or rugged, scarcely ever angular, while in mineral character they are generally of greenstone and syenite.

Fig. 2.—*Diagram showing the position of the Boulders at the top and on the surface of the Gravel-mounds at Menie Coast-guard Station.*



In a field on the farm of Drums a gigantic boulder of granite occurs, known as "the Grey Stane." I found it to measure 54 feet in circumference, with a height of about 7 feet above the ground. It has no sharp angles, and most of its exterior is rounded. Another immense block, also apparently a transported mass, is seen lodged in the surface of a field near Menie. I found it to be 78 feet in circumference, and projecting 6 feet out of the ground. It is a coarse-grained greenstone.

Drums seems to take its name from these tumuli and hillocks of gravel,—*Druim* in the Celtic language meaning a ridge or little hill, and being of frequent application in the names of places.

I found these ridges to consist of highly-rolled fragments of rock of all sizes, from coarse gravel up to boulders 2 feet in diameter. Those of gneiss are perhaps most numerous, often of a hard, tough, crystalline nature, yet much worn and rounded, showing the great attrition which they have undergone. Granite, both grey and red, is also plentiful, and lumps of serpentine occasionally occur, with other varieties of trap; but, besides these, there are a good many rounded fragments of red sandstone in several places, both at Drums and near Menie. On the top of one of these gravel-ridges, a little to the north of Drums, I found a boulder of coarse crystalline rock, of a greenish tint, measuring 8 feet in length by 5 in breadth. No sharp angles occur on its surface. A layer of red clay, about 9 inches thick, overlies the gravel at this spot; and I found traces of a similar clay covering the gravel at Drums. This boulder rested immediately upon the gravel; but the clay encircled its base. Another large boulder of greenstone lay beside it; and many other blocks were observed in the adjoining fields.

Here, then, are clear instances of large transported boulders sitting on the top of these abrupt ridges of water-worn shingle. It seemed rather remarkable to me that I had never met with any of these larger blocks imbedded in the gravel itself; nothing larger than 2 or 2½ feet in diameter has occurred to me. I have, however, been informed by workmen that they do occasionally find boulders even of very large size in the interior of these gravel-mounds.

Reaching the estuary of the Ythan, we find the coast much encumbered by great heaps of drifted sand; and tradition relates that a small parish, called Forvie, was here suddenly overwhelmed by the sandy drift. Coarse gravel and stony earth generally cover the surface, on piercing through which, however, the stratified beds are often exposed at the lower levels. For instance, on the north side of the estuary, at Westfield of Auchmacoy, the following section has been laid open:—

	Feet.
1. Gravel and coarse water-worn shingle	3
2. Strata of fine clay, varying from red to pale grey, with occasional seams of fine sand	7
3. A layer of gravel	0½
4. Pure red clay	2
5. Gravel; depth unascertained.	

The bottom of this section is rather below high-water mark. Fragments of shells occur occasionally in the sandy seams, chiefly in No. 3.* Up beside the dwelling-house, at a level of probably 50 feet higher, in sinking a well, the layers passed through were—

	Feet.
1. Shingle and coarse gravel	3
2. Coarse red clay, containing small fragments of stone	9
3. Fine brownish sand, quite devoid of all stones or gravel	26

The bottom of this sand was not reached; and no water was got.

Finely-laminated clay, I find, occurs up the valley of the Ythan for some miles, but is seldom exposed to view. In sinking a well in the village of Ellon, 4½ miles inland, the beds exposed were—

	Feet.
Coarse water-worn gravel.......................	11
Fine laminated clay, varying in colour from brick-red to pale-greenish grey	33

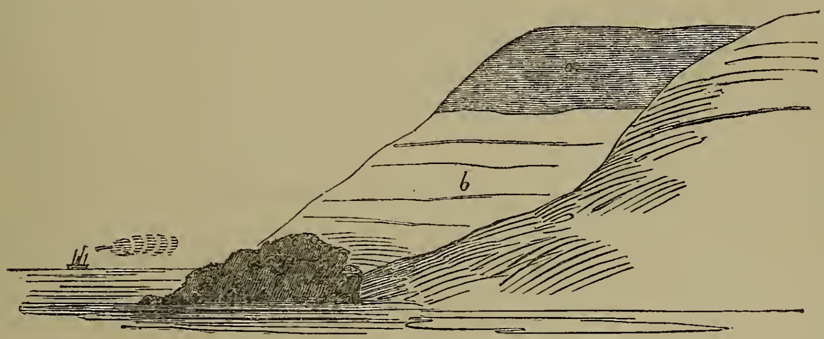
This clay was not passed through, so that its depth was not ascertained; and the bottom of the bore here would also be about as low as the sea-level.

Along the south bank of the Ythan, below Ellon, the same fine stratified clay occurs, covered by masses of water-worn gravel, and sometimes by a stratum of stony earth, full of boulders of all sizes,

* Since the above was written, I have obtained the fragments of what seems to be the skull of a Common Seal (*Phoca Vitulina*, Linn.), from the layer of red clay No. 4.—October, 1858. T. F. J.

up to a weight of about a ton and a half, and of a mineral character similar to rocks which occur further up the valley.

Fig. 3.—*Section at Collieston Coast-guard Station.*



a. Clay. *b.* Sandy strata. *c.* Gneiss.

About a couple of miles to the north of the River Ythan the sandy beach gives way to a rocky coast of gneiss and mica-schist, which continues without interruption to the Bay of Cruden, a distance of more than five miles. These cliffs very commonly present a face from 60 to 100 feet high towards the sea: where the rock itself attains this elevation it is generally destitute of superficial covering, or has sometimes a thin layer of coarse clay; where, however, the rock sits low, the additional height is made up of grassy banks, which appear to be composed of red clay and sand, stratified, frequently in an undulating manner. Owing to the grassy surface, the interior of these banks is seldom disclosed by any good section. At the Collieston Coast-guard Station (fig. 3), however, a slip has laid the mass open from top to bottom, showing—

	Feet.
1. Red clay, devoid of stones, but without any stratification-lines apparent	17
2. Strata of the finest sand, varying in colour from pale brownish-grey to reddish	56
3. Gneiss-rock, covered by a foot or so of its own debris	30

The sandy strata lie horizontally with some gentle undulations: they are quite devoid of all stones, pebbles, or coarse gravel. In some small seams of coarser sand, near the bottom of the mass, I found traces of broken shells, but so comminuted as to render any knowledge of the species unattainable. The junction of the clay and sand forms a line nearly horizontal; and the sea-waves wash the foot of the rock.

At a cliff, a mile or so to the north of Collieston, some slips show that the gneiss is covered by 30 or 40 feet thick of strata, composed almost entirely of fine sand varying in hue from red to grey. Some seams of pebbly gravel occur in several places, interstratified with the fine sand in undulating layers. These gravelly seams contain fragments of broken shells, amongst which I could distinguish the hinge of the *Cyprina Islandica,* also bits of smaller Pectens and pieces of a bivalve shell, ornamented with fine radiating striæ between the growth-lines. Along with these shells there occur also many small bits of grey and yellow limestone, which appear to have been derived from secondary formations.

All along the coast of Slains, the mass of sandy strata seems to rest directly upon the gneiss-rock, without the intervention of any other deposit. Sometimes the top of the bank consists partly of fine red clay, occasionally interstratified with the sand.

No large boulders are seen in these strata; but large boulders occur in the fields immediately back from the brink of the cliffs, as if resting on the surface of the deposit. These blocks are of greenstone, gneiss, and granite.

Further north, towards the Bay of Cruden, the rocks get higher, and the Pleistocene deposits retire from the cliffs, which are generally bare. The gneiss is thrown into long undulations, and gets more contorted and altered in texture as it approaches the granite, which first shows itself at the southern side of the Bay of Cruden. At the bay itself the rocks disappear, and a low expanse of drifted sand is backed by steep grassy banks, which appear to be composed almost entirely of Pleistocene beds. These banks attain a height of about 120 feet above high-water mark, presenting a steep front to the sea. Their base is perhaps 10 or 12 feet above the sea-level. No good section reveals the structure of these slopes; but near the top of one of them, about 5 feet of coarse red clay is seen resting on fine soft sand, of a reddish-brown tint, indistinctly stratified, and quite free from stones. The clay shows no stratification-lines, and contains pebbles of greenstone, granite, quartz, &c., more or less rounded. I picked out one fragment about 5 inches long, smoothed on one side, and covered with many striæ in different directions. Towards the northern side of the bay these banks appear to have suffered denudation, and are much lower and more undulating. A section, 18 feet deep, shows fine, soft, reddish sand, containing several thin seams of red clay. Following up the Burn of Cruden, deep masses of fine sand and clay appear to occupy the ground on both sides; and at Ardiffery we find the stream flowing along the foot of steep banks about 130 feet high, and the ground slopes up behind perhaps 20 feet higher, making a total height of 150 feet. These banks appear to be composed, to their very base, of sand and clay. The stream here cannot be many feet above high-water mark—perhaps 15 feet. No deep extensive section occurs; but slips in various places reveal the structure of the mass almost from the top to the bottom. The lower part of the bank, to the height of about 20 feet above the stream, is concealed by the low slope of the ground, beyond which several small sections disclose regular horizontal strata of very fine sand, mostly of a pale-grey tint, but occasionally reddish. Amongst this sand there occur a few thin layers of fine brick-red clay. The appearance of these sandy strata, deep down in this bank, very closely resembles the lower part of the cliff at Collieston; and in like manner I found them to contain minute fragments of shells. A shell, said to have been obtained in these banks, is in my possession, which I received from Mr. Dawson of Cruden. It appears to be the *Mangelia turricola* of Forbes and Hanley, and is somewhat water-worn, although almost entire. The only stone of any kind which I found in these sandy layers was a small pebble of flint. The strata here are horizontal, not undulated, but often finely rippled.

Higher up, the sandy strata seem to be of a more reddish hue, containing seams of red clay; and some coarser stuff, with boulders, appears to occur occasionally, as if it had slipped down in some places. The upper part of the bank is not exposed by any good section, but seems still sandy; while higher up still, where the ground slopes back, there is some coarse gravel or stony stuff exposed at the side of the adjacent fields.

These Pleistocene deposits, although still of great depth in this locality, have no doubt been worn down and washed away to some extent during the course of events which intervened betwixt the period of their deposition and the last movement of elevation. This denuding agency, in cutting down the stratified beds, must have thrown their materials, together with other debris, into positions which are now difficult to be explained. It will be safest, therefore, to rest any theories upon good, clear, extensive sections, where this disturbing element can work no mistake.

To the north of Cruden Bay the coast is composed of red granite all the way to Peterhead, forming cliffs from 70 to 150 feet high, and upwards. The top of these rocks is more or less bare, and destitute of any considerable covering of loose matter. In some places a depth of 3 to 4 feet of clay and stony rubbish occurs; and it is worthy of note that the stony debris is not made up of granite, but of the detritus of slaty gneiss, with varieties of porphyry and quartz: sometimes a few bits of red sandstone may be found. Some slight difference may be occasionally remarked in this superficial mass, the upper part being less stony, and of a red colour, more of the nature of red clay, while the lower portion next the granite is little else than a mass of small stony debris, the fragments mostly angular or little worn, although there are also many rounded pebbles. One large boulder of red granite, perhaps 6 feet in diameter, I noticed amongst this stony stuff, resting on the top of a narrow precipitous ridge jutting out into the sea, immediately south of the Bullers of Buchan.

To the north of the Buchan Ness the rocks sink down to a low height, and in some places disappear, and the Pleistocene deposits again show themselves. No good section is seen, however, except at Invernettie, where a brick- and tile-work has long been established. The excavations are made in the face of a bank, which rises up from the sea-beach to a height of nearly 50 feet. I found its structure to be as follows:—

		Feet.
1.	Blackish loamy earth	1
2.	Reddish-brown clay, apparently devoid of stratification or lamination, and containing stones of various kinds, and of all sizes up to 4½ feet in diameter; often striated and grooved on the surface	30 to 40
3.	Clay of a brick-red colour and finer nature, and apparently free from boulders	1 to 2
4.	Very fine, laminated, dark-brownish clay, quite free from stones	2 to 4
5.	Fine brownish-grey sand, devoid of all stones or pebbles of any kind: the bottom of it has not been reached; but it has been penetrated to a depth of	20

The foreman of the work told me that this finely-stratified clay and sand had occurred regularly at the base of the bank all along, covered deeply by the coarser clay with boulders. The fine sand at the base of the bank must extend beneath the sea-level. The stones which I found in the deep mass of boulder-clay were of granite—both red and grey, crystalline schist of different varieties, greenstone and other kinds of trap, sandstone, and flints. The largest block was of a fine-grained, tough, greenish rock, 4½ feet long by 2½ feet broad and 1½ thick. It was rough and angular on all sides but one, which was smooth and worn, as if it had been rubbed strongly over some hard surface. There were several sets of scratches, grooves, and furrows, mostly short, and tending in one general direction, viz. parallel to the longest diameter of the block. The granite-blocks were generally more rounded, and occasionally grooved, but much less distinctly; those of greenstone are also occasionally smoothed and scratched. The largest piece of sandstone was greyish, moderately fine-grained, measuring in feet $3 \times 2 \times 1$, angular and rough on the surface.

Many of the boulders are striated on all their sides. The stones in this upper bed of clay do not bear a very large proportion to the whole mass; so that the clay is used for making bricks and tiles after the stones are extracted. In this boulder-clay I found also traces of broken shells, occurring in films of coarse reddish sand in various parts of the deposit. I also picked a broken fragment of shell out of the finely-laminated clay No. 4.

Several years ago, the skeleton of a bird was found in this bank, at a depth, it is said, of 25 feet from the surface, and about 15 or 20 feet above the level of the sea. I have not hitherto discovered what became of this skeleton. When in search of it, in the Arbuthnot Museum, Peterhead, I found an organic remain with the following label:—"Fossil vertebra found in excavating clay at the Brickwork, Peterhead, August 1825, 38 feet below the surface, *placed on what has been the sea-beach*." The words in italics were somewhat indistinct, the ink being much faded. This fossil

I found to be $6\frac{1}{2}$ inches in diameter and $4\frac{1}{2}$ inches thick, and of a general roundish aspect. What animal it had belonged to, I cannot say—probably some large fish. There are no spinous processes or bony projections from it. From the depth at which it was found, it would seem to have been about the top of the mass of fine sand.

No rock is exposed at the bottom of this section; but it protrudes in the beach at a short distance on both sides.

Here, then, at Invernettie is a very good instance of a clay, containing numerous boulders, overlying stratified clay. I found the same thing at a place called Downiehills, nearly three miles to the west of Peterhead, and at a higher elevation. At this spot there is also a brickwork, and the brickmaker informed me that he had sunk a well 40 feet deep, and bored 12 feet further, without reaching the bottom of the clay, and that the section was—

	Feet.
Unstratified stony clay, of a reddish-brown colour, containing some large boulders and stones of many varieties, which are occasionally striated..........	20
Stratified clay, containing layers of different colours, but no stones	32

This uppermost boulder-clay is also fine enough for making bricks and tiles, after extracting the stones. He told me that he had got one block of granite in it about 3 tons in weight, some of the fragments of which he showed me, built into some adjoining masonry. It was of the red Peterhead granite, and showed the traces of the boring-iron upon it. No others had occurred nearly so large as this; but boulders are often found from 2 to 3 feet in diameter, and indeed I saw some of this size in the clay myself. In a heap of smaller stones which had come out of the same mass of clay, I observed fragments of granite of different varieties, also gneiss, trap, porphyry, and a few of red sandstone and flint, and one bit of limestone 4 inches long and striated on the surface, apparently belonging to secondary strata: it was fine-grained, but of impure quality. Two or three scratched and striated stones were observed by me; but they were far from numerous.

This boulder-clay, according to my informant, also contains shells, generally broken, but sometimes whole. They are, for the most part, so decayed that they cannot be preserved; but some of them appear to have been thick and strong. I have not ascertained the elevation of this spot, but should think it to be somewhere between 150 and 200 feet above the sea-level, or perhaps scarcely so much.

At the north side of the town of Peterhead some low granite-rocks, the base of which is washed by the sea, are seen to be covered by a mass of coarse gritty earth or mud, of a dirty-grey hue, full of small stones, some of which I found to be striated or scratched on the surface. They are of trap, quartz, and granite. This mass of stuff is about 8 feet deep, and rests immediately upon the solid granite-rock, without the intervention of any other layer whatever. Some indistinct undulations seem to occur in this deposit; but otherwise it is unstratified. No high banks occur here.

A little beyond this, the Ugie flows into the sea, draining a low basin of ground. I have found fine laminated clay composing the ground along its banks in many places, for several miles up its course, but frequently concealed by a deep covering of coarse gravel. At Ednie this fine stratified clay rests upon a mass of coarse stony stuff, which, however, is not clearly exposed. In sinking a well there was found, I am told—

	Feet.
Fine stratified clay	13
Coarse stony clay, dark-coloured, and apparently devoid of stratification	20

I found some traces of broken shells in the stratified clay here also. I am not aware that any large boulders occur in the lower mass. In the part of it which I saw, the stones were not of large size. This section, although little more than two miles distant from the sea in a straight line, is yet much more following the course of the Ugie. It is at no great height above the sea.

The coast to the north of the Ugie for many miles presents a broad sandy beach, backed by undulating banks of various height, but seldom, if ever, exceeding 100 feet. The drifting sand which blows off the coast hides everything, so that the interior of these masses is rarely to be seen. In some places, however, their structure is indicated, and seems to be a fine tenacious clay of a bluish tint.

About five miles to the north of Peterhead is the Annochie Brickwork, close upon the sea-beach. Here the excavations are made into the heart of these sand-covered banks, and disclose a fine, blackish-blue, sandy clay, quite unmixed with stones or pebbles of any kind. This clay has been penetrated to a depth of 25 feet, and found to pass into fine sand of a similar hue; but it is not known what lies beneath.

Deeply imbedded, then, in this fine bluish clay-mud, I found perfect shells occurring, in some places rather abundantly. The species were—

Nucula tenuis. Leda pygmæa. Lucina ferruginosa.

The last-mentioned is a very minute shell, and seems to be much less numerous than the two others. All the three are very delicate thin-shelled bivalves; but their preservation is so perfect that the greenish-yellow epidermis, or skin-like pellicle that covers them, is quite uninjured. They are, however, so friable, that the slightest touch converts them into powder; and on exposure to the air for some time, the epidermis loses its lustre, and sometimes shrivels up. Sometimes both the valves are in conjunction and shut; but more frequently, I think, they occur as single valves. It is also worthy of notice, that no broken or comminuted shell-fragments were observed occurring in this clay *.

* At a subsequent visit to Annochie, in company with Mr. Winter, the manager of the work, who most kindly gave me all the assistance in his power, I succeeded in finding nearly a dozen other fossils. Amongst these were several

Here, then, we seem to have the remains of the animals imbedded in their native mud. The assemblage and the deposit itself both indicate deep water; and these same species have been found congregating at a depth of from 30 to 100 fathoms on the western coast of Scotland, where they have all been dredged alive by Mr. MacAndrew. They are species, however, which are characteristic of a more northern region at the present day: in fact, until within these few years, the *Leda pygmæa* was not known to occur so far south as Britain, being principally developed in the Arctic seas; and even now it is known in only one locality, namely the neighbourhood of Skye.

This clay-bed appears to have suffered much denudation, and has an irregular undulating surface. No considerable section is exposed; and, as far as I could see, it appeared to be of a very uniform texture, without any distinct stratification-lines. The position of the shells is little above the present high-water mark; and the clay-bed appears to pass in below the beach.

We have here a great change indicated, from this old muddy sea-bottom to the present sand-encumbered coast, which abounds at this place in broken shells. In the course of a short search along the beach, I picked up specimens of the following species, mostly in broken fragments:—

Purpura lapillus.
Littorina littoralis.
Patella vulgata.
—— pellucida.
Cyprina Islandica.
Cypræa Europæa.
Trochus cinerarius.
—— zizyphinus.
? Astarte sulcata.
Mactra solida.
Tapes pullastra.
Donax anatinus,
Pecten pusio.
—— opercularis.
Nassa incrassata.
Buccinum undatum.
Mytilus edulis.
Solen ensis.
Venus striatula.

In some of the banks in the neighbourhood I found fine blue clay, of a similar appearance to that in the brickwork, but containing numerous minute regular crystals of sulphate of lime.

I have now sketched the greater part of the eastern coast of Aberdeenshire, and have shown that a deposit of stratified sand and clay, often of great thickness, appears to occur with considerable

specimens of Foraminifera. Of Mollusca there were two or three species of *Cylichna* (one of which seems to be *C. cylindrica*, the others resembling *C. obtusa* or *C. mammillata*),—a single valve of *Kellia*, apparently *K. suborbicularis*,—decayed specimens of *Panopæa Norvegica* and *Mya truncata*, variety *pullus* of Wood's 'Mollusca of the Crag.' These shells, however, were so decayed and friable as to render their determination difficult and doubtful. They did not occur in broken fragments, but were perfect in form, although the shelly substance was gone. I was told also that the skeleton of a fish had been found some years ago, but had not been preserved. Messrs. W. K. Parker and Rupert Jones have kindly examined microscopically some of the Annochie deposit, and they inform me that in about two thimblefuls of the dark-slate-coloured, fine, sandy clay, with roundish quartz-grains and some brownish mica, they have found several fine specimens of the *Polystomella crispa*, var. *striatopunctata*, two large specimens of *Cornuspira foliacea*, and a few little fragments (plates) of *Echinus*. —October, 1858. T. F. J.

regularity wherever the rock sits low, and that these fine strata are covered in some places by extensive masses of coarse gravel and shingle, and in others by a clay or earth full of boulders of many kinds, often of large size, and sometimes striated and grooved in a singular manner. It has also been shown that great boulders occur on the surface of the gravel-ridges, and, according to the accounts of workmen, occasionally imbedded in their interior, although I have not observed this latter fact myself*.

These stratified masses have been found resting on Old Red Sandstone conglomerate at Millden, and on gneiss and mica-slate along the sea-margin of Slains; and no clear instance along the coast has occurred to me of any mass of coarse stuff, containing large boulders, lying beneath them; nor have any large blocks been seen by me imbedded in the fine strata themselves. These are evidently the remains of an old sea-bottom of the later Tertiary period,—the laminated clay and sand having accumulated in the deeper troughs of the ancient coast, where they were beyond reach of the surface-agitation produced by the winds.

In the parishes of Slains and Cruden there are many knolls and ridges of water-worn shingle and gravel, which I have found in various places to contain broken marine shells. Perhaps the most remarkable of these are the gravel-ridges beside the Loch of Slains, locally known by the name of the Kippet Hills. They vary in form and size, but generally rise to the height of about 30 or 40 feet above their base. The sides are commonly steep, and their summit or ridge often so narrow that two carts could scarcely pass each other on them, while their breadth is such that a person standing on one side can easily pitch a pebble quite over them. In these features they would seem to resemble the Eskars of Ireland, the Kaims of the south of Scotland, and the Osar of Sweden, concerning the origin of all which there has been some discussion.

Our Kippet Hills can be traced, with hardly any interruption, for a distance of beyond two miles, in a tortuous, curving, or zigzag line without any definite direction. They are connected also with other gravel-deposits in the district; and their extent and relations are obscured to some degree by a deposit of red clay which covers them in many places.

Fig. 4.—*Diagram showing the Red Clay covering, and filling up the hollows of the Gravel-ridges at the Kippet Hills.*

a. Clay. *b.* Gravel.

* I am inclined to think that the gravel on the top of which these erratic blocks lie is of older date than the gravel covering the stratified beds at Aberdeen and elsewhere. It may belong to the same period as the gravel of the Kippet Hills.

As to the composition of these ridges, I have found them to consist of sand, gravel, and water-worn pebbles. In some places the mass is very coarse, showing no regular arrangement, but abounding in rolled stones of all sizes up to a diameter of $2\frac{1}{2}$ feet; few, however, exceed 1 foot in length. In other places the materials are much finer, passing from coarse pebbly gravel into undulating sandy layers. Broken shells occur in both sorts. The pebbles are of many different kinds; the most abundant seems to be micaceous schist, similar in character to what occurs along the adjoining coast, while gneiss, quartzose schist, granite, and greenstone are also plentiful. A bit of felspar and a flint or two may be occasionally found; and upon one occasion I picked up two small pieces of serpentine. But, besides all these, there are in many places a great abundance of red and grey sandstone, together with a multitude of limestone fragments, which vary in character and hue. They are always more or less water-worn; some are of a yellowish tint, and of a soft, tough nature, effervescing strongly with acids, while others are finely laminated, varying in colour from greyish-white to dull grey and yellow: these are generally of a fine earthy texture, and effervesce more feebly on being treated with nitric acid. The limestone fragments occasionally, though rarely, contain fossils. I have found a bit or two containing traces of small shells, and have seen one fragment of laminated grey limestone with the impression of a small fish: both the head and tail were wanting, owing to the wearing of the fragment; but when complete, it might have been about 6 inches long. According to the reverend author of the statistical account of the parish, these limestones were formerly sought out by the farmers, and burned for lime, being found "generally from 1 to 16 lbs. in weight."

I may mention that I have found similar bits of limestone in various parts of Cruden and Slains, and also more rarely in Logie-Buchan and Foveran; they are, however, more plentiful in these Kippet Hills than anywhere else. I have never found them either scratched or striated in these gravel-ridges, but have occasionally found them so in other places, where they occurred in clay or stony earth. No rock of the same nature is known to me in this part of Aberdeenshire; but, from the abundance of the fragments, confined as they are to a limited tract near the coast, I am inclined to think that the source from whence they came must be within the district, and that patches of similar strata probably occur deeply buried beneath the Pleistocene deposits which drape the whole country hereabouts.

With regard to the broken shells which are mixed up with this gravel, they are generally in very small pieces, and much worn. I can distinguish at least eight different kinds, and probably more. The hinge of the *Cyprina Islandica* is of frequent occurrence, its massy thickness having stood the wear and tear better than most others. I have found also some almost complete valves of a *Tellina*, which seems to differ from the *T. solidula* only in being thicker and stouter. It is a strong opaque shell, very tumid in the valves. Is this the *Tellina Grœnlandica*? Another is a shell of larger size, also a bivalve, and strong and thick, but very compressed in form. A fourth (of which, however, I have got nothing but small fragments) is a bivalve with strong concentric growth-lines, having the interstices ornamented with peculiar radiating striæ. It is also crenated along the ventral margin similar to the *Venus Casina*. Some of the bits have evidently belonged to a good-sized shell, and are thickened along the edge, while others are the remans of individuals of smaller size, or perhaps of a different species. I have found it in many different places. Fragments of *Astarte* and *Pecten* are also not uncommon.

I have stated (p. 516) that, in a cliff on the coast of Slains, and immediately opposite these gravel-ridges, I found in the sandy strata seams of gravel containing similar fragments of shells along with pieces of the same kind of limestone. It would therefore appear that these mounds are formed out of the same materials, and may, perhaps, be a development of those gravelly layers which are interstratified with the fine sand. They may be old submarine banks of gravel, which have subsequently been moulded into the form of ridges by denudation.

Their base is at about the same elevation as the top of the coast-cliffs, or perhaps a little lower, and they can be traced almost close to the cliffs, while it is also found that a stratum of red clay overlies both them and the stratified sand at Collieston; and further, in some places the gravel of these ridges appears to pass into fine sandy layers, similar to the masses along the coast.

The district in which these shelly gravels occur lies between the estuary of the Ythan and the Burn of Cruden, comprising an area of about 15 square-miles. This tract of ground culminates, with gentle slopes, in an eminence called Highlaw, whose height I found to be 299 feet above the mean level of the sea. The summit consists of a mound of gravel, while banks and knolls of coarse water-worn shingle form the most of the adjoining ground. In some places these masses of gravel show many undulating layers and seams of sand, while in others the disposition of the materials is more irregular. No broken shells nor fragments of sandstone or limestone occurred to me here. The materials were of gneiss, granite, quartzose rock, felspar, porphyry, and other kinds of trap, sometimes not much rounded. It appears then that, while fine sand and mud were accumulating in the deeper recesses of the ancient sea, here, on the shoals and higher portions, under some 40 fathoms less water, the soundings would have shown coarse gravel, sand, and shingle.

I remarked, however, that a deposit of red clay in many places overlies this gravel, filling up the irregularities and hollows of its surface. It is never of great thickness, and is generally absent on the higher mounds, or forms but a very thin layer over them.

A similar clay was found in many places overlying the gravel of the Kippet Hills (p. 522); and a thick mass of it covers the stratified sand in the cliff at Collieston. Do not all these instances point to a depression of the sea-bottom, converting its shoals into sunken banks, and its deeper hollows into yet profounder depths?

I did not observe any large boulders beside Highlaw itself, but some distance to the north, between it and the Episcopal chapel of Cruden, I found several occurring on the surface of the land, especially beside some small croft-houses. The largest were from 5 to 6 feet in diameter, but many were from 2 to 3 feet; and they consisted of red granite, gneiss, and trap. One of these blocks I observed to be much smoothed or ground down, and covered with striæ and scratches on part of its surface; and this occurred in a fragment of hard crystalline quality. On drawing the attention of one of the crofters to this circumstance, he said that he had noticed the fact, and that these markings were confined to the lower surface or *bed* of the stone. It had been a large block, some 6 feet in diameter, and had been blown to pieces by gunpowder when I saw it. Much of the ground here (which is at an elevation of probably 200 feet or upwards) seems to consist at the surface of coarse stony earth, varying in colour from reddish to a dirty bluish-grey, and contains many small stones of gneiss, granite, trap, micaceous schist, compact felspar, and quartzose rock. I picked up also two or three small bits of limestone of different colours, and similar in quality to those which occur in the gravel of the Kippet Hills. One of these limestone-bits was covered with striæ and scratches on both sides. I noticed also some nodules of flint, and a rounded pebble of red sandstone. Several striated fragments were observed by me in this coarse earth, the stones of which are seldom sharply angular.

In the Rev. Mr. Pratt's entertaining volume upon the district of Buchan, I find it stated that the outer walls of the parish-kirk of Cruden, erected in 1777, are said to have been all built "from the greystone of Ardendraught, a huge boulder of granite on the Oldtoun Farm, upon which, from time immemorial, *Hallow fires* had had been lighted."

I have pointed out that the stratified sand and clay can be traced for some distance up the rivers which fall into the sea along the eastern coast. The same is the case along the Moray Firth.

The Kinedart Water, a tributary of the Deveron, flows through a Pleistocene deposit of considerable thickness; and deep down in the high banks along which it runs, I found specimens of the following shells imbedded in a fine, dark, sandy mud:—

Tellina proxima.	Leda pernula.	Nucula tenuis.
? Tellina solidula.	? Dentalium.	

The most plentiful was *T. proxima*, always complete, with the two valves in connexion and shut, the dark-brownish epidermis remaining. What is, however, remarkable, the valves were always more or less cracked, especially the upper one, which was often quite *squashed* into the lower. It looks as if the shell had been crushed with the animal in it, as it is generally filled with a dark powder, and a blackish stain frequently extends to the sand around it. The specimens were often of large size, measuring $1\frac{1}{2}$ to $1\frac{3}{4}$ inch across. Pressure from above, and suddenly applied, seems necessary to account for the condition of these shells: the crushed fragments were never shifted *sideways* out of their position.

A thick mass of gravel and sand, forming the upper part of the bank, appears to have been thrown down upon this fine sandy mud; but there is no good section, at the place, to show their connexion. I found this sand and gravel in some places containing a great abundance of broken shells. There were many entire single valves of *Tellina solidula*, and fragments of *Astarte arctica*. Pieces of the *Cyprina Islandica* were also numerous.

The *Tellina proxima* is characterized by MacAndrew as the Tellina of Arctic seas, and is not now found alive on the British coasts. He gives its principal development at a depth of from 4 to 10 fathoms, but ranging down to 40. The *Leda pernula* is also now extinct in our seas, but is found from Drontheim to the North Cape, having a great vertical range of from 35 to 160 fathoms. The *Tellina solidula* is still found from Britain to Finmark, in more shallow water.

Here then, again, are the remains of the animals apparently where they had lived and died. The prevalence of *Tellina proxima* marks shallower water than the assemblage at Annochie does, as might have been expected; for this Kinedart deposit must be at an elevation perhaps 150 feet higher, situated in a sheltered ravine. Of the other shells I found but one specimen each; and these were single valves although uninjured, with the epidermis in fine preservation.

The evidence still points to a chilly climate, and a sea undisturbed enough for mollusca to flourish at least for a certain lapse of time.

In the valley of the Deveron itself, as far up as Huntly, I found finely laminated silt and loam exposed on its banks, at the height of 360 feet above the sea-level, and perhaps 50 or 60 feet above the river. No organic remains, however, occurred to me. Passing over to the valley of Spey I there discovered finely laminated silt, capped by sand and gravel, lining the base of the hills to a great height. On the east side of the stream, from Cairnty to Ben Aigan, it may be traced with little interruption, running up the Burn of Mulbain at a corresponding elevation; and I found it also on the west side. Having borrowed a spirit-level from one of the gentlemen engaged with the railway now in process of construction across the Spey, I proceeded to measure the height of these terrace-like banks on Eastertown of Cairnty, and found them to reach an elevation of 247 feet above the river, and 375 feet above the sea, at high-watermark, ordinary spring-tides of the Moray Firth.

Fixing the instrument on the summit, I took a sight across the Spey to the flat-topped fragment of a similar terrace on the west side, and found it to be at the same level. Turning my view up the river to a similar bank opposite Rothes, I ascertained that it was several yards higher, after allowing for curvature. I then swept the view towards the Moray Firth, and found, what was very apparent even to the naked eye, that I quite overlooked everything between me and its waters.

It thus became evident that here was no freshwater deposit accumulated in the depths of some dammed-up lake, but an indubitable portion of the ancient sea-bottom, when salt-water lochs stretched their arms far inland. No remnant of any barrier appeared, that could account for a lake at such a height; no glacier descending from Ben Aigan or any hill on the east side could have barred the valley down here; for there is no height on the opposite side that the icy avalanche could have rested on.

Thinking that the spirit-level I had used might be out of adjustment, and consequently not trustworthy for a long sight, I procured the loan of another good instrument made by Troughton and Simms, which had been adjusted but a few days previously, and with it also I found the Rothes bank to be considerably higher than Cairnty, and also that terrace-like deposits, equal in height to that of Rothes, occurred for some distance up the glen on the opposite side of the Spey. Whether, therefore, the elevating power had increased towards the interior, or whether it is that the strata in the lower part of the valley have suffered more denudation, may be questioned; yet the fact remains, that these banks rise in height as we ascend the valley. Those at Rothes are higher than those at Cairnty; and similar terraces which I observed above Aberlour, and also opposite Ballindalloch, seemed to me higher still; but want of time compelled me to leave their measurement unascertained.

The best section of these masses is at Rothes, where the bank that looks down upon the village, from an altitude of about 190 feet above the stream, presents the following section at its highest part:—

	Feet.
1. Loose gravel, sand, and shingle, stratified	30
2. Fine stratified sand and sandy mud, of a pale grey tint, containing no stones of any kind	45
3. Gravel and fine sand interstratified.............	15
4. Unstratified pebbly clay, some bands indistinctly seen here and there, colour dirty grey, somewhat reddish, no large boulders	15
5. Fine stratified sand and sandy mud, often rippled and waved, some seams containing a considerable proportion of clay, colour pale-grey, occasionally reddish. It contains no gravel, stones, nor pebbles of any kind........................	35
6. Base of the bank descending to the edge of the river, concealed by loose debris.............	50

In some parts of the bank the unstratified stony earth attains a considerably greater thickness; but at the time of my visit there was a very clear section at the point described. The arrangement of the beds was nearly horizontal. The stones and pebbles were of gneiss, granite, quartz, and similar crystalline rocks. No large boulders were seen; and I was disappointed to find no fossil remains in these beds, although a longer search might have been more successful.

Standing on the top of these high banks, and looking down upon the fertile lowlands of Moray, dotted with farms and thriving villages, I could not but picture to myself a time when the ocean rolled over its plains, and threw its breakers ashore even at my feet; here, far up on these hillsides, must once have been the old high-water-mark.

I shall now mention some other circumstances that tend to throw light upon the depth of the sea during a part at least of the Pleistocene epoch. The evidence of the Mollusca, so far as it goes, indicates that, at the period of their existence, the depth of the sea was not beyond a few hundred feet, even over the lowest part of the present land; and it is important to bear in mind that their remains have not been found anywhere in this part of the country at an elevation exceeding 250 feet. What I am now going to allude to, however, is the occurrence of beds of gravel and water-worn pebbles on the summits of some of the hills in this eastern part of Aberdeenshire.

I have shown that the top of the ridge about Highlaw, at an elevation close upon 300 feet, is occupied by gravel; there is also a ridge in the neighbourhood of Ellon, called Cross-stone, the top of which consists of great masses of water-worn pebbles and gravel at an elevation of 226 feet. The Hill of Auchleuchries, in the parish of Cruden, has also a crest of gravel, reaching a height of 356 feet.

Again, there is a ridge of hills which, commencing at the Buchan Ness, runs inland for seven or eight miles, rising gradually till it culminates, near its western extremity, in the Hill of Smallburn, at an elevation of 464 feet above the mean level of the sea. This ridge is remarkable for an abundance of flints, which are found along its summit from one end to the other. They are always water-worn, and sometimes contain chalk-fossils. Associated with them is a similar abundance of quartzose pebbles, which are also finely rounded and water-rolled.

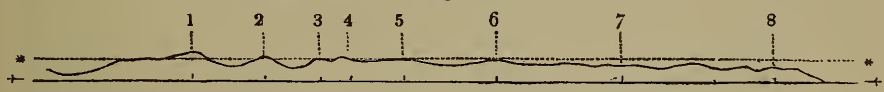
Both the flints and quartz-pebbles extend a little further west, to the hills of Skelmuir and Dudwick; but towards the western extremity of the latter the flints gradually die away, and finally cease.

These chalk-flints appear to have been first brought under notice by Dr. Knight of Marischal College, Aberdeen, who read a paper upon them to the meeting of the British Association, at Edinburgh, in 1834, and exhibited a series of specimens; and they have since then been commented upon by various observers*. Their abundance is in many places surprising; but they are often hidden by a covering of peat-moss. In some places the flints predominate, in others the quartz; but they are both highly water-worn, the hard quartzy pebbles being often as smooth as an egg, with a clean washed aspect, like the pebbles on the beach. I found that both kinds occur in a thin stratum of reddish or yellowish-brown earth or earthy clay; and in some places the pebbles form almost the entire mass, as is very observable in several pits at the side of a road which crosses the ridge between Tarhenry and Smallburn (fig. 5). This earthy clay appears to repose immediately upon the subjacent rock. I have seen it covering the granite at the Blackhill, and gneiss at Smallburn, and

* See a Memoir by Messrs. Salter and Ferguson on this subject, Quart. Journ. Geol. Soc. vol. xiii. pp. 83, &c.—Edit.

rock of doubtful character in other spots. It is also not without interest to observe that a stratum of coarse reddish clay, containing pebbles of granite, quartz, and flint, covers the greensand-deposit at Moreseat*.

Fig. 5.—*Outline-section along the hilly ridge from the Buchan Ness to Dudwick.* Length about 12 miles.



** Level of 450 feet above the sea-level.
+—+ Level of the sea.

1. Dudwick, 563 ft.
2. Skelmuir, 482 ft.
3. Kinknockie.
4. Smallburn, 464 ft.
5. Tarhenry, 451 ft.
6. Moreseat.
7. Cruden Hill.
8. Stirling Hill, 282 ft.

In addition to the water-worn pebbles, a few larger stones occur, with a rougher exterior and shapeless form. Some of them occasionally reach from two to three feet in length; and I believe they are sometimes found still bigger. They are granite of different varieties, and compounds of quartz and felspar varying in quality.

Now, upon the top of the adjacent Hill of Dudwick, which reaches a height of 562 feet, I found the quartz-rock covered by its own debris, but the fragments *all quite angular and unworn*; and on a lower projection of the hill at an elevation of 480 or 500 feet the same thing occurred. But, searching along the eastern flank of the ridge, I found, to the north of a croft called Backhill of Dudwick, the water-worn pebbles of quartz and flint occurring with considerable regularity to a height of about 450 to 470 feet, beyond which they appeared to cease. It seemed, however, as if some agency had disturbed them since they were rounded, and had washed them up at certain points to a higher level; and a small flint or two may be picked up even on the very summit of the hill.

Whatever may be thought of this, I would at least draw attention to the great extent of water-worn pebbles that clothe the long ridge before mentioned, with great regularity, up to a height which I have measured and ascertained to be 464 feet above the mean level of the sea. They seem to attain their greatest development along a zone from 350 to 450 feet high. They are strikingly displayed over the Hill of Kinknockie, and also at Hillhead of Auquharney, where there is a croft or cottage, whose foundation I ascertained to be 398 feet above the sea-level. The flints are also particularly abundant on the top of Cruden-hill, which is the point where the three parishes of Cruden, Longside and Peterhead meet; they cover the ground there with a uniform close stratum; but over a great part of the ridge the peat lies so thick as to hide everything.

I shall now describe a great accumulation of highly water-worn shingle covering the top of a ridge in the parish of Fyvie, about twenty miles inland.

* See the Memoir above referred to.—EDIT.

The tract is known by the name of the Windyhills, and is situated close beside the hamlet of Woodhead, in the neighbourhood of the River Ythan. The whole crest of the ridge is thickly covered with great sheets of quartz-pebbles, mixed with a fine whitish sand derived from the grinding down of the fragments. These pebbles are of all sizes below that of an egg, for the most part a good deal smaller. It is true that bigger pieces occur; but there are no large boulders. Several holes or excavations show the mass to be very homogeneous and remarkably devoid of any foreign fragments. A few coarse water-worn flints occur, generally of large size—often nearly six inches in diameter, and frequently with a white chalk-like exterior. I did not find any trace of shells or other fossils in those I picked up. They are for the most part of a very coarse quartzy character, and are whitish, blackish-blue, or yellowish in colour, and are generally unlike the flints of the ridge previously described.

The peculiar significance of this gravel (which covers a tract about two miles long and a mile broad) lies in the fact that it is not a drift-gravel, but an accumulation of local origin, derived from the quartz-beds of the clay-slate strata on which it rests. The pebbles are not pure quartz, but contain a considerable proportion of felspar, whose decay gives to the mass a particularly white aspect.

Thinking it of some importance to determine the precise height of this ridge, I levelled it from a point of known elevation in the immediate neighbourhood, and found the summit to be 412 feet above the mean level of the sea.

No clay was found overlapping this deposit; nothing covers it but some peat-moss. I should say that it had formed a shoal or bank covered by very shallow water, the lashing of which had ground down the quartz into the shingle that we now see. Had the water been of any depth, there would have occasionally occurred seams of clay or fine sand interstratified with the pebbles; but such is not the case.

No transitory flood can account for these extensive shingle-banks; a lengthened period of time is demanded for grinding down the hard quartzy fragments into their present smoothly-rounded form. The thick accumulations of finely-laminated silt which line the lower part of the Spey valley and margin the surrounding coast, the evidence of the molluscs found imbedded in their native mud, together with the silent testimony of these gravelly shoals, all converge to prove that the sea-waters had long stood over this part of Scotland some 450 feet higher than the present coast-line.

On the emergence of the land from the waters of this Pleistocene sea, I find evidence that the country had attained a greater elevation than it does at present. This is shown by superficial beds of peat passing down below the present sea-margin.

In the links, or low sandy flats, adjoining the beach at Aberdeen, I have seen peat beneath the surface of the sea-sand; and at the mouth of a small rivulet, which divides the parishes of Belhelvie and Foveran, I have observed a formation of peat passing directly under the sea-beach.

Again, in the statistical account of Belhelvie, by the minister of the parish, the late Rev. Dr. Forsyth, the following interesting passage occurs :—"There is a great quantity of peat-moss in the parish. Some of it near the coast is considerably under the level of the sea, and is covered to the depth of 10 or 12 feet by sea-sand. It is probable that this moss extends a considerable length out to sea, and that there is a submarine forest in this bay at no great distance. For on Christmas 1799, when there was perhaps the most dreadful tempest that any person remembered to have seen on this part of the coast, several cubical blocks of peat-moss were cast by the sea upon the sandy beach, some of them containing upwards of 1700 cubic feet. Pieces of wood, like branches of oak-trees, apparently converted to a consistence like moss, passed through these blocks in every direction. Both moss and wood were perforated by a number of auger-worms of a large size; and most of them were alive in their holes. The moss was of a much harder consistence than any found in this part of the country. Such large blocks could not have been carried to the sea by any of the neighbouring rivers ; for they were not swelled at that time, but were all firmly bound up with ice. In general, when anything like a tempest occurs at sea, a considerable quantity of peat-moss of the same kind is cast upon this sandy beach; but no person remembers to have seen it in so large masses as at Christmas 1799." The late Prof. MacGillivray, in his account of the Mollusca of this part of Scotland (p. 306.), also states, "Dr. Fleming informs me that he has seen *Pholas candida*, as well as *Pholas crispata*, in masses of peat cast on the beach near Donmouth."

I have further been told that, in the Bay of Peterhead, peat is occasionally brought up by the anchors of vessels ; and in the Statistical Account of Fraserburgh I find it stated that "many of the benty hillocks which skirt the bay stand upon moss or clay ; and in 1760, a tree with roots and branches and a stem 20 feet long was found entire under the sand within high-water mark."

In the Moray Firth a submarine forest is known to exist between Burghead and Nairn.

The occurrence of extensive fields of peat, abounding in remains of trees such as the Birch, Fir, Oak, and Hazel, and situated on exposed tracts close to the sea, where trees can hardly be got to grow at the present day, also renders it probable that the coast was further off when these woods flourished.

Horns of large extinct species of oxen have been found in the surface-beds of peat, but are very rare. A specimen got in Belhelvie is now in Marischal College Museum; another found at a place called Tuchin, in the parish of Cruden, is in Slains Castle*.

I have also in my possession the root-fragment of a stag's horn found in a bed of peat overlying the clay at Annochie in St. Fergus. For this specimen, as also some other interesting fossils, I am indebted to Dr. Gordon, R.N., St. Fergus.

Into the subject of the transport of boulders, and other phænomena

* Both of these specimens I have seen, and find them to be remains of the *Bos primigenius*.—October, 1858. T. F. J.

of the drift, I do not now enter, merely remarking that blocks from a distance and striated fragments are found at elevations far above what I have mentioned regarding the stratified deposits and water-worn gravels.

In this paper I have chiefly sought to point out two distinct periods, or resting-points, in the Pleistocene history of this part of Scotland:—one when, under a climate much colder than what we now enjoy, the land sat some 450 feet lower than at present; and a subsequent period when it stood higher than it does now, and when deer and great wild oxen roamed amongst its woods.

Note.—Mr. S. P. Woodward, F.G.S., author of the well-known 'Manual of the Mollusca,' has favoured me with his opinion on some of the shells from the Pleistocene beds described in the foregoing paper, and remarks as follows:—

"Most of the shells from the Annochie clay at St. Fergus are examples of *Nucula tenuis* and *Leda pygmæa.* All the largest shells from the same spot are *Saxicava arctica.* The *Lucina ferruginosa* appears to be rightly named. One shell is a *Cryptodon,* apparently, but quite new to us. The *Cylichna* is like *C. obtusa.*

"Of the broken shells from the Kippet Hills, beside the Loch of Slains, are—

"*Cyprina Islandica, Astarte borealis, Fusus carinatus, Tellina solidula,* and *Cardium Norvegicum.*

"There are two specimens of the *Tellina* of unusual thickness; but they are like no other species.

"Those from Cruden include—

"*Pecten opercularis, Cardium Norvegicum,* and *Trichotropis borealis.*"—October, 1858.

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3. Mr. Kennedy Macnab, of Inverness, communicated, in a letter to the Secretaries, the fact of flint arrow-heads and whelk-shells having been found at the depth of about 3 ft. 6 in. beneath the surface of a moss, covered with wood, in the parish of Abernethy (Inverness and Elgin).

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4. Mr. Richard Mason, of Tenby, in a communication to the Secretaries, offered a *résumé* of the evidences, traditionary, historical, and physical, of—1st, the probable depression at some pre-historic period of an extensive tract of country, covering the site of the Bristol Channel and Cardigan Bay; and 2ndly, of the more recent elevation of the land in the neighbourhood of Tenby, South Wales; the elevated district being apparently confined to that lying on the Carboniferous Limestone. Evidences of a comparatively recent depression of the Cardiff area were also alluded to.

MARCH 10, 1858.

Alfred Williams, Esq., C.E., Newport, was elected a Fellow; A. Escher von der Linth, Zurich, and E. Deslongchamps, Caen, were elected Foreign Members.

The following communications were read:—

1. *On the* GEOLOGY *of the* GOLD-FIELDS *of* VICTORIA. By ALFRED R. C. SELWYN, Esq., Geologist to the Colony of Victoria. (In a Letter* to Professor A. C. RAMSAY, F.R.S. and F.G.S.)

I HAVE now a very large collection of genera and species of Silurian fossils, many of them known forms, and many new. M'Coy is going to examine, describe, and figure the new ones. I shall, I hope, soon be able to define the boundaries of the Upper and Lower Silurian rocks in this colony. Melbourne stands on "May Hill Sandstone;" and to the eastward I find a very gradually-ascending series, including probably Wenlock, Ludlow, Devonian, and true Carboniferous rocks, with Oolitic coal-bearing beds resting unconformably on the Palæozoic strata. To the westward there is a descending series, from Melbourne towards Ballarat, which I much suspect to be Cambrian.

Lingulæ, like those of Tremadoc, are abundant in the rock associated with the Bendigo gold-quartz mines. In beds which I take to be equivalents of the Llandeilo flags, Trilobites are very abundant—many of them recognizable European species. I enclose a list of genera (p. 537). This list is now, however, much increased, and is being added to daily.

Gold-bearing quartz-veins extend throughout the Silurian rocks; and their richness appears to me to be dependent more on their proximity to some granitic or other plutonic mass than on the age of the rocks in which they occur. As far as I am aware, these gold-quartz veins do not extend into the Oolitic (?) coal-bearing rocks, which are evidently of newer date than any of the granitic masses I have yet examined.

At Steiglitz (fig. 1), we have granite (*a*) intruded among Silurian sandstone, conglomerate, slate, &c. (*b*), which are cleaved and intersected by veins of auriferous quartz (*c*), and contain *Graptolites*, *Lingulæ*, &c., and perhaps represent both Upper and Lower Silurian strata. The granites here never contain gold or quartz-veins. Similar auriferous quartz-veins traverse the Lower Silurian cleaved sandstones and slates at Bendigo and Ballarat, as shown in figs. 2 and 3. These strata also contain *Graptolites*, *Lingulæ*, and other fossils.

One somewhat remarkable point, in connexion with nearly all the great granitic masses that I have examined, is that, though they invariably alter the slate-rocks near their junction, and send veins into them, they do not in the slightest degree affect the general strike or dip of the latter, but appear to have themselves partaken

* Dated 10th September 1857.

of the movements which have placed the Silurian rocks in their present highly-inclined and contorted positions, and given them their very uniform meridional direction. There is very little true slaty cleavage until we get low in the Llandeilo beds.

The gold-bearing drifts that rest on these strata are of, at least, three distinct ages. The oldest drifts (No. 1, figs. 1, 2, 3) are, I believe, for the most part, freshwater *Miocene* deposits. The only fossils hitherto found in them are, however, vegetable—consisting of large quantities of wood, trunks of trees, seed-vessels, &c., at various depths to 780 feet.

The deposits themselves consist of fine clays—black, yellow, white, red, and mottled, siliceous sands and quartz-gravel, with large waterworn pebbles. These are often overlaid by sheets of lava, in the manner shown in the Bendigo and Ballarat sections (figs. 2 and 3, 2). The rock consists of basaltic lava, &c., sometimes porous, sometimes solid and concretionary ("bluestone"), with interposed red, white, and yellow sometimes sandy clay (intersected in the lava in fig. 3). Whether this is a volcanic or ordinary sedimentary deposit, is at present uncertain.

Near the coast there are distinct and undoubted *Miocene* beds, full of marine shells, occupying (apparently) the same geological position relative to the tertiary sheets of basaltic lava that the gold-bearing drifts do, which I consider to be freshwater Miocene deposits. By far the greater portion of these immense sheets of lava were spread out towards and during the close of the Miocene period; and their irruption has evidently had nothing whatever to do with the formation of the gold. The trap-plains to the westward are very extensive; and there is every probability of gold-deposits existing underneath the trap over the greater portion of them. The limit, therefore, to the period during which these Tertiary gold-deposits of Victoria may be profitably worked may be regarded as indefinitely remote. I wrote to Jukes four years ago about the passage of these Miocene gold-drifts under the lava-plains*.

The gold-beds above referred to as being probably of Miocene age extend to elevations of about 2000 feet above the present sea-level; and their greatest thickness, including contemporaneous trappean beds, is about 300 feet; at least, there are no places where they have yet been proved to exceed that thickness.

Resting on the lava-sheets is a Pliocene drift (No. 3, figs. 1, 2, 3), containing gold and bones of extinct and living marsupial quadrupeds. It consists of clays, sands, and angular and waterworn gravel, formed during the denudation of the Miocene drifts and trap, and the granites and Silurian strata. It often rests on the Miocene beds without the intervention of basalt; and thus two gold-bearing "bottoms" occur. I have only seen one instance of this Pliocene drift, or rather marine beds of the same age, being overlaid by volcanic matter,—viz. at "Tower Hill," near Warnambool, where raised

* Mr. H. Rosales also adverts to the gold-drifts that are older than the basalt, in his paper in the Quart. Journ. Geol. Soc. vol. xi. p. 397.—Edit.

Fig. 1.—*Section of the Gold-deposits at Steiglitz.* (Water-shed to the South, into Bass's Straits.)

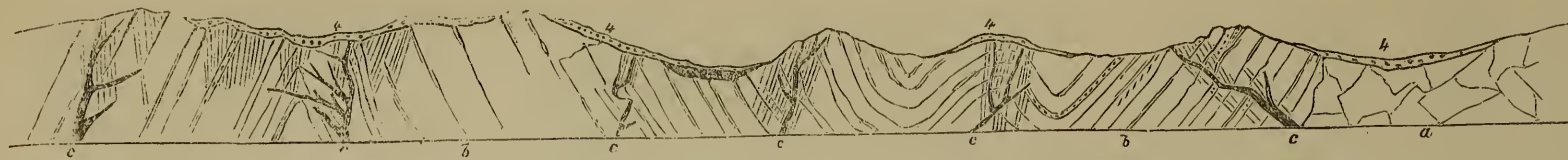
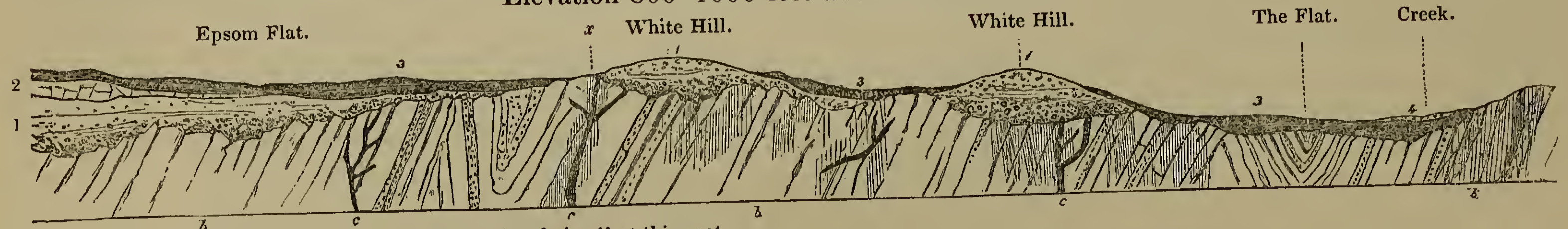
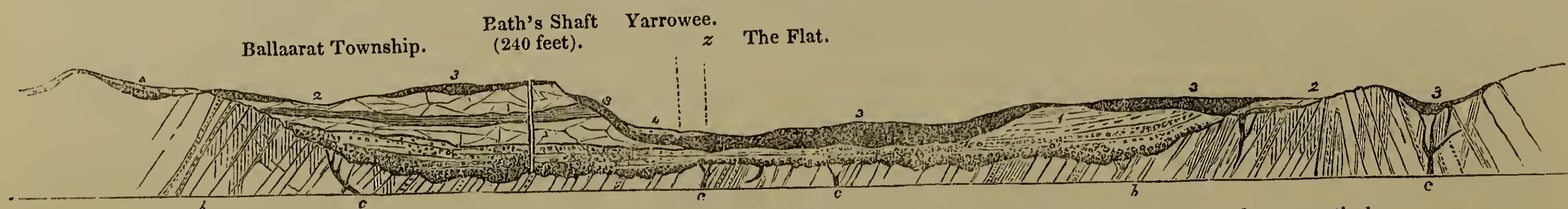


Fig. 2.—*Section of the Gold-deposits at Bendigo.* (Water-shed to the North, into the Murray River.) Elevation 800–1000 feet above the Sea-level.



x. Rich "surfacing" at this spot.

Fig. 3.—*Section of the Gold-deposits at Ballarat.* (Water-shed to the South, into Bass's Straits.) Elevation 1400–1900 feet above the Sea-level.



z. At this point three "bottoms," or deposits of gold, would be found in sinking, at the base of the Nos. 1, 3, and 4, respectively.

a. Granite. *b*. Upper and Lower Silurian Rocks. (Sandstone, slate, &c. much cleaved, intersected by veins of auriferous quartz, and containing *Graptolites*, *Lingulæ*, &c. *c*. Quartz-veins.

4. Third or recent gold-drift.
3. Second or post-trappean gold-drift, with bones of extinct and existing Mammalia (Pliocene ?).
2. Basalt, lava, &c.
1. Oldest gold-drift.

estuary beds, with shells of living species, are overlaid by thick deposits of volcanic ashes*.

Resting indifferently on any of the older deposits is a third or recent gold-drift (No. 4, figs. 1, 2, 3), the result of recent and existing atmospheric and fluviatile action. It is formed by the waste of all the older deposits.

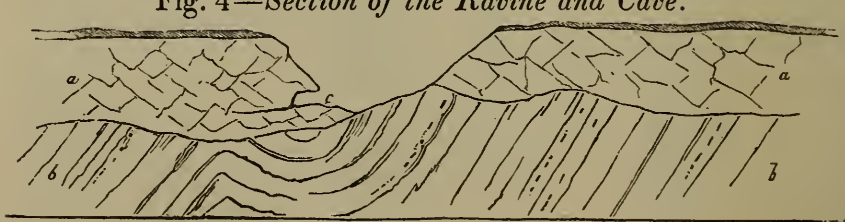
The mode of occurrence of the gold is as follows:—It is found at the base of 1, 3, and 4, when resting on each other, or on the Silurian gold-bearing rocks (*b*); never when resting on the trap (2) or the granite (*a*) if far removed from the Silurian or Miocene rocks (*b* and 1). The gold-bearing gravels are the result of the *immediate* waste of older masses, and have not been transported far. This, however, does not altogether apply to the eastern gold-fields, where gold is found in the granite.

As a general rule, the heaviest gold-deposits and the largest nuggets are found only at the base of the Miocene, Pliocene, and recent drifts (1, 3, and 4) when they rest *directly* on the Silurian strata. In the Ballarat section (fig. 3), at the line marked *z*, three "bottoms" or deposits of gold would be found in sinking through the bases of 4, 3, and 1.

I have never yet been able to discover evidence of anything resembling glacial action; but I have not been in those parts of the colony where, if in existence, it would be most likely to be seen, viz. on the flanks of the Australian Alps.

I have discovered a cave in the basalt of Mount Macedon, a few miles north of Melbourne, containing bones of many living species, including the "Devil" of Tasmania, not now living on the mainland; and also the Dingo, or native dog. In the bones sent by my assistant Aplin and myself to Professor M'Coy, he recognized "two fragments of the superior maxillary bone, with the long transverse molar, the smaller molar, and the second molar, together with two rami of the inferior maxillary bone, beyond all doubt, of the Dingo at present

Fig. 4—*Section of the Ravine and Cave.*



a. Basalt (Miocene?).
b. Schists and sandstones (Lower Silurian).
c. Mouth of Cave.

living in this country." In the cave were also found fragments of the skulls of what appear to be a "new genus of carnivorous ani-

* See Mr. R. B. Smyth's paper on the Extinct Volcanos of Victoria, above, p. 231.—Edit.

mal," mingled with numerous others, in the same state of preservation, belonging to species of *Halmaturus, Dasyurus, Hypsiprymnus, Macropus,* and other living forms. The cave itself is in the Miocene trap (fig. 4) ; and the sides and top of the passages are smoothed and polished by the friction of the backs and sides of the animals passing in and out.

The elevation of the ravine is, I think, about 1000 feet above the sea-level, and 30 miles inland. The matter in the cave consists entirely of a very dry, powdery, brown earth. There is not a particle of moisture in any part of the cave, and no calcareous incrustations. The bones are not in the least degree mineralized. When we found it, all the passages were so completely filled up that no animal larger than a rat could have entered them. It must, I imagine, have been filled up during the Pliocene, or what I call the "post-trappean gold-drift period." (See sections.)

In various places round the coast I have found what I believe to be Eocene tertiary beds. They consist chiefly of blue clays, with septarian bands and nodules and fine sandy loam, full of selenite, and very rich in fossils,—the whole being exceedingly like London Clay, both in mineral character and organic contents. They are certainly the lowest tertiary beds I have yet seen in this country.

List of some of the Palæozoic Fossils collected by the Geological Survey of Victoria during the years 1855–56–57 :—

Locality.	Genera, &c.
Quarries near Princes Bridge, Melbourne	Atrypa, Leptæna, Pentamerus, Theca, Chonetes (5).
Collingwood	Orthis, Crinoidea (2).
University Quarries	Crinoid stems.
M'Ivor Gold-field (75 miles north of Melbourne)	Atrypa, Pentamerus, Orthis.
Moone Ponds Creek, Flemington, 3 miles north of Melbourne.—17 Genera	Orthis, Pentamerus, Atrypa, Lingula, Calymene, Murchisonia, Chemnitzia, Sanguinolites, Stenopora, Cucullella, Orthoceras, Loxonema, Theca, Uraster, Favosites, Gasteropoda, Cycloceras, and Starfish (20).
Merri Creek, 15 miles north of Melbourne	Orthoceras, Atrypa, Chonetes, Lingula, Orbicula, Cucullella, Orthis, Petraia, Murchisonia, Graptolites latus.
View Hill Creek, Upper Yarra, 35 miles east of Melbourne	Leptæna, Petraia, Theca, Starfish.
Yerring, ditto, ditto	Orthis, Atrypa, Leptæna, Strophomena, Rhynchonella, Pentamerus, Petraia, Stenopora, Crinoid stems, Holopella, Esmondia, Starfish, Cheirurus (30).

Locality.	Genera, &c.
Simmonds Bridge, Upper Yarra, 40 miles east of Melbourne ...	Calymene, Belerephon, Psammobia, Othoceras, Nucula, Leptæna, Atrypa, Strophomena, Pentamerus, Cycloceras, Conularia.
Anderson's Creek, 25 miles east of Melbourne. Impure lime stone	Stenopora, Palæopora, Favosites, Petraia, Orthis, Spirifer, Crinoid stems.
Deep Creek, ditto, ditto	Stenopora, Calymene, Pentamerus, Atrypa.
Watson's Creek, Upper Yarra, 15 miles east of Melbourne.........	Atrypa, Strophomena, Pentamerus, Orthis, Avicula, Actinocrinus, Stenopora, Cyathocrinus.
Woori Yalloch Creek junction with Yarra, 45 miles east of Melbourne	Pleurodictyum (2 sp. new), Beyrichia, Petraia, Pleurotomaria, Portlockia, Orthoceras, Favosites, Atrypa, Bellerophon, Sanguinolites, Cheirurus, Pentamerus, Conularia, Orthis, Cucullella, Lichas, Loxonema, Stenopora, Palæopora, Actinocrinus, Sphærexochus.
Holden, 18 miles N. by W. from Melbourne	Diplograpsus rectangularis, D. pristis, Didymograpsus, Siphonotreta.
Keilor, 10 miles N. W. from Melbourne..............................	Graptolites, Cheirurus.

Thence 75 miles N.W., Graptolites in great variety, and Lingulæ. No other in the beds to the N.W.

Thus we have about 60 genera of Silurian fossils, including many new species.

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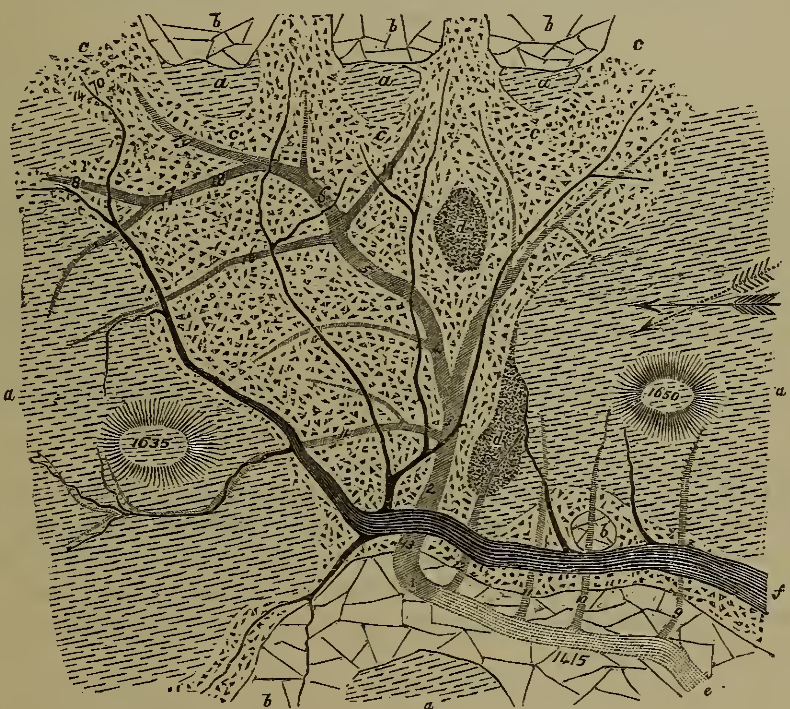
2. *On the* Gold-field *of* Ballaarat, Victoria. By Mr. John Phillips, C.E., Surveyor in the Government-Service of Victoria. (Communicated by Sir R. I. Murchison, V.P.G.S.)

[Abstract.]

All the Victorian gold-fields are near granite, and some are on it. The granite at Ballaarat is fine and even-grained; and the schists lie against it. Between these rocks the junction is abrupt; there is little or no gneiss, and no porphyritic or other veins were observed. The schists are greenish, and are occasionally chloritic, micaceous, aluminous, and siliceous, and are traversed by quartz-veins, from less than an inch to one foot in thickness. The schists in the upper portion are more quartzose, and contain oxides of iron; lower down they are more aluminous and contain pyrites. Their strike is rather uniform, nearly coinciding with the true meridian, while the cleavage and quartz-veins are not regular in strike.

The workings at Ballaarat have exhibited a section of 300 feet in thickness, consisting of gravels, sands, clays, and trap-rocks. The oldest drift or gravel (a beach-like conglomerate) is found not in the deep section, but on the surface of the schist-country. It is regarded as of marine origin by the author, and is composed of quartz, and contains gold at its base. Another drift has been deposited in gullies cut through the oldest drift and deep into the schists. This also is auriferous, and is covered by an ancient humus, which, in the deep section, is found to contain stems of trees, and to be covered over by a trap-rock enclosing upright trees. This fossil wood is usually but little altered in its texture and ligneous qualities ; its colour is changed from that of red birch to cocoa or lignum-vitæ. But some of it has passed into jet ; and both the charred and the uncharred woods have

Sketch-plan of a part of the Valley of the Yarrowee, showing the relations of the ancient and the existing gullies.



a. Schists. *b.* Trap-rocks.
c. Gravels, mostly diluvial and partially lacustrine.
d. Gravels, marine (?).
e. Former course of the river and its branches.
f. Present river-course.

Diggings.	Elevation.	Depth.
1	1182	190
2	1200	162
3	1250	130
4	1280	180
5	1300	160
6	1325	165
7	1347	115
8	1430	22

(Some other points of elevation are given on the plan.)

Diggings.	
9	Milkmaid.
10	Malakoff.
11	Nightingale.
12	Golden Point.
13	Gravel-pits.
14	Bakery Hill.
15	Canadian.
16	Black Hill.
17	Lady Berkeley.
18	Eureka.

much bright pyrites in them. The flora of this old land-surface resembles that of the present day.

This first trap is covered by green and brownish clay and sand, which are succeeded by another trap, having a line of charred vegetable matter at its base, and also having a similar covering of clay and sand. These clay- and sand-deposits are regarded by the author as being of lacustrine origin; the volcanic rocks having dammed up the old river-courses that formed the gully-drifts, and caused the drainage water of the region to be accumulated in lakes.

The next deposit is a coarse ochreous quartzose drift, considered by the author to be the effect of some sweeping deluge; and this is also overlaid by a third bed of trap-rock, with the charred remains of a forest intervening. This trap is covered by a mottled clay of pure quality, also regarded as lacustrine.

A fourth trap succeeds, covered by a superficial quartzose drift (of diluvial origin, according to the author), and lying on one side of the schistose hills, which are clearly denuded on the other.

In the basin of the Yarrowee, which is covered chiefly with this gravel, the author traces the run of the "gold-leads" or old gullies, which have only an approximative resemblance to the ramifications of the present river (see the Plan). These ancient gullies or leads had a very uniform fall, which, from the smallness of the contents of the gullies, must have been as rapid as 16 in 1000, while the present fall of the Yarrowee is only 8 in 1000.

Mr. Phillips urges that all the basin between the gold-leads may be wrought by the aid of the water-power of the Yarrowee,—a thousand horse-power being now allowed to run waste, which, by means of reservoirs could be made available.

The author adds that silver-nuggets have been reported on good authority to have been found within thirty miles of Ballaarat. He further observes that, whilst surveying the district, oscillations of the spirit-bubble indicated a rocking of the earth, and that the country in places sounds hollow, like a wooden bridge, horses even noticing it in passing.

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3. *On the* Gold-diggings *at* Creswick Creek *and* Ballaarat. By Mr. W. Redaway. (Communicated by Sir R. I. Murchison, V.P.G.S.)

[Abstract.]

Mr. Redaway noticed first the "bluestone" or concretionary basaltic lava at Creswick Creek, which composes also the rough bouldered surface of the country to a great extent. In the plains formed of this volcanic rock, small lakes or water-holes, from 3 to 12 feet in diameter, are in some places frequent.

At Creswick Creek the different diggings perforate varying thicknesses of the bluestone, from 17 to 20 feet. Under this is 30 feet of solid clay; then darkish-coloured quartzose gravel, with abundant remains of wood, to a depth of about 80 feet; and under this the "gutters," "leads," or "runs" of auriferous quartzose gravel—or "wash-dirt"—are met with on the surface of the slate or on pipe-clay. The pits vary considerably in the sections they afford.

The fragments of wood in the gravel are of all sizes, from tree-trunks 3 or 4 feet in diameter, to branches and twigs; and this drift is throughout impregnated with woody particles, giving it a black appearance, especially towards the bottom. The cones of the "honeysuckle," or *Banksia* *, have been found not unfrequently in this drift. These are very brittle; but the wood is often well preserved. Thin horizontal layers of very hard rock are imbedded in the gravel.

Some of the "gutters" or "leads" were drawn by the author on plans, showing their course beneath this drift across the present gullies and from hill to hill—especially the "Black Lead" and the "White Lead," underlying Little Hill,—one of them having a branch from under Clarke's Hill, and both uniting before passing under Slaughter Yard Hill.

At Ballaarat, Mr. Redaway observed, in a pit on Sevastopol Hill, two layers of bluestone (the second bed about 80 feet thick) above the gold-drift or "wash-dirt," together with stiff clays and quartzose gravels. Here the author traced some gold-runs—the "Frenchman's Lead," "White Horse Lead," and "Terrible Lead"—running parallel to each other in a direction transverse to that of the present gully, and from hill to hill. Like all other "leads," these rise generally in the neighbourhood of a quartz-vein ("quartz-reef"), are shallow at first, 2 or 3 feet in depth, and gradually get deeper.

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4. *On some* Outline-drawings *and* Photographs *of the* Skull *of* Zygomaturus trilobus, Macleay, *from* Australia. By Prof. Owen, F.R.S., F.G.S.

[Abstract.]

(The publication of this Memoir is unavoidably postponed.)

About a month since, Prof. Owen received from Sir R. Murchison seven photographs, three of which are stereoscopic, of perhaps the most extraordinary Mammalian fossil yet discovered in Australia.

These photographs, with a brief printed notice of their subject by William Sharp Macleay, Esq., F.L.S., and some MS. notes by J. D. Macdonald, M.D., R.N., had been transmitted to Sir R. Murchison by His Excellency Governor Sir W. Denison, from Sydney, New South Wales; and by desire of Sir Roderick the Professor brought the subject under the notice of the Geological Society of London, to whom Sir Roderick desires to present the photographs on the part of His Excellency Sir W. Denison.

Professor Owen had some weeks previously received from George Bennett, Esq., F.L.S., of Sydney, outlines of the same fossil skull,

* Some of the cones brought by Mr. Redaway were submitted by Sir R. Murchison to the late Dr. Robert Brown, who identified them as belonging to the *Banksia*.

made by him on the reception of the specimen by the authorities of the Australian Museum at that town; and the Professor had penned notes of his comparisons of these sketches before receiving the photographs and descriptions of the fossil skull from Sir R. I. Murchison.

This unique and extraordinary skull of a probably extinct Mammal, together with other bones, but without its lower jaw, were found at King's Creek, Darling Downs,—the same locality whence the entire skull and other remains of the *Diprotodon* had been obtained.

Mr. Macleay has described the fossil under notice as belonging to a marsupial animal, probably as large as an Ox, bearing a near approach to, but differing generally from, *Diprotodon*. He has named it *Zygomaturus trilobus*. The skull has transversely ridged molars, and a long process descending from the zygomatic arch, as in the *Megatherium* and *Diprotodon*, and exhibits an extraordinary width of the zygomatic arches. The skull at its broadest part, across the zygomata, is 15 inches wide, and is 18 inches long. In *Diprotodon* the skull is about 3 feet long by 1 foot 8 inches broad; so that while the latter must have had a face somewhat like that of the Kangaroo, the *Zygomaturus* more resembled the Wombat in the face and head.

Prof. Owen stated that, from the evidences afforded by the photographs, he finds the dentition of this upper jaw to consist of three incisors and five molars on each side, of which the first appears to be a premolar and the rest true molars, *i.e.* $i.\ \frac{3-3}{\quad}$, $c.\frac{0-0}{\quad}$, $p.\frac{1-1}{\quad}$, $m.\frac{4-4}{\quad}$, agreeing, in this formula, with *Macropus* and *Diprotodon*. The modifications of this dentition resemble those of the latter genus in the retention of the premolar after the last true molar has come into its place, and in the superior size of the first, as compared with the second and third incisors. He then described in detail the sockets of the incisors, and the form and conditions of the molar teeth, which are highly characteristic of the marsupiality of this huge and most strange extinct quadruped. The cranial characters, which were next described, equally elucidate this affinity. The peculiar facial bones were then described in detail, that portion in advance of the orbits forming, as it were, a short pedunculate appendage to the rest of the skull, increasing in a remarkable manner in both vertical and lateral extent as it approaches the muzzle, but not offering sufficient evidence of having borne a nasal horn, as thought to be probable by Mr. Macleay. The cavity of the nose is divided by a bony septum,—a character which Prof. Owen has lately found to exist also in a rare species of living Wombat—to a much greater extent than in other known marsupials. Wholly concurring in Mr. Macleay's conclusions as to the marsupial nature of the fossil in question, Prof. Owen does not find, in the absence of an opportunity of comparing the structure of the teeth themselves, that it exhibits evidences of a generic distinction from *Diprotodon*. The Professor suggested, however, that probably the lower jaw, when found, may show some peculiarities of dentition and proportions similar to those on which he had founded the genus *Nototherium*, with one species of which, *N. Mitchelli*, the cranium in question agrees in size.

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5. *On the* Gold-Diggings *at* Ballaarat. By Henrique Rosales, Esq. (In a letter to W. W. Smyth, Esq., Sec. G.S.)

"By the aid of machinery, and through the alteration of the mining-regulations granting extended claims, the old ground has been profitably re-worked: and, by the introduction of the frontage-system, which, according to the difficulties to be overcome, grants extensive claims on new ground, the present 'leads,' most of which are N.W. of the Gravel Pits, under the townships, are advantageously worked. The amalgamation of three or more claims is also allowed, the miners having then to put down only one shaft.

"The engines most in use are stationary, of from 15 to 20 horse-power, with winding and reversing gear. To the end of the winding-gear-shaft is attached the crank for the pump; and the motion is also taken to drive a puddling machine, which is nothing but the *arrastra* working without mercury. The depth of sinking averages about 300 feet, of which in some instances there are as much as 200 of basalt to be cut through.

"At the junctions of the Frenchman's and White Horse Leads, in the Eldorado, the remains of a tree were found in an undisturbed position, with the roots fast in the wash-dirt.

"It might also be interesting to you to know that at Poverty Point the deep gold-channel, with a N.W. strike (figs. 1 & 2, 1,1), is

Fig. 1.—*Horizontal plan of the "Runs."*

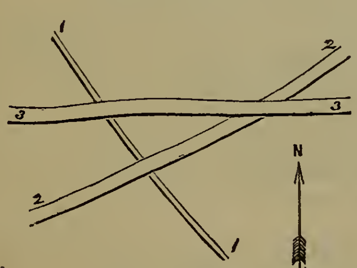
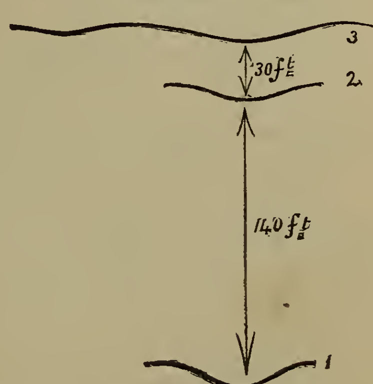


Fig. 2.—*Vertical plan of the "Runs."*



1. Present water-course, at the surface.
2. An older water-course, or "run."
3. The oldest and lowest "run," or "gold-channel."

crossed at about 140 feet higher by the shallow gold-channel (2,2), which has a strike of N.E. by E., and which again, in its turn, is crossed at a level of 20 or 30 feet still higher, by the present water-course (3,3), the strike of which is W."

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Berlin. Monatsbericht Königl. Preuss. Akad. Wissensch. Sept.–Dec. 1857.

Ehrenberg,—Ueber die organischen Lebensformen in grossen Tiefen des Mittelmeeres, 538.

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A. Perrey.—Documents sur les tremblements de terre au Pérou dans la Colombie et dans le bassin de l'Amazone.

Caen. Bulletin de la Société Linnéenne de Normandie. Vol. i. Année 1855-56. 1856.

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ALPHABETICAL INDEX

TO THE

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

[The fossils referred to are described, and those of which the names are printed in italics are also figured.]

THE

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PART II. MISCELLANEOUS.

CONTENTS OF PART II.

Alphabetically arranged—the Names of the Authors in capital letters.

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

Classification and Description of Rocks. By Dr. Ferdinand Senft, &c. 8vo. Breslau, 1857, pp. 442; with 12 Tables.

[*Classification und Beschreibung der Felsarten, &c.*]

To the above work by Dr. Senft, of Eisenach, was accorded in 1855 the Demidoff prize, offered by the Leopold and Caroline Academy of Breslau, for the best essay on the Classification and Description of Rocks.

The work is divided into two principal parts: the first (pages 3 to 82) contains the general introductory matter necessary to a knowledge of rocks, followed by descriptions of the distinction and determination of the classes, orders, genera, species, and individual varieties of rocks, which are arranged in a series of tables, with a brief diagnosis of each individual rock. The second and far larger portion of the work (pages 83 to 422) embraces the detailed characterization and the chemical analyses, with full indications of the position and mode of occurrence of every variety of rock-mass known to the author.

The copious information, both special and general, contained in this second part is very important, interesting, and highly useful, and indicates the vast amount of care and labour which the author has bestowed in rendering this work not only serviceable to the student, but a necessary work of reference to the geologist. To this end the author subjected a very large series of specimens to mechanical and chemical analysis. That omissions may occur and corrections be necessary, there is no doubt; but the mass of information embodied in the volume is far larger than is to be found in any present treatise on rocks and rock-structure,—subjects to which but little attention has been paid in this country since the publication of the useful work of Macculloch. References to the writers and works on the subject which the author has consulted are given, but the names of several good authorities are not mentioned in the list. A series of large folding tables are also appended; one coloured, which contains a sketch of the position, age, and relation of the crystalline eruptive rocks, with reference to their localities in Germany and adjoining countries; the others showing the relations of the superposition of the stratified rocks in Germany and other countries, together with their mineral characters and fossil contents.

In the introduction, which treats of simple minerals as materials for the formation of rocks, the importance of a knowledge of minerals for the study of rocks is pointed out, with general instructions as to the method and instruments necessary for the examination of rocks, such as the action of the blowpipe, mechanical division, &c. This is followed by short descriptions of the more important rock-component minerals, arranged according to the classification of Naumann.

The participation of minerals in the formation of rocks is next treated of; (1) as essential characteristics or chief constituents, and (2) as accidental, foreign, or accessory minerals, arranged in the following order:—

A. Minerals which occur as essential components of rocks.

I. Minerals which of themselves form rocks.

a. Those which form homogeneous rocks only.

Anthracite, stone-coal, brown-coal, ice, rock-salt, gypsum, dolomite, marl, brown and red iron-ore, iron-spar, perlite, pitchstone, obsidian, serpentine, opal, siliceous schist (kiesel-schiefer), hornstone, and fire-stone (flint).

b. Those which form rocks, not only alone, but also mixed with other minerals.

Quartz, augite, hornblende, chlorite, talc, clay, and limestone.

II. Minerals which occur as essential components only in combination with others.

a. Those which occur as essential minerals in one variety of rock, but often as accessory in various other rocks.

Leucite, nephelin, topaz, zircon, garnet, tourmaline, hypersthene, smaragdite, and andesine.

b. Those occurring in some varieties of rock as essential, in others as accessory components only.

Zeolite (natrolite, scolezite, desmine?), labradorite, orthoclase, sanidine, albite, oligoclase, iron-chlorite, mica, diallage, and magnetic iron.

B. Minerals which appear generally as accidental only.

Titaniferous iron, iron-pyrites, olivine, chabasite, stilbite, chiastolite, and talc-spar (magnesite).

The three following sections treat of

I. The formation of rocks from crystalline minerals: (1) as regards the distinction between simple and compound crystalline rocks; (2) as to the structure or texture of rocks, whether granular, slaty, foliaceous, fibrous, compact, porphyritic, sphæroidal, amygdaloidal, or vesicular.

II. Rock-fragments as materials for the formation of rocks; whether round or angular, large or small, cemented together by clay, marl, limestone, silex, &c.; these are termed *clastic* rocks; their structure is either *psephitic*, when the fragments are at least the size of hazel-nuts, as breccias and conglomerates; *psammitic* or sandstones; *pelitic* or mud- and clay-deposits.

III. Organic remains as materials for the formation of rocks, either alone or mixed with or imbedded in other rocks; as plants, corals, shells, and infusorial remains.

In the section on the systematic classification of rocks, the author states the difficulties of making a good petrographic system of rocks, founded on their structure, colour, or external characters: (1) as the structure of rocks is in many cases so uniform that the individual component parts cannot be distinguished even by the aid of a magnifying glass, as in *melaphyre*, *aphanite*, *phonolite*, *basalt*, &c.; (2) the mass of rock may vary in its range, being simple in one lolity, and acquiring additional constituents in another, thereby approaching the character of the mixed rocks, as *pitchstone*, *pitchstone-porphyry*, *granular limestone*, and *calcareous mica-schist*; or again, in one locality a certain mineral may predominate, which is absent, or sparingly distributed, in the same rock in another locality; or, further, to the mineral constituents of a rock may be added a new substance, or one of the original elements may be replaced by another mineral in more or less abundance, thus producing, or passing into, another variety of rock; (3) the structure of the same rock may vary, presenting either a granular, slaty, compact, porphyritic, amygdaloidal, or even slaggy structure, as *basalt*, &c. From the above reasons the author considers that the chief divisions of rocks should not be founded on their texture, as one and the same rock might otherwise be placed in different divisions,—or on external appearance or colour, as rocks of very different composition might be arranged together, while others, closely allied, would be separated.

In consequence of the difficulties arising from other principles of classification, Dr. Senft proposes an arrangement based on mineral and chemical composition; as the analysis of a rock affords the clearest indication of its constituents: and hence he has adopted, so far at least as leading to the determination of the mineral constituents of a group of rocks, the arrangement of which the following analyses of his elaborate Tables present a general synoptical view.

DIVISIONS AND CLASSES OF ROCKS.

A. **INORGANIC ROCKS.**—Rocks, the chief mass of which consists of true mineral substances, and which on heating are neither partly nor entirely volatilized.

I. Division. **Crystalline Rocks.**—Rocks of crystalline minerals united together, or combined without any cement.

1. Class. **Simple Crystalline Rocks.**—Homogeneous rocks, composed of one mineral substance.

2. Class. **Mixed Crystalline Rocks.**—Heterogeneous rocks, consisting of different crystalline mineral species, indistinct, or more or less distinctly visible : (Crypto-, micro-, or macro-crystalline : crypto- and phanero-merous rocks).

II. Division. **Clastic Rocks.**—Rocks the mass of which consists of fragments (gravel or grains) of various sizes, rounded or angular, fresh or weathered, which are cemented by an earthy or crystalline matrix ; or also loose (cementless) agglomerations of more or less rounded weathered blocks, gravel, sand, and earthy masses.

a. Subdivision. **Compact fragment-rocks with a cement.**

1. Class. **Pseudoclastic rocks.**—Large and small, angular, rarely rounded fragments imbedded in a crystalline or slaggy matrix of the same mineral character as the fragments. Partly stratified, partly unstratified.

2. Class. **Hemiclastic Rocks (Tufas).**—Matrix dense, porous, soft, friable, more or less earthy, often effervescing with acids, and sometimes resembling clay or chalk (but in no way possessing the physical properties of these substances), and which on lævigating appear as a mixture of those rocks of which fragments are included in it. Besides the contained fragments, which are often indistinct, this matrix also contains characteristic admixtures of purely crystalline minerals. Generally stratified, and often containing organic remains. Greatly resembling the rocks of the previous class, and passing into them.

3. Class. **Holoclastic Rocks.**—Matrix more or less compact, earthy, argillaceous, calcareous, areno-argillaceous, areno-calcareous, or marly, with rounded or angular fragments, gravel or grains of rocks having a different mineral character to the matrix. Stratified.

b. Subdivision. **Loose aggregates or detritus.**

1. Class. **Boulders, Gravel, Sand.**—Determined or named according to their mineral characters.

2. Class. **Soils.**—Loose, crumbling aggregates, more or less tenacious when moist, or crumbling under pressure.

B. **ORGANIC ROCKS.**—Rocks the chief mass of which consists of carbon or the product of organic putrefaction, and which, on heating in the absence of air, blacken, but which, heated in contact with air, are converted into carbonic acid with evolution of flame, and emitting an empyreumatic, ammoniacal, or bituminous odour, therefore volatilizing, and leaving a more or less earthy residue (ash).

I. Class. SIMPLE CRYSTALLINE ROCKS.

I. Order. (Hydrolyte.) Rocks soluble in water.

a. Constituents of water. [1. Group. *Ice.*]
b. Pure saline taste, but contaminated with oxide of iron, sulphate of magnesia, or glauber-salt. [2. Group. *Rock-salt.*]

II. Order. (Anhydrolyte.) Rocks insoluble or very little soluble in water.

A. Soluble only in excess of water, particularly when containing common salt or sal-ammoniac. Heated on charcoal, becoming a sulphide. The solution gives the reaction of lime and sulphuric acid. [3. Group. Sulphate of lime. *Anhydrite* and *gypsum.*]

B. Totally insoluble in water, and forming no sulphide on charcoal.

1. Soluble in hydrochloric or sulphuric acid, or altered by them.

a. Entirely soluble in acids.

aa. With evolution of carbonic acid.

The solution containing lime and also magnesia. [4. Group. Carbonate of lime. *Limestone* and *dolomite.*]

The solution contains protoxide of iron. [5. Group. Carbonate of iron. *Spathose ironstone.*]

bb. Without evolution of gas.

Protoxide and peroxide of iron; reddish-brown to blackish, with red streak; or metallic grey-black, with blackish streak. [6. Group. Iron-ores. *Red iron-ore, magnetic iron-ore, sphæro siderite, iron-oolite,* and *pisolitic iron-ore.*]

2. Partially soluble in acids.

aa. With deposition of clay.

Without evolution of carbonic acid. A mechanical mixture of clay with oxide of iron, of ochre-yellow or brown colour. [Iron-ores, as B. 1, *bb.*]

With evolution of carbonic acid (see Group 4). *Marl.*

bb. With deposition of gelatinous silica. Dark-coloured, grey to blackish-green, and greyish-black, soft rocks, dense or slaty, greasy or meagre. [7. Group. Magnesia. (In part argilloid.) *Clay-slate, slaty clay, chloritic slate,* and *serpentine.*]

cc. With deposition of scales of mica, talc-, or clay-slate. (See II. Class. Group of Stilpnolites.)

3. Insoluble or unaltered in hydrochloric or sulphuric acid. (Silicates.)

a. Silicate of magnesia with oxydulous iron, lime, &c. Dark-coloured, garlic-green to black-green, and black. [7 *a.* Group. Silicate of magnesia (magnesite). *Amphibolite, pyroxenite,* and *talc-slate.*]

b. Strong silicates, crystalline or amorphous; hardness=7 or 2–3. Soluble in fluoric acid. Variously coloured. [8. Group. Silicates. *Quartzite, hornstone, lydianstone, flint,* and *opal.*]

c. Silicate of alumina with potash, soda, &c. Natural slags and glasses. Grey, pitch-brown, or black. [9. Group. Hyalolites. *Pitchstone, perlite, obsidian,* and *pumice.*]

II. Class. MIXED CRYSTALLINE ROCKS.

I. Order. (Alabradorite.) Rocks without labradorite, never containing augite, but generally quartz.

Essential constituents: Orthoclase, talc, albite, sanidine, quartz, mica, chlorite, hornblende; or, instead, smaragdite and garnet. Accessory constituents: Quartz, mica, garnet, tourmaline, topaz, zircon, pistazite, iron-pyrites, magnetic pyrites, titanite; seldom magnetic iron or zeolites. Never present: Pyroxene, diallage, and hypersthene. Mixture: generally distinct.

I. Suborder. Partially soluble in hydrochloric acid.

1. Without effervescence; containing 12–30 per cent. of decomposable and 70–88 per cent. of undecomposable parts. Chief constituents: sanidine and potash-albite indistinctly mixed, often with prominent sanidine-crystals, and then porphyritic. Accessory constituents: Quartz, magnetic iron, titanite, and zeolite. Colour: white-grey, greenish-grey, dark-grey, or reddish-brown, and then resembling felsite. Sp. gr.=2·5 to 2·68. Texture: dense, granular, or porphyritic, generally rough and porous. Weathering: leather-yellow, white, and clayey. [1. Group. Sanidite. *Trachyte* and *domite, trachytic porphyry, perlite* in part, *phonolite,* and *andesite.*]

2. With effervescence; containing 20–80 per cent. of soluble parts (carb. lime). The residue consists of mica- and talc-scales. (See Group 3. Talc-mica-slate, &c.)

II. Suborder. Not decomposable in hydrochloric or sulphuric acids, and giving no water on heating to redness. Never containing sanidine, and perhaps no zeolites.

1. With white, yellow-white or reddish-white, rose-red, greyish-brown, or reddish-brown orthoclase, or, instead, oligoclase or albite, as the chief constituent; with it are combined quartz, mica or talc, and elæolite or hornblende. Accessory constituents: garnet, tourmaline, zircon, iron-pyrites, and titanite. Colour: whitish, reddish, grey- or red-brown. Texture: distinct. Weathering: white, yellow, or clayey. [2. Group. Orthoclasite (granite-rocks). *Pitchstone-porphyry, felsit-porphyry* (*with or without quartz*), *granite* and *protogine, syenite* and *zircon-syenite, myascite, granulite,* and *gneiss.*]

2. Mica or talc is the chief constituent, or, instead, occasionally damourite; mixed with it are quartz-grains or granular limestone. Texture: foliaceous. Accessory minerals: chiefly garnet and tourmaline (by taking up orthoclase, it passes into Group 2). Weathering: ferruginous, and loamy. [3. Group. Stilpnolite (mica-rocks). *Mica-slate* (*paragonite* and *iron-mica-slate*), *calc-mica-slate,* and *talc-mica-slate.*]

3. Quartz as the chief constituent, in combination with mica and talc, or with schorl and topaz. Whitish-grey and dark-grey. Texture: granular or thick-slaty. Accessory constituents: Orthoclase, tin-ore, and mica. [Group 4. Quartzite. *Quartz-slate, itacolumite, greisen,* and *schorl-rock* (and *topaz-rock.*)]

4. Blackish-green or black hornblende as chief constituent, combined with white or greenish-white albite. Mixture: distinct or indistinct. Texture: granular, slaty, dense, and porphyritic. Accessory constituents: quartz, mica, iron- and magnetic-pyrites. Colour: grey-green, black with white, or grey with red. Weathering: dirty white, grey, or greenish-yellow, and clayey. [Group 5. Amphibolite (diorite). *Diorite* (*ophite, norite, nodular diorite,* and *diorite-slate*), and *diorit-porphyry* (and *epidosite*).

II. Order. Labradorite. Rocks containing labradorite, but without orthoclase or quartz. Essential constituents: labradorite or oligoclase, nephelin, leucite, hypersthene, diallage, augite, titaniferous magnetic iron-ore. Colour: greyish-green to black. Accessory constituents: iron-pyrites, talc, chlorite, calc-spar, zeolite, and olivine. Mixture: often indistinct. Always partly decomposable in sulphuric acid; losing water and becoming lighter on heating.

1. Suborder. Mostly decomposable in hydrochloric acid. On heating to redness in a tube, become lighter. Essential constituents: labradorite, or, instead, saussurite; besides hypersthene, diallage, augite, iron-chlorite, and calc-spar. Distinctly and indistinctly mixed.

a. Rocks containing pyroxene and diallage (chlorolites).

1. Undecomposable in hydrochloric acid. Grass-green, greenish-grey, or greenish-brown diallage or bronze-coloured hypersthene as chief constituent, combined with labradorite, saussurite, or garnet. Accessory constituents: strahlstein, magnetic pyrites: no calc-spar

or chlorite. Colour: spotted greyish-green and brown. [Group 6. Hyperite. *Eclogite* (and *garnet-rock*), *gabbro* (*smaragdite-gabbro*, or *diallage-gabbro*), and *hypersthenite*.]

2. Decomposable in hydrochloric acid, and becoming brownish-green or reddish on heating to a red heat. Augite as the chief constituent, mixed with labradorite, and grey- or bluish-green iron-chlorite; generally also calc-spar. Colour: green to greenish or blackish. Accessory constituents: iron-pyrites, calc-spar, seldom magnetic pyrites. Weathering: ferruginous, often calcareous clay. [Group 7. Diabasite (Greenstone). *Diabase* (*diabase-slate* and *aphanite*), *diabase-* or *augite-porphyry*, and *calc-diabase* (and *schalstein*).]

b. Without pyroxene. Partly soluble in hydrochloric acid, often with effervescence. Melting easily before the blowpipe into greenish or greenish-yellow glass. Magnetic. Sp. gr. = 2·63 to 2·76. Labradorite in intimate union with magnetic iron-ore, iron-spar, calc-spar, and iron-chlorit, which often pervades the mass and coats the amygdaloid kernels and cavities with a green earthy incrustation. Colour: greenish- or reddish-brown, and grey-greenish, to black. Accessory constituents: rubellan, iron-mica: amygdaloids of calc-spar and quartz. Weathering: leather-brown to red-brown, often calcareous clay. [Group 8. Melaphyre (Trap in part). *Simple, porphyritic*, and *amygdaloidal melaphyre*.]

2. Suborder. Always decomposable in hydrochloric acid, and generally with effervescence, showing 35 to 55 per cent. of decomposable, and 45 to 65 of undecomposable parts. Sp. gr. = 2·76 to 3·1.
Black augite, as the chief constituent, is combined with labradorite or leucite and magnetic iron-ore. Colour: blackish-grey or black. Accessory constituents: chiefly olivine, zeolites, and mica; also calc-spar and apatite. Distinctly and indistinctly mixed. Weathering: ochre-yellow to leather-brown, generally calcareous clay. [Group 9. Basaltite (Trap). *Dolerite* and *dolerite-lava*, *anamesite*, *basalt* (*amygdaloidal basalt* and *basaltic lava*), *wacke*, *leucite-porphyry*, *nephelin*, and *trachyte-dolerite*.]

The relations of minerals, as rock-components, are shown in a Table exhibiting a diagrammatic synopsis of the principal minerals that enter into the composition of rocks, and so arranged that at a glance the reader is enabled to recognize the principal mineral in any special rock, and the accessory mineral with it in that or any other rock.

I. CLASTIC ROCKS.—Pseudoclastic Rocks.

I. Order. The cement or matrix is orthoclase, but never quartz, lime, or iron-ore; it is crystalline or slaggy. The rocks of this division frequently resemble the simple, but more often the mixed crystalline rocks; they are generally unstratified, and form the mantle of those rocks from which they derive their origin. Chiefly found in the immediate vicinity of extinct and active volcanos.

1. Light-grey, yellow, rust-brown, crystalline, or slaggy trachyte-mass, in which nodules or fragments of trachyte, or pebbles, of different sizes are closely impacted: compact and hard. [Group 1. Trachytic. *Trachyte-breccia.*]

2. Reddish-brown, grey-white, grey-brown, often bluish, yellowish, or green-spotted or striped felsite-mass, in which either fragments, or pea- or millet-sized grains of felsite-porphyry are imbedded. [Group 2. Porphyritic. *Porphyry-breccia* and *porphyry-sandstone.*]

3. Greyish-green, dirty or blackish-green diabase-mass, in which various-sized, often very large angular or rounded fragments of diabase, aphanite, or diabase-porphyry lie imbedded. [Group 3. Diabasitic. *Diabase-breccia* and *diabase-sandstone.*]

4. Impure black, porous, spongy, or slaggy tenacious melaphyre-mass, in which large and small fragments of varieties of melaphyre lie imbedded. [Group 4. *Melaphyre-breccia.*]

5. Blackish-grey, also grey-brownish, slaggy or crystalline, compact, more or less hard basalt-mass, in which lumps of dolerite and basalt, and occasionally of limestone and sandstone, are included. [Group 5. *Basaltic breccia* and *doleritic breccia.*]

II. Order. The cement consists of quartz, limestone, dolomites, or iron-ore; crystalline. These fragmentary rocks are generally stratified.

1. Quartz- or hornstone-matrix, in which angular, variously-sized fragments or grains of common quartz, kieselschiefer (lydite), or flint lie imbedded. [Group 6. *Siliceous and lydian breccias, flint-conglomerate,* and *arkose.*]

2. Calcareous or dolomitic, crystalline, granular, or dense matrix, in which more or less angular fragments or pebbles of limestone, dolomite, or stinkstone are imbedded. [Group 7. *Calcareous breccia, oolitic limestone* in part, and *dolomite-* and *stinkstone-breccias.*]

3. Matrix dense, consisting of brown or red iron-ore, in which angular fragments or grains of different varieties of iron-ore, principally magnetic iron, iron-glance, iron-mica-schist, are imbedded. [Group 8. Iron rocks. *Tapanhoacanga.*]

II. Hemiclastic Rocks.

I. Order. Tufas, which, besides indistinct rock-fragments, enclose numerous crystalline minerals, chiefly mica, augite, hornblende, leucite, and magnetic iron.

1. Grey, whitish, yellowish, brownish, generally soft and earthy matrix. Contents: small and often indistinct fragments of trachyte, phonolite, or pumice, and well-preserved crystals of sanidine, horn-

blende, mica, and magnetic iron, also quartz and garnet, besides nodules of opal, &c. [Group 1. Sanidine-tuff. *Trachyte-, phonolite-, pumice-tuff,* and *alumstone* in part.]

2. Grey to blackish-brown, earthy and soft, wacke-like matrix. Contents: numerous crystals and fragments of augite, hornblende, magnetic iron, rubellan, and calc-spar, also of basalt and leucite. [Group 2. Basalt-tuff. *Basaltic* and *doleritic tuff, peperino,* and *palagonite-tuff.*]

3. Distinct or indistinct slaty or fine earthy matrix, generally effervescing with acid and partly soluble; green or grey, yellow to brown-red; containing limestone; and resembling diabase-tuff or clay-slate; enclosing layers, nests, or grains of calc-spar, and often also plates of clay- and chlorite-slate. [*Schalstein* in part.]

II. Order. Tufas, with a matrix similar in composition to the enclosed fragments, and which but rarely or never enclose crystals of other minerals. Closely allied to the Tufas of Order I.

1. Matrix: more or less earthy, of a clayey nature, dense or porous, grey, or yellowish to brown. Contents: various-sized, generally half-weathered fragments of trachyte, pumice, or phonolite. [Group 3. Sanidine-conglomerate. *Trachyte-, phonolite-, pumice-conglomerate,* and *trass.*]

2. Matrix: earthy, of a calcareo-argillaceous nature, greyish-brown, yellowish, or earth-coloured. Contents: half-weathered, rounded blocks, pebbles, or grains of *basaltic* and other *rocks.* [Group 4. *Basalt-conglomerate.*]

3. Matrix: soft, often slaty, consisting of earthy diabasic detritus, often calcareous, greenish-grey, dirty-green, or leather-brown. Contents: rounded fragments and grains of diabase. [Group 5. Chlorolite-conglomerate. *Diabase-tuff* and *diabase-conglomerate.*]

4. Matrix: consisting of fine indurated orthoclasic rocks, often areno-argillaceous in character. Fragments of gneiss, granite, porphyry, and syenite. [Group 6. Orthoclasite-conglomerate. *Gneissic, granitic, syenitic conglomerates,* and *felsite-tufa* or *clay-porphyry.*]

III. Holoclastic Rocks.

I. Order. (Conglomerate.) Fragments at least as large as a hazel-nut.

a. Simple. Fragments derived from one variety of rock.

1. With argillaceous or areno-argillaceous matrix. [Group 1. Argillaceous conglomerate, containing either *quartzite, gneiss, granite, clay-slate, porphyry,* or *mica-schist.*]

2. With calcareous matrix. [Group 2. Calcareous conglomerate. *Siliceous* and *phonolitic conglomerates.*]

3. With carbonaceous matrix. Bleaches on heating. [Group 3. *Coal-conglomerates.*]

b. Compound. Fragments derived from various rocks.

1. With argillaceous or areno-argillaceous matrix. [Group 4. Argillaceous conglomerates, with *quartz, gneiss,* &c., *quartz, granite,* &c., or *granite, syenite,* &c.]

2. With areno-calcareous matrix, and fragments of sandstone, limestone, &c. [Group 5. Calcareous conglomerate, containing various rocks. *Nagelfluh* and *Bone-breccia.*]

II. Order. Fragments about the size of a pea, generally consisting of grains of quartz, mica, and felspar. (Sandstones.)

a. Argillaceous matrix. *Kaolin-sandstone, common clayey sandstone, siliceous clayey sandstone,* and *ferruginous sandstone.*

b. Calcareous matrix. *Calcareous, marly,* and *green* or *glauconitic sandstones.*

c. Carbonaceous or bituminous matrix. *Bituminous* and *asphaltic sandstones.*

III. Order. Slaty rocks, generally grey to black. (Slates.)

a. Argillaceous. Principally clayey, mixed with mica and sand; grey to reddish. *Greywacke-, clay-,* or *alum-slates* and *slaty clay.*

b. Marly and sometimes bituminous. Marl- and bituminous marl-slate (copper-slate).

c. Highly carbonaceous. Carbonaceous slates. *Coal-shale* and *brandschiefer.*

DETRITAL ROCKS.

A. Formed by the mechanical fracture of rocks. Detritus.

1. Volcanic or eruptive detritus. Principally formed by the destruction of lava in the volcanic crater. *Lava blocks and bombs, lapilli,* and *lava sand and ash.*

2. Weathered detritus. Formed of various rocks. *Blocks, gravel,* and *sand.*

B. Earth and soils, partly arising from chemical decomposition. Loose, crumbling or friable aggregates, cohering when damp.

I. Purely mineral soils. Not becoming paler on heating, and not forming a brown solution when boiled with potash.

a. Argillaceous.

aa. Fat clays; tenacious, containing little or no sand. Slightly adhesive, unalterable by heat. *Fuller's earth* and *kaolin.* Strongly adhesive and alterable by heat. *Clay.*

bb. Meagre clays, containing much coarse sand. *Letten* (unequal parts of clay and sand) and *loam* (equal parts of clay and sand).

b. Calcareous.

aa. Calcareous clays, more or less plastic, with at most 15 parts of lime, and at least 75 per cent. of clay. *Common and marly clays.*

bb. Marl. Scarcely adhesive or plastic, with at least 15 per cent. of lime, and at most 75 per cent. of clay.

Clay-marl, 25–50 per cent. lime; 50–75 per cent. clay; 0–5 per cent. sand.

Loam-marl (*loess*), 15–30 per cent. lime; 10–40 per cent. clay; 25–50 per cent. sand.

Calcareous Marl, 50–90 per cent. lime; 10–40 per cent. clay; 0–20 per cent. sand.

Dolomitic Marl, 10–30 per cent. lime; 10–40 per cent. carb. magnesia; 20–50 per cent. clay; 0–30 per cent. sand.

II. Organo-mineral soils. Composed of organic and mineral matters: greyish-black to blackish-brown. Losing colour on heating, and giving a brown solution on boiling with potash.

c. Carbonaceous soils. Clays, letten, loam, or marls, mixed with more or less humus. Humus-, marsh-, or turf-soils.

THE ORGANIC ROCKS.—I. Class. Anthracides.

Anthracitic or carbonaceous rocks, as products of organic decomposition, principally of plants. Compact; with or without visible organic structure; brown or black; lustrous or dull.

The Anthracides are divided into two orders,—1. the perfect or true coals, not containing *ulmine*; 2. the imperfect coals, or those containing *ulmine*.

The first group comprises two kinds, viz. the anthracites, such as the graphitic, common, slaggy, prismatic, fibrous, and wood-like varieties of anthracite; and the coals proper, such as the cannel, glance, slaty, thick-bedded, fibrous, and sooty varieties.

The second group, or those without *ulmine*, are such as the brown-coals or peat. The former afford as varieties, pitch-coal, and the common, flat, woody, needle, paper, waxy, earthy, and other brown-coals. Amongst the latter the author enumerates pitch-turf, sward-turf, paper-turf, turf-earth, mud-turf, and vitriol-turf.

II. Class. Zoogenites.

Aggregates, showing more or less clearly animal structure, and possessing always the chemical composition of animal substances.

1. Coprolitic rocks; nodules with phosphatic matter. 2. Infusorial rocks.

[J. Morris.]

THE GEOLOGY OF LANZAROTE AND FUERTAVENTURA. By GEORGE HARTUNG. 4to, pp. 164; 1 Map and 11 Plates. [1857.]

Die geologische Verhältnisse der Inseln Lanzarote und Fuertaventura von GEORG HARTUNG. [No place or date.]

MR. HARTUNG is a German naturalist, who, having studied under Sir Charles Lyell the volcanic phenomena of Madeira, Teneriffe, Grand Canary, and Palma*, subsequently went alone to Fuertaventura and Lanzarote, two other islands of the Canary group. He carefully examined these little-known islands, and now gives us an account of them in the interesting memoir before us, which may be pronounced a valuable contribution to science, and one that shows he is a pupil of whom his master may be proud.

The memoir is illustrated by a large map of the islands, two large panoramic views, and nine plates of sections, &c. It is divided into three parts: in the first, the author presents us with a personal narrative of his wanderings and a sketch of the fauna and flora (in the latter he discovered some plants hitherto undescribed); in the second, he gives a sketch of the physical geography; and in the third, he describes the geological phenomena.

The islands in question are the most easterly of the Canary group. They lie end to end, Lanzarote being the nearest to the African coast, from which it is distant only twenty-eight geographical miles. Fuertaventura has a length of about thirty-two geographical miles, and a superficies of about four hundred and eighty square-miles. Lanzarote has a length of about twenty-one geographical miles, and a superficies of about two hundred and ten square-miles. The two are separated by a channel some six or eight miles wide, in which lies a small island called Lobos (Seal's Island); and at the eastern extremity of Lanzarote are three islets bearing the flattering titles of Graciosa, Clara, and Allegranza, names strongly contrasting with the barren realities. The shape of Lanzarote is rather like that of an ill-formed S, that of its neighbour is tolerably straight, and its western extremity terminates in a long narrow promontory containing a lofty ridge, and separated from the main island by a low neck covered with white calcareous sand. The islands are altogether volcanic, and are studded with a great number of cones, the highest of which in Fuertaventura reaches the altitude of 2770 feet, in Lanzarote of 2240 feet. Both are extremely barren, having few springs of water (in Lanzarote there is only one spring of fresh water), and being exposed in summer to great heat.

Looking at the geological structure of these islands with reference to age, Mr. Hartung tells us that four formations may be distinguished, viz.—

1. The syenitic greenstone and trap formation; and 2, 3, and 4, the oldest, middle, and newest basalt formations.

1. The first consists of syenitic greenstone, trachyte, and basaltic greenstone, without any intermixture of scoriaceous matter. The

* See Lyell's 'Manual of Geology,' 5th edit. p. 498, &c.

basaltic greenstone is in the shape of dykes of various thickness, but so numerous, that it forms nearly half of the whole mass. These dykes appear at the surface towards the edges of the formation, but in the middle are covered with compact beds with a smooth exterior which is never scoriaceous or porous, and these beds rise into chains of bell-shaped hills.

The syenitic greenstone is limited to a comparatively small space at the middle of the formation, where it forms the foundation of the bell-shaped elevations, being penetrated by dykes like the accompanying rock. This formation is only disclosed in Fuertaventura, where it forms no more than about one-fifth of the entire superficies of the island, occupying the middle portion; and, stretching for about twelve miles along the north-west coast, it reaches its highest point on the Atalaya peak, 2450 feet.

The elevations of this formation are distinguishable at the first glance, by their rounded wave-shaped outlines, from those of the other formations, the hills of which are marked by cones and steep ridges. If surprise be expressed as to the conjunction of syenite and trap in one formation, Mr. Hartung remarks, that both at Palma and Grand Canary, there occurs along with volcanic rocks of the oldest visible formation a crystalline schistose rock compared by Von Buch to granite; and this formation is quite as distinct as in Fuertaventura. In Madeira likewise, syenite is seen along with beds of agglomerate and basalt in positions which show that the whole must there also be called the oldest formation of the island.

2. The *oldest Basalt-formation* consists partly of compact rock, partly of scoriaceous deposits; the whole arranged in such a way that we must attribute their origin to the effect of a succession of eruptions from cones. The lowest portion is not marked by layers; appearing to consist almost entirely of scoriaceous materials, and reaching the surface only at the middle of the formation. Above is compact basalt in beds, the thickest of which are columnar, the others more or less vesicular, and alternating with scoriæ and layers of yellow or burnt-red tufa. This system is inclined from the middle, where the subjacent rocks are disclosed towards every point of the compass; and amongst it are found detached heaps of scoriaceous materials of limited extent. The dykes strike for the most part in one direction, namely, in that of the chain of hills. They are most numerous where the under scoriaceous materials are most developed. Of the mountainous masses once exhibited by this formation, only fragments remain; a great portion having been removed by the sea and by atmospherical influences. Still, in many cases the original forms are still indicated, especially in the peninsula of Handia, the highest point of which attains the elevation of 2770 feet. In the other part of the island of Fuertaventura, the highest point of this formation reaches the altitude of 2240; in the island of Lanzarote the height of 1860 feet. It would appear that these oldest basalts formed a series of elevations and crests through the longer axis of the island. On the side of the prevailing winds the sea has in places removed large portions, and much has been altered by weathering, assisted by rents caused by earthquakes or up-

heavals. The direction of the valleys is outwards from the hills, being parallel where the line of heights is straight, and radiating when curved. The sides of the valleys are by no means vertical, but inclined at an angle of about 30°; the floors are flat, and the valleys themselves have been so much widened by lateral breaches that the interjacent ridges have been reduced at their summits to a line of peaks more or less detached.

The basalts of this formation resemble in general structure those of Madeira. They are, however, a good deal more varied than the latter in their lithological character and contents. For instance, in some places are found very large pieces of augite imbedded in a basaltic paste; at others, various crystallized minerals or small amorphous materials are met with in a matrix of basalt.

3. *The middle Basalt-formation.*—At the first glance the oldest parts of this formation appear to be of the same age as the preceding, but they may be distinguished by the fact that the forms of the cones, craters, and lava-streams may be clearly made out. The lavas are already covered with a thin layer of vegetable soil, which supports scanty crops of grain, whilst the most modern lavas only support a plant here and there. This formation is altogether wanting in the south-western part of Fuertaventura. The first cone on that side is met with in the middle of the syenite and trap formation. Two others are in its north-eastern border. In the remaining parts of the island there are about twenty cones, mostly detached; but altogether the space occupied by this formation forms a comparatively small portion of the surface in Fuertaventura. In the other island, however, it occupies nearly one-half of the whole. About the middle of the island is a chain of cones extending in the direction of the longer axis, the highest of which has an altitude of 1959 feet. In other parts are many detached cones; one, called Corona, with a very perfect crater, at the north-east extremity of the island, reaches the height of 1940 feet. The four islets, Graciosa, Clara, Allegranza, and Lobos, belong to this formation. In the lava which flowed from Corona, Mr. Hartung remarked one of those subterranean channels not uncommon in volcanic districts; but, singular to relate, he found that its floor was the roof of a similar channel underneath. A stream of lava flowing in the opposite direction fell over the cliffs of the north coast, and is a conspicuous object to this day. Of these two phenomena Mr. Hartung has given sketches.

4. *The newest Basalt-formation.*—In the year 1730 violent subterranean commotions commenced in Lanzarote, which continued for six years. During this period a fourth part of the island was laid waste by the materials ejected. Villages were overwhelmed, cattle were destroyed, and the inhabitants fled from the island. A large district on the west coast, the floor of which is about 900 feet above the sea, was formed by this series of eruptions. The chief elevations are a line of cones with craters, out of which the lavas, ashes, &c. issued, which covered the surrounding country. The highest point, and in every way the most striking mountain, is the Montaña del Fuego, with an altitude of 1750 feet. The surrounding district is an utter

waste, entirely without vegetation. All is black ashes; and Mr. Hartung draws a vivid picture of the utter desolation of the tract. The islanders, however, in order to increase their scanty means of subsistence, have adopted the curious expedient of making funnel-shaped holes through the ashes of the plain, and planting grain in the old vegetable soil. On the summit of the Montaña del Fuego there is a vent which emits both smoke and very hot steam. The ground has so high a temperature that a person cannot remain standing at the same place for more than a minute, and a stick thrust through the ashes to the depth of a couple of feet is drawn up charred at the end.

The general strike of the volcanos of this period is nearly parallel with that of the cones of the middle basalt-formation. Although the great mass of the lavas, following the inclination of the ground, ran to the west coast, one narrow stream found a passage to the east coast by winding in a singular manner amongst the hills of the middle basalt-formation. In 1824 the inhabitants were again alarmed by subterranean movements, and a volcano broke out a little to the east of the Montaña del Fuego. The products of this volcano (Volcan Nuevo) were however trifling; a small stream of lava issued from it, and ran towards the west coast, but did not reach the sea. In the crater of this volcano is a bed of lava, which is pierced by round holes, having an unknown depth. A stone thrown into any of them is heard to strike the sides on some impediments for a considerable time in its descent. One of these holes emits a small quantity of steam. A calcareous deposit, of a yellowish-white colour, encrusts all the preceding formations, except No. 4. This deposit is similar in structure to that found in other localities (*e.g.* at King George's Sound (Australia), in St. Helena, and at Porto Santo); its origin has given rise to many different opinions. Mr. Hartung's appears to be, that it has been formed by the decomposition of the outer portion of the basalt throughout a long series of ages, for it is not found on the summits of the peaks, but in the hollows, and on the plains it has accumulated to a considerable depth, and it is absent altogether from the newest lavas. It is composed of a carbonate of lime, pure enough to be burnt into a material capable of use in building, and for this purpose it is quarried at Fuertaventura, and conveyed to Teneriffe. [J. Y. Johnson.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On the GEOLOGY *of a part of* NORTHERN BOHEMIA. By HERR JOKELY.

[Proceed. Imp. Geol. Instit. Vienna, August 1857.]

THE environs of Leitmeritz, Aussig, Teplitz, and Klostergnab (North Bohemia), having been geologically surveyed by M. Jokely, he finds that the subdivisions of the Pläner (cretaceous) limestone prevail round Leitmeritz and Aussig; the middle Pläner-marl usually overlying the lower; the latter resting on Pläner-sandstone, which is based on mica-schist and gneiss.

The middle Pläner-marl is generally overlaid by tertiary sandstones; and these by lignitiferous shales. Basalt occurs here in the form of tuffs and sandstones, both resting on these shales. The lignite-deposits, worked in a great number of mines, are a continuation of the tertiary carbonaceous deposits of Paatz, corresponding to their upper series. Extensive diluvial deposits occur along the Elbe, near Theresienstadt and Leitmeritz.

The prevailing rock of the Erzgebirge (as far as included in M. Jokely's survey) is grey gneiss, cut off near Graupen by an extensive "mass" of euritic porphyry (felsit-porphyr), extending in insular prominences within cretaceous and lignitiferous strata as far as Teplitz and Schönau, where thermal springs issue from it. The metalliferous veins intersecting the gneiss in the vicinity of the euritic porphyry are generally most productive along the line of contact of these rocks. Several of the silver- and lead-bearing veins are still untouched; so that it might be possible to revive the mining enterprises which in ancient times gave fame and riches to this district.

[COUNT M.]

On the GEOLOGY *of the Neighbourhood of* INNSPRUCK. By FR. RITTER VON HAUER.

[Proceed. Imp. Geol. Instit. Vienna, August 1857.]

Having finished the survey of the environs of Innspruck*, assisted by Prof. Pichler and Herr Prinzinger, M. von Hauer reports that the Cardita-bed, interposed as a distinct boundary between the light-coloured upper triassic limestone and dolomite, continues as far as Scharnitz, between the Eiwaldberg and the Arnstritz, to Gars, in the

* See Quart. Journ. Geol. Soc. vol. xiii. part 2, Miscell. p. 39.

Leutsch Valley; it appears again in the west near Widum, along the south slope of the Guhren Mountain to the Ross-Alpe, and further in the Gais Valley, and on the east and south slopes of the Hochmundi Mountain. The main mass of the dolomite contains distinct remains of the *Megalodus scutatus*, proving this rock—and, with it, the Ichthyolite-schists of Seefeld—to be of Lower Liassic age. It is worth remarking that along the whole tract between Zirl and Telfs, the Dachstein-dolomite appears on the inner margin of the calcareous chain, while the older trias appears only further northward. The light-coloured triassic limestones continue from Scharnitz to the Bavarian frontier.

Well-developed neojurassic and neocomian strata occur in the Koiten Valley, north of Leutsch, as in the ravines north-east of Innspruck, where they are associated with Koessen-strata.

The Waldrast Mountains, and the Saile Mountain (south-west of Innspruck) consist of light-coloured, frequently crystalline limestones and dolomites, overlying dark slaty limestones and slates, which rest on mica-schist. The light-coloured limestones contain *Chemnitziæ*, like those of the upper triassic limestone north of Innspruck.

[Count M.]

On the Geology *of the* North-Western Tyrol.
By Fr. Ritter von Hauer.

[Proceed. Imp. Geol. Inst. Vienna, August 1857.]

M. von Hauer, assisted by two Bavarian mining-officers, M. Gümbel and Baron Andrian, has examined the district including the Leutsch- Gurgel-, and Lech-valleys (North-west Tyrol). The prevailing rock is dolomite, with distinct remains of *Megalodus scutatus* near Telfs. A tract of light-coloured upper triassic limestone extends westward from the Hochmundi mountain, gradually narrowing until it totally disappears south of Boden: it is connected on the north with the same formation in the Bavarian Alps (Wetterstein and Zugspitz). Along the southern slope a narrow strip of Cardita-beds runs between the dolomite and the light-coloured triassic (Hallstadt) limestone. Along the north slope this line is generally overlaid by spotted marls of a later age. North of the Hinterwend mountain, dark-coloured Bacillar-slates, without organic remains, are interposed between the Hallstadt and Gutterstein limestones.

Deposits of later date—namely Koessen, Adneth, jurassic, and neocomian strata, spotted marls, &c., generally in narrow zones—lie in irregular superposition over those of an earlier date; conglomerates, alternating with yellowish marls, and occurring on the Mutterkopf mountain (8755 feet), may probably rank among the Gosau series. The zone of Gutterstein limestones includes, near Reutte, organic remains characteristic of the true Muschelkalk, and are the same (*Terebratula trigonella, Spirifer fragilis, Sp. Mentzellii*, &c.) as have recently been discovered in nearly the same locality by M. Escher von der Linth. [Count M.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On the Borders of the Fossiliferous *and so-called* Primitive Formation*; and On the so-called* Primitive Formation *of the* South Coast *of* Norway*. By David Forbes, F.G.S.

["Geologiske Undersögelser ved Groendsen af det Forsteenings förende og den saakaldte Urformation."
"Om den saakaldte Urformation ved Norges Sydkyst." 'Christiania Naturforskere Mödets Forhandlinger,' 1857.]

The trap-dykes are, in this notice, first described as being the most modern rocks in the district, and particularly frequent in the Silurian strata, cutting through the beds and sending numerous branches along the lines of stratification to considerable distances, and frequently extremely thin—sometimes less than one inch in thickness.

The zircon-syenite, next in age, covers a vast extent of territory as a cap; and under this, in parts, a similar cover of augitic porphyry is visible.

In contact with these igneous rocks are thin beds of a hardened white or grey sandstone, so altered, that any fossils, if ever present, have been obliterated. These rest conformably on the Upper Silurian beds, and, from their position, are regarded by the author as of Devonian age. The Silurian series with its fossils are next noticed; and, as the lowest beds of this series contain in abundance, in the more northern parts of the basin, *Fenestella socialis*, *Agnostus pisiformis*, and a *Lingula*, they are considered as the equivalent of the British Lingula-flags. The whole of these beds have a dip to the east, which is due to a series of north and south faults, which make the apparent thickness much greater than in reality is the case.

Below these the rocks have been described and mapped by Keilhau as belonging to his primitive or gneiss formation. The examination by Mr. Forbes showed, however, that gneiss was but rarely present, and that the coast-line was formed by a series of basin-shaped beds of metamorphic schists and quartzites. Below, and conformable to the lowest Silurian bed above-mentioned, is found a

* The latter of these Memoirs being but a continuation of the former, they are both here noticed together.

yellow sandstone, broken through by trap; under this a mica-schist, resting on a quartzite, which was greatly disturbed by granitic eruptions; below this a bed of hornblende-schist, attaining, in places, a thickness of 300 feet; and in its lower part containing a thin but extremely characteristic bed, remarkable for the predominance of silicates of alumina and magnesia, as chiastolite, andalusite, cyanite, rhœtizite, iolite, aspaziolite, chlorite, &c., which rendered it at once recognizable and of great service in the examination of the country further west; under this a true mica-schist, consisting of quartz and mica, resting upon a quartzite, which formed the upper bed of a series of six quartzites and six hornblendic schist beds alternating. None of these beds, in their normal state, contained felspar; the hornblendic schists are very variable in thickness, whilst the quartzites were found more constant.

As seen from the sections accompanying these memoirs, the above series of beds formed the coast-line between Langesund and Oster-risoer.

The gneiss present in the district was divided into two classes :—

1. A foliated granite, or an ordinary eruptive granite, in which the direction of the mica-planes had caused a parallel structure to be visible;

2. A rock formed *in situ* by the contact of the igneous rocks of the district with the metamorphic schists above described.

The first of these classes was well developed at Edisvand, where a section alongside a lake, about fourteen miles long, showed several mountains of this rock, with sides descending almost perpendicularly to the water's edge, and showing large fragments of hornblende and mica-schist enclosed in the granite-gneiss. These were often of immense size, and, from their dark colour, formed a striking contrast with the pinkish-white colour of the granite-gneiss. In parts the gneiss loses all traces of foliated structure, thus passing insensibly into an ordinary granite. At other parts the gneiss sends veins into the schists, which veins presented the appearance of ordinary granite; yet the change of structure was so gradual, that no line of demarcation could be drawn between the granite and the gneiss: the mineralogical character of both was the same; and, combined with the frequent occurrence of enclosed fragments of other rocks, no doubt could be entertained of its true eruptive origin; and everywhere the rounded and dome-shaped contour of the mountains made the same impression on the observer. In this gneiss no bedding was observed, only foliated structure.

The gneiss of Ekeberg and the Christiania Fjord, as also at Fossund, near Skien, is also considered by the author as pertaining to this class.

The second species of gneiss was very distinct from the above; and, by following out the beds, they were invariably found, sooner or later, to assume the character of the original schist. When greater masses of granite or diorite came in contact with the more fusible beds of these schists, they were sometimes so fused *in situ* as to be with difficulty distinguished from true igneous rocks; thus the hornblende-schists occasionally, under such circumstances, assumed the appearance of a dioritic rock. When, however, the alteration was not so intense, the schists became felspathic for some distance from the points of contact; and thus hornblende-schists became converted into hornblende-gneiss, mica-schists into micaceous gneiss. Even when a granite-vein cut through the schists, these became felspathic near the points of contact, although otherwise the beds themselves did not contain felspar.

When granite broke through the quartzites and mica-schists, epidote was generally developed; if through hornblende-schist, mica and felspar generally made their appearance near the points of contact.

The eruptive rocks of this district are divided into two classes, viz. acid and basic silicates.

To the former class belonged three varieties of granite:—

(*a.*) Granite consisting of oligoclase, quartz, and mica, and containing, as accessory minerals, moroxite and sulphuret of molybdenum, as at Skrubben, near Krageroe.

(*b.*) Granitec omposed of orthoclase, mica, and quartz, as at Hestnoesoerne, near Grimstad, and not known to contain other minerals.

(*c.*) Granite which, when normal, contains two felspars (orthoclase and oligoclase), mica, and quartz, and is considered as younger than the two preceding varieties, and probably more modern than the Silurian beds, and also than the norite of the west coast. The mineral orthite is particularly characteristic of this granite wherever it makes its appearance; and it is also remarkable for the presence of minerals containing cerium, lanthanium, yttrium, &c.; and even many common minerals, otherwise not known to contain these elements, were found, on analysis, to contain them in considerable amount when present in this granite,—as, for example, epidote, apatite, titanite, garnet, scapolite, &c. Many rarer minerals also occurred, as curenite, alvite, tyrite, ytterspath, &c.; and these minerals, though enclosed in the granite, generally contained a considerable amount of water.

This granite is very widely distributed from the western coast-line of Norway to the Baltic; and at Arendal the recent cuttings have shown that over considerable areas the vertically-foliated gneiss is in reality only a crust of comparatively few feet in thickness resting upon this granite, as can be seen in a section of Helle Felspar Quarry in a former Number of this Journal.

To the basic silicates belong,—

(*a.*) Diorite, consisting of a felspar with hornblende and titanite of iron. It had not been previously noticed, although occurring very largely in the district, and under very varied appearances—sometimes coarse-grained and in large mass, principally felspar with a little hornblende—at other times a fine-grained rock, which is a mixture of felspar, hornblende, and titanite of iron: when in veins it generally consists principally of hornblende, with a little felspar and titanite of iron. It forms the centre of many of the mountains at Walbjerg, near Krageroe, and much alters the schists with which it comes in contact. It contains, frequently, fragments of granite and schist, through which it has broken, and, as accessory minerals, rutile, copper-pyrites, magnetic oxide of iron, apatite, asbestos, &c.

(*b*.) Trap-dykes, varying considerably in character from one another, apparently according to the nature of the rocks through which they have passed — generally small, but occasionally, as at Dybvig, above 20 feet wide. These are considered to be of the same age as those mentioned in the commencement of this notice.

To this class also belong the zircon-syenite and augitic porphyry previously noticed. [D. F.]

On the Triassic Strata *of the* Vorarlberg. By Baron Richthofen.

[Proceed. Imp. Geol. Instit. Vienna, August 1857.]

Baron Richthofen, who has made the triassic and liassic beds in the Vorarlberg* and Lichtenstein the object of special investigation, finds that the northern limit of the crystalline schists runs from the Arlberg along the Klosterthal, as far as Dalaas; it then turns to the south-west, crosses the Montaron near Schrums, and passes into the Swiss Prättigau near Weiss-blatten on Mount Rheticon. This line and another running in a nearly parallel direction, from Feldkirch to the upper Iller Valley, are the boundaries of the triassic and liassic regions. The Trias and Lias are wanting to the north of this, and do not continue westward into the Helvetian territory.

The succession of strata, in ascending order, as clearly exposed to view in the Klosterthal, is—1. Verrucano and the Werfen-strata; 2. Guttenstein-limestone; 3. Marls with *Bactryllium Schmidii* and *Halobia Lommeli*; 4. Dolomite and porous limestones, passing into pumice-like "Rauchwackes;" 5. Main dolomite, in enormous development; 6. Koessen-strata; 7. Dachstein-limestones; 8. Adneth-strata and spotted marls, both of these forming some of the highest mountains. [Count M.]

On some Native Iron *in the* Chalk *of* Bohemia. By M. Neumann.

[Proceed. Imp. Geol. Instit. Vienna, August 1857.]

M. Neumann, whose father had first discovered the meteoric iron of Ellbogen (Bohemia), in presenting the Museum of the Imp. Geol. Institute with specimens of the metallic iron found in 1844 in the Pläner of Chotzen (Bohemia) on occasion of the driving of a rail-road-tunnel, stated that he himself found sixteen specimens of this iron, of a concentrically laminated structure, partly surrounded with the nodules of the marl in which they were originally found. The weight of the largest specimen was 3¼ ozs. It is stated beyond any doubt that these fragments have all been found in the centre of the hill traversed by the tunnel, at a depth of 120 feet below the surface. They resemble soft iron; their structure, however, is more distinctly fibrous, without a vestige of crystallization, and not showing Wid-

* See also Quart. Journ. Geol. Soc. vol. xi. Part 2. Miscell. p. 16.

mannstatter's figures when etched. Their chemical constitution is $\frac{98 \cdot 33}{100}$ iron, $\frac{0 \cdot 61}{100}$ nickel, $\frac{0 \cdot 32}{100}$ arsenic, $\frac{0 \cdot 74}{100}$ graphite.

M. Neumann's investigations, and those of Prof. Reuss, prove the Chotzen iron to be a natural production, and not artificial; nor can it be the result of a reductive natural process undergone by any ferriferous mineral substance. M. Neumann considers it to be meteoric iron which had fallen to the surface during the cretaceous period, and similar in every way to the iron which has frequently fallen in modern times. The native iron discovered (October 1852) by M. Borneman in the argillaceous Keuper coal of Mühlhausen (Thuringia) differs essentially from the Chotzen native iron, having been found associated with black magnetic oxide of iron. [COUNT M.]

On the DEVONIAN ROCKS, *near* AVESNES.
By M. J. GOSSELET.

[Bulletin de la Société Géologique de France, tom. 14. pp. 364–373.]

The limestones of Oetrœungt, near Avesnes, have hitherto been regarded as Carboniferous, and are so coloured in the great Geological Map of France. M. Gosselet, at the request of M. Hébert, has investigated them, and confirms the suspicions of the latter as to their Devonian character. By careful sections, and tables of fossils, he has enlarged our acquaintance with the middle rocks of this series, and, by connecting his researches with the labours of M. Dumont, has thrown some additional light on the still vexed question of correlation among the Devonians.

There are quarries of undoubted Carboniferous limestone at Oetrœungt with *Productus sublævis*; but their relations with the lower strata are nowhere displayed in visible contact.

The section of the great lower limestone at the Parc Quarries, shows fourteen well-characterized beds with occasional *Clymeniæ*, and constantly-recurring *Terebratula concentrica* and *Spirifer aperturatus*. These beds may be grouped into four divisions :—

1. The first from above, characterized by *Pentamerus acutolobatus*.
2. The next, by large *Spirifer aperturatus*.
3. Grey limestones, with *Terebratula pugnus*.
4. Slates of Notre-Dâme-des-Monts.

M. Gosselet then examines other quarries on the line of strike, and shows the persistence of the subdivisions eastward as far as Givet, and establishes distinct fossil horizons in the great Eifelian limestones round that picturesque town. The line of *Stringocephalus Burtini* (elswhere typical) passes at the base of the frowning cliffs of Charlemont.

He then carefully alludes to sections down the Meuse towards the mountain-limestone of Dinant, and upwards towards the Ardennes slates of Meziers. We left M. Gosselet near the latter, verifying the singularly accurate work of Dumont in his local divisions. The Ahrian, which succeeds the Eifelian, appears to be a gritty representative of our Plymouth limestones. The Coblentzian series is a more solid form of the Looe slates, with occasional plants; whilst the underlying Gedinian appears to be a feeble exhibition of the lower Silurian.

The uppermost Devonian—the Cypridina-slates or Petherwin rocks—do not occur on the Meuse; but the Carboniferous series rests on the middle Devonians, which are much overthrown, but may be seen to be supported by lower Devonians, and these by lower Silurians. Cambrian rocks form the contour of the beautifully wooded gorge of the river southwards; and slate-quarries mark the commencement of their reign. [S. R. P.]

On the Fossil Faunæ of the Equivalent of the Bone-bed *between the* Keuper *and the* Lias. By Dr. A. Oppel and Dr. Fred. Rolle.

[Proceed. Imp. Acad. Vienna, October 1857.]

The organic remains common to the Triassic, Liassic, and Jurassic formations of Central and Northern Europe and to the coeval, although very differently developed, deposits in the Alpine and Mediterranean regions, are but few in number; their closer investigation, however, is one of the most promising objects of Palæontological studies. Dr. Albert Oppel and Prof. E. Suess's paper "On the probable Equivalents of the Alpine Kössen-strata in Suabia* " opened a new way for stating the real relative age of the Alpine Secondary rocks, showing the Kössen-strata † to have their equivalent in Würtemberg in the yellowish-white quartzose sandstone intercalated between the Keuperian red marls and the Liassic blue limestones.

Two other papers‡,—one by Dr. Oppel, "Further proofs of the existence of Kössen-strata in Suabia and Luxemburg," the other by Dr. Fred. Rolle, "On some organic remains, appearing in Suabia on the limit between the Keuper and the Lias,"—may be considered as complementary to the before-mentioned memoir.

Dr. Oppel added to the fossil forms known to occur in the Bone-bed-Sandstones (Prof. Quenstedt's "upper or yellow Keuper-Sandstone") a new species of *Anatina* (*An. Suessi*), and described an identical fauna of some other Suabian localities but very imperfectly known before. Among these localities Täbingen § is particularly interesting, as being the place in south-western Germany where the Bone-bed sandstone has been first recognized and described. Alberti ‖ was the first geologist who described, under the name of fossiliferous sandstone of Täbingen, the strata now acknowledged to be the equivalents of the Kössen-beds (Alpine Limestone) as a distinct member of the Triassic group. The presence of *Mytilus minutus*, Goldfuss, and *Cardium cloacinum*, Quenstedt, affords sufficient evidence of the

* Quart. Journ. Geol. Soc. vol. xiii. Part 2. Miscell. p. 1.

† See Quart. Journ. Geol. Soc. Part 2. Miscell. p. 25.

‡ Proceed. Imp. Acad. Vienna, October 1857.

§ Täbingen is not to be confounded with Tübingen, near Stuttgart, the seat of a celebrated University.

‖ 'Monographie des bunten Sandsteins, Muschelkalkes und Keupers,' Stuttgart, 1834.

strata being coeval with those of Nellingin, Nürtingen, &c. in Suabia, and with the Kössen-strata of the Alps.

Dr. Oppel has discovered the same stratum in Luxemburg, resting, as in Suabia, on the red Keuper marls, and overlaid by blue Liassic limestones. In this country, the localities of Dahlheim and Ellingen afford the following fossils:—

Sargodon tomicus, *Plien.*
Sphærodus minimus, *Ag.*
Gyrolepis tenuistriatus, *Ag.*
Saurichthys acuminatus, *Ag.*
Schizodus cloacinus, *Quenst.* sp.
Cardium Rhæticum, *Merian.*
Avicula contorta, *Portl.*
Mytilus minutus, *Goldf.*
Pecten Valoniensis, *Defr.*

Dr. Rolle has described the organic remains, occurring in the calcareous Bone-bed of Täbingen, which rests on the above-mentioned yellow sandstone, and is overlaid by blue Liassic limestone. These fossils are

Hybodus sublævis, *Ag.*
H. minor, *Ag.*
Acrodus minimus, *Ag.*
Saurichthys acuminatus, *Ag.*
Sargodus tomicus, *Plien.*
Gyrolepis tenuistriatus, *Ag.*
Serpula exigua, *Rolle.*
Ammonites Hagenovi, *Dunk.*
Pleuromya Suevica, *Rolle.*
Cardium Philippianum, *Dunk.*
Astarte Suessi, *Rolle.*
Leda Oppeli, *Rolle.*
Lima tecticosta, *Rolle.*
Pecten Hekli, *d'Orb.*
Ostrea, *sp.*

Dr. Rolle concludes from these fossils, that the Molluscan fauna of this stratum bears a decidedly Liassic character, but the Ichthyologic fauna is in some sort related to that of the Lower Triassic beds. It may be inferred from these circumstances, that between the Keuperian and Liassic epochs the destruction of the then existing fauna had been neither sudden nor total, Triassic animals disappearing, and Liassic ones taking their places gradually, deposit by deposit; so that Liassic Mollusca were coexistent with the last of the Triassic fishes. The two memoirs, analysed in this notice, will be of special interest for British geologists, the deposits considered in them corresponding to the "Bone-bed" of England and Ireland (Axmouth, Austcliff, Lisnagrib, &c., and to the "Portrush Beds").

[Count M.]

On the Geology *of a part of* Hungary. By Dr. Peters.

[Proceed. Imp. Geol. Instit. Vienna, August 1857.]

Professor Peters, in continuing his investigations, commenced around Pesth and Buda, as far south-eastward as Tokod, Dömös, and Perball, finds that this region comprises the western circumference of the Pesth trachytic massif with great deposits of tuffs, including near Gran Neogene marine shells, and, near Dömös, lignites and vegetable remains. Limestones, appearing partly close to trachyte, partly in isolated hills amid the Tertiaries, are all of the Dachstein series, and in some localities are overlaid by white Nummulitic dolomite. The great Eocene deposits of fossil fuel at Tokod, Dorog, &c. are imbedded in freshwater strata, overlaid by Eocene marine deposits. Estuarine deposits are found at Sarisap. The Neogene epoch is represented by inferior plastic clay ("Tegel") occurring in a few localities near Gran, by far-spread sandstones and sands, and in the south-west by Cerithium-limestone. These deposits, together with extensive layers of diluvial clay ("Löss"), rest on the isolated and evidently disturbed strata of the Eocene period. The Eocene coal of this district, being unfit for the preparation of coke, has hitherto been set aside by the use of the Banat and Fünf-kirchen coal, and on account of the little attention paid in Hungary to fossil fuel in general. The beds of argillaceous Ironstone occurring on the limits between the Tertiary sandstone and Dachstein-limestone or Nummulitic dolomite, are too insignificant to be of practical value.

[Count M.]

On the Coal-beds *of* Offenburg. By M. Ludwig.

[Proceed. Imp. Geol. Instit. Vienna, August 1857.]

The coal of *Offenburg* (Grand-Duchy of Baden) is imbedded in a zone of Carboniferous Sandstone, 720—840 feet in breadth, between the steep gneiss rocks at the mouth of the Kinzig valley. The coal-beds themselves, dipping at high angles, have originally been thought to be *veins*. The author proves them to have been deposited horizontally, or nearly so, in the bottom of a basin, the upper portions of which have been subsequently brought together by a sinking movement along a diametral line, so that at present the disturbed beds offer many difficulties to regular mining operations. The thickness of the upper (anthracitic) chief bed varies between 1 and 30 feet; the lower chief bed, the scantily coking coal of which resembles the variety called Pitch-coal, is between 1 and 4 feet in thickness. The chief bed continues beneath the depth of 570 feet hitherto attained.

The anthracitic variety of the Offenburg coal has been recently, on M. Haumann's instigation, tried as fuel for railroad-locomotives; and the experiment has perfectly succeeded.

The bed, and especially the slate, immediately covering the chief bed, contains a number of fossil plants, among which Professor Geinitz has found the following species:—

Calamites cannæformis, *Schl.*
Asterophyllites longifolius, *Sternb.*, sp.
Hymenophyllites dissectus, *Brongn.*
Cyclopteris flabellata, *Brongn.*
Cyatheites asper, *Brongn.*
Sphenopteris lanceolata, *Gutb.*
Sph. Hœninghausi, *Brongn.*
Sph. microloba, *Göpp.*
Aspudiaria undulata, *Sternb.*
Asp. tetragona, *Sternb.*, &c.

South of Offenbach, near Zursweiler, the gneiss is overlaid by variegated sandstone, spreading far off southward, together with the Carboniferous strata, found in a shaft which was sunk near Diersburg.

[Count M.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On Fluor-spar *in the* Lombardy Alps. By Dr. Curioni.

[Proceed. Imp. Geol. Instit. Vienna, Feb. 23, 1858.]

Sig. Curioni's paper 'Come la Geologia possa contribuire piu direttamente ai progressi delle Industrie *,' gives a detailed notice of nearly inexhaustible veins of flour-spar in the Lombardian Alps. One vein of about four feet in breadth, and known along a considerable tract of its run, occurs on Monte Presolana, in the Val di Scalve, N.W. of Lago Palzone; another, of more than twenty-one feet breadth, is imbedded in the red sandstone of Val Torgola, a branch of Val Trompia, and runs N.E.–S.W.

The fluor-spar of the second vein is nearly milk-white, of splintery fracture, and contains $1\frac{1}{2}$ per cent. of water, evaporating in elevated temperature. It is but locally mixed with minute crystals of iron pyrites. Its central portion includes galena, which, in the middle of the fifteenth century, was an object of important mining enterprizes. [Count M.]

On Crystallized Euclase *in the* Ural. By Col. Kokscharow.

[Proceed. Imp. Geol. Instit. Vienna, Feb. 23, 1858.]

Colonel Kokscharow noticed, in a letter to Director Haidinger, his having discovered three specimens of crystallized euclase in the gold-stream-works of the South Ural, near the River Sanarka, occurring there associated with emeralds, red corundum, disthene, &c. The mountain-chain, the detritus of which is deposited in these stream-works, seems to Col. Kokscharow to bear a peculiar character. On the map appended to Baron A. Humboldt's and Prof. G. Rose's 'Travels to the Ural,' this chain differs completely in its direction from the other chains of the South Ural.

[Count M.]

* Giornale del R. Istituto Lombardo, vol. ix.

On a Bed of Polishing-slate *found near* Leitmeritz (North Bohemia) *in* 1854. By M. Foetterle.

[Proceed. Imp. Geol. Instit. Vienna, Feb. 23, 1858.]

This infusorial bed, about 240 feet in extent, and in some parts twelve feet thick, rests on Brown-coal sandstone. The lowermost portion (about five feet) is mixed with basaltic tuff; then follows six inches of unmixed yellowish-white slate, eminently rough to the touch: this is separated by four inches of tuff from the upper slate-bed, about six feet in thickness. This upper slate is of a more argillaceous nature, therefore softer and nearly greasy to the touch, with thin alternating layers of darker and lighter tint. The whole is overlaid by a basaltic tuff and humus, and the surface is covered with wood.

The upper slate-layer includes a number of leaf-impressions, such as *Cinnamomum Schuretseri* (Heer), *Salix varians* (Heer), *Ulmus bicornis* (Unger), and an indeterminable species of *Acer*, together with remains of *Leuciscus brevis* (?), Ag., which last occurs also in the lower slate, but more rarely and less distinct, the bones of the head and the vertebræ being generally obliterated by the deposit of a menilite-like substance. The impressions from the upper slate are of admirable distinctness, even in their most minute details. *Galionella varians* is the only infusorial form hitherto found in these slates, and possibly the exclusive contributor to their formation.

[Count M.]

On the Secondary Rocks *of the* Eastern Alps. By M. E. Suess*.

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The secondary strata of the eastern portion of the Alps, especially those of the Triassic and Jurassic groups, are so different from those in the rest of Europe, that their real nature has been but recently cleared up by assiduous palæontological studies. Fr. Von Hauer was one of the first geologists whose exertions succeeded in bringing some light on this intricate and important subject.

The petrographical peculiarity of the secondary rocks in the Austrian Alps, taken as a whole, is an enormous predominance of pure calcareous deposits of considerable thickness,—marly or schistose deposits being, in proportion, of rarer occurrence and insignificant thickness.

The palæontological features of these secondaries are characterized by frequent diversity and size of the Cephalopoda and Brachiopoda, keeping (with some few exceptions) all other mollusca in the background as far upward as the Cretaceous strata, while the occurrence of corals and echinoids is limited to the subordinate marls. These characters concur in denoting the pelagic origin of the deposits in

* M. Suess's memoir will be printed in full in the 'Beiträge zur Palæontologie von Oesterreich,' which M. Fr. Von Hauer intends to publish.

question. Any geological map of Germany shows, at the first aspect, that, northward of a line running from Passau, through Ratisbonne, to Basel, the several Jurassic and Triassic series of deposits (*étages*) dip regularly with each other, appearing on the map as concentric zones, the geological age of which becomes of older date, and the contact of which with the older rock-massifs of Central Europe becomes closer, in proportion to their progression in the north-west direction. The same phænomenon, although by far more indistinct, may be observed as far as the south of Lyons. It becomes very apparent again on the margin of the great Paris- and London-basin, where it has been studied by Elie de Beaumont, Hébert, and many other geologists.

The diffusion of the "variegated sandstone" throughout these regions indicates approximatively the form of the land-areas at the beginning of the secondary period. The most interesting among them are the central plateau of France, the great continent east and west of Coblenz, and the continent of Bohemia. Smaller islands, between these three large continents, occur in the Rhenish countries (Gresly's "Hercynian," "Vogesian," and "Bruchsal" Islands), and are represented in the present Alpine chain (especially in the Tyrolian portion) by deposits of littoral character. As the deposits retrograde to the centre of the single basins, the separate islands of this archipelago unite, sooner or later, into coherent masses. During the close of the Jurassic period, a continuous tract of land extended from Silesia to Namur; and the inhabitants of the narrower and scarcely connected seas of this epoch lose their uniformity of character. The contrast between the Jurassic seas of Northern and Southern Europe becomes more and more striking; and the littoral or subpelagic deposits in Württemberg and Bavaria, as they decrease in geological antiquity, assimilate themselves more and more to the pelagic deposits of the coeval seas in the Alpine region.

The only explanation to be given of these phænomena is a general upheaval (although occasionally interrupted by oscillations) of the whole secondary archipelago during an extremely protracted lapse of time. This upheaval not only connected the single islands, and brought them nearer the shore-line, but also imparted a more and more littoral character to the strata deposited on the surface at present occupied by the Alps. Under such circumstances, and under the influence of the vast deposits already formed, the pelagic character could not give way to another of more subpelagic aspect.

Palæontological facts tend to confirm the induction, that (generally taken) the more recent an Alpine secondary deposit is, the more it must agree with the secondary deposits of Franconia and Suabia. Whilst nearly the whole of the Alpine trias is perfectly different from the coeval deposits in the rest of Europe, the basis of the Jurassic group shows a series of strata of generally a very pure calcareous nature, and containing two or three littoral species, extending as far as Ireland. The number of concordant forms increases in the Upper Lias, and they acquire a very considerable share in the Upper Jurassic fauna.

The strata of Stramberg, in Moravia, belong to the Upper or White Jura. M. Suess has examined thirty-seven species of Brachiopods occurring in them: eight of these species are to be found in the Scyphia-limestone of Suabia, and three of them are known in the "Terrain Corallien" of the Département de l'Yonne. A rather considerable number of species peculiar to the Scyphia-limestone of Suabia seem to be associated with Northern-French forms in Moravia, and even as far as the Salzkammergut in Upper Austria. This fact affords a proof that, during the secondary period, the Suabian forms extended along the southern, and the North-French forms along the northern margin of the great Centro-European continent. Above these "Stramberg-strata" M. Suess has observed, near Nitholsburg in Moravia, others of more marly nature, palæontologically identical with those of Mattheim (Württemberg), which last by this fact are proved to be later in age than the "Terrain Corallien" of Northern France.

Besides these Suabian and French forms, the Stramberg-strata of Moravia have others, prevailing in localities somewhat more distant from the shore-line of the Bohemian continent, and consequently more adapted for living in deeper water.

M. Suess concludes with noticing that, among a series of Carinthian fossils sent to him for the purpose of determination by M. F. Von Rosthorn, he met with forms undoubtedly indicating the presence of strata older than those of the Carboniferous period. Their locality is at Kappel. The matrix, a light-grey, partly rose-coloured limestone, is petrographically identical with the limestone of the same locality, which has been separated by M. Lipold from the true Gailthal (Carboniferous) strata, under the denomination of "Lower Gailthal Limestone." These organic remains are, the pygidium of a large species of *Bronteus*, fragments of a Cephalopod, and a *Spirifer* very similar to a species from the Silurian limestone of Koniezerus, near Beraun (Bohemia).

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