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LONDON GEOLOGICAL SOCIETY
QUARTERLY JOURNAL

21

1865





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GEOLOGICAL SOCIETY OF LONDON.

ANNUAL GENERAL MEETING, FEB. 17, 1865.

REPORT OF THE COUNCIL.

IN laying before the Geological Society of London their Annual Report for the past year, the Council have great satisfaction in announcing that the extraordinary increase in the numbers of the Society, noticed in their last Report, has continued through the year 1864 in even a more marked degree.

The Fellows elected last year number no less than 75, or 7 more than those elected the year before, which was at that time the largest addition to the lists ever made in one year. Of these 75 Fellows, 61 have paid their fees, making with 11 previously elected, who paid their fees in 1864, the large total of 72 new Fellows. On the other hand, the Society has sustained the loss of 19 Fellows by death, and of 4 more by resignation, thus giving a net increase of 49 ordinary Fellows.

One Foreign Member and one Foreign Correspondent have been reported as deceased.

Eleven Foreign Correspondents were elected last year; ten to make up the full number authorized to be elected by the resolutions passed at the Special General Meeting held on January 8, 1863; and one to supply the place of a Foreign Correspondent elected to fill the vacancy in the list of Foreign Members.

The total number of the Society at the close of 1863 was 1033; at the close of 1864, 1092.

The financial condition of the Society is not less satisfactory than is indicated by the statistics just given. The Income has exceeded the expenditure by £85 19s. 5d., notwithstanding that the arrears of subscription have increased during the year by the large sum of £160; and that several special items (including a new carpet for the Council-room, and a large expenditure on account of the new edition of the Greenough Map) are comprehended in the Balance Sheet.

The funded property of the Society has been increased by the sum of £210, and is therefore £4560.

The Council have to announce the completion of Vol. XX. of the Journal, and the publication of the First Part of Vol. XXI.

They have also to report that in March last Mr. Ralph Tate was appointed to fill the office of Library and Museum Assistant, rendered vacant a few months previously by the resignation of Mr. Stair.

The New Edition of the Greenough Geological Map has been completed, and will shortly be ready for distribution and sale.

The Council have further to announce that they have unanimously awarded the Wollaston Medal to Thomas Davidson, Esq., F.R.S., for the highly important services he has rendered through many years to the science of Geology, by his critical and philosophical works on Fossil Brachiopoda, the illustrations of which have been drawn by himself, and entirely at his own expense; and the balance of the proceeds of the Wollaston Fund to J. W. Salter, Esq., F.G.S., in recognition of his valuable services in the elucidation of Palæozoic Fossils, and to assist him in completing his Monograph on British Trilobites.

Report of the Library and Museum Committee, 1864-65.

The Museum.

The Society's Foreign Collection has received several important additions since the last Anniversary, of which the following are more particularly worthy of notice:—An extensive and interesting collection of Fossil Foraminifera from India, including several preparations showing microscopic structure, presented by Dr. H. J. Carter, F.R.S. A remarkably large specimen of Graphite, and a smaller one exhibiting a Prismatic or Crystalline structure, from the Lower Tourgouska District of Northern Siberia, presented by M. Sidoroff, of St. Petersburg. A series of Miocene Fossils from Messina, and one from Poland, presented by Sir Charles Lyell, Bart., F.G.S., and Alfred Evans, Esq., respectively. A collection of Neocomian Fossils from Nice, presented by Alan Lambert, Esq., F.G.S.; and one of Cénomaniens Fossils from Normandy, presented by R. Tate, Esq., F.G.S. The collections in illustration of the Geology of the colonies have been enlarged by the presentation of a suite of Fossils from the Cape of Good Hope, by Dr. Rubidge, F.G.S.; of Tertiary Corals from South Australia and from Jamaica, by Dr. P. Martin Duncan, Sec.G.S.; of Rocks and Fossils from the Coal-measures of New South Wales, by W. Keene, Esq.; and especially by the gift of a very fine specimen of *Eozoon Canadense*, and a Section showing its minute structure, by Sir W. E. Logan, F.G.S.

Considerable progress has been made during the past year in the rearrangement of the collections and the naming of the specimens. Mr. Tate has named and placed upon new tablets the whole of the British Liassic and Rhætic specimens, occupying about 36 drawers; and has filled up many of the gaps in the Society's Collection by donations from his own cabinet. Dr. Duncan has continued the work in the Museum which he began last year, and has now named nearly all the specimens of Fossil Corals in the Foreign Collections; these have been placed upon tablets by Mr. Tate and Mr. Horace Woodward, and, to prevent injury to fragile specimens, some

of the drawers containing them have been fitted with glass. Dr. Duncan has also nearly completed the determination of the Foreign Echinodermata in the Society's possession, and the collection of Bordeaux Tertiary Fossils has been cleaned and partially rearranged by the President and Mr. Jenkins.

The following table, containing the number of drawers of Fossils that have been entirely named and mounted from each country and formation, will show more clearly the progress that has been made in this division of the Museum-work during the past year.

		Drawers.
England	Lias	36
*West Indies.....	Miocene.....	7
Alabama	Eocene	3
Cutch	Eocene	3
*Scinde.....	Tertiary.....	1
*Jamaica	Cretaceous and Eocene	1
Normandy	Cretaceous.....	4
Miscellaneous Corals		1
		—
		56

In addition to the above, the Gosau Collection of Corals referred to in Murchison and Sedgwick's memoir on the 'Structure of the Alps,' has been named and arranged; as also have the Italian and French Miocene and Eocene Corals.

The Sharpe Collection of Palæozoic Zoantharia, in 18 drawers, has been examined, and most of the specimens named by Dr. Duncan, who intends to arrange the species zoologically, their duplicates being arranged geologically in other cabinets. Several American Lower Silurian species have also been determined. It is proposed shortly to form a catalogue of all the series of Corals, and it is believed the Society will then have a named collection of Zoantharia, easily accessible. The Committee hope that Fellows will present the Society with Liassic and other rare groups of Corals, in order that the collection may be as complete as is possible.

Other portions of the Museum-work have not been neglected, Mr. Horace Woodward having completed the Catalogue of the Foreign Specimens in the Sharpe Collection of Mollusca, and the List of Memoirs containing references to specimens in the Foreign Collections, both of which were begun last year.

A number of small mahogany tablets having been obtained, in accordance with the recommendation of the Library and Museum Committee of last year, the formation of a collection of Fossil Polyzoa, uniform with that of the Foraminifera formed by Mr. T. Rupert Jones, has been commenced by the Assistant-Secretary.

J. GWYN JEFFREYS.
THOS. WILTSHIRE.
S. P. WOODWARD.

* Corals, named by Dr. Duncan.

The Library.

Since the last Anniversary some important additions have been made to the Library, both by gift and purchase. Amongst the purchases may be mentioned Gaudry's 'Animaux Fossiles de l'At-tique,' Opper's 'Palæontologische Mittheilungen,' Dollfus's 'Faune Kimmeridienne,' Nordmann's 'Palæontologie Südrusslands,' the 'Exploration de l'Algérie,' and Le Coq's large Map of Auvergne, in sheets.

The Map-collection has also been enlarged by the gift of a large number of sheets of the Ordnance Survey of Great Britain, on the 1-inch and 6-inch scales, presented by the Director-General, Col. Sir Henry James, F.G.S.; a series of Geological and Topographical Maps of parts of New Zealand, presented by Dr. Hochstetter; some of the sheets of the Geological Survey Map of the Netherlands, presented by His Excellency the Minister for the Netherlands; six sheets of Erdmann's 'Sveriges Geologiska Undersökning,' presented by the Author; the fifth edition of Sir R. I. Murchison's Geological Map of England and Wales, presented by the Author; and a number of French charts, given by the Dépôt de la Marine.

The Assistant-Secretary reports that he has found Mr. Horace Woodward of much use in making Diagrams for the Evening-meet-ings, and in doing the current work of the Library.

J. GWYN JEFFREYS.
THOS. WILTSHIRE.
S. P. WOODWARD.

*Comparative Statement of the Number of the Society at the close of
the years 1863 and 1864.*

	Dec. 31, 1863.	Dec. 31, 1864.
Compounders	144	156
Contributing Fellows	329	373
Non-contributing Fellows	479	472
	<hr/>	<hr/>
	952	1001
Honorary Members	3	3
Foreign Members.....	47	48
Foreign Correspondents ..	30	39
Personage of Royal Blood	1	1
	<hr/>	<hr/>
	1033	1092
	<hr/>	<hr/>

General Statement explanatory of the Alteration in the Number of Fellows, Honorary Members, &c. at the close of the years 1863 and 1864.

Number of Compounders, Contributing and Non-contributing Fellows, December 31, 1863	952
<i>Add</i> Fellows elected during former year and paid in 1864	11
<i>Add</i> Fellows elected and paid in 1864	61
	<hr/>
	1024
<i>Deduct</i> Compounders deceased	4
Contributing Fellows deceased	8
Non-contributing Fellows deceased	7
Contributing Fellows resigned	4
	<hr/>
	23
	<hr/>
	<u>1001</u>
Number of Personages of Royal Blood, Honorary Members, Foreign Members, and Foreign Correspondents, December 31, 1863	81
<i>Add</i> Foreign Member elected in 1864	1*
<i>Add</i> Foreign Correspondents elected in 1864	11*
	<hr/>
	93
<i>Deduct</i> Foreign Member deceased	1
Foreign Correspondent deceased	1
	<hr/>
	2
	<hr/>
	91

Number of Fellows liable to Annual Contribution at the close of 1864.

Ordinary Contributors	326
Non-residents elected before March 1st, 1862	47
	<hr/>
	<u>373</u>

DECEASED FELLOWS.

Compounders (4).

W. Terry, Esq.	|	The Ven. Archdeacon Burney.
Leonard Horner, Esq.	|	John Atkinson, Esq.

* Numbers corrected with respect to Minute of General Meeting, Jan. 7, 1863.

Residents and other Contributing Fellows (8).

Major-General Portlock.	W. J. Dunsford, Esq.
C. W. Giles-Puller, Esq.	William Taprell, Esq.
Lord Ashburton.	Rev. William Lister.
Duke of Newcastle.	C. Sturtivant Wood, Esq.

Non-contributing Fellows (7).

Joseph Woods, Esq.	William Llewellyn, Esq.
J. H. Slater, Esq.	William Hulton, Esq.
Rev. R. Daniel.	John Moreton, Esq.
James Farrer, Esq.	

Foreign Member (1).

Professor Benjamin Silliman.

Foreign Correspondent (1).

Professor Hitchcock.

The following Persons were elected Fellows during the year 1864.

January 6th.—Nelson Boyd, Esq., 2 Great George Street, Westminster; Henry Hakewill, Esq., C.E., 38 Harrington Square; John Robinson McClean, Esq., V.P.I.C.E., 23 Great George Street, Westminster; and Rev. Frederick Silver, M.A., F.R.A.S., Norton in Hales, Salop.

— 20th.—William Roby Barr, Esq., Norris Bank, Stockport; John Sidney Crossley, Esq., M.I.C.E., The Field, Litchurch, Derby; Colin Wilson Macrae, Esq., Oriental Club, 18 Hanover Square; Rev. Henry Housman, Northall, near Dunstable; E. J. Routh, Esq., M.A., St. Peter's College, Cambridge; George St. Clair, Esq., Holford House, Regent's Park; John Benjamin Stone, Esq., Holly Villa, Sutton Street, Ashton, near Birmingham; and Mutu Coomara Swamy, Esq., Athenæum Club, Pall Mall.

February 3rd.—Charles William Villiers Bradford, Esq., B.A., St. Catherine's College, Cambridge, and Greatham Rectory, Petersfield.

— 24th.—Edward Easton, Esq., 49 Upper Bedford Place, Russell Square; George Maw, Esq., F.L.S., F.S.A., Benthall Hall, near Broseley, Salop; Joseph Elliot Square, Esq., 4 Stanley Crescent, Kensington Park; and Edward B. Tawney, Esq., Luleston, Bridgend, South Wales.

March 9th.—William Eassie, Esq., High Orchard House, Gloucester; Francis Ablett Jesse, Esq., F.L.S., Llanbedr Hall, Ruthin; and Henry Lucas, Esq., 19 Hyde Park Gardens.

— 23rd.—Sidney Beisley, Esq., The Cedars, Laurie Park, Sydenham; James Samuel Cooke, Esq., 12 Abingdon Street, Westminster; Robert Damon, Esq., Weymouth; Rev. Dr. Dendy, 12 Vicarage Gardens, Kensington; John Whitfield, Esq., M.I.C.E.,

89 Great Portland Street; and Rev. Henry H. Winwood, M.A., Cavendish Crescent, Bath.

April 13th.—James Cope, Esq., Wolverhampton; Rev. Burford Waring Gibsons, M.A., B.Sc., F.C.S., Mercers' School, London; Dr. James Alexander Grant, Ottawa; James Pilbrow, Esq., F.S.A., M.I.C.E., Apsley House, Queen's Road, Richmond; and Rev. J. L. Rome, Hull.

— 27th.—Dale Knapping, Esq., Blackheath Park; Archibald Travers, Esq., St. Swithin's Lane, E.C.; John Plant, Esq., Peel Park, Salford; and Searles Valentine Wood, Jun., Esq., Brentwood, Essex.

May 11th.—Thomas Carrington, Jun., Esq., Chesterfield, Derby; J. B. Even, Esq., C.E., 36 Rue Montague, Brussels; Rev. John Henry Timins, M.A., West Malling, Kent; and Henry Woodward, Esq., F.Z.S., British Museum, and 144 Leighton Road, Camden Town.

— 25th.—Rev. J. Chadwick Bates, M.A., F.R.A.S., Castleton Moor, near Manchester; William Brooke, Esq., Brook Street, Manchester; William Henry Nevill, Esq., Llangennech Park, Llanelli, Carmarthenshire; and John Pentecost, Esq., F.C.S., 1 Park Street, Torquay.

June 8th.—Christopher Oakley, Esq., 10 Waterloo Place, Pall Mall; George Edward Roberts, Esq., Geological Society, Somerset House, and 7 Caversham Road Villas; and Rev. Henry W. Watson, M.A., Harrow.

— 22nd.—T. Currie Gregory, Esq., C.E., 149 West George Street, Glasgow; John Hamilton, Esq., Fyne Court, Bridgewater, Somersetshire; Edward Langdon, Esq., New College, Oxford; and George Paddison, Esq., M.I.C.E., Petersham, Surrey.

November 9th.—Frederick Braby, Esq., 28 Osnaburgh Street, Regent's Park Road.

— 23rd.—William Stephen Mitchell, Esq., Gonville and Caius College, Cambridge.

December 7th.—William Guybon Atherstone, M.D., M.R.C.S., Graham's Town, Cape of Good Hope; James Brogden, Esq., Tondou Iron Works, Glamorganshire; Lieut. Alexander Beerton Brown, Royal Artillery, Gibraltar; F. H. Dickinson, Esq., Kingweston, Somerset; George Dowker, Esq., Stourmouth House, near Wingham, Kent; George Baker Forster, Esq., Backworth Hall, near Newcastle; Charles Graham, Esq., B.Sc. Lond., University College, London; Thomas B. Lloyd, Esq., Spring Hill, Birmingham; William Crighton Maclean, Esq., Great Yarmouth; William Molyneux, Esq., Branston Cottage, Burton-on-Trent; William Prosser, Esq., M.R.C.P., Wilmslow, near Manchester; James E. Randall, Esq., Rudloe Lodge, Corsham, Wilts; James William Hamilton Richardson, Esq., 27 East Parade, Leeds; R. N. Rubidge, M.B., M.R.C.S., of Port Elizabeth, Cape of Good Hope, 83 Gower Street, Bedford Square; Rev. Richard Norris Russell, M.A., Brachampton Rectory, Stoney Stratford; William Walter Stoddart, Esq., 9 North Street, Bristol; Rev. Robert Boog

Watson, B.A., F.R.S.E., 4 Bruntsfield Place, Edinburgh; and J. Harris Wills, Esq., Houndiscombe Place, Plymouth.
 December 21st.—Henry Bowman Brady, Esq., F.L.S., Newcastle-upon-Tyne; Richard Brown, Esq.; Major William Howley Goodenough, R.A.; John Jones, Esq., The Trindle, Dudley; and John Reginald Yorke, Esq., M.P., Tewkesbury.

The following Persons were elected Foreign Correspondents during the year 1864.

January 6th.—M. Charles Gaudin, of Lausanne; Herr Gumbel, Bergmeister, of Munich; Professor Steenstrup, of Copenhagen; M. Paul Gervais, of Montpellier; Herr George F. Jäger, of Stuttgart; Dr. A. Oppel, of Munich; Dr. Hitchcock, of Amherst; M. Desor, of Neuchâtel; and Dr. T. Kjerulf, of Christiania.
 June 22nd.—Dr. Charles Martins, Director of the Botanical Gardens of Montpellier; M. Jules Desnoyers, Jardin des Plantes, Paris; and M. Bosquet, of Maestricht.

The following Persons were elected Foreign Members during the year 1864.

January 20th.—Cavaliere Paolo Savi, Professor of Geology in the University of Pisa.
 December 21st.—M. Jules Desnoyers, Jardin des Plantes, Paris.

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

British Specimens.

Five recent Corals; presented by Dr. P. Martin Duncan, Sec.G.S.
 Specimens of *Montlivaltia Haimeii*, and *Montlivaltia*, sp., from the Lower Lias, Warwickshire; presented by the Rev. P. B. Brodie, M.A., F.G.S.
 Specimens of Coal from the Chalk of Kent; presented by R. A. C. Godwin-Austen, Esq., F.R.S., F.G.S.
 A series of Cretaceous Fossils from Dover; specimens of *Nautili* from the London Clay; and an Apiocrinite from the Bradford Clay; presented by Alan Lambert, Esq., F.G.S.
 Fossils from the Lias of England and Ireland; presented by Ralph Tate, Esq., F.G.S.
 Casts of *Ostrea*, &c., from the Upper Chalk of Grays, Essex; presented by R. Meeson, Esq., F.S.A., F.G.S.

Foreign Specimens.

Four Minerals from New South Wales; presented by Sir Daniel Cooper, Bart.
 Cast of *Comarocystites punctatus* from Ottawa; presented by Dr. James Grant, F.G.S.

- Miocene Fossils from Messina ; presented by Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S.
- Specimens of Mud from the Nile ; presented by Miss Horner.
- A large Collection of *Foraminifera* from India ; presented by Dr. H. J. Carter, F.R.S.
- Miocene Fossils from Poland ; presented by Alfred Evans, Esq.
- Specimen of Kalktuff from Cannstatt, with impressions of Shells and Plants ; specimen of Siliceous Tertiary Rock with Gasteropods from the Paris Basin ; and specimen of Triassic Plant-bed with Copper-ore from Württemberg ; presented by George E. Roberts, Esq., F.G.S.
- Three specimens of Datholite, two of Apophyllite, and one of Pectolite from the Bergen Tunnel, New Jersey ; presented by Professor McChesney.
- Two large specimens of Graphite from the Lower Tourgouska district in Northern Siberia ; presented by M. Sidoroff.
- A Collection of Norman Fossils from the *Etage Cénomancien* ; presented by Ralph Tate, Esq., F.G.S.
- Specimens from the May Sandstone of Caen ; presented by John Evans, Esq., F.R.S., F.G.S.
- A large specimen, and a microscopic section of *Eozoön Canadense*, Daws. ; presented by Sir W. E. Logan, LL.D., F.R.S., F.G.S.
- A series of Fossils and Rocks from the Coal-measures of New South Wales ; presented by William Keene, Esq., Government Inspector of Coal-mines.
- Specimens from the Island of Sombbrero ; presented by E. B. Webb, Esq.
- A Collection of Jurassic Plants and Fossils from the Cape of Good Hope ; presented by Dr. R. N. Rubidge, F.G.S.

MAPS, CHARTS, ETC., PRESENTED.

- Geologisch-topographischer Atlas von Neuseeland bearbeitet von Dr. F. von Hochstetter und Dr. A. Petermann ; presented by Dr. Hochstetter.
- Carta Geologica dei dintorni del golfo della Spezia e val di Magra Inferiore de Prof. Giovanni Capellini ; presented by Prof. Capellini.
- Geological Map of Parts of Middlesex, Hertfordshire, Buckinghamshire, Berkshire, and Surrey, with accompanying memoir, by W. Whitaker, F.G.S. ; presented by the Director-General of the Geological Survey of the United Kingdom.
- Eleven Miscellaneous Maps ; presented by Miss Horner.
- Carte Géologique du département de la Loire-Inférieure, par F. Cailliaud ; presented by M. Cailliaud.
- Geologische Karte von der Umgegend Mjösens in Norwegen, von Th. Kjerulf ; presented by Dr. Kjerulf, For.Corr.G.S.
- Geognostisch-geographische Karte der Umgebung des Laacher See's entworfen von G. von Oeynhausen ; presented by Herr von Oeynhausen.

Sheet No. 15 of the Geological Survey of Switzerland, by G. Theobald; presented by Dr. Theobald.

Geological Survey of Victoria. Sheets 1, 2, 4-8, 12, 19-21, 23, 28, and 29; presented by R. A. C. Selwyn, Esq.

Ninety Miscellaneous Charts, published by the Dépôt de la Marine; presented by the Dépôt de la Marine.

Ordnance Survey of Great Britain. Maps, 6-inch scale:—Northumberland, Sheets 88, 97 to 99, 114, 115. Berwickshire, Index-sheet. Dumbartonshire, Sheets 15, 19, 19*a*, 20 to 22, 24, 25, 28. Lanarkshire, Sheets 1 to 5, 7 to 14, 16 to 27, 29 to 53, 55. Roxburgshire, Sheet 28. Renfrewshire, Sheets 1 to 8, 10 to 19. Selkirkshire, Index-sheet.—Ordnance Survey of England. 1-inch scale:—Sheet 103, N.E. Sheet 105, S.E.—Ordnance Survey of Ireland. 1-inch scale:—Sheets 25, 28, 36.—Ordnance Survey of Scotland. 1-inch scale:—Sheets 10, 13, 18, 105. Presented by the Board of Ordnance through the Director-General, Colonel Sir Henry James, F.G.S.

Photograph of Fish-palate (*Gyrodus*) from the Greensand; presented by the Earl of Enniskillen, D.C.L., F.R.S., F.G.S.

Ten Plates illustrating the Cretaceous Fossils of South India; presented by Miss Horner.

Panorama from the summit of Mount Davidson, Washoe Country; presented by W. W. Smyth, Esq., M.A., F.R.S., F.G.S.

Photograph of *Paradowides Harlani*; presented by M. J. Marcou.

Photograph of Fossil Annelid; presented by O. C. Marsh, Esq., F.G.S.

Photograph of *Palaeoniscus* from a quarry near Fulwell, Sunderland; presented by E. L. Biden, Esq.

Photograph of Rocks near Ilfracombe, by F. Bedford; presented by E. Walker, Esq., F.R.G.S.

Six Photographs of Gravel-beds near Broseley, Salop; presented by Sir C. Lyell, Bart., D.C.L., F.R.S., F.G.S.

The following Lists contain the Names of the Persons and Public Bodies from whom Donations to the Library and Museum have been received since the last Anniversary, February 19, 1864.

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

Berlin, German Geological Society at.	Dublin, Geological Society of.
— Saxon and Thuringian Natural History Society.	Dudley, Geological Society of.
Brussels. Royal Academy of Sciences of Belgium.	Edinburgh, Royal Observatory of.
Calcutta. Bengal Asiatic Society.	France, Geological Society of.
— Geological Survey of India.	Hamburgh, Natural History Society of.

- Heidelberg, Natural History Society of.
- Lisbon, Academy of Sciences of.
- Liverpool, Geological Society of.
- . Lancashire and Cheshire Historic Society.
- London. British Association.
- , Chemical Society of.
- . Committee of Council on Education. Science and Art Department.
- . Geologists' Association.
- . Institute of Actuaries of Great Britain.
- . Institute of Civil Engineers.
- , Linnean Society of.
- , Mendicity Society of.
- , Microscopical Society of.
- , Palæontographical Society of.
- , Photographic Society of.
- . Ray Society.
- . Royal Asiatic Society of Great Britain.
- , Royal Astronomical Society of.
- . Royal Geographical Society.
- , Royal Horticultural Society of.
- . Royal Institution of Great Britain.
- , Royal Society of.
- . Secretary of State for War.
- , Zoological Society of.
- Manchester, Geological Society of.
- Melbourne. Geological Survey of Victoria.
- Milan. Royal Institute of Lombardy.
- . Italian Society of Natural Sciences.
- Montreal, Natural History Society of.
- Moscow, Imperial Society of Naturalists of.
- Munich, Academy of Sciences of.
- Neuchatel, Society of Natural Sciences of.
- Paris. Dépôt Général de la Marine.
- , Geographical Society of.
- . Imperial Government of France.
- . School of Mines.
- Philadelphia. Academy of Natural Sciences.
- Plymouth Institution.
- Stockholm. Royal Swedish Academy.
- Toronto. Canadian Institute.
- Truro. Royal Geological Society of Cornwall.
- Turin, Royal Academy of Sciences of.
- Tyneside Naturalists' Field-club.
- Vienna, Imperial Academy of.
- , Imperial Geological Institute of.
- Washington. Smithsonian Institution.
- . Patent Office.
- . U. S. War Department.

II. List of Persons from whom Donations of Books and Specimens
have been received since the last Anniversary.

- Adolph, W., Esq.
Agassiz, Prof. L., For.Mem.G.S.
American Journal of Science,
Editor of the.
Andrew, J. C., Esq.
Athenæum, Editor of the.
- Bagster and Sons, Messrs.
Beaumont, M. Elie de, For.
Mem.G.S. †
Bendyshe, T., Esq.
Biden, E. L., Esq.
Blanford, H. F., Esq., F.G.S.
Brodie, Rev. P. B., F.G.S.
- Cailliaud, M. F.
Capellini, Il Cav. H. G.
Carter, Dr. H. J.
Cautley, Col. Sir P. T., F.G.S.
Chambers and Co., Messrs.
Chatel, M. V.
Churchill and Sons, Messrs.
Cocchi, Il Cav., Prof. H.
Colliery Guardian, Editor of the.
Cooper, Sir Daniel, Bart.
- Davidson, T., Esq., F.G.S.
Davis, Dr. J. Barnard.
Dawkins, W. B., Esq., F.G.S.
Dawson, Dr. J. W., F.G.S.
Deshayes, Prof. G. P., For.Mem.
G.S.
Deslongchamps, Dr. E., For.
Mem.G.S.
Dittmar, Dr. von.
Doyne, W. D., Esq.
Duncan, Dr. P. M., Sec.G.S.
- Edwards, Dr. H. M., For.Mem.
G.S.
Egerton, Sir P. de M. G., Bart.,
F.G.S.
Enniskillen, Earl of, F.G.S.
Erdmann, Dr. A.
Evans, Alfred, Esq.
Evans, John, Esq., F.G.S.
- Forchhammer, Dr. J. G., For.
Mem.G.S.
Francis, Dr. W., F.G.S.
- Gaudin, Dr. C. T., For.Corr.G.S.
Gervais, M. Paul, For.Corr.G.S.
Godwin-Austen, R. A. C., Esq.,
V.P.G.S.
Grant, Dr. J. A., F.G.S.
Grewinck, Dr.
Guppy, R. L., Esq.
- Hartung, Dr. G.
Helmersen, Gen. G. von, For.
Mem.G.S.
Hitchcock, Dr., For.Corr.G.S.
Honeyman, Rev. Dr. D., F.G.S.
Horner, Miss.
Hörnes, Dr. M., For.Corr.G.S.
- Intellectual Observer, Editor of
the.
- James, Col. Sir H., F.G.S.
Jeffreys, J. G., Esq., F.G.S.
Jones, Prof. T. R., F.G.S.
Journal of the Society of Arts,
Editor of the.
- Keene, W., Esq.
Koninck, Prof. L. de, For.Mem.
G.S.
- Lambert, Alan, Esq., F.G.S.
Lartet, M. L., For.Mem.G.S.
Logan, Sir W. E., F.G.S.
London Review, Editor of the.
Longman and Co., Messrs.
Lyell, Sir Charles, Bart., F.G.S.
- MacChesney, Prof.
Marcou, M. Jules.
Marenzi, Count F. von.
Marschall, Count A. G., For.
Corr.G.S.
Marsh, O. C., Esq., F.G.S.

- Martins, Dr. C., For.Corr.G.S.
 Meneghini, Prof. G., For.Corr.
 G.S.
 Milligan, Dr. J., F.G.S.
 Mingaud, M.
 Mining and Smelting Magazine,
 Editor of the.
 Monck, Lord.
 Montagna, M. C.
 Morlot, M., For.Corr.G.S.
 Murchison, Sir R. I., F.G.S.

 Oldham, Dr. T., F.G.S.

 Peters, Dr. K.
 Pictet, Prof. F. J., For.Corr.G.S.
 Prestwich, J., Esq., F.G.S.

 Quaritch, B., Esq.
 Quarterly Journal of Science,
 Editor of the.
 Quatrefages, M. de.
 Quetelet, M.

 Ramsay, Prof. A. C., F.G.S.
 Reader, Editor of the.
 Renevier, M. E.
- Roberts, G. E., Esq., F.G.S.

 Salmon, H. C., Esq., F.G.S.
 Sandberger, Prof. F., For.Corr.
 G.S.
 Scott, T., Esq.
 Selwyn, A. R. C., Esq.
 Sidoroff, M.
 Simpkin and Co., Messrs.
 Solaro, J. M., Esq.
 Studer, Prof. B., For.Mem.G.S.
 Symonds, Rev. W. S., F.G.S.

 Tate, Ralph, Esq., F.G.S.
 Tehihatcheff, M. P. de.
 Triübner and Co., Messrs.

 Waagen, Herr W.
 Walker, E., Esq.
 Whitley, N., Esq.
 Winchell, Prof. A.
 Winkler, Dr. T. C.
 Woods, Rev. J. E. T., F.G.S.
 Woodward, Dr. S. P., F.G.S.

 Zittel, Prof. K. A.

*List of PAPERS read since the last Anniversary Meeting,
February 19th, 1864.*

1864.

February 24th.—On Further discoveries of Flint Implements and Fossil Mammalia in the Valley of the Ouse, by James Wyatt, Esq., F.G.S.

————— On some recent Discoveries of Flint Implements in the Drift Deposits in Hants and Wilts, by John Evans, Esq., F.G.S., F.S.A.

March 9th.—On the Discovery of the Scales of *Pteraspis*, with some remarks on the Cephalic Shield of that Fish, by E. Ray Lankester, Esq.; communicated by Prof. T. H. Huxley, F.R.S., F.G.S.

————— On some remains of *Bothriolepis*, from the Upper Devonian Sandstones of Elgin, by G. E. Roberts, Esq.; communicated by Prof. J. Morris, F.G.S.

————— On Missing Sedimentary Formations from Suspension or Removal of Deposits, by J. J. Bigsby, M.D., F.G.S.

March 23rd.—On some New Fossils from the Lingula-flags of Wales, by J. W. Salter, Esq., F.G.S., A.L.S.

————— On the Millstone-grit of North Staffordshire, and the adjoining parts of Derbyshire, Cheshire, and Lancashire, by E. Hull, Esq., B.A., F.G.S., and A. H. Green, Esq., M.A., F.G.S.

April 13th.—On the Geology and Mines of the Nevada Territory (Washoe Silver Region, U.S.), by W. P. Blake, Esq.; communicated by Sir R. I. Murchison, K.C.B., F.R.S., F.G.S.

————— On the Hunstanton Red Rock, by Harry Seeley, Esq., F.G.S.

April 27th.—On the Geology of Arisaig, Nova Scotia, by the Rev. D. Honeyman, D.C.L., F.G.S.

————— On some Remains of Fish and Plants from the "Upper Limestone" of the Permian Series of Durham, by J. W. Kirkby, Esq.; communicated by T. Davidson, Esq., F.R.S., F.G.S.

————— On the Fossil Corals of the West Indian Islands. Part III., Mineral Condition, by P. Martin Duncan, M.B. Lond., Sec.G.S.

May 11th.—On a Section with Mammalian Remains, near Thame, by T. Codrington, Esq., F.G.S.

————— On a deposit at Stroud, containing Flint Implements, Land and Freshwater Shells, &c., by E. Witchell, Esq., F.G.S.

————— On the Earthquake which occurred in England on the morning of the 6th of October, 1863, by Fort-Major T. Austen, F.G.S.

————— On the White Limestone of Jamaica, and its associated intrusive Rocks, by A. Lennox, Esq., F.G.S.

May 25th.—On the Geology of part of the North-western Himalayas, by Capt. Godwin-Austen; with Notes on the Fossils, by T. Davidson, Esq., F.R.S., F.G.S., R. Etheridge, Esq., F.G.S.,

1864.

and S. P. Woodward, Esq., F.G.S.; communicated by R. A. C. Godwin-Austen, Esq., F.R.S., V.P.G.S.

May 25th.—On the Cetacean Fossils, termed "*Ziphius*" by Cuvier, with a notice of a New Species (*Belemnziphius compressus*) from the Red Crag, by Prof. T. H. Huxley, F.R.S., F.G.S.

June 8th.—On the Rhætic Beds and White Lias of Western and Central Somerset, and on the Discovery of a new Fossil Mammal in the Grey Marlstones beneath the Bone-bed, by W. Boyd Dawkins, Esq., B.A., F.G.S.

————— On the Geological Structure of the Malvern Hills and adjacent district, by Harvey B. Holl, M.D., F.G.S.

June 22nd.—On some Bone- and Cave-deposits of the Reindeer-period in the South of France, by J. Evans, Esq., F.R.S., F.G.S.

————— On the Carboniferous Rocks of the Donetz, and on the Granite and Granitic Detritus of the neighbourhood of St. Petersburg, by Prof. J. Helmersen; communicated by Sir R. I. Murchison, K.C.B., F.R.S., F.G.S.

————— On a supposed Deposit of Boulder-clay in North Devon, by G. Maw, Esq., F.L.S., F.G.S.

————— On the Former Existence of Glaciers in the High Grounds of the South of Scotland, by Dr. J. Young; communicated by Prof. A. C. Ramsay, F.R.S., F.G.S.

————— On the Formation and Preservation of Lakes by Ice-action, by T. Belt, Esq.; communicated by Prof. A. C. Ramsay, F.R.S., F.G.S.

————— On the Principal Geological Features of Hobart, Tasmania, by S. H. Wintle, Esq.; communicated by Sir R. I. Murchison, K.C.B., F.R.S., F.G.S.

November 9th.—On the Geology of Jamaica, especially with reference to the District of Clarendon, with Descriptions of the Cretaceous, Eocene, and Miocene Corals of the island; by P. Martin Duncan, M.B. Lond., Sec.G.S., and G. P. Wall, Esq., F.G.S.

————— On the Correlation of the Cretaceous Formations of the North-east of Ireland, by Ralph Tate, Esq., F.G.S.

————— On the Recent Earthquake at St. Helena, by Governor Sir C. Elliott, K.C.B.; communicated by the Colonial Secretary through Sir C. Lyell, Bart., F.R.S., F.G.S.

November 23rd.—On the occurrence of Organic Remains in the Laurentian Rocks of Canada, by Sir W. E. Logan, LL.D., F.R.S., F.G.S.

————— On the Structure of certain Organic Remains in the Laurentian Limestone of Canada, by J. W. Dawson, LL.D., F.R.S., F.G.S.

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

————— On the Mineralogy of certain Organic Remains from the Laurentian Rocks of Canada, by T. Sterry Hunt, Esq., M.A., F.R.S.; communicated by Sir W. E. Logan, F.G.S., &c.

1864.

December 7th.—On the Geology of Otago, New Zealand, by J. Hector, M.D., F.G.S.

————— On the Excavation of Deep Lake-basins in hard rocks in the Southern Alps of New Zealand, by J. Haast, Ph. D., F.G.S.

————— Notes to a Sketch-map of the Province of Canterbury, New Zealand, showing the glaciation during the Pleistocene and recent times, by J. Haast, Ph.D., F.G.S.

————— Notes on Dr. Haast's papers, by Sir R. I. Murchison, K.C.B., F.R.S., F.G.S.

December 21st.—On the Coal-measures of New South Wales, with Spirifers, *Glossopteris*, and *Lepidodendron*, by W. Keene, Esq.; communicated by the Assistant-Secretary.

————— On the Drift of the East of England and its Divisions, by S. V. Wood, Jun., Esq., F.G.S.

1865.

January 11th.—On the Lias Outliers at Knowle and Wootton Wawen in South Warwickshire, by the Rev. P. B. Brodie, M.A., F.G.S.

————— On the History of the last Geological Changes in Scotland, by T. F. Jamieson, Esq., F.G.S.

January 25th.—On the Excavation of Valleys by Ice, by J. Haast, Ph.D., F.G.S.

————— On the Order of Succession in the Drift-beds in the Island of Arran, by J. Bryce, M.A., LL.D., F.G.S.

————— On the occurrence of Beds in the West of Scotland in the position of the English Crag, by J. Bryce, M.A., LL.D., F.G.S.

————— On the *Tellina proxima* Bed at Chappell Hall, near Airdrie, by the Rev. H. W. Crosskey; communicated by Dr. J. Bryce, M.A., F.G.S.

February 8th.—On the Sources of the Mammalian Fauna of the Red Crag, with a Description of a New Mammal allied to the Walrus, by E. Ray Lankester, Esq.; communicated by Prof. T. H. Huxley, F.R.S., F.G.S.

————— Note on the Geology of Harrogate, by Prof. J. Phillips, M.A., LL.D., F.R.S., F.G.S.

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

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

It was afterwards resolved,—

1. That the thanks of the Society be given to R. A. C. Godwin-Austen, Esq., retiring from the office of Vice-President.

2. That the thanks of the Society be given to Dr. Bigsby, Sir Charles Lyell, Robert Mallet, Esq., and Alfred Tylor, Esq., retiring from the Council.

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

OFFICERS.

PRESIDENT.

W. J. Hamilton, Esq., F.R.S.

VICE-PRESIDENTS.

Edward Meryon, M.D.

J. Carrick Moore, Esq., M.A., F.R.S.

Sir R. I. Murchison, K.C.B., M.A., D.C.L., F.R.S.

Professor A. C. Ramsay, F.R.S.

SECRETARIES.

P. Martin Duncan, M.B. Lond.

Warrington W. Smyth, M.A., F.R.S.

FOREIGN SECRETARY.

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

TREASURER.

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

COUNCIL.

Robert Chambers, Esq., F.R.S.E.
& L.S.

P. Martin Duncan, M.B.

Sir P. de M. G. Egerton, Bart.,
M.P., F.R.S. & L.S.

Robert Etheridge, Esq., F.R.S.E.

John Evans, Esq., F.R.S.

Rev. Robert Everest.

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

W. J. Hamilton, Esq., F.R.S.

Professor T. H. Huxley, F.R.S.
& L.S.

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

Professor T. Rupert Jones.

M. Auguste Laugel.

John Lubbock, Esq., F.R.S.

Edward Meryon, M.D.

J. Carrick Moore, Esq., M.A.,
F.R.S.

Professor John Morris.

Sir R. I. Murchison, K.C.B.,
M.A., D.C.L., F.R.S.

Robert W. Mylne, Esq., F.R.S.

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

Professor A. C. Ramsay, F.R.S.

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

Rev. Thomas Wiltshire, M.A.

S. P. Woodward, Ph.D.

LIST OF
THE FOREIGN MEMBERS
OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1865.

- Date of
Election.
1817. Professor Karl von Raumer, *Munich*.
 1818. Professor G. Ch. Gmelin, *Tübingen*.
 1819. Count A. Breuner, *Vienna*.
 1819. Signor Alberto Parolini, *Bassano*.
 1822. Count Vitaliano Borromeo, *Milan*.
 1823. Professor Nils de Nordenskiöld, *Helsingfors*.
 1825. Dr. G. Forchhammer, *Copenhagen*.
 1827. Dr. H. von Dechen, *Bonn*.
 1827. Herr Karl von Oeynhausen, *Dortmund, Westphalia*.
 1828. M. Léonce Elie de Beaumont, Sec. Perpétuel de l'Institut. France,
 For. Mem. R.S., *Paris*.
 1829. Dr. Ami Boué, *Vienna*.
 1829. J. J. d'Omalius d'Halloy, *Halloy, Belgium*.
 1839. Dr. Ch. G. Ehrenberg, For. Mem. R.S., *Berlin*.
 1840. Professor Adolphe T. Brongniart, For. Mem. R.S., *Paris*.
 1840. Professor Gustav Rose, *Berlin*.
 1841. Dr. Louis Agassiz, For. Mem. R.S., *Cambridge, Massachusetts*.
 1841. M. G. P. Deshayes, *Paris*.
 1844. Professor William Burton Rogers, *Boston, U.S.*
 1844. M. Edouard de Verneuil, For. Mem. R.S., *Paris*.
 1847. Dr. M. C. H. Pander, *Riga*.
 1847. M. le Vicomte B. d'Archiac, *Paris*.
 1848. James Hall, Esq., *Albany, State of New York*.
 1850. Professor Bernard Studer, *Berne*.
 1850. Herr Hermann von Meyer, *Frankfort-on-Maine*.
 1851. Professor James D. Dana, *New Haven, Connecticut*.
 1851. General G. von Helmersen, *St. Petersburg*.
 1851. Hofrath W. K. Haidinger, For. Mem. R.S., *Vienna*.
 1851. Professor Angelo Sismonda, *Turin*.
 1853. Count Alexander von Keyserling, *Dorpat*.
 1853. Professor Dr. L. G. de Koninck, *Liège*.
 1854. M. Joachim Barrande, *Prague*.
 1854. Professor Dr. Karl Friedrich Naumann, *Leipsic*.
 1856. Professor Dr. Robert W. Bunsen, For. Mem. R.S., *Heidelberg*.
 1857. Professor Dr. H. R. Goepfert, *Breslau*.
 1857. M. E. Lartét, *Paris*.
 1857. Professor Dr. H. B. Geinitz, *Dresden*.
 1857. Dr. Hermann Abich, *Tiflis, Northern Persia*.
 1858. Dr. J. A. E. Deslongchamps, *Caen*.

1858. Herr Arn. Escher von der Linth, *Zurich*.
 1859. M. A. Delesse, *Paris*.
 1859. Professor Dr. Ferdinand Roemer, *Breslau*.
 1860. Professor Dr. H. Milne-Edwards, For. Mem. R.S., *Paris*.
 1861. Professor Gustav Bischof, *Bonn*.
 1862. Señor Casiano di Prado, *Madrid*.
 1862. Baron Sartorius von Waltershausen, *Göttingen*.
 1862. Professor Pierre Merian, *Basle*.
 1864. Professor Paolo Savi, *Pisa*.
 1865. M. Jules Desnoyers, *Paris*.

LIST OF
 THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1865.

Date of
 Election.

1863. Professor Beyrich, *Berlin*.
 1863. M. Boucher de Perthes, *Abbeville*.
 1863. Herr Bergmeister Credner, *Gotha*.
 1863. Professor Daubr e, *Paris*.
 1863. M. Desor, *Neuch tel*.
 1863. Professor Favre, *Geneva*.
 1863. Signor Gastaldi, *Turin*.
 1863. Dr. C. T. Gaudin, *Lausanne*.
 1863. M. Paul Gervais, *Montpellier*.
 1863. Herr Bergmeister G mbel, *Munich*.
 1863. Franz Ritter von Hauer, *Vienna*.
 1863. Professor E. H bert, *The Sorbonne, Paris*.
 1863. Rev. Dr. O. Heer, *Zurich*.
 1863. Dr. Moritz H rnes, *Vienna*.
 1863. Dr. G. F. J ger, *Stuttgart*.
 1863. Dr. Kaup, *Darmstadt*.
 1863. Dr. Theodor Kjerulf, *Christiania*.
 1863. M. von Kokscharow, *St. Petersburg*.
 1863. Dr. Leidy, *Philadelphia*.
 1863. M. Lov n, *Stockholm*.
 1863. Lieut.-Gen. Count Alberto Ferrero della Marmora, *Turin*.
 1863. Count A. G. Marschall, *Vienna*.
 1863. Professor G. Meneghini, *Pisa*.
 1863. M. Morlot, *Berne*.
 1863. M. Henri Nyst, *Brussels*.
 1863. Dr. A. Oppel, *Munich*.
 1863. Il Marchese Lorenzo Damaso Pareto, *Genoa*.

1863. Professor Pictet, *Geneva*.
 1863. Signor Ponzi, *Rome*.
 1863. Professor Quenstedt, *Tübingen*.
 1863. Professor F. Sandberger, *Bavaria*.
 1863. Signor Quintino Sella, *Turin*.
 1863. Dr. F. Senft, *Eisenach*.
 1863. Dr. Benjamin Shumard, *St. Louis, State of Missouri*.
 1863. Dr. Steenstrüup, *Copenhagen*.
 1863. Professor E. Suess, *Vienna*.
 1863. Marquis de Vibraye, *Paris*.
 1864. M. J. Bosquet, *Maestricht*.
 1864. Dr. Ch. Martins, *Montpellier*.

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE "DONATION-FUND"

ESTABLISHED BY

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

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

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

TRUST-ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
Balance at Banker's, January 1, 1864, on the Wollaston } Donation-fund	31	8	9	Award to M. Deshayes	20	18	9
Dividends on the Donation-fund for 1864 on £1084 1s. 11d. } Reduced 3 per Cents.	31	12	10	Cost of striking Gold Medal awarded to Sir R. I. Murchison Balance at Banker's (Wollaston-fund)	10	10	0
	£63	1	7		£63	1	7

VALUATION OF THE SOCIETY'S PROPERTY ; 31st December, 1864.

PROPERTY.	£	s.	d.	DEBTS.	£	s.	d.
Due from Longman and Co., on acc. of Journ. Vol. XX.&c.	51	1	6	Balance in favour of the Society	5294	1	6
Due from Subscribers to Journal	30	0	0				
Due for Authors' Corrections in Journal	30	0	0				
Balance in Banker's hands, Dec. 31, 1864	225	10	5				
Balance in Clerk's hands	116	7	2				
Funded Property :—							
Consols, at 95	4801	*	3 7				
Arrears of Admission-fees (considered good)	4561	2	5				
Arrears of Annual Contributions (ditto)	80	0	0				
	200	0	0				
	£5294	1	6		£5294	1	6

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

JOSEPH PRESTWICH, Treas.

Feb. 13, 1865.

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

ESTIMATES *for*

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Due for Subscriptions on Quarterly Journal (con- sidered good)	30	0	0			
Due for Authors' Corrections	30	0	0			
Due for Arrears (See Valuation-sheet)	280	0	0			
	<hr/>			340	0	0
Estimated Ordinary Income for 1865.						
Annual Contributions :—						
From Resident Fellows, &c., and Non-residents of 1859 to 1861	620	0	0			
Admission-fees (supposed)	300	0	0			
Compositions (supposed)	250	0	0			
Dividends on Consols	140	0	0			
Sale of Transactions, Proceedings, Library-catalogues, Geo- logical Map, and Ormerod's Index	100	0	0			
Sale of Quarterly Journal	180	0	0			
Due from Longman and Co. in June	51	1	6			
Due from the Bequest-fund on account of monies expended on Map, Library, and Museum	213	9	9			

£2194 11 3

JOSEPH PRESTWICH, TREAS.

Feb. 13, 1865.

the Year 1865.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
General Expenditure :						
Taxes and Insurance	45	0	0			
House-repairs	20	0	0			
Furniture	30	0	0			
Fuel	35	0	0			
Light	35	0	0			
Miscellaneous Printing, including Abstracts....	40	0	0			
Tea for Meetings.....	21	0	0			
Miscellaneous House-expenses	80	0	0			
Stationery	25	0	0			
				<hr/>	331	0 0
Salaries and Wages :						
Assistant-Secretary	200	0	0			
Clerk	120	0	0			
Assistants in Library and Museum.....	100	0	0			
Porter	90	0	0			
Housemaid	40	0	0			
Occasional Attendants	15	0	0			
Collector	20	0	0			
				<hr/>	585	0 0
Library	100	0	0			
Museum	50	0	0			
Diagrams at Meetings	10	0	0			
Miscellaneous Scientific Expenditure	50	0	0			
Publications: Quarterly Journal	560	0	0			
,, Transactions	5	0	0			
,, Geological Map	50	0	0			
				<hr/>	615	0 0
					1741	0 0
Balance in favour of the Society	453	11	3			
				<hr/>		
					£2194	11 3
				<hr/> <hr/>		

Income and Expenditure during the

INCOME.

	£	s.	d.	£	s.	d.
Balance at Banker's January 1, 1864	365	9	6			
Balance in Clerk's hands ditto	90	8	8			
Compositions received	350	3	6			
Arrears of Admission-fees	69	6	0			
Arrears of Annual Subscription	28	7	0			
Admission-fees, 1864	384	6	0			
Annual Contributions for 1864, viz.—						
Resident Fellows	£508	14	6			
Non-Resident Fellows ...	31	10	0			
	540	4	6			
Dividends on Consols	133	13	0			
Legacy, B. Botfield, Esq.	31	10	0			
Publications :						
Longman and Co., Sale of Journal in 1863....	59	4	1			
Sale of Transactions	2	18	9			
Sale of Journal, Vols. 1-6	5	9	6			
" Vols. 7-12	1	7	0			
" Vols. 13-15	2	0	6			
" Vol. 16	9	12	9			
" Vol. 17	10	19	0			
" Vol. 18	10	10	10			
" Vol. 19	42	15	2			
" Vol. 20*	117	15	11			
	262	13	6			
" Miscellaneous Scientific Expenditure," amount twice entered		0	10	6		
Sale of Geological Map	1	10	3			
Sale of Library-catalogues	1	13	0			
Sale of Ormerod's Index	1	12	0			
	4	15	3			

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

(Signed)	ALFRED TYLOR, THOS. F. GIBSON,	}	Auditors.	£2261 7 5
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* Due from Messrs. Longman and Co., in addition to the above,
 on Journal, Vol. XX., &c. £51 1 6
 Due from Fellows for Journal-subscription, estimated 30 0 0
 Balance due from Bequest-fund on expenditure on Map, Library,
 and Museum 213 9 9
£294 11 3

Year ending December 31st, 1864.

EXPENDITURE.

General Expenditure :	£	s.	d.	£	s.	d.
Taxes	49	17	0			
Fire-insurance	3	0	0			
New Furniture	23	12	3			
House-repairs	2	17	8			
Fuel	35	5	0			
Light	29	5	2			
Miscellaneous House-expenditure	89	3	4			
Stationery	24	19	5			
Miscellaneous Printing	51	13	1			
Tea for Meetings	22	13	0			
	<hr/>			332	5	11

Salaries and Wages :

Assistant-Secretary	200	0	0			
Clerk	120	0	0			
Library and Museum Assistants	79	0	0			
Porter	90	0	0			
Housemaid	40	0	0			
Occasional attendants	12	3	6			
Collector	16	17	6			
	<hr/>			558	1	0

Library	112	14	8			
Museum	14	17	3			
Diagrams at Meetings	2	19	2			
Miscellaneous Scientific Expenses, including Postages..	51	7	3			

Publications :

Geological Map	83	2	6			
Journal, 1860	0	4	0			
„ 1863	3	1	0			
„ 1864	560	17	1			
	<hr/>			647	4	7

Invested in 3½ per Cent. Consols	200	0	0			
Balance at Banker's, Dec. 31, 1864	225	10	5			
Balance in Clerk's hands, Dec. 31, 1864	116	7	2			

£2261 7 5

PROCEEDINGS

AT THE

ANNUAL GENERAL MEETING,

17TH FEBRUARY, 1865.

AWARD OF THE WOLLASTON MEDAL.

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

MR. DAVIDSON,—It is with great pleasure that I find myself charged with the agreeable duty of handing to you this Medal, which the Council have awarded to you, as already stated in their Report, for the very important services you have rendered through many years to the science of Geology, by your critical and philosophical works on Fossil Brachiopoda. Without alluding to the many valuable papers which you have contributed to this and other Societies, I may safely say that the vast amount of scientific work which you have performed for the Palæontographical Society, would alone entitle you to this award. I find on referring to the publications of that Society that, including the Monograph on the Devonian Brachiopoda which you are now completing, you have contributed no less than 121 plates, containing about 4300 figures, all of which you have drawn on stone yourself, and nearly 850 pages of letter-press. But labour of this description is not to be estimated by quantity; and although I have thus ventured to allude to its amount, your friends, and all who are acquainted with these Monographs well know that their great merit consists in the manner in which you have described the fossils of the different formations, eliminating all useless specific names, and showing the gradual progress of brachiopodous life from one formation to another. You have shown us that all the Palæozoic formations have their characteristic faunæ; that in the Permian, Carboniferous, and Devonian systems the great majority of forms are peculiar to each system, and that only a small proportion of species passes from one into the other.

Nor can I avoid alluding to the great artistic skill you have shown in your drawings of these various forms. Your perfect knowledge of the features and physiological characters to be drawn has given to these plates a value which they never could have acquired had they been drawn by a mere mechanical copyist. But

I must not dwell any longer on such topics in your presence; I will only add, in conclusion, that we all trust that health and strength may be spared to you to enable you to complete the great task you have undertaken, and that ere long we may have the satisfaction of congratulating you on the completion of the Monograph on the Silurian Brachiopods, which I understand you propose shortly to commence. It only remains for me, in placing this Medal in your hands, to express my own satisfaction with the award of the Council.

Mr. DAVIDSON, on receiving the Medal, replied as follows:—

Mr. PRESIDENT,—I beg you will convey to the Council of the Geological Society my sincere and grateful thanks for the great honour they and yourself have conferred upon me by the award of the Wollaston Medal; and I trust that, by renewed exertions, I may continue to deserve their indulgent approbation. My thanks are also due to you, Sir, for the very kind and favourable manner with which you have alluded to my researches. Thirty or more years have elapsed since I first commenced my geological and palæontological studies; and although I have always considered it essential to keep up a general knowledge of all that concerns both sciences, still I have likewise felt that, if I desired to contribute my mite towards the advancement of science, I could not do better than devote the larger portion of my time to an intimate and searching study of a single class of fossils. I hailed with delight the formation of the Palæontographical Society, as I felt that, by division of labour, our British fossils would be sooner or later thoroughly investigated; and I am sure, Sir, that the very remarkable series of Monographs already published does sufficiently attest that, with time, we shall be able to work out our British Palæontology, in all its branches, without requiring foreign assistance. Since the progress of Geology is a subject of the greatest importance, we naturally feel that it is to the Geological Society of London that we must look for support and encouragement; and it gives me additional pleasure to receive this Medal at your hands, from the fact of your being at the same time President of both these Societies. I am also proud in being able to attest that the objects of the Palæontographical Society have met with the warmest support from every Geologist, Palæontologist, and collector of fossils in Great Britain, who have also, in the most praiseworthy manner, assisted to their utmost, those who were engaged in the preparation of these works. I beg you will therefore allow me, Sir, on the present occasion to tender our most grateful acknowledgments to the many gentlemen who have kindly afforded us such important assistance.

I will not encroach further upon your valuable time, but beg you will assure the Council that I shall endeavour to accomplish what is still expected from my pen and pencil, and thus show my gratitude for the great kindness and honour they have so generously conferred upon me.

AWARD OF THE WOLLASTON DONATION-FUND.

The President then addressed Mr. SALTER, as follows :—

MR. SALTER,—In handing to you these proceeds of the Wollaston Fund, which have been awarded to you by the Council, I cannot refrain from expressing to you the satisfaction I experience at seeing your efforts in a very interesting and important field of palæontological investigation thus recognized. You have laboured for many years at the hard task of unravelling the mysteries of Palæozoic fossils, and besides carrying out your own investigations, have ever been willing to assist your fellow-labourers in this field of research with the free use and communication of the knowledge you have acquired. When, moreover, we look at the work you have done for the Palæontographical Society, and the manner in which you have executed it, we cannot but look forward with anxiety to the early completion of your Monograph on the British Palæozoic Trilobites; and when I recollect the expression of Dr. Wollaston which accompanied his bequest, I feel convinced that there is no worthier mode of complying with the spirit of his intention than by awards like the present, which, while recognizing the merit of work already done, are intended to assist the prosecution of further researches.

Trusting that the time may speedily arrive when you will have completed your present work, and when you will be enabled to apply your energies to new paths in the great field of Palæozoic Palæontology, I have now the pleasure of handing to you this award, with the expression of my best wishes for your future success.

MR. SALTER replied in the following manner :—

SIR,—It is pleasant to receive a purse full of money at all times, and especially so when it is given for work that is done, as well as for that we are going to do.

I think the palæontologists have been for some time receiving the lion's share of Wollaston's bequest. It can hardly be that in future years there will not be a reaction in favour of the physical and mineralogical studies to which Wollaston devoted his life, and therefore we must make hay while the sun shines.

I cannot forget, Sir, that nearly twenty years ago it was the liberal construction put by the Council upon the use to which a surplus fund should be applied, which was the chief means of introducing me to the Society. And I have spent so many profitable hours here, that I should be ungrateful indeed to forget this circumstance, or the men (now, alas! not with us) who proposed this kindness for a very young naturalist.

I must not detain you further. My family of Trilobites is a large one, and requires much attention, and therefore I am grateful for this help. I beg to thank you very heartily for the honour you have done me.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,
WILLIAM JOHN HAMILTON, ESQ., F.R.S.

Before reading those observations which, as your President, it is my duty to make respecting the recent progress of geological science, I have a more painful duty to fulfil, in bringing before you the Obituary Notices of those Members of the Society whose loss we have had to deplore during the past year, and who have contributed by their exertions to the advancement of our science. Sad as such a list must always be, it is more particularly so on the present occasion, when we remember that it contains the names of several of the most distinguished ornaments of our science; men who have spent their lives in the zealous prosecution of geological and palæontological investigations, and who have been most active in promoting the welfare and prosperity of our Society. Two of these have filled the Office of President, and another was one of the most distinguished Palæontologists of his day,—I need hardly say that I allude to the names of Horner, Portlock, and Falconer. The loss of Mr. Horner is one which we shall long feel. From the very first moment when he became connected with this Society until almost the last day of his life, he was one of its most active members. The zeal and interest which he displayed in its prosperity were unceasing; he was ever ready to contribute his assistance when required, and in his later years, when less capable of making excursions in the field, which were his delight in his younger days, he was no less usefully employed in our service by the efforts he made in promoting the arrangement of our collection. From his earliest days his tastes had led him to the cultivation of mineralogy and the study of rocks, and it was from this point of view that his aid was so valuable in re-arranging the numerous collection of rock-specimens in our Museum.

Mr. HORNER was born in Edinburgh, on the 17th of January, 1785. He was the son of Mr. John Horner, a prosperous merchant and linen manufacturer in that city, and the younger brother of Francis Horner, whose early death was so deplored by all who knew him, and who, having begun life as a lawyer at the English bar, had given such promise of intellectual powers as to justify his friends in anticipating for him a successful public career. Leonard Horner, on the other hand, ever showed from his earliest youth a decided preference for scientific pursuits, and at an early age attended the lectures of Prof. Playfair on Mathematics, and of Dugald Stewart on Moral Philosophy, and in November 1802 he entered as a student Dr. Hope's class of Chemistry. From that time his scientific tastes developed themselves; he took a particular interest in Mineralogy, began to make a collection of specimens, cultivated the acquaintance of his fellow students who had the same turn of mind, and studied Playfair's 'Illustration of the Huttonian Theory.'

At the age of nineteen he became a partner in his father's business, and came to England in 1804. At the age of twenty-one he married Miss Lloyd, and settled in London. His brother Francis had by this time established his position in the House of Commons, and was looked upon as one of the rising men of his party; he was thus at once received into the society of the scientific and literary men of the day, and continued his devotion to science. His favourite pursuits, however, were Mineralogy and Geology, and in those days geology was more closely associated with mineralogy than at present; for palæontology had not then made such rapid strides and given such impulse and direction to geological investigations as it has done within the last half century. We have only to look at the papers published in the volumes of the first series of our 'Transactions' for a proof of this statement. They are chiefly purely mineralogical or chemical; and although some descriptions of stratigraphical arrangements are given, scarcely an allusion is made to the organic contents of the strata, either in the text or in the illustrations which accompany them.

It was an auspicious moment when Mr. Horner settled in London; for in the following year (1807), notwithstanding the opposition of the then President of the Royal Society, Sir Joseph Banks, and other influential Members, the Geological Society of London was founded, chiefly through the strenuous exertions of Mr. Greenough, to which I have alluded on a former occasion. In the following year (1808) Mr. Horner became a Fellow, since which period the progress of Geology and the prosperity of our Society have always claimed his most zealous attention, and were amongst the principal objects of his life. In 1810 Mr. Horner was elected one of the Secretaries of the Society, and in 1811, while his brother Francis, who, although in Parliament, must have shared his tastes for scientific pursuits, was one of the Trustees of the Society, he read his first paper "On the Mineralogy of the Malvern Hills*." In this paper Mr. Horner first describes the general physical features of the Hills, in the course of which he suggests hints to geologists, which, peculiarly applicable as they then were, are not altogether unworthy of notice in the present day. After alluding to the difficulty, not to say the impossibility, of giving names to the many varieties of granitic and syenitic rocks met with in the Malvern Hills, he adds, "But in the present state of geological science, and more especially when the great imperfection of the nomenclature of rocks is considered, it would be well if geologists made a practice of describing the simple minerals of which a rock is composed, whenever they can be distinguished, instead of giving specific names, without any explanation of the nature of the compounds to which their terms are applied, and particularly those in which theory is involved." He then describes the general structure

* Geol. Trans. vol. i. 1st ser. p. 281.

of the great masses which are irregularly heaped together, and in which granitic rocks predominate; he gives a detailed account of the unstratified rocks, and minutely describes their peculiar contents and the localities in which they occur. Amongst the rarer minerals found in the Malvern Hills is epidote; and after describing several varieties from various localities, he alludes to the similarity between his specimens and those which Dr. Wollaston had found under similar circumstances in the islands of Guernsey and Jersey.

The general remarks with which Mr. Horner concludes his paper clearly show the difficulties with which the geologist had to contend in the earlier days of geological investigation. Mr. Horner at once saw that the phenomena which he so carefully observed exhibited appearances very inconsistent with the Wernerian System of Geognosy. Reform was already at work. He remarks on the great contrast between the two sides of the range; on the east a level plain for many miles, on the west a constant succession of hills; and then he shrewdly observes, "If the unstratified rocks in the centre are to be considered as the oldest, and if the stratified rocks have been deposited upon them, how does it happen that they are only found on one side, that not a vestige of the strata that occur on the western side is to be met with on the eastern, and *vice versâ*, &c.;" and he then observes that the Huttonian theory offers the only satisfactory explanation of these phenomena, and that the position of the stratified rocks can only be accounted for on the supposition of some violent force which has elevated them from their original horizontal position. His concluding remarks will be read with interest even at the present day.

The next paper which Mr. Horner read before the Society was on the Brine-Springs at Droitwich*. In this paper he gives an account of the natural and chemical history of the brine-springs, chiefly derived from his own observations in 1810, together with the results of some experiments which he subsequently made, with the view of determining the chemical composition of the brine.

In 1815 Mr. Horner read a paper entitled "Sketch of the Geology of the South-Western part of Somersetshire," accompanied by a geological map of the district. This paper consists chiefly of a mineralogical account of the different rocks which came under his notice, with scarcely any attempt at classification. The general arrangement of the Palæozoic rocks was at that time so imperfectly understood, that it is not surprising that Mr. Horner should have failed to perceive the true relations of the rocks in this district, and that he should not have distinguished the Devonian rocks of the western part of the country he describes from the New Red Sandstone in the eastern portion. It is true he draws a distinction between what he calls

* Geol. Trans. vol. ii. 1st ser. p. 94.

grauwacke and the red sands and conglomerates, but the limits of his two formations do not correspond with those of the two series which more recent investigations have established.

Mr. Horner concludes his paper by recommending to the attention of future geologists, the singular accumulations of conglomerates which he had described, and adds, "The apparent alternation of the *lyas* (*sic*) strata with the red rock on the shore also deserves an attentive examination, and there appears to me an excellent opportunity in this district of investigating the history of that red rock, about which so little is yet known, though occurring to so great an extent throughout England."

On the whole, it is impossible to read these early papers of Mr. Horner without admiring the cautious manner in which he avoids a too hasty generalization. He clearly saw, as it were, glimmering in the distance, some of the great principles and laws which have regulated the order of superposition and the stratification of the various formations; but the great laws of palæontology, and the now well-known order of succession in the history of organic life were then only just beginning to be understood. Facts were wanting to enable the geologist to understand the true order of superposition, and we thus find Mr. Horner carefully avoiding theories, but anxiously endeavouring to collect all the facts he could, for the use of those who might follow him, and thus helping to lay the foundation of those principles which have, chiefly by the labours of Murchison and Sedgwick, been so successfully applied to the history of the Palæozoic rocks.

About this time, however, it appears that, in consequence of the state of his father's business, with whom he was a partner, Mr. Horner was obliged to leave London, and again to take up his residence in Edinburgh. But these plans were soon interfered with by other duties. The declining health of his brother Francis compelled him to seek a warmer climate for the restoration of his health, and Mr. Horner accompanied his brother to Italy. Alas! the attempt was useless. His hopes were disappointed, and the career of the rising politician was cut short. Francis Horner died in Italy in 1817, and Leonard Horner returned sorrowing to Scotland to resume his former occupation.

But Edinburgh in those days was not a place where a man like Mr. Horner could long remain inactive. He soon found himself in a circle of friends of congenial taste, and, combining his love of science with that of literature and politics, he formed one of the band of Whig politicians for which Edinburgh had become so well known. The biographer of Francis Jeffrey, Lord Cockburn, gives Mr. Horner the chief merit in the organization of their political meetings. It was whilst living in such companionship that in 1821 he first conceived the idea of founding, in Edinburgh, an institution for the instruction of mechanics, similar to that which already existed in Glasgow; and in October of that year the School of Arts was formally opened by the Lord Provost. He was also one of the chief founders of the Academy established

for the purpose of giving a higher classical education to the sons of gentlemen and of the middle classes in Edinburgh. This Academy still flourishes, and to the last year of his life Mr. Horner was engaged in schemes for its improvement, and for the reform of its original construction.

But though absent from London, Mr. Horner was not forgotten there. The interest he had taken in Edinburgh in promoting various plans for the advancement of knowledge and the improvement of education was fully appreciated; for in 1827 he was invited to London to take the office of Warden in the London University, which had then been but recently founded. But the duties of this office, great as they must have been during the first years of the existence of this institution, did not distract Mr. Horner's thoughts from his old associations; he was elected a Member of the Council of this Society in 1828, on the very first Anniversary after his return to London, and was chosen as one of the Vice-Presidents in 1829. After a few years, however, he found the duties of Warden too much for his health, and he resigned the office in 1831. He then went abroad with his family, and fixing his residence at Bonn, on the Rhine, again devoted himself to his favourite pursuit of mineralogy; here he had ample opportunities of studying the phenomena of igneous and eruptive rocks in the classic region of the Siebengebirge and the Drachenfels, whilst cultivating the friendship of many literary and scientific men, who were collected together under the auspices and by the attractions of a flourishing German University. The names of Schlegel, Goldfuss, Mitscherlich, Nöggerath, and Brandis, with whom he ever afterwards kept up most intimate relationship, will give some idea of the intellectual society afforded by the place where he had fixed his residence.

In 1833 Mr. Horner returned to England. On the 13th of March he laid before the Society the results of his observations while abroad, in a paper entitled "Geology of the Environs of Bonn*." In this paper Mr. Horner gives a full and minute account of the various trachytic rocks which, with numerous modifications, constitute the chief portion of the Siebengebirge, as well as of the basaltic rocks, in many places columnar, which have burst out in the neighbourhood, apparently at a more recent period. The lowest sedimentary rock described is called Grauwacke. It is now known to belong to the Devonian system; but though this classification was not then understood, Mr. Horner correctly recognized many beds as resembling the Old Red Sandstone of Herefordshire and Shropshire, and came to the conclusion that it probably "belonged to the later periods of the Grauwacke deposit." None of the Secondary strata occur here, and the grauwacke is covered unconformably by deposits of the Tertiary period, which constitute a brown-coal formation, and this again is overlain by beds of gravel and loess. But I must refer you to

* Trans. Geol. Soc. vol. iv. 2nd ser. p. 433.

the paper itself for the many interesting details it contains, particularly with reference to the age of the Brown-coal formation.

On the 26th of February in the following year Mr. Horner read an interesting paper "On the quantity of solid matter suspended in the water of the Rhine." His experiments showed that about 145,981 cubic feet of solid matter are borne past Bonn every twenty-four hours. He also ascertained that, when dried, the residuum was, both in appearance and properties, undistinguishable from the *loess* of the Rhine Valley.

But other public duties now engaged his attention. On his return to England in 1833 he had been named as one of the Commissioners appointed to inquire into the employment of children in the factories of Great Britain; and when the Act founded on their report was passed, Mr. Horner was appointed one of the Inspectors to see that its provisions were properly carried out. It would be foreign to my present purpose to go into any detail of Mr. Horner's labours in this field, but I may perhaps be allowed to mention that the manner in which he carried out the difficult duties which devolved upon him was such as to meet with universal approbation. Feeling the greatest sympathy for the purpose for which the Act was introduced, he refused no labour, he avoided no responsibility necessary for the protection of those whose interests he had to defend. And even they, whose interests were at first supposed to be injuriously affected by the measure, could not but admire the temper and judgment of Mr. Horner, and were at last compelled to acknowledge the beneficial consequences of the Act itself. With regard to the feelings of the working classes themselves, I need only quote a passage from a communication recently addressed to his daughters by the Delegates from the operative cotton-spinners of Lancashire and other districts, in which, amongst other things, they say, "His impartiality in the administration of the laws made for the protection of our wives and children, and his firmness in their vindication, have long commanded our esteem, and of which, while we live, we shall cherish a grateful remembrance."

But during all these laborious exertions, Mr. Horner still found his relaxation in the pursuit of science. He had become a Fellow of the Royal Society in 1813, and in 1846 he was elected President of this Society; and during the period that he held that Office, he was unremitting in his attendance at the apartments of the Society, superintending the arrangements of the Museum, and devising plans for its improvement.

A reference to the first Address, which he delivered on the 26th of February, 1846, will at once prove the correctness of this statement. When he alludes to the state of the Library and Museum, he says that "it is a part of the general scheme contemplated for the Museum, to have a full catalogue for each formation or principal group of all the known fossils belonging to it, and of the lithological characters of its prevailing rocks, both British and foreign, distinguishing the specimens in the possession of the

Society, and containing a list of all the works and memoirs that treat especially of the particular group." This important work has unfortunately never been completed, but such portions of it as were finished were compiled by his own hand or under his immediate inspection. He also undertook, with the assistance of Mr. Morris, to prepare an illustrated copy of that gentleman's Catalogue of British Fossils, and of this work also a considerable portion was completed by Mr. Horner.

This Address is also remarkable for the able summary it gives of Sir Roderick Murchison's valuable work on the Geology of Russia, then recently published, and this is done both directly and indirectly; for after giving a general sketch of the geology of Russia as described by Sir R. Murchison, Mr. Horner proceeds to offer some remarks on the recent discoveries in the several great groups of formations, beginning with the lowest fossiliferous deposits; and he then institutes a careful comparison between the recent discoveries in Russian geology, extending over so vast a tract of country, and what was already known respecting the rest of Europe, illustrating the one by the other, and showing how the phenomena observed by Sir R. Murchison and his companions, Count Keyserling and M. de Verneuil, in Russia, had tended to solve many problems hitherto scarcely understood in European geology. This was particularly the case with regard to the Permian system, which, as the result of this investigation, became permanently separated from the overlying Trias, constituting a separate zoological system, comprehending the Lower New Red Sandstone, our Magnesian Limestone, and the sandstones and conglomerates that constitute the lower member of the Bunter Sandstein of the Germans. At the same time, while it contains some animal and vegetable remains of the Carboniferous series, and is thus connected with the true Palæozoic rocks, it contains a peculiar fauna and flora of its own, thus forming a distinct system between the Carboniferous and Triassic systems.

There are many other portions of this Address well deserving of notice even in the present day, particularly the account of the different theories of the formation of coal, and the observations on the Boulder formation, the northern drift, and the erratic blocks.

Mr. Horner delivered his second Address on the 19th of February, 1847; in it he principally dwells on the recent additions to the knowledge of the Tertiary and more modern formations, and on terrestrial changes now in progress, to which of late years the attention of geologists had been more particularly directed. On this occasion he also reviewed, at considerable length, the Essay of Prof. Edward Forbes on the connexion between the distribution of the existing Fauna and Flora of the British Isles, and the geological changes which have affected their area, especially during the epoch of the Northern drift.

It was during this same year that Mr. Horner took an active part in bringing about certain changes in the management of the

Royal Society, which resulted in limiting to fifteen the number of new Members to be annually elected, and in introducing very important changes in the mode of election. He was also for some time engaged in publishing and editing the memoirs of his brother, Francis Horner.

In April 1850 Mr. Horner communicated to this Society a notice of some observations of Prof. Lepsius respecting the change of level of the water of the Nile during the last 4000 years, from which it appeared that the bed of the river had been lowered about 28 feet during that period. Mr. Horner could not agree with these conclusions, and it is probable that the difficulty of explaining the phenomena described by Prof. Lepsius induced him to undertake those investigations respecting the levels of the Nile, which he afterwards carried out.

In May 1854 he read a paper on some intrusive igneous rocks in Cawsand Bay, near Plymouth. After describing the conditions in which these porphyritic rocks occur amidst the argillaceous schistose rocks and hard arenaceous red sandstones and conglomerates, he concludes with some suggestions as to the theory of this association of igneous and sedimentary rocks, and thinks it probable that the igneous rock was poured into a vast irregular cavity, parallel to the plane of stratification, during a submarine outburst.

In the volume of the Philosophical Transactions for 1855, he published an account of the recent researches near Cairo, which he had caused to be undertaken with the view of throwing light upon the geological history of the alluvial land of Egypt. The method adopted by Mr. Horner in this investigation was to compare the depth of sediment which had accumulated, to a considerable height, above the base of the oldest works of art near the Nile, with that of the sediment deposited below the base of these same monuments on the rock forming the bottom of the channel. If, he observes, the depth of sediment above the base of these works of art be divided by the number of centuries that have elapsed since the date of their erection, we may obtain a measure of the secular increase of the sediment; requiring, however, a correction for causes that might make a difference in the rate of increase between earlier and later periods.*

Shortly after this Mr. Horner resigned the Inspectorship of Factories, and from that time his attention was more particularly, I might say exclusively, devoted to the interests of this Society. The question of the arrangement of the contents of our Museum had been seriously taken up by the Council, and a Committee, of which Mr. Horner was the Chairman, had been appointed for the purpose of carrying out their views. It is not too much to say that of this Committee he was the most active Member. Very elaborate catalogues of the fossils of the different formations, both in the British and Foreign Collections, were prepared by Mr.

* Quart. Journ. Geol. Soc. vol. xii. President's Address, p. xcix.

Horner himself, and were laid before the Council in 1860 and 1861; and the Reports of the Museum Committees in every successive year since 1860 bear ample testimony to the laborious zeal with which Mr. Horner applied himself to the execution of the task he had undertaken, and of the manner in which his labours were appreciated both by the Council and the Committee. For, besides the preparation of these systematic Catalogues, which are arranged both geographically and geologically, and are so constructed that all future contributions can be at once added under their proper heads, Mr. Horner himself undertook the formation of a typical collection of rock-specimens, at the same time preparing a catalogue of the whole, with illustrative notes. This could not be undertaken without a laborious examination of many separate collections dispersed throughout the Museum, and hitherto useless for want of proper arrangement. The following extracts from the Reports of the Museum Committees show how his labours were appreciated in 1861. They say that they "think it their duty, in referring to this subject, to call especial attention to the continuous labour and great zeal of the President, who, in superintending the rearrangement, has given his constant personal attendance to the details of the business, and during the past year has spent several hours of stated days in every week in actual labour in the Museum." And again, in 1864, I find this sentence, "The Committee cannot conclude this Report without drawing the attention of the Council to the unremitting zeal and continuous labour bestowed upon the rearrangement of the Society's Collection by Mr. Horner, who has spent several hours almost daily in the Museum." I mention these circumstances to show that, whether as President or not, Mr. Horner devoted the principal portion of his time to the improvement of our Museum and the arrangement and cataloguing of our collections, in a manner which, I may safely say, has never been equalled by any other Member of the Society, and which will ever deserve our best acknowledgment and our warmest thanks.

In 1860 Mr. Horner was again elected President, and in his Address of the following year I find an interesting notice of Mr. Darwin's work "On the Origin of Species," an able vindication of the experiments of Sir James Hall against the adverse criticisms of Prof. Gustav Rose*, and an account of the theories of Metamorphism, chiefly based on the experiments and works of M. Daubrée, who, in papers quoted by Mr. Horner, gives full credit to the illustrious Hutton as the first who pointed out that subterranean heat had not only consolidated and mineralized the deposits at the bottom of the sea, but had, moreover, raised up and thrown into inclined positions beds which had been originally horizontal, and who also showed the successive cooperation of water

* See Quart. Journ. Geol. Soc. vol. xix. part 2, p. 1, containing Prof. Rose's subsequent recantation, translated by Mr. Horner himself.

and the internal heat of the globe in forming the same rocks, and that Hutton is truly the founder of the fertile principle of the transformation of the sedimentary rocks by the action of heat.

But perhaps the most remarkable portion of this Address of Mr. Horner, was that in which he collected the evidence of the early existence of the human race. It is impossible to read these remarks without being struck with the conviction that, however impossible it must be to assign even a probable limit to the past existence of the human race, there is satisfactory, I might say almost conclusive, evidence that our earth was inhabited by man for a very long period antecedent to the date which is usually supposed, on religious grounds alone, as marking the period of his creation.

In the course of this same year (1861) Mr. Horner was compelled to leave England to seek a milder climate for the restoration of Mrs. Horner's health; he resided for some time in Florence, and was thus precluded from giving us the usual Address in the following year. During his stay in Florence he occupied his leisure hours with the translation from the Italian of the *Life of Savonarola*, by Prof. Villari of Pisa. I had frequently the pleasure of seeing him at this time, and I shall never forget the touching and tender resignation with which he alone of his family then contemplated the approaching probability of the loss he feared. When I took leave of him in the month of May 1862, he said, with touching pathos, that it was no small calamity for a man at his age to lose the constant companion of fifty-six years of his life. Alas! the event he foresaw occurred only a few days afterwards.

On his return to England, after he had somewhat recovered the first effects of his severe loss, he again returned to his labours in arranging our Museum—to him a labour of love, in which he was almost daily occupied until his declining strength put an end to its continuance. But he still contemplated returning to Florence in the spring of 1864. Here again his hopes were disappointed; his increasing weakness precluded his moving, and on the 5th of March death put an end to an honourable existence, and deprived his friends and relations of one of the most upright and pure-minded men who have devoted their time and energies to the welfare of their fellow creatures or the advancement of science and truth. This is not the place to attempt a sketch of the character of our lamented associate, but I cannot omit quoting from an Italian paper a few words, said to have been written by Pasquale Villari, for his loss was heavily felt in Italy, where he had also made himself many friends. After alluding to the Address of the Workmen of Lancashire, which I have already mentioned, he concludes as follows:—"And truly, if anything could console his family for the loss of one so beloved, it was just that sympathy which arose spontaneously from the hearts of men whom he had benefited. They with their words elevated and sanctified the image of the venerable man. The monument which he himself erected in the hearts of the workmen need not

surely envy those which raise their proud heads in St. Paul's or Westminster Abbey. Happy is that nation which can boast of possessing many men who leave their simple but eternal monuments in the hearts of the people."

Major-General PORTLOCK was the only son of Capt. Nathaniel Portlock, of the Royal Navy, who was one of the loyal colonists of America. He had entered the Navy as a Midshipman under Capt. Cook, and was with him at his death, and he afterwards became one of the leaders of that hardy band of circumnavigators whose discoveries ornamented the last century. In command of the 'Arrow,' a frigate of peculiar construction and of light draught of water, he distinguished himself in many a gallant action with the enemies of his country, and established a name for his family which was honourably sustained by his son, our late lamented President.

Major-General Portlock was born in 1794. He left the Royal Military Academy in 1813, and in April of the following year was ordered to Canada, where he was not undistinguished in the operations on the American frontier. He took part in the siege of Fort Erie, and when the army retired, was the officer who constructed the lines and *tête de pont* of Chippewa, at which Sir Gordon Drummond made his successful stand and saved Upper Canada. Lieutenant Portlock continued in Canada for several years.

After his return to England new and important duties awaited him. In 1824 the Ordnance Survey was about to be extended to Ireland, and Lieutenant Portlock was one of the first officers selected by Colonel Colby to be employed on it. I need not here dilate on the more extended system, beyond that to which the Survey of Great Britain had been confined, which was contemplated in the Irish Survey. The work required in Ireland was not a map, but a general-estate survey on a much larger scale, though intended for a public purpose.

Much had to be done in the creation of the machinery and arrangements for this great work, which ultimately led to the formation of a Topographical Department. With the cordial assistance of the Duke of Wellington, Colonel Colby succeeded in carrying out his plans and organizing his arrangements. In all these Portlock was the confidential officer and companion of Colonel Colby, and he was retained at head-quarters at the Tower for that purpose. Thus passed his first year on the Survey. In 1825 the first detachments were moved to Ireland, and were established in the Co. of Londonderry, where the first base was to be measured. The first trigonometrical station was taken upon the eastern coast, on Divis Mountain, near Belfast, to connect the triangulation of Ireland with the points already fixed in Great Britain. Colonel Colby, accompanied by Lieutenant Portlock, then proceeded to Ireland and joined the trigonometrical party on Divis, from which, at the close of the season, the

first observations made by the aid of the lamp and heliostat were successfully effected. This was Portlock's start in Ireland; and all the preliminary arrangements being complete, he remained attached to the trigonometrical branch of the work, of which he soon became the senior, and ultimately the sole officer.

In the following year (1827), with one other officer, he accomplished the observations with the great theodolite at the Vicar's Cairn and other mountain-tops, remaining at Slieve League under canvas 2000 feet above the sea until the middle of January. Indefatigable in his duty, and carried forward by his zeal, he exposed his health to such an extent as to call down the friendly remonstrances of his chief, Colonel Colby. In addition to this laborious work, he also undertook in the following year to direct the operations connected with the secondary triangulation, and subsequently organized an elaborate system of vertical observations and calculations for altitude, and personally carried a line of levelling across the island, from the coast of Down to the coast of Donegal, and caused similar lines to be observed in other places.

This laborious work he continued for several years. In 1832 it was determined to compile a descriptive memoir on the physical, social, and productive aspects of Ireland. In this effort Captain Portlock, having completed the great triangulation, actively cooperated, and undertook the geology and productive economy. He had, however, great difficulties to contend with. As he said himself, "Geology was permitted, not commanded." In 1834, however, he was enabled to engage competent assistants in the various branches; and in 1837 he formed a geological and statistical office, a museum for geological and zoological specimens, and a laboratory for the examination of soils. The results soon appeared in his section of the memoir, but unfortunately the work was suspended by the Government on the score of expense. It was a miserable shortsighted policy. Various retrenchments were suggested, and it was even proposed to drop the figures of altitude as a useless topographical luxury! Better counsels, however, at last prevailed to a certain extent; the survey was resumed in an efficient manner, but the memoir was doomed, notwithstanding the efforts of the British Association, the Royal Irish Academy, the Grand Juries of Ireland, and men of science and progress in both countries. So strongly, however, was public opinion expressed that in 1843 a Commission was appointed by Sir Robert Peel, which recommended its resumption and continuance. The memoir, however, never was resumed, and Captain Portlock was ordered to draw to a close the work he had already begun. This was done in 1843, when he published the volume which bears his name, on the "Geology of Londonderry, Tyrone, and Fermanagh, with portions of the adjacent Counties;" after this he was restored to the general duties of the corps of Royal Engineers, and the surveying parties were removed to England.

This valuable work of Captain Portlock's, which may be justly termed the commencement of the Geological Survey of Ireland, is

too well known to geologists to require any further notice at my hands, and time and space would hardly permit me to attempt it.

In 1831 the Geological Society of Dublin had been established. Captain Portlock took a great interest in it, he was one of its early Presidents, and contributed to it no less than twenty separate papers, including his Presidential Addresses in 1838 and 1839. When the British Association met in Dublin in 1835, Captain Portlock was a Member of the local Committee and Secretary of the Section of Geology and Geography. In 1837 he also contributed to the British Association a paper on the New Red Sandstone of England and Ireland, and again in 1838 one on the Silurian rocks in Tyrone.

In 1843, when his labours on the Irish Survey ceased, he was stationed in Corfu. He took part in the remodelling and erection of the fortresses, devoted himself to the study of military science, and by way of relaxation to botany and scientific pursuits. A mere catalogue of the various papers written by him during his residence in Corfu would be a long and tedious list. It contains many papers addressed to the British Association and other bodies. Amongst them, however, I may mention a short notice in a letter to Professor Phillips on the geology of Corfu, forwarded to the Meeting at Cork in 1843, immediately after his arrival in that island. In the same year a grant was made by the Council to Major Portlock for the exploration of the marine zoology of Corfu. Other papers on the Natural History of Corfu he communicated to the 'Annals of Natural History.'

In February 1844 Captain Portlock communicated to this Society an account of the White Limestone of Corfu and the neighbouring island of Vido. He does not appear to have been very successful in finding organic remains. But in the compact limestone of Vido he found *Terebratulæ* and *Ammonites* in abundance, from the characters of which, some of them being apparently new, he concluded that the strata belonged to the Oolitic series; and with respect to the Tertiary strata, he believed that all the varieties occurred which had been found by Mr. Strickland in Zante; and that there is little doubt that the strata extend from the Lower Pliocene down to Miocene, if not to Eocene.

In 1847 Major Portlock was removed to Portsmouth. Here also, amidst the duties of his profession, he found time for much scientific labour. In 1848 he communicated to the British Association a paper on the evidences he had observed at Fort Cumberland and the Block-house Fort, of change of level on both sides of Portsmouth Harbour; and he also wrote articles on Galvanism, on Geology and Geognosy, on Heat, and the Appendix (F) to Dr. Ryan's article on Gun-Cotton in the second volume of the "Aide-Mémoire." He also published a treatise on Geology, in Weale's 'Rudimentary Series.'

In 1849 Lieutenant-Colonel Portlock was appointed Commanding Royal Engineer at Cork, and was warmly welcomed on his return to Ireland by the Irish geologists, who had not forgotten

his former contributions to the geology of Ireland, or his services in favour of the Geological Society of Dublin, of which he was again elected President. He contributed a paper "On the variations in depth in the Tertiary deposits, as exhibited in a section of borings at Portsmouth;" and another "On the schistose condition of the rocks in Bantry Bay," in addition to his Annual Addresses on the 12th of February 1851 and 12th of February 1852. He also furnished an excellent article on Palæontology in the third volume of the "Aide-Mémoire."

In 1850 he read a paper to the British Association at Edinburgh, on the manner in which Trap or Igneous Rocks intrude into the Sandstone and Conglomerate near North Berwick.

During this period he also entered with great zeal into the question of the employment of convicts on military public works in Ireland, a measure which has since received so great a development, and in Ireland at least has been attended with such beneficial consequences. In 1851 Lieutenant-Colonel Portlock became Inspector of Studies at the Royal Military Academy at Woolwich. Here he found full scope for those occupations to which his thoughts and attention were becoming more and more exclusively devoted. He was an ardent advocate for education in the army, and particularly for that of the scientific corps. He took an active share in all the plans and schemes for the improvement of military education, which were at that time occupying the attention of the military authorities; but in the meantime, dealing with the then existing state of things, he devoted himself to the improvement of the course of education at the Academy, by extending the mathematical course, and the study of chemistry; and by introducing, amongst other details, the addition of lectures in Geology, in Mineralogy, and in Natural Philosophy. During this time he also furnished to the 8th edition of the 'Encyclopædia Britannica' the articles on "Cannon," "Fortification," and "Gunnery."

In 1852 Colonel Portlock was President of the Geological Section of the British Association at Belfast; and about this time it was that he wrote an admirable memoir of his former chief, Major-General Colby, of which Major-General Larcom, from whose memoir I have collected most of the materials in this notice, speaks in the highest terms, as recording, in the life of General Colby, the origin and progress to maturity of the topographical branch of the service.

In 1856 he resigned his post at Woolwich; influenced by a sense of public duty, he retired at the very moment when the result of his labours was beginning to appear. He carried away with him the esteem and the regret both of the authorities and of all connected with the Academy; and by no one was this regret, and the approbation of his useful labours, more warmly expressed than by Lord Panmure, then Secretary of State for War. On leaving the Royal Military Academy he held the command at Dover from November 1856 to May 1857, when another field was

opened to him for the exercise of his zeal and talents in superintending the education of the Army.

In the mean time, however, on the 18th of June, 1856, at the last Meeting of the Society for the Session, the death of Mr. Daniel Sharpe, who had then been recently elected our President, was announced, and Colonel Portlock was unanimously elected to fill the vacant Office; and it is unnecessary for me to remind you of the kind and judicious manner in which he invariably fulfilled the duties he had undertaken. In the two Addresses which he subsequently delivered on the occasion of the Anniversary Meetings, he gave us full and detailed accounts of the principal geological discoveries which had marked the progress of our science during the two years he occupied this chair. But if I were called upon to select any special matter in those Addresses, which appear to me to have been eminently successful, I would point to the able and elaborate *résumé* which he gave, in 1858, of the work of M. Delesse, entitled "Études sur le Métamorphisme," and in which the important discoveries of that able mineralogist and geologist are fully explained.

At length, in consequence of the great discussion which had for some time been going on respecting Military Education, the recommendation of the Commission appointed to inquire into the subject was adopted, and a Council of Military Education was appointed. Major-General Portlock, from his antecedent duties, was naturally one of those selected for the first council; and it may well be supposed by those who knew him, that no employment could be more congenial to his tastes than this. On all occasions he was one of the most forward advocates of education. He looked upon competition, and especially open competition, as the great principle on which public appointments should be made. He was also a warm advocate of the claims of science upon the education of youth; nor was he indifferent to the claims of classical education, but he considered that it should be cultivated on better principles and in a sounder manner.

But in the midst of these important duties he did not neglect literary occupation; in 1858 he translated from the Italian a work on Strategy by Sponzilli, and in 1860 he revised the article "War" for the 8th edition of the 'Encyclopædia Britannica.'

Thus, during the last periods of an active life, his energies and interests were divided between the Council of Military Education and the Geological Society of London, to which, from the time of his Presidentship, he was more closely drawn than ever, until in 1862 sudden illness warned him to withdraw from active and public duty. After a partial recovery, he returned to the scene of his early labours, and settled near Dublin, in the hope of being able to be at least a not altogether useless member of scientific society. But this hope was not destined to be fulfilled. His illness increased until he calmly breathed his last on February 14, 1864, in the 70th year of his age.

Amongst the many honours conferred upon him, he received in

Trinity College, Dublin, the honorary degree of Doctor of Laws. He was also a Fellow of the Royal Society, the Royal Astronomical Society, the Royal Geographical Society; and he was a Member of the Royal Irish Academy, and of the Geological and Zoological Societies of Dublin.

And now I have to add to the list of our losses the name of Dr. HUGH FALCONER, who has been suddenly taken from us within the last few days, at the early age of 56. When we recollect the zeal and ability with which he had directed his attention to the study of Palæontology, and more especially to that of the extinct Mammalia, the vast amount of information he had collected, and the judicious and cautious use he made of it, we may safely say that the Palæontologists of the present day have suffered an irreparable loss.

HUGH FALCONER was born at Forres in the North of Scotland in 1809. He studied successively at the Universities of Aberdeen and Edinburgh, and went out to India in 1830, as Assistant-Surgeon on the Bengal Establishment. Taking a lively interest in all branches of Natural History, his chief pursuit at this time was Botany; and in 1832 he succeeded Dr. Royle as the Superintendent of the Botanic Gardens at Suharunpoor. Placed thus at the early age of twenty-three in a responsible and independent position, his natural talents and tastes had a full field for their development. Having already in Calcutta examined a collection of fossil bones from Ava, he now began his explorations in the Sub-Himalayan or Sewalik range of hills, which on his very first visit he pronounced to be of Tertiary age analogous to the Molasse of Switzerland. With the help of his friend and companion Captain, now Col. Sir Proby T. Cautley, fossil remains of Miocene mammalian genera were quickly found in great abundance. A still richer deposit of these remains was found in 1834 by Lieutenants Baker and Ducand, to which the attention of Dr. Falconer and Capt. Cautley was at once directed, and it is perhaps not too much to say that such a mine of mammalian remains has never yet been met with in any other portion of the globe; nor was it less remarkable for the great number and variety of species thus unexpectedly brought to light. The results of these discoveries were published by Dr. Falconer and Capt. Cautley in various scientific journals both in India and in England, and so important were they considered, that in 1837 the Council of this Society awarded to them the Wollaston Medal.

About the same time also his botanical duties led him to explore the snowy range of the Himalayas, whose lofty summits, visible from his post at Suharunpoor, must have been long a constant object of interest to his active and inquiring mind. Falconer never forgot what he had once seen or learnt, and they who had the good fortune to hear his observations on the glaciers and the physical structure of that mountain-region, made on a recent occasion at one of the meetings of the Royal Geographical Society,

must have been struck with the vividness of his recollection of scenes which he had visited many years before, as well as with the sound and philosophical views which he then brought forward. It was also chiefly owing to information obtained by him that we are indebted for the introduction of the cultivation of tea into India, as well as for that of the Cinchona plant.

In 1837 Dr. Falconer accompanied Sir Alexander Burnes's second mission to Cabool. During this expedition and in the following year he explored many parts of the Trans-Indus region and Cashmere, and examined the great glaciers of the Mooztagh range and of other regions, returning towards the end of 1838 to Suharunpoor, to resume his duties.

In 1842 the state of his health compelled him to return to England on sick leave, bringing with him the valuable natural-history collections which he had made on his many exploratory expeditions and during his residence in India. On his return to England he occupied himself with the description and disposal of his collections, most of which he presented to the India House and the British Museum, to which national institution Capt. Cautley had already presented his collection. To Dr. Falconer was confided the charge of superintending their arrangement, the result of which has been the formation of a collection of fossil mammalian remains unequalled in any museum in the world.

In conjunction with Capt. Cautley he communicated many interesting and valuable papers respecting these fossil remains, which were published at various times in the different scientific journals of the day. Amongst these was a discourse communicated to the Royal Asiatic Society on the Fossil Fauna of the Sewalik Hills.

Our own Proceedings for 1844 contain a valuable paper by these authors on some fossil remains of Anoplotherium and the Giraffe from the Sewalik Hills in the North of India. In this paper they allude to the remarkable mixture of extinct and recent forms which constituted the ancient fauna of Northern India. With regard to the remains of fossil Crocodiles, one species is considered as identical with its recent analogue. They occur together with extinct species of such modern types as Monkey, Camel, Antelope, and Giraffe. The Anoplotherium, hitherto only found, as they believe, in the older and middle Tertiaries of Europe, continued in India to live down to a period when existing Indian Crocodiles, and probably other recent forms had become inhabitants of that region. In the following year Dr. Falconer read before the Society a paper on Dinotherium, Giraffe, and other Mammalia from Perim Island in the Gulf of Cambay, including a description of the remains of a new Ruminant, the Bramatherium, allied to the fossil Giraffe. One of the most interesting facts connected with the Perim fossils is, that they belong to the same genera and species as are found in the Sewalik Hills, and in the ossiferous beds of the Irawaddi in Ava. But besides these the Perim Island collection contains numerous remains of Mastodon, Elephant,

Rhinoceros, Hippopotamus, Sus, Equus, several species of Antelope, Bos, Crocodiles, Tortoises, and Fish.

But the most important work undertaken by Dr. Falconer and Capt. Cautley was the publication of the great work entitled "Fauna Antiqua Sivalensis," published under the patronage of the Government and the India House. It was intended to illustrate fully the fossils of the Sewalik Hills. The plates of nine parts were brought out between 1844 and 1847, but the letterpress was greatly in arrear, and, having been stopped in consequence of Dr. Falconer's return to India on the expiry of his leave, has never been resumed.

In 1848 Dr. Falconer was appointed Superintendent of the Calcutta Botanical Garden, and Professor of Botany in the Medical College; in 1850 he visited the Tenasserim provinces to examine the teak forests, and subsequently contributed to the introduction of the Cinchona plant into India. In the spring of 1855 he retired from the Indian service, and returned to England, with his health greatly impaired by the effects of his hard labours and exposure to an Indian climate. Ever since that period he has been an active member of our Society, and an ardent investigator of Tertiary mammalian geology. Scarcely had he returned to England when he communicated to this Society a very important paper "On the Species of Mastodon and Elephant occurring in the Fossil state in England." Unfortunately only the first part of this paper, namely on Mastodon, has as yet been published. His object was to ascertain what are the species of Mastodon and Elephant found fossil in Britain, what ought to be their specific names, and what are the localities where they are found, as well as to remedy the almost chaotic confusion which had crept into the nomenclature of these proboscidian Pachydermata, by pointing out the distinctive characters of the several species of Mastodon and Elephas. The following are the conclusions at which he arrived.

1. That the Mastodon-remains which have been met with in the "Fluvio-marine Crag" and "Red Crag" belong to a Pliocene form, *Mastodon Arvernensis*.

2. That the Mammalian Fauna of the Fluvio-marine Crag bears all the characters of a Pliocene age, and is identical with the Subapennine Pliocene Fauna of Italy.

3. That the Red and Fluvio-marine Crag, tested by their Mammalian fauna, must be considered as beds of the same geological age.

Following up these investigations, and having come to the conclusion that the mammalian fauna of the Pliocene age must be distinguished from that of the Quaternary period of Europe, he was naturally led to the examination of the Cave-fauna of England. In 1860 he communicated to the Society a Memoir on the ossiferous caves of Gower. The existence of *Elephas antiquus* and *Rhinoceros hemiteachus*, as belonging to the same fauna, was thus for the first time established, and the age of that fauna defined as posterior to the boulder-clay or glacial period. At the same

time he zealously prosecuted the same line of investigation in Sicily and in Italy, particularly in the Val d'Arno, where he endeavoured to reduce to something like systematic order the mass of fossil bones there found. In Sicily he discovered the famous Grotto di Maccagnone, where flint implements of great antiquity were found adhering to the roof-matrix, mingled with remains of *Hyæna*, now extinct in Europe. An account of these discoveries was published in our Journal*, with a description of other similar caves, and of the enormous quantity of fossil bones of extinct animals, amongst which those of *Rhinoceros* were so abundant, that they represented the remains of many hundreds if not thousands of individuals. These were found in a bone-breccia forming the bottom layer in the caves, as well as an enormous talus outside resting on the Hippurite-limestone.

Besides other communications on this and cognate subjects, Dr. Falconer communicated to the British Association at Cambridge an account of the *Elephas Melitensis*, the pigmy fossil Elephant of Malta, discovered with other extinct animals by Capt. Spratt in the ossiferous cave of Zebbug.

The question of the antiquity of man had always been a subject of great interest to him, and the investigation of the cave-deposits, evidently of very different ages, of which fact additional evidence was being almost daily accumulated, was constantly urging him on to fresh inquiries and new discoveries. In 1863 he took an active share in the perplexing discussion on the human jaw, said to have been found in the gravel-deposits of Moulin Quignon. Dr. Falconer was inclined to doubt its authenticity, and there seems little reason to question the correctness of his conclusions.

He also took a great interest in the discovery of those remarkable deposits in the caverns of the Dordogne, where flint implements and other curious remains of human art are so abundant, together with remains of animals now extinct in that part of France, of which those of the Reindeer are the most numerous; these have been ably investigated by Messrs. Lartêt and Henry Christie, but they belong undoubtedly to a much more recent period.

His last expedition was undertaken last September to visit the remarkable cave-deposits recently discovered in Gibraltar. A copy of the report which he made, in conjunction with Prof. Busk, to the Government, has lately been forwarded to us by the Secretary of State for War, and will, I trust, shortly be read before this Society.

His loss, I am sure, will long be most deeply felt by those who were personally acquainted with his merits, and by all who could appreciate profound scientific knowledge. His memory was most remarkable, as was also his caution in giving an opinion. The store of scientific materials which he had accumulated, and of

* Quart. Journ. Geol. Soc. vol. xvi. p. 99.

which he was the sole possessor, was such that science will long deplore his loss as a palæontologist of the first order, and it will be long before any follower in his footsteps can collect the mass of information which he had made his own. For several years the state of his health had led him to pass the winter season amidst the milder climates of Italy or Sicily, and it is much to be feared that the want of this precaution during the past winter has led to the sad result which we now all deplore. Dr. Falconer became a Fellow of this Society in 1842. He was also a Fellow and Vice-President of the Royal Society. In him we have also lost a useful Foreign Secretary, an office which he has held for three years.

The DUKE OF NEWCASTLE was born in 1811, and, like most young men in his position, was educated at Eton and at Christchurch. Devoted to public life, he was an admirer rather than a cultivator of geological science. His political career is, however, so well known that it is needless for me to allude to it on this occasion. At the same time I cannot omit stating that, having twice held the office of Secretary of State for the Colonies, we are indebted to him for communicating to us from time to time copies of interesting reports received from Colonial Governors, several of which have appeared in our Journal.

The EARL OF ILCHESTER, better known to us as Mr. Strangways, was born in 1795. For many years he followed the diplomatic career.

In 1821 Mr. Strangways read a paper entitled "An Outline of the Geology of Russia," published in the following year in the first volume of the second series of our Transactions. Although now rendered obsolete by the more perfect and detailed accounts of the Geology of Russia by Sir Roderick Murchison and his companions, it must at the time have been a very valuable addition to the knowledge of continental geology. But, like most of the geological memoirs of that time, it is decidedly more mineralogical than geological. It principally consists of lithological descriptions of the various formations observed by the author, with full accounts of their mineral contents. At the same time many of the geological features which have since been so fully illustrated did not escape the keen observation of Mr. Strangways. He points out the analogy between the primitive rocks of Finland and those of Sweden, of which he considers them a prolongation. He describes the evident traces of diluvial action throughout the whole of Finland as existing on the most astonishing scale, every hill-top of granite or primitive rock presenting a surface as much rounded and as visibly water-worn as the boulders or colossal pebbles that lie around their bases. He clearly perceived the Palæozoic character of the fossil remains in the limestone of the Valdai Hills, and compares the Madreporcs to those of the Mountain-limestone in Northumberland. A sort of Briarean

Pentacrinite is particularly described, and allusion is made to Encrini, minute Corallines, and other marine fossils resembling those in the limestone of Dudley, as well as large Terebratulites. The saliferous sands with vast deposits of gypsum are also described, as are their accompanying red marls, now known as the Permian group. Nor did the great limestone-formation, extending across the middle of Russia, escape his notice. It is described as generally of a pure white colour, completely filled with broken Encrinites, large Terebratulites, Caryophyllites, Pectinites, and the exuvia of marine animals. The paper is accompanied by a sketch-map of Russia, in which the author has dotted down the various formations he observed. No attempt is made to give anything like a chronological sequence of the different beds.

The Ven. Archdeacon CHARLES PARR BURNEY was born at Chiswick, October 19, 1785. He was descended from a family long distinguished for their literary attainments. His grandfather, Charles Burney, was the author of the 'History of Music,' and his father, Dr. Charles Burney, was a distinguished Greek scholar and a successful schoolmaster. Educated by his father, he became a member of Merton College, Oxford, and subsequently assisted his father in the management of his school at Greenwich. After holding various livings he was appointed to the Archdeaconry of St. Alban's, and in 1845 he was transferred to that of Colchester. Both in private and in public life he was equally respected and esteemed; his knowledge of business was great, and his advice and assistance were always ready for those who needed them. I am not aware of his having ever contributed any paper to this Society, but on account of his literary name he deserves notice on such an occasion as the present. He died at Brighton on November 1, aged 79.

The Rev. WILLIAM LISTER was a contributor to our Journal. In February 1862 he read a paper on the Drift containing recent shells in the neighbourhood of Wolverhampton. He describes three points where this drift is exposed containing marine shells, some of which are purely Arctic, but most of them are common British species.

Amongst the Foreign Members whom we have lost, I must mention Professor EDWARD HITCHCOCK, a name well known to all who have studied the Geology of the United States. He was born at Deerfield in Massachusetts, May 24, 1793. In early life he devoted himself to the study of astronomy. His first geological paper was his "Remarks on the Geology and Mineralogy of a Section of Massachusetts on Connecticut River," published with a map in the first volume of Silliman's Journal, dated Deerfield, October 1817. For many years he was pastor of a church in Conway, Massachusetts, but he still continued to write papers on Mineralogy and Geology, which were published in the first

ten volumes of Silliman's Journal. From 1825 to 1845 he filled the chair of Chemistry and Natural History in Amherst College, with whose history his name is inseparably connected. In 1845 he became President of the College. But even after his resignation of the Presidency, he continued to be the instructor in Geology and Natural Religion.

His name will also always hold a place in the history of governmental geological surveys, for it was on his suggestion that the government of Massachusetts added a geological surveyor to the corps charged with the preparation of a trigonometrical survey of that State, to which post he appears to have been appointed; he made several reports on the State Geology between 1833 and 1841. These were followed by other reports on Surface Geology, on the Hematite of Berkshire, and finally on the Ichnology of New England. In 1856 he undertook with his two sons the geological survey of Vermont. This, notwithstanding many difficulties, was completed in 1862 by the publication of the final report of about a thousand pages. His last geological paper, entitled "New Facts and Conclusions respecting the Fossil footmarks of the Connecticut Valley," was published in Silliman's Journal in 1863. He then expressed his opinion that it would be his last production. He lived, however, to complete his 'Reminiscences,' the preface of which is dated September 1, 1860. He died at Amherst on the 27th of February, 1864, in his 71st year. He is described as earnest, simple and sagacious, and as being indefatigable under all discouragements.

Professor BENJAMIN SILLIMAN, the venerable and distinguished Editor of the Journal which bears his name, and which has been long known as the best of the scientific journals in the United States, was born in 1780, and died at New Haven on the 24th November last, at the age of 84. He graduated at Yale in 1798, studied law, and was admitted to the bar in 1802. He afterwards accepted the Chair of Chemistry, Mineralogy, and Geology in Yale College. In 1820 he visited Europe to prosecute his studies, then at the age of 40, in sciences which were at that time almost unknown in America. On his return to America in 1821 he published an account of his travels in England, Holland, and Scotland. He again revisited this country in 1851, of which he also published his notes, entitled "Narrative of a Visit to Europe in 1851." He afterwards assisted Dr. Ware in his experiments with the oxyhydrogen blowpipe.

In 1818 Professor Silliman had founded the American Journal of Science and Arts on the extinction of the Journal of Mineralogy, the only scientific periodical which had previously existed in the United States.

To this work he devoted himself with energy and perseverance for the remainder of his life. He was always an ardent promoter of science, and continued to give lectures long after he had resigned his professorship. He is said to have been a man of simple

tastes, and he preserved his activity of mind and body to the last, ever taking a deep interest in the progress of science, humanity, and freedom all over the world. His quiet manners and general knowledge rendered him widely popular.

Although not a Member of this Society, I must not omit the name of ANDREW GEDDES BAIN, to whose explorations we owe so much of our knowledge of South African Geology. He was a native of Scotland, and emigrated to the Cape in early life. The earlier years of his colonial life were passed in various occupations, including the construction of a military road through the Ecca Pass, in which he displayed great engineering talents, and he subsequently had the direction of most of the roads constructed in the colony.

Here it was that a perusal of Lyell's 'Elements' turned his attention to Geology, and while exploring the rocks with which his daily avocations were connected, he discovered the remains of the Dicynodon and other fossil Reptiles in the Lacustrine or Karoo beds near Fort Beaufort. Of these he sent a large collection to England; and some idea of their scientific value may be formed from the large sums of money expended by the British Museum and by this Society in having the organic remains chiselled out of the hard rocky matrix in which they were imbedded, and by the interesting account given of them by Professor Owen in our 'Transactions,' vol. iii. second series, p. 53. In 1845 the Council of this Society awarded him the balance of the proceeds of the Wollaston Donation-fund, as a mark of their high appreciation of the importance of his discoveries.

He subsequently examined the rich Devonian deposits in the Western province, and added many new species to their fauna. In fact, wherever he was employed, the whole of his leisure moments were devoted to the study of the geology of these little-known regions, and he crowned his labours by the construction of a Geological Map of Southern Africa, which was afterwards published by this Society.

After an absence from England of many years, Mr. Bain revisited this country last year, and I need not remind you of the satisfaction with which most of us then saw for the first time the discoverer of the Dicynodon. The state of his health had brought him to England, and the same cause hastened his departure after a short stay in this country on the approach of winter. He returned to the Cape, where the milder climate was considered as the only chance of prolonging his life. He died a few days after landing, and with him we have lost our best hopes for the present of seeing the geology of Southern Africa completed.

In addressing you on the present occasion I regret that I have been unable to take up any one particular subject, which, after the example of some of my immediate predecessors, I might have

handled in detail and developed in all its bearings. I therefore trust that the course I have adopted of endeavouring to lay before you some account of the principal events of the last twelve months, though it may lack the interest of the plan I have alluded to, may yet prove satisfactory, inasmuch as the subjects which have lately occupied our attention, embrace the extreme limits of our geological horizon, extending from the earliest dawn of organic life down to the period when the human race dwelt on the surface of our globe, together with animals which, having run their allotted time, are now extinct. The history of these two extreme periods has recently been remarkably developed, and although many gaps still remain to be filled up by the exertions of future labourers, we seem to be enabled to embrace in one comprehensive glance the whole history of created life from the Eozoön of the Laurentian epoch down to the gravels of Amiens and St. Acheul, and the rich cave-deposits of the South of France.

Geological Survey of the United Kingdom.—The progress of the Geological Survey of the United Kingdom deserves our first attention. Carried on as this Survey has been by an able staff under the immediate superintendence of the Director-General of the Museum of Practical Geology and Professor Ramsay, it is not surprising that its progress has been satisfactory, and that a large tract of country has been surveyed during the last twelve months.

It has long been a desideratum felt by all English geologists to parallel with accuracy the Palæozoic rocks of Cumberland, Westmoreland, and Lancashire with those of North Wales and the Silurian region, and I learn from Sir Roderick Murchison that their examination is now in active progress by the Government Surveyors. The researches of Professor Harkness have already demonstrated, by a complete examination of the fossils, that the Skiddaw Slates, the oldest rocks of Cumberland, are not of the high antiquity which had been assigned to them, but are simply of Lower Llandeilo date, as proved by their Graptolites, Orthidæ, and other Lower Silurian fossils. As it will now be an interesting subject of investigation to assign all the slaty rocks of the wild region south of Skiddaw, with their numerous intercalated porphyries, to their exact equivalents in North Wales, so no one can be more capable of effecting this than Professor Ramsay, who has devoted so much labour to the examination of the last-mentioned region.

The correlation of the Upper Silurian rocks of Windermere, Kendal, and Kirkby Lonsdale, with their equivalents in Wales and the counties of Salop, Hereford, &c., has already been established, and is, indeed, laid down on the new edition of Greenough's map, but their correct lines of demarcation have yet to be worked out; and the services of Mr. Aveline, whose skill in defining the boundaries of the several Silurian formations was prominently brought out in Wales, are now happily applied in Cumberland.

Exploring, in ascending order, from the Silurian base of the Lake region, and working eastwards, the surveyors will next have to develop the structure of the great mineral fields of Durham and Northumberland. The vast importance of these counties, in respect to their ores of lead and beds of coal, has rendered it, the Director-General thinks, imperative to hasten their survey, by carrying on the work into them from the West and North Ridings of Yorkshire before the geology of the eastern counties of England is begun upon, the latter being void of all valuable minerals, save Coprolites.

In the mean time every tract south of London, and extending from the metropolis inclusive to some distance directly north of it, has been surveyed.

It would be out of place here to dwell upon the good services of the various surveyors, most of them Fellows of this Society, who are now working out the details of geological outlines and relations in various parts of Great Britain, or those of Ireland under the able direction of Mr. Jukes; but I may call attention to a change in, or rather addition to, the classification adopted in maps already published. I allude to the interpolation of the Rhætic beds of foreign geologists as a zone lying between the Keuper and the Lias. This has been carried out in certain sheets of Somerset, Gloucester, &c. by the labours of Messrs. Bristow and Etheridge. In searching for the best name to be used as a British equivalent for the word "Rhætic," the Director-General, after personal inspection of some of the best typical localities, has adopted the name of "Penarth," first suggested to him by Dr. Wright, because in the headland of that name near Cardiff, these beds are most clearly exhibited, lying between red Keuper strata beneath and the Lower Lias above them.

I must also say, in reference to the Survey, that I learn with pleasure that the sale of the Government Geological Maps has largely increased, this being the best proof that the public are taking increased interest in the advancement of our science.

In addition to the progress of the Survey itself, several memoirs have also been published under its auspices, and amongst them is one by Professor Huxley "On the Structure of the Belemnitidæ," clearing up many points in their organization that have hitherto remained more or less obscure. The specimen which has enabled Professor Huxley to work out the details on which his discoveries are founded is from the collection of the Rev. Mr. Montefiore, and is the most complete Belemnite ever found. One of the new points contained in this Memoir is the account of that rarely preserved organ hitherto known as the "pen" or *osselet*, but to which Professor Huxley has given the name of *pro-ostracum*, as he considers it to correspond to only a part of the structure known as the "pen" in recent Cephalopods. He then states his belief in the systematic importance of the variations in form of the *pro-ostracum*, and on this account is disposed to favour a subdivision of the genus *Belemnites* itself; the difference between the *pro-ostraca* of certain

Belemnitic forms being probably of generic importance. Another new point furnished by this beautiful specimen is the existence of beaks and acetabular hooks in the genus *Belemnites*, in which they have never hitherto been found, although known to exist in *Belemnoteuthis*.

Another memoir is by Mr. Whitaker "On the Geology of parts of Middlesex, Hertfordshire, Buckinghamshire, Berkshire, and Surrey." It is intended to accompany and to illustrate sheet 7 of the Geological Survey of Great Britain. Embracing as it does such a considerable area of the neighbourhood of the metropolis, it will have an interest for many who have not the leisure to undertake distant excursions, but who may wish, nevertheless, to be made to understand the geological phenomena which come under their notice in the neighbourhood of their daily walks.

Commencing with the Chalk, of which a useful though succinct account is given, the author then proceeds to describe the different beds which constitute the Lower Eocene series. Lists of the fossils are introduced whenever necessary, and numerous descriptive sections are given. Another chapter is devoted to the Middle Eocene series, consisting of the Lower Bagshot sand; and the remainder of the memoir is devoted to the Postpliocene series, the different elements of which, with their respective localities, are fully described. This is a rather interesting point, as the author observes that it is very rare in this district to find any two of these elements at one place, so arranged that we can be sure of their relative age.

Mr. Edward Hull also publishes a memoir giving an account of the country around Oldham, including Manchester and its suburbs, with an Appendix on the Fossils by Mr. Salter. The rocks described in this memoir begin with the Limestone-shale underlying the Millstone-grit, over which are placed the Lower and Upper Coal-measures. Above them come the Permian rocks, consisting of Lower Permian sandstone and Upper Permian marls, and these are again overlain by the Pebble-beds or Conglomerate of the New Red Sandstone or Trias.

No fossils are mentioned as occurring in this conglomerate; but as it is described as conformable to the underlying Permian, with an inclination of about 10° to the S.W., they may possibly turn out to belong to the Permian series, like the sandstones described by Sir R. I. Murchison at St. Abbs Head in Cumberland, and then the Trias would be here altogether wanting. No other sedimentary rocks, whether Secondary or Tertiary, occur here, and the whole is overlain by Postpliocene boulder-clay and drift.

Geological Map of England.—I must now congratulate you on the completion of the new edition of the Geological Map of England, which you see exhibited before you. The name of Mr. Greenough will ever be associated with this work; for although his map was to a large extent based upon that of his predecessor, William Smith, the acknowledged father of English geology, and who deserves to be remembered as the first author of the geological maps of England, yet it was owing to the liberality of Mr.

Greenough, who not only presented to this Society the plates of his map, but bequeathed to us a large sum of money, that we have been enabled, by a judicious application of a portion of that money, to produce the present result. But it must also not be forgotten that this result could not have been obtained without the active labours of the Committee appointed by the Council for this purpose, the members of which have for many years devoted much of their time and energies to its completion. Nor can I refrain, on this occasion, from mentioning the names of those members of the Committee who have been most active in communicating the results of their previous labours and investigations. At the same time you will understand that a very large proportion of the improvements and corrections which have been introduced into this edition, particularly in Wales and some of the Western and Central counties of England, is taken from the published documents of the Geological Survey, which, as far as they have been completed, have served as the basis of the new edition.

The most active private contributors to this work have been Sir Roderick Murchison, Professor Phillips, Mr. Prestwich, and Mr. Godwin-Austen. The corrections of Sir R. Murchison refer principally to the Vale of the Eden and St. Bees Head in Cumberland, where, with the assistance of Professor Harkness, he has shown that a considerable portion of the Red Sandstone series, which had hitherto been coloured as belonging to the lower portion of the Trias, is in fact the upper portion of the Permian system, with which it is most intimately connected. He has also shown, with the aid of Professor Harkness, that the Skiddaw Slates, the oldest rocks of Cumberland, are not of such high antiquity as has hitherto been assigned to them, but that they belong to the Lower Llandeilo period.

Professor Phillips's share consisted of a careful revision of the six northern counties, and a considerable portion of the N.E. of England, extending from Nottingham to Lincoln, through his already published area of Yorkshire into Durham and the greater part of Northumberland, in which he obtained the assistance of Mr. Tate of Alnwick. He likewise furnished the data for North Lancashire, Westmoreland, and Cumberland, and, with the aid of Mr. Binney, for South Lancashire and Cheshire, and the Lias of the plain of Carlisle. His residence at Oxford also enabled him to give some useful assistance in that neighbourhood.

Mr. J. Prestwich has supplied the geological data for the Tertiaries round London and Kent, and the Bagshot series in Surrey and part of Berkshire, from his own MS. notes on the 1-inch Ordnance Maps, at which he had worked from 1835 to 1855. From the Newbury district to the Isle of Thanet and Harwich, the new map adopts Mr. Prestwich's divisions and outlines as far as could be done with the imperfect topography of the original plates. Mr. Prestwich also undertook to put in the Chalk, Crag, and Drift areas in Norfolk and Suffolk, and adopted the division

of only two Crag, a conclusion at which he had arrived after some years' labour, but which he had not laid down on any previously published map.

This sheet of the map, embracing the counties of Norfolk and Suffolk, is, perhaps, with the exception of the Crag, the least perfect portion of the work. With regard to the Boulder-clay, Mr. Greenough had only laid it down in the Eastern counties, whereas, as Mr. Prestwich observes, it should have been carried over half of England. Unfortunately there was no one who could undertake this, and the colour has therefore been entirely omitted in this edition. I think it necessary to mention this circumstance, as a mere inspection of the map might otherwise lead to some misunderstanding.

Mr. Godwin-Austen contributed greatly to the revision of the S.E. sheet, including the Wealden of Kent and Sussex, and the members of the Cretaceous series. He also superintended and laid down from MS. notes, a small portion of France, including the Boulonnais, as being the physical continuation of the Wealden area, and of Kent, Surrey, and Sussex; and south of that area some Tertiary outliers were mapped by Mr. Prestwich.

As a considerable portion of the N.E. sheet, which includes the S.W. of Scotland and parts of Ireland, had been left blank in the previous editions of Mr. Greenough's map, it was considered by the Committee desirable that these portions also should be coloured geologically. As respects Ireland, that portion included in the map has been executed from MS. notes of Mr. Godwin-Austen, aided by the map of Sir Richard Griffiths; and as regards the S.W. of Scotland, considerable portions have also been filled in by Mr. Godwin-Austen; the Ayrshire coal-field is from the original MS. of Mr. Geikie; and the remaining areas are taken from the published Geological Map of Scotland by Sir R. Murchison and Mr. Geikie, and a small portion of the Pentland district from the 1-inch Geological Survey.

In conclusion I must not omit the name of Mr. Mylne, one of the most active members of the Committee, who acted as its Secretary, and who deserves the greatest praise for his diligence and good management in superintending most of the arrangements with the engraver, and generally assisting the other members of the Committee in the execution of their joint and laborious undertaking. Although some few points still remain for the last touch of the engraver, I trust that in a very few weeks the map will be ready to be placed in the publisher's hands.

Laurentian Formation.—I have already stated that it is impossible for me to allude even briefly to the many communications which have been read before this Society during the past year; as a rule, indeed, I have followed the example of several of my predecessors in abstaining altogether from any notice of them, except under peculiar circumstances, as, in consequence of the more rapid system of publication which we have recently adopted, they are, with very few exceptions, already printed in our Journal.

I cannot, however, pass over the paper of Sir W. E. Logan, "On the Occurrence of Organic Remains in the Laurentian Rocks of Canada." These Laurentian rocks consist principally of gneiss, and are now admitted to be amongst, if not, the oldest-known metamorphic rocks on the surface of our globe.

The existence of these rocks in the British Islands was first pointed out by Sir R. Murchison in Sutherlandshire and Ross-shire as far back as 1858, when he applied to them the term of Fundamental Gneiss, and described them as having a N.N.W. and S.S.E. strike, almost at right angles with the prevailing strike of all the other and younger metamorphic rocks of the British Isles. In the sketch-map of the North of Scotland which accompanies a subsequent memoir published in the following year, this fundamental gneiss is described as the Laurentian gneiss of Canada; and again in 1861, in a paper by Sir R. Murchison and Mr. Geikie, it is generally described as the Laurentian or older gneiss; and the remarkable N.W. and S.E. strike is alluded to as persistent both on the mainland and in the Hebrides. This formation also covers a large area in Scandinavia; and certain gneissic rocks in Bohemia and Bavaria, previously divided by Gumbel and Crejci into two series, are referred by Sir R. Murchison to the same Laurentian group. And in a paper recently read before this Society, Dr. Holl has suggested the existence of this Laurentian or pre-Cambrian series as forming the nucleus of the Malvern Hills.

The Laurentian formation of Canada has been subdivided into two groups, named respectively the Upper and Lower Laurentian, the united thickness of which cannot be less than 30,000 feet. Zones or bands of limestone of great thickness are known to occur in both, and at least three such bands have been ascertained to belong to the lower group. Now it had been stated, more or less vaguely during the last few years, that organic remains had been discovered in these Laurentian rocks, but it was reserved for Sir W. Logan to bring the first notice of this discovery before the Society in a paper read on the 23rd November last, but which had already been communicated to the British Association at Bath in September. It is accompanied by a paper by Dr. Dawson, on the Structure of these Organic Remains, with a Note by Dr. Carpenter; and another paper by Mr. Sterry Hunt, on the Mineralogy of these same Organic Remains. After describing the localities where, and the circumstances under which these fossiliferous beds were formed, Sir W. Logan shows how recent investigations have resulted in the discovery of distinct organic remains in the limestone-bands at the Grand Calumet on the River Ottawa, and at Grenville and Burgess in Canada. These were at first supposed to be corals, but, with the aid of the microscope, such evidence of organic structure has been obtained, that Dr. Dawson has identified the fossil as a Foraminifer growing in large sessile patches, after the manner of *Polytrema* and *Carpenteria*, but of much greater dimensions. Its peculiar characteristics are (1) small

cellular sessile shell-growth, and (2) radiating and otherwise arranged tubuli in the shell-walls, only represented in recent or fossil forms by the tubular system of the shells of some *Foraminifera*. Hence, notwithstanding a few slight discrepancies, Dr. Dawson finds it to be foraminiferal in its character, and therefore refers it to the Rhizopods, with the name of *Eozoön Canadense*. It seems to have attained an enormous size, and by the aggregation of individuals to have assumed the aspect of a coral reef. Mr. Sterry Hunt's paper gives some details of the process by which the original animal matter has been replaced by mineral silicates, which are found not only in the chamber-cells and canals left vacant by the disappearance of the animal matter, but in many cases in the tubuli of the shell-walls. These silicates are pyroxene, serpentine, loganite, and pyralolite. The pyroxene and serpentine are often found in contiguous chambers in the fossil, and were evidently formed in consecutive stages of a continuous process while the *Eozoön* was still growing or had only recently perished; and he concludes by stating his opinion that these silicated minerals were formed, not by subsequent metamorphism in deeply buried sediments, but by reactions going on at the earth's surface.

It is difficult to overrate the geological importance of this discovery. Those beds of enormous thickness which underlie the Lower Silurian and Cambrian deposits, and which, under various forms of gneiss, mica-schist, hornblende-slate, &c., are known under the general term of metamorphic rocks, and have been supposed to have been formed and even re-formed or metamorphosed before the appearance of animal life on our globe, are now found, instead of being azoic, to contain remains of organic beings. These traces, too, are found in the very lowest depths of those deep-seated beds. The bands of limestone to which they are attached, and to the formation of which they may have contributed, occur in the lower subdivision of the Laurentian gneiss. If, then, this Laurentian gneiss represents the first solidified stratum of the earth's crust, we find animal life commencing at the very earliest period after it had attained that state of solidification, of course under water, and before it underwent the process of metamorphism. Nature appears to have lost no time in availing herself of the newly-prepared field for her operations, and of introducing those forms of animal life best suited to the new condition of the planet, and which having performed their task were destined soon to pass away, and having themselves helped to modify the conditions of life, were to make room for other more highly organized beings adapted to a new state of things. But our astonishment does not cease here. These gigantic Foraminifera required food and aliment, and although no traces of other organisms have yet been found, we know they must have existed. These animals could not, like Algæ and other vegetables, draw their sustenance from the rock on which they grew. They required organic matter, whether animal or vegetable, for their food.

Hence we may be certain that, contemporaneously with the *Eozoön*, there must have existed other creatures, probably minute Infusoria, floating in the waters of this Laurentian ocean, as well as marine Plants and Algæ, from which they derived their nourishment, growing on the muddy bottom of the sea, which has since been metamorphosed into gneiss. It is true no trace of them has been found. This is probably owing to the metamorphic action having operated more violently on marls and sands deposited in the ocean, than on the intercalated bands of limestone or *Eozoön*-reefs, and to the subsequent crystallization and rearrangement of the constituent molecules having destroyed all traces of the minute Infusoria, or of the tissue of the Algæ.

At all events we may be sure that this important question will not escape the notice of Sir W. Logan and his associates, and that no endeavours will be neglected on their part to render their search for fresh evidence of these fossil remains successful; and even should they fail in their endeavours to complete our knowledge of these early pages of the book of nature, we shall still owe them our thanks for having thus deciphered these ancient writings, and extended our knowledge of organic life so far beyond its previously recognized limits.

Since writing these remarks, my attention has been directed to a notice by Mr. Sanford, in the last Number of the Geological Magazine (No. VIII. p. 87), of the discovery of the *Eozoön Canadense* in the Green Marble of Connemara, in a quarry of the Binabola Mountains. The correctness of this statement is confirmed by Prof. T. R. Jones, who, on submitting thin slices to the microscope, discovered all the essential features described by Dr. Dawson and Dr. Carpenter. This formation, therefore, must be considered as Laurentian; and it is a strong confirmation of this view, that Mr. Sanford describes these green marbles as having a N.W. and S.E. strike, precisely like the fundamental or Laurentian gneiss of the N.W. of Scotland already mentioned.

In connexion with this subject I may also refer to Sir R. Murchison's description of these Connemara mountains (*Siluria*, third edition, p. 190), where he mentions the green marble or serpentine as interstratified with the lower portion of the series of altered or metamorphic micaceous and quartzose schists which, resting on granite and syenitic and hornblendic rocks, underlie the fossiliferous Silurian beds.

Amongst the recently published reports of the Geological Survey of Canada is a memoir on the Graptolites of the Quebec Group, by Professor James Hall, accompanied by twenty-two plates representing the singular and diversified forms in which this remarkable family of Palæozoic polypiform Radiata occur. In the first chapter will be found a carefully digested description of the structure and mode of growth of these animals, in some cases closely resembling that of the Sertulariæ of the present day, and of the different classes into which they have been subdivided. This, however, notwithstanding many attempts, the author thinks

cannot be strictly carried out, in consequence of so many of these fossil remains, which extend no higher up than the Silurian series, being in such a fragmentary state that it is impossible to decide upon their complete characters. Professor Hall then shows that, although found in other countries and other Silurian beds, the Quebec beds mark the period of the greatest prevalence of the Graptolitidæ, and that the subsequent conditions of these Quebec beds in Canada have been so favourable to their preservation, that they have been there found in a more perfect condition than in any other formation.

M. Barrande has published, in the 'Bulletin de la Société Géologique de France,' an account of the occurrence of the Bohemian colonies in the Silurian basin of the north-west of France and in Spain. He says that the Primordial fauna, which appears to be wanting in France, is spread over a large extent of ground in Spain as in Bohemia. To it belong the limestones with *Paradoxides* in the Cantabrian chain of mountains, and the slates with *Paradoxides* near Murero, north of Daruca in Aragon. On the other hand, the Second Silurian fauna is considerably developed in France as well as in Bohemia and Spain. This is followed in all these countries by the Third fauna, characterized alike by the presence of *Cardita interrupta*, *Orthoceratites*, and several Graptolites, traces of which are found in the Second fauna, both in several Departments of France and in Spain.

Permian.—We are indebted to Sir R. Murchison and Professor Harkness for an important communication respecting the true limits of the Permian rocks in the north-west of England. The principal feature in this new arrangement is the absolute connexion with the Zechstein (Magnesian Limestone) or its equivalents, of great masses of superposed red sandstone, which, in the north-west of England, they propose to remove from the New Red Sandstone or Trias, to which they have hitherto been assigned, and to consider them as the natural upper limit of the Permian and Palæozoic deposits.

Professor Sedgwick had long ago pointed out, in the Western region at St. Bees Head and in Furness, the existence of the equivalents of the Magnesian Limestone, but without referring the beds to the Permian formation, to which the Magnesian Limestone belongs. In the introduction to this paper, Sir R. Murchison observes that this transference of the sandstones of St. Bees and Corby to the Permian group does not depend on fossil evidence, but on clear and unmistakeable sections, which show that these upper sandstones are connected with the lower sandstone or Rothliegende through the intervention of the Magnesian Limestone or its equivalents; and that thus united, all these strata, from the base to the summit, form one continuous series. And he adds, that a careful examination of the various localities, both in England and in Scotland, has satisfied him that, notwithstanding their very striking lithological dissimilarity, the Magnesian strata to the east of the Pennine chain and the Red Sand-

stones to the west of it, are truly synchronous groups. One great result of this tripartite arrangement of the Permian group, viz., lower and upper sandstones, with an intermediate limestone or its fossiliferous equivalent, is that we are thus enabled to correlate the British deposits of this age with the Permian formations of the Continent.

It is further stated in this memoir, that the Upper Permian consists of red sandstones with courses of red shales, all perfectly conformable to the underlying Permian rocks, there being a regular transition or passage into these from the Middle Permians. Wherever they have been examined, whether in Westmoreland, the east of Cumberland, or in the north portion of St. Bees Head on the west coast, they are not only perfectly conformable to the Middle Permian strata on which they rest, but are in intimate connexion with them. Whatever may be the angle of inclination of the one is always that of the other; and there is no trace of erosion on the surface of the lower or supporting strata, as might have been expected between rocks of Palæozoic and Mesozoic age.

The authors then observe, that although there are certain shales and sandstones in the neighbourhood of Carlisle which are referred to the Trias, they have found no evidence in any portion of Cumberland of the mode in which the lower members of this Mesozoic group were associated with the upper portion of the Palæozoic division. In conclusion, they add some remarks on the comparison between the Permian beds in the county of Durham and those of Westmoreland, and point out the great distinction between the flora of the Permian strata and that of the Coal-measures. Looking also at this great extension of the Permian rocks in the north-west of England, they suggest the possibility of productive Carboniferous deposits being obtained at some future day by sinking through some of these overlying Permian sandstones.

Avicula-contorta Bed.—The question of the true relations of these *Avicula-contorta* beds, about which so much has been lately written, as to whether they strictly belong to the Triassic or Liassic series, has been ably discussed by M. Renevier of Lausanne, in a paper read before the Société Vaudoise des Sciences Naturelles*. Having carefully explored the fossiliferous beds near Villeneuve, at the eastern end of the Lake of Geneva, he ascertained the existence of two distinct zones of fossils closely connected together, but yet characteristically distinct. The upper zone corresponds with the true *Infralias* of Valogne, Hettange, the Lyonnais, &c., and with the beds of *Ammonites angulatus* and *A. planorbis* of Würtemberg. The lower zone is the true *Avicula-contorta* zone of the Alps, parallel to the Bone-bed of England and Würtemberg, and to which the name of Rhætic beds has been generally applied. They constitute an intermediate series between the Liassic and Triassic formations; and the great

* Quart. Journ. Geol. Soc. vol. xx. part 2. p. 26.

question is, "To which do they show the greatest affinity?" After describing the seventy-one fossil species, with their separate localities in these two zones, he points out the complete independence of the two faunas. In the Alps only one species, *Placunopsis Schafhäutli*, is common to the two zones, although it is admitted that in other districts the separation between the two is not so complete. *Pecten Valoniensis* and *P. Lugdunensis* of the lower zone appear in the Lyonnais to belong to the Infralias. *Mytilus semicircularis* of the upper zone is said to occur in Lombardy in the *Avicula-contorta* bed; and *Spondylus liasinus* of the upper zone is probably the same as *Plicatula interstriata* of the *Avicula-contorta* zone. But even admitting these identifications to be correct, there would be only 10 per cent. of the species common to the two faunas, whereas at least 13 per cent. of the species of the upper zone pass upwards into the Gryphæa-limestone. This independence is fully admitted, he proceeds to say, by those geologists who, like MM. Oppel, Gümbel, Winkler, Wright, and Moore, place the Infralias (zone of *Ammonites planorbis* and *A. angulatus*) in the Lias, and the *Avicula-contorta* zone in the Trias. But others look upon these two zones as mere subdivisions of the Infralias, which they consider as the lower division of the Lias. M. Renevier then objects to what he considers the undue extension of the term Infralias. He proposes that this term should be rejected altogether, and that the upper zone should be called the Etage Hettangien, and the *Avicula-contorta* beds the Etage Rhætien.

After all, he admits that the question is not of very great importance, the chief point being that geologists should be agreed as to the stratigraphical position of the beds; and he observes, with great justice and candour, that as the fauna of a formation does not everywhere consist of the same species, but varies considerably in different localities, it is not impossible that the fauna of these transition-formations should in one district have a greater analogy with that of the overlying beds, whilst in another locality it might have greater affinities with the fauna of the underlying beds. In this case, however, the twenty-one genera hitherto found in the Rhætic beds of the Vaudois Alps have a much greater affinity with the Liassic and Jurassic beds than with the Trias, inasmuch as there are only two genera common to these beds and the Trias, whereas thirteen genera are common to them and the overlying formations; so that, as far as the Vaudois Alps are concerned, he considers the Rhætic beds as belonging rather to the Liassic than to the Triassic formation. This result is intermediate between the two theories. With the one he recognizes the independence of the two formations, and with the other he is disposed to consider the Rhætic as Liassic rather than Triassic. The main point, however, is that he considers them as distinct formations intermediate between these two great divisions. I will merely further observe, that the conclusions at which M. Renevier arrives are mainly the same as those of Mr. Boyd Dawkins in his paper on

the Rhætic Beds and White Lias of Somersetshire; although Mr. B. Dawkins would extend the Rhætic formation into the grey marls usually considered as belonging to the Keuper, and would place the lower boundary of the Rhætic formation in the red marls below, considering the alternations of red and grey marls as the passage-bed between the two formations. These two apparently slight discrepancies may, however, be explained by a more gradual passage between the Keuper and the Rhætic beds occurring in England than in the Alps, as evidenced by the existence of these unfossiliferous red and grey marls*.

The Abbé Stoppani has also published a Memoir on the relative position of the *Avicula-contorta* beds in Lombardy. After carefully considering the recent publications on the subject, he maintains the conclusion at which he had formerly arrived, that these beds have a greater affinity to the Liassic than to the Triassic series. He supports this view both on stratigraphical and palæontological grounds, and shows that the *Avicula-contorta* beds are far more extensively developed in Lombardy, where they have a thickness in some places of from 300 to 400 metres, than elsewhere. After describing the fauna which he considers peculiar to these *Avicula-contorta* beds, he comes to the conclusion that they must be considered as a distinct formation between the Trias and the Lias. To this formation he gives the name of Etage Infraliasien, a name already adopted by many authors, and places it between the Upper Trias or Keuper and the *Gryphæa-arcuata* beds of the Lias. Like M. Renevier he divides it into two distinct zones, the upper one of which is the equivalent of the beds of Hettange and of the Dachstein of the Austrian geologists. This Dachstein-formation has already been recognized as intimately connected with the *Avicula-contorta* beds, and always occurs below those with *Gryphæa arcuata* and *Ammonites Bucklandi*; and is the Alpine equivalent of the *A. planorbis* and *A. angulatus* zones of the Hettange beds. At the same time the Dachstein is placed rather above the *contorta* beds.

The Abbé Stoppani admits, however, that his Infralias has some points of resemblance with the Upper Trias. It could not indeed be otherwise, when we consider the progressive development of organic life. But these Triassic characters are very slight and even doubtful, analogies rather than identities, whereas the lowest beds of the Infralias have very decisive characters, and even a large number of species identical with those of the Lias, and these go on increasing as we approach the upper beds with *A. planorbis* and *A. angulatus*. Hence he concludes that the Etage Infraliasien is the commencement of the Jura-liassic series. At the same time it must not be confounded with the Lias. Each of these formations has, in connexion with a regular stratification, peculiar petrographical characters, and particularly its own rich fauna, with well-marked features, of which only a very small portion passes from one into the other.

* Quart. Journ. Geol. Soc. vol. xx. p. 408.

In conclusion he observes that this "Etage Infraliasien" may be separated into two subdivisions, which he calls the upper and lower. The upper subdivision contains all the equivalents of the *Ammonites-planorbis* and *A.-angulatus* zones; the lower contains the true equivalents of the *Avicula-contorta* beds. The petrographical characteristics of the former are chiefly sandstones (grès), limestones, and dolomites; the second also consists of sandstone, but preferably of calcareous marls. He also proposes to subdivide each of these subdivisions into two zones. Those of the Upper Infralias are already well established. The separation of the two zones of the lower division is for the present only founded on the author's observations in Lombardy. He distinguishes them by certain fossils which are abundant in and peculiar to each, and draws up the following Table:—

Et. Infralias.	{	Upper, Hettange	{	<i>A. Ammonites-angulatus</i> zone.
		beds.		<i>B. Ammonites-planorbis</i> zone.
		Lower, <i>Avicula-</i>	{	<i>C. Terebratula-gregaria</i> zone.
		<i>contorta</i> beds.		<i>D. Bactryllium-strolatum</i> zone.

He then briefly describes the palæontological characteristics of the two divisions of the Infralias, which need not here be introduced, and gives a list of the distribution of species in the two strata of the *Avicula-contorta* beds.

Another work on this subject is by Dr. v. Dittmar, recently published at Munich. The object of this author is to point out the extent and distribution of this *Avicula-contorta* bed now found to exist in so many parts of Europe, and to describe the different characters under which it is developed, in order to arrive at the solution of the question, whether it belongs to the Trias or the Lias.

The author first points out its geographical distribution, and quotes the different authors by whom it has been described, whether under this denomination, or as the "Bone-bed," the form in which it generally occurs in Würtemberg, the north of Germany, and in England, but which is altogether wanting in the Alps and in Sweden, and is only slightly developed in France. He then describes the different palæontological features of the formation in different countries, showing from its various contents how it was generally a littoral deposit in England, France, and Germany, formed in shallow seas and near the coast of continents or islands; whereas in the Alps, the thick massive limestone-beds by which it is almost everywhere characterized, give it a predominantly oceanic character.

With regard to the stratigraphical phenomena of the *Avicula-contorta* bed, the author points out various localities, both in Germany and the Eastern provinces of France, where the lower Liassic beds lie unconformably on the Keuper, whereas in other places these two formations are conformable. He then comes to the really important question as to its geological position, and admits that, after repeated researches in different localities, the main result obtained was that the "*contorta* zone" appeared to be

equally connected with the Keuper and the Lias as a true natural transition-formation. In England the bone-bed is petrographically as much connected with the Keuper as with the Lias. The bone-bed arkose of Central France is equally referable to both. In Eastern France and Germany, the hard yellow bone-bed sandstone is conformable to the similar formations of the Keuper, and quite unconformable to the limestone-beds of the Lower Lias. In the Alps it appears to be equally conformable to both. Stratigraphically, the "*contorta*-beds" are more conformable to the Keuper than to the Lias; and he comes to this conclusion, that although no universal unconformability to the Lias can be found, yet there is nowhere a want of conformability to the Keuper.

The author concludes with a list of the characteristic fossils of the "*contorta*-beds," and then points out where these or representative forms occur in the older or younger formations, with this result—that of 162 species in the "*contorta*-beds," 90 occur in the older and 72 in the newer formations, and 12 occur in all. It has been well said that anything may be proved by numbers, and the author admits that the representative species are not all of equal typical importance. He adds to the name of each species the number of D'Orbigny's Etage in which it is found, to show that the analogues of the *Avicula-contorta* zone in the older beds are placed much nearer to it than those which occur in the newer or overlying beds. And finally, relying much on the opinions of Alberti and Quenstedt, he concludes that the *Avicula-contorta* zone should be referred to the Keuper rather than to the Lias. A list of the authors who have adopted these different views is also given, as well as a list of 458 species of organic remains of all classes from the "*contorta*-zone."

In connexion with this subject, I must notice a paper read by Mr. Bristow at the Meeting of the British Association at Bath. Mr. Bristow had been instructed, on the part of the Geological Survey of Great Britain, to examine those beds between the New Red and the Lower Liassic strata, to which the term Rhætic had been applied. Having visited several localities in the neighbourhood of Bristol and elsewhere, from Cheltenham to Penarth, near Cardiff, Mr. Bristow was enabled to map these beds in the neighbourhood of Bristol, Saltford, Keynsham, and Uphill, on the borders of the Lias to the North and South of Bristol, and at Penarth and other places in the district. He described them as everywhere underlying the true Liassic strata, but owing to their comparative thinness they are seldom fairly exposed. They consist chiefly of a central mass of black shales, resting on and passing into the underlying red and variegated Keuper marls, whilst beds of marl and marly or argillaceous limestone, constituting their uppermost division, form the base of the Lias, characterized by the presence of *Ammonites planorbis* and the great abundance of *Ostrea liassica*.

The upper limit of these Rhætic beds is well marked by the "White Lias," which Mr. Bristow considers its uppermost mem-

ber; it appears in places to have been drilled by boring shells; it also appears to have been furrowed by the action of water prior to the deposition of the true Liassic strata, thus indicating a break or interval between the close of its deposition and the commencement of the Lias. The black shales, constituting the middle division, are characterized by the well-known and peculiar shell, *Avicula contorta*, and when the beds are more calcareous, by the *Pecten Valoniensis*. The bone-bed occurs towards the lower part of the shales, and has been found extending as far as Penarth, where it contains bones and teeth of fish, and coprolites in great abundance. It also contains much iron pyrites. But it appears from Mr. Bristow's remarks that it is difficult to define with exact precision the lower limits of this formation, except the top of the red and green marls of the Keuper, into which there is a gradual downward passage. The organic remains, however, appear to be distinct, particularly above the bone-bed; and therefore there appears to be every reason for considering it as an intermediate formation between the Keuper and the Lias.

Whether there is any necessity for introducing a new name for this formation, which has already received so many, is a question we can hardly here discuss. But it appears, as I have already stated, as well as from the conclusion of Mr. Bristow's paper, that the Director-General of the Geological Survey has determined to adopt the name of Penarth beds as the British synonym of the Rhætic beds, to be employed in the construction of the Government Geological Maps of our own country. As Sir Roderick Murchison admits that the word Rhætic should continue to be used in general geological parlance on account of the greater thickness of those beds in the Rhætic Alps and in Lombardy, and I suppose also out of justice to priority of nomenclature, it seems, to say the least, unnecessary to overburthen our scientific terminology with additional synonyms.

Lias and Oolite.—Ascending the scale of geological formations, I find an important work by M. Eudes Deslongchamps entitled "Sur les étages jurassiques inférieures de Normandie." The object of this work is to describe the Lias and the Lower Oolitic system. The first portion contains a description, in great detail, of the different beds of which these two formations are composed, their mineralogical and palæontological characters, and the modifications which they have undergone in different districts, and the passages from one to the other. The second portion contains the geological and palæontological consideration of their beds under the three following heads:—1st, the different fossiliferous deposits in great detail; 2nd, the dislocations which the different beds have undergone subsequent to their deposition; and 3rd, the extent of the different formations, and the limits of the seas during their different phases of *sedimentation*, with numerous sections; to this is added an account of the extension of the different sheets of water, which are indicated by the occurrence of the argillaceous beds in the several districts.

The limits of these two formations lie between the Triassic and the Oxford clays, the latter known under the local name of *Argile*, or Dives clay. The author quotes M. Hébert as having pointed out that a long period of time must have elapsed between the close of the Upper Oolitic and the commencement of the Oxford clay period, during which the former became indurated and subsequently eroded on the surface; for wherever the contact was observed between the Oxford clay and the Great Oolite, the existence of numerous holes, caused by rock-boring mollusks, was noticed, as well as Oysters and *Serpulæ* adhering to the surface.

The author divides the Liassic system in Normandy into three groups:—

1. The Calcaire de Valonges, or Infralias.
2. The *Gryphæa-arcuata* limestone, or Lower Lias.
3. The limestone with Belemnites and *Gryphæa cymbium*.

The clays generally known as Upper Lias, he thinks ought, on palæontological grounds, to be referred to the Lower Oolitic system. The Calcaire de Valonges is again subdivided into three series, in the lowest of which are certain dolomitic beds, which M. Eudes Deslongchamps looks upon as probably representing in Normandy the *Avicula-contorta* beds, which everywhere form the base of the Infralias.

It will be remembered that M. Renevier, basing his views on a very careful examination of the Vaudois Alps, near the eastern extremity of the Lake of Geneva, also shows that the true Infralias overlies the *Avicula-contorta* beds.

The Lower Oolitic system is divided by the author into four groups:—

1. Inferior Oolitic marls.
2. Inferior Oolite.
3. Fuller's earth.
4. The Great Oolite.

These again are subdivided into various series, all of which are carefully described. The Great Oolite, however, is the most extended, the most developed, and the best characterized of all the Jurassic deposits in this region; it almost invariably rests upon the Fuller's-earth, and has a thickness of at least 40 metres. The sea-bottom is thus shown to have been continually sinking since the period of the Inferior Oolitic marls, and deposits of great thickness replace the former thin beds, deposited in ill-defined basins, the limits of which were easily modified by the smallest oscillations of the earth's surface.

In describing the principal features of the Great Oolite, M. Eudes Deslongchamps makes an observation so suggestive, that I have no hesitation in reproducing it here, namely, "At the commencement of this new period (Great Oolite) the fauna appears very poor; the first or lowest deposits are almost void of organic bodies, at least in a portion of the Gulf. Fossil remains only occur occasionally, around certain reefs, and the prevailing forms are chiefly Lamellibranchiata and Polypi; but at a later period,

and when the water of the sea became shallower in consequence of the matter which had been deposited, animal life again began to swarm, and the upper part of the Great Oolite is as rich in fossils as the lower is poor." But the Cephalopods were scarce, and the character of the fauna was altogether different from that of the Fuller's earth, and particularly of the Inferior Oolite, where Cephalopods abounded, which in the former attained to a colossal size.

Dr. Waagen has published at Munich during the past year an interesting work entitled "The Jura in Franconia, Swabia, and Switzerland." His object is to describe the Liassic and Oolitic formations from their base upwards to the Kelloway, Oxford, and Kimmeridge clays, ending with slight indications of the Purbeck beds in the Canton of Neuchâtel. The author considers the *Avicula-contorta* beds to form the basis of the Jura, but he does not go into any detailed account of it, and adopting the views of the geologists of the south-west of Germany, he looks upon it as forming the upper member of the great Keuper formation.

Dr. Waagen has carefully studied his subject, and has looked beyond the mere physical facts which came under his notice. His views respecting the nature of the continents and shores washed by the ancient seas during the Liassic period, the gradual changes which took place in the sea-bottom by the rising or sinking of the land, thereby facilitating the growth of coral-reefs in deepening seas, or the increase of the littoral genera of Mollusks by their becoming shallower, and, by still further risings, again producing swamps and marshes fitted for the wallowings and sustenance of Teleosaurian, Pterodactyle, and gigantic Saurians, are full of interest, and are not altogether devoid of a certain amount of poetic feeling in the description. As when he describes in the following words the satisfaction which the true inquirer of nature must feel on leaving the barren wastes of sand and marls of the Keuper, when he comes upon the Jurassic deposits, so rich in their remains of organic life; "there is something very elevating in thus examining these witnesses of a long past period, witnesses which tell us of events which no human eye beheld. They unfold a picture, and place us on the shores of that ancient ocean, the dwelling-place of all those organic beings, where the waves of the sea rolled on a sandy shore, where woods of curiously branched Coniferæ stretched along the coast, mixed with groups of palmiferous Cycadeæ. The land must during all that Liassic period, as well as probably during that of the Dogger or Brown Jura, have sloped very gradually towards the sea, and the ebbing tides must have left exposed large tracts of country covered with a peculiar vegetation, affording an abode to the Teleosaurians and Pterodactyles of the Lias."

As the author has evidently devoted great attention to his subject, it may be useful to point out how, in ascending order, he divides and subdivides the formations to which he gives the comprehensive name of Jura.

- I. Lias formation, including,
 - 1. Lower Lias.
 - 2. Middle Lias.
 - 3. Upper Lias.
- II. Dogger formation (Brown Jura).
 - 1. Lower Oolite.
 - 2. Bath group.
- III. Malm formation (White Jura).
 - 1. Kelloway group.
 - 2. Oxford group.
 - 3. Kimmeridge group.
 - 4. Purbeck beds.

The author has added three large tabular diagrams, in which the different formations in the three countries under consideration are paralleled, and the principal fossils of each are given, as well as the various Ammonitiferous zones which have been hitherto looked upon as chiefly characteristic.

M. Auguste Dollfus has published an important Monograph on the Kimmeridge Fauna of the Cap de la Hève, near Havre, a locality described by M. d'Archiac as being most rich in the organic remains of this deposit. He first shows that this formation, almost purely argillaceous in the north, becomes more calcareous towards the south, and that this lithological change is accompanied by a corresponding change in its organic contents; that while *Ostrea* and similar types predominate in the northern portion of the basin, the Cephalopods and Gasteropods become more numerous as we approach the calcareous districts.

After describing the beds in the neighbourhood of Havre, he proceeds to compare them with those of other localities. Towards Boulogne the beds become more argillaceous, but as we proceed to the south of England, the formation becomes so entirely argillaceous that it is no longer possible to distinguish the different subdivisions, and throughout the whole series, *Ostrea*, *Gryphæa*, and other Lamellibranchiata are the predominant forms. Further north, in the Speeton clay, the lower portion of which represents the Kimmeridge beds, the only hitherto known fossils belong to the Lamellibranchiata.

He then extends his comparison to the Department of the Meuse, S.E. from Havre. Here the beds become more calcareous, and offer but few points of palæontological comparison with those of Cap de la Hève. M. Buvignier has pointed out about eighty species of Lamellibranchiate bivalves, of which only nine are common to the beds near Havre, while the Gasteropods become very abundant, showing about fifty species, chiefly belonging to genera unknown in the more northern region. This preponderance of the Gasteropods increases still more to the S.E., towards the extreme limit of the basin; the same thing occurs with the Cephalopods, while the Lamellibranchiata remain the same.

Another point of comparison occurs in the Departments of La Charente and La Charente Inférieure. But here we are no longer

in the Anglo-Parisian basin. It is the extreme northern point of a new (the Aquitanian) basin. Here argillaceous beds predominate, and the general facies of the fauna approaches that of Cap de la Hève. But the calcareous element is not altogether wanting, the upper beds consisting of a marly limestone and clays, and the lower of calcareous marls; and we find this remarkable fact, that in proportion as the clays predominate, the fauna, rich in Lamellibranchiata, resembles that of the north. When the limestones prevail, as in the upper and lower zone, the Gasteropods and Cephalopods resume the preponderance. Thus it is impossible to compare exactly the faunas of the different subdivisions, since they must be considered as accidental assemblages peculiar to the localities, and the result of the contest between the limestone and the clay formations. But looking at the whole from a higher point of view, we find towards the north the *Ostrea* and similar forms selecting those localities where argillaceous deposits were being formed, whilst towards the south-east the higher forms of Mollusks sought out those spots where the sea was impregnated with calcareous matter. The author concludes by remarking that, without attaching too much importance to the theory of migration, we might imagine these animals moving from place to place, according as local influences modified more or less the nature of the sea which they inhabited; thus assembling, as it were, round those points which were most favourable to their existence. At all events, the close connexion of the Cephalopods and Gasteropods, particularly the Nerinææ, with the calcareous deposits, is a very interesting fact, which establishes the great and unquestionable difference between the faunas of the northern and of the south-eastern portions of the basin.

The second part of the work contains a list of 132 species of organic remains found in the Kimmeridge beds of Cap de la Hève; and in the third part is a detailed description of the new or doubtful species, with eighteen plates of figured illustrations.

Prof. Credner has contributed to our knowledge of the Geology of Northern Germany, by the publication of a valuable work "On the subdivision of the Upper Jura formation and the Wealden formation in the North-West of Germany." An inquiry into the extent of the Coal-deposits in the North German Wealden formation, and into the occurrence of salt-springs in the underlying beds, first led him to construct several sections of the strata which exist in that district between the Brown Jura and the Chalk. These beds belong in the north-west of Germany to two principal divisions:—1st, marine deposits of the Upper Jura formation; and 2nd, the fresh or brackish water deposits of the Wealden formation, which alternate with each other in a remarkable manner. They extend from the north-western flank of the Hartz Mountains to the frontiers of Holland, where they disappear under the thick diluvial covering. They appear to have been formed in several distinct basins, the deposits of which show a great amount of diversity.

Amongst the numerous sections given in this work is one on the Deister, which shows the conformable position of all the beds from the Brown Jura up to the Hilsthon or Hills clay, in the following order:—Lias, Brown Jura, Lower Oxford group, Dolomite, Oolitic limestone, Kimmeridge group, Flaggy limestone, Marls, Serpilit, Wealden sandstone, Wealden clay, and Hills clay. The Wealden sandstone is from 540–550 feet thick, and consists of alternating beds of argillaceous marly shale, coal, and sandstone of a yellowish colour and fine grain, constituting the principal mass of the whole series. Three workable beds of coal, from one to two feet in thickness, are met with in this formation, but the coal-beds near Osterwalde are stated to have a much greater thickness. The order of stratification of these formations and of their geological grouping in North-Western Germany is given in a tabular form; another Table shows a general view of the vertical distribution of the principal fossils in the Upper Jura and Wealden formations. A separate Appendix gives some interesting palæontological information respecting *Nerinea* and *Chemnitzia*, as well as several new or little-known species of the genera *Trigonia*, *Cyprina*, *Corbis*, and *Greslya*. The *Nerinea* are subdivided into groups according to their having one, two, three, four, or five plaits.

The Cavaliere Capellini has published a geological account of the neighbourhood of the Gulf of Spezzia, and of the lower valley of the Magra, for the purpose of illustrating the Geological Map of that district, which he had published in 1863. In this work he gives us some interesting details respecting the progress of the Geological Map of the Kingdom of Italy. This progress is not so satisfactory as could be desired. In July 1861 a Commission had been appointed to meet at Florence to discuss the method of, and to lay down the rules for, the construction of this map. A report on the projected plan was sent in to the Government in the following September; it was talked about for a few months, and suggestions for carrying it out were discussed, but, as with so many other projects, it was gradually lost sight of, and nothing more was heard either of geologists or of a geological map.

Under these circumstances, Capellini determined to publish at his own expense this sheet, which was then nearly finished, and at which he had been working for many years, with the intention of following it up with maps of other regions, constructed on the same plan. Encouraged by the success which has attended his attempt, he informs us that, besides the Map of the Province of Pisa by Prof. Savi, other maps are being undertaken for other provinces in Tuscany and the Romagna, and that he himself has been working for two years in the Bolognese district.

The Gulf of Spezzia lies between two parallel ridges of mountains, which form its eastern and western shores. The oldest rocks here described occur near Lerici and Cape Corvo at the southern point of the eastern chain. They consist of arenaceous and chlo-

ritic schists, quartzites, conglomerates, and grey saccharoid limestones; all these have been hitherto known under the vague name of Verrucano, but are now referred by Capellini to the Palæozoic series, and even to strata below the Carboniferous. But as no fossils have hitherto been found in them, it is impossible to decide on their exact position. Other overlying limestones and conglomerates are referred to the Permian series, and these are again overlain by rocks which there is no difficulty in referring to the Trias.

But the Infralias is by far the most interesting and most extensively developed formation in the neighbourhood of the Gulf, on both sides of which it forms a long and elevated band. A tabular list of 81 species of fossils is given, of which 17 are found in Lombardy, 23 in the beds of Hettange, and 28 are new.

We come next to the Liassic formation, and here Chevalier Capellini explains the errors into which former geologists had fallen respecting the stratigraphical order of superposition on the western side of the Gulf, where the red Ammonitiferous limestone overlies the *Posidonomya*-schists, by showing, from a comparison with other localities where the beds were more horizontally disposed, that the strata which are now in an almost vertical position have here been really inverted. He then shows that all the three subdivisions of the Lias series are here represented between the Oolites and the Infralias. Thus the Upper Lias is represented by the schists with *Posidonomya Bronni*; the Middle Lias by the red Ammonitiferous limestone, schists with impressions of Ammonites, and interstratified limestones; and the Lower Lias by flaggy limestones, and calcareous schists with Belemnites.

Up to a very recent period all the overlying rocks were supposed to be Eocene, but the discovery of Turrilites and other Cretaceous fossils has proved the existence of a narrow Cretaceous band, which, under the name of Macigno and Pietra forte, had previously been classed with the Nummulitic beds. The white Alberese limestone also belongs to the Chalk.

The following chapters are devoted to the description of the Eocene and Miocene formations in the district, the eruptive masses of serpentine, the ossiferous caverns of Cassana, and the other Post-pliocene and recent formations. There is also an interesting account of the remarkable spring of fresh water which rises up in the sea near Marola. Many ingenious hypotheses have been started to account for this singular phenomenon. After relating these, Chevalier Capellini endeavours to account for it by showing that it occurs in the direct prolongation of the great fault which runs from N.W. to S.E. along the foot of the hills, between the Eocene formation and the apparently *overlying* Triassic and Infralias rocks. All the springs and fountains of Spezzia occur along this line of fault, which being prolonged under the sea, conducts the freshwater drainage from the hills by a subterranean channel to the most distant and principal opening by which the water returns to the surface.

Cretaceous Formations.—Prof. Pictet of Geneva has published during the past year the second volume of his great work on the Cretaceous fossils of Switzerland, entitled “Description des fossiles du terrain Crétacé des environs de Sainte Croix,” which forms the third series of the “Matériaux pour la Paléontologie Suisse,” or “Collection of Monographs on the Fossils of the Jura and the Alps.” Prof. Pictet had already pointed out in the former volume the necessity of local monographs carefully describing the different portions of a formation in which the various fossils occurred. He shows that serious and numerous errors would be introduced, if, in describing the fossils of any given formation from different localities, we were to overlook the importance of these local lists. Fossils would then appear to have been synchronous, or to have lived together, when such was by no means the case. As the fauna in each formation gradually changes from its commencement to its end, so also does the fauna of the same age vary in different places according to geographical or other conditions of life, in space as well as in time, horizontally as well as vertically, and therefore these carefully prepared local monographs become essentially important.

This second volume completes the description of the organic remains, and is accompanied by 55 plates, from pl. 44 to pl. 98. It contains the conclusion of the Cephalopods, and an account of the Gasteropods, and will form, from the great number of species described, a most valuable addition to our knowledge of the Cretaceous fossils. For, as M. Pictet observes, the great number and perfect state of preservation of the fossils of St. Croix will make this locality a type for the better explanation and elucidation of other less rich or less extensive deposits.

Dr. Carl Zittel has published the first part of his work on the Bivalves of the Gosau formation in the North-Eastern Alps. Dr. Zittel alludes to the great progress which has been made of late years in describing the organic remains of the Chalk formation. In Austria, particularly, great interest has been taken in this field of inquiry. Herr Zekeli has published a monograph of the Gasteropods; Reuss has given an excellent work on the Corals and Foraminifera; Von Hauer one on the Cephalopods; and Dr. F. Stoliczka on the Freshwater Mollusks of the Neualpe. He has therefore undertaken to fill up the gap caused by the want of a monograph on the Bivalves.

This part contains the great group of the Dimyaria; the second part, which he hopes to publish in the course of this year, will comprise the remaining division of the Asiphonidæ or Monomyaria, the Rudistæ and Brachiopoda. With the completion of this monograph, and another which Prof. Suess has undertaken respecting the recently discovered Saurian remains, the interesting Fauna of the Gosau formation will be well known, and a foundation will be laid for a full geological inquiry into the Alpine Chalk formation in Austria.

In a small work, lately published by Signor Perazzi at Turin,

will be found a notice on the cupriferous deposits contained in the Serpentine of Central Italy. It is well known that indications of copper, connected with the outbursts of ophiolitic rocks in Italy, are very abundant, but many of them are so unfavourably placed as not to admit of their being worked advantageously. The mine of Monte Catini is the only instance of successful operations amidst the ophiolitic rocks of Central Italy. The author commences by describing the eruptive rocks of this region, which have already been subdivided by Prof. Savi into four classes, each of which corresponds with a distinct period of formation.

I. Old Serpentine, posterior to the Lower Eocene, but anterior to the Upper Eocene. This is often traversed by dykes of Euphotide and Diorite.

II. Euphotide or *Granitone*, contemporaneous with the deposition of the Upper Eocene.

III. Diorite, Afanite, and Ophite; contemporaneous with and subsequent to the ophiolitic Macigno.

IV. Serpentine rocks of the second eruption, newest Serpentine; subsequent to the deposition of a part of the Miocene formation.

All these rocks vary much locally in their mineral characters. Their chronological position is fixed by the dykes and veins which they successively send forth into the preexisting rocks.

The author then proceeds to describe the metamorphic rocks which are found in close juxtaposition with the ophiolitic rocks in Central Italy. He shows how the preexisting sedimentary rocks must have been more or less altered and metamorphosed in proportion as they were exposed to the influence, both chemical and mechanical, of one or more of the outbursts of the eruptive rocks. He quotes Prof. Savi as having long ago demonstrated the existence and origin of many metamorphic rocks in Tuscany; and also quotes his account of the *Gabbro rosso*, so characteristic and important a rock to the Tuscan miner, as containing the most important cupriferous formations in that part of Italy. The position of the metamorphic sedimentary rocks is generally very remarkable, following the outlines of the eruptive rocks. This he believes to be one reason why so many distinguished geologists have looked upon the *Gabbro rosso* of the Serpentine mountains as an eruptive rock, although Savi had long ago pointed out its metamorphic origin.

The metamorphic rocks are divided into two classes:

I. Argillaceous rocks altered by ophiolitic outbursts. There is great variety in the extent to which these are altered; some have only undergone a change of colour, and have preserved their stratified structure. Others have undergone a complete modification of structure as well as change of colour, and have acquired a siliceous hardness; their structure then becomes compact or brecciated, or spherical, besides undergoing many other changes, having sometimes been almost fused or melted by contact with the eruptive rock. It is to the third of these structural changes

(the spherical) that Savi gives the name of *Gabbro rosso*, and of the mineral appearance and character of which we have a minute description.

II. Calcareous rocks modified by ophiolitic. To these the name of Ophicalce has been given, inasmuch as they consist of carbonate of lime mixed with serpentinous elements. They must not, however, be confounded with the ophiolitic admixtures with a calcareous matrix, consisting of a great variety of eruptive and sedimentary rocks imbedded in a matrix frequently calcareous, and having all the characters of eruptive rocks.

The calcareous metamorphosed strata have undergone every possible variety of change, according to the greater or less degree of metamorphic action to which they have been subjected; but as they are not metalliferous, they are not further alluded to in this paper, although, in a geological point of view, they are of great interest.

In the second part of the work the author describes the localities in Central Italy where cupriferous deposits have been found. These metalliferous deposits occur under two different forms, whether situated in the eruptive or metamorphic rocks, or along the line of contact of the two. These two forms are either as metallic veins deposited in fissures, or as nodules and rounded masses imbedded in a steatitic clay. The latter is the most frequent, and affords the richest deposits in Tuscany.

Tertiary.—M. von Kœnen read before the Society not long ago a very interesting paper "On the Correlation of the Oligocene Deposits of Belgium, Northern Germany, and the South of England." In this paper he particularly refers to the fossils recently discovered in the railway-cutting near Brockenhurst, and at Lyndhurst in the New Forest. These beds are shown to be of the same age as the Middle Headon beds of Colwell Bay and Whitecliff Bay; but as they have a richer and true marine fauna, they are of great importance in comparing the Headon beds with the Tertiary strata of Belgium and the North of Germany.

From a careful examination of the fossils from this locality in the collection of Mr. Edwards, M. von Kœnen has come to the conclusion that they represent the Lower Oligocene of Germany. Of the 56 species contained in this collection, 43 exist in the Lower Oligocene, and 6 are peculiar to the English Brockenhurst and Headon beds; 21 of them are also found in the Upper Eocene; and 4 pass over to the Middle Oligocene of Germany; 23 of them are characteristic Lower Oligocene species, which have never yet been met with either in the older or in the younger beds; there can be no doubt, therefore, that the Brockenhurst beds, and with them the Headon series at Colwell Bay and Whitecliff Bay, belong to the Lower Oligocene.

The Tertiary formations of Bordeaux and of Dax have always been a subject of great interest to all who have occupied themselves with Tertiary, and particularly with Miocene Geology. Many attempts have been made to fix their exact synchronism with

the Faluns of Touraine, and even with our own English Crag. Amongst the many labourers in this field, no one of late has devoted so much zeal and labour to the subject as M. Raoul Tournouër, who has published most of the results of his investigations in the 'Bulletin' of the Geological Society of France. One of the most interesting features in the Bordeaux beds is the remarkable sequence of fossiliferous strata, from those which appear to be newer than anything in Touraine, down to the Asteria-limestone containing *Natica crassatina*, the equivalent of the Fontainebleau sands, and of the lowest marine bed in the Mayence basin. In the Bordeaux beds, however, the sequence extends still lower, whilst at Dax, further south, the stratigraphical sequence is supposed to extend higher, until it reaches a level which has been supposed to be identical with the British Crag.

I have recently received from M. Tournouër some account of the results of his recent investigations respecting the Miocene deposits in the South of France. He says that he has continued and is still continuing the researches which he had commenced in the Department of the Gironde, following up the Garonne into the Department of Lot and Garonne, and the neighbourhood of Agen. By this work he has been enabled to confirm in all essential points, and usefully to complete in many others, the observations which had hitherto only been made in the Department of the Gironde. In fact the Miocene lacustrine limestones play a very important part in the country of Agen (Agenais), and the intercalation of various marine deposits on the left bank of the river enables us to assign to them very exact limits. At the same time, the remains of vertebrated animals, which are very scarce near Bordeaux, are here much more abundant, and he has already been able to fix for them several interesting horizons. Amongst others, the bones of *Dinotherium* and *Mastodon* have been found in the upper beds which represent the Faluns of Saucats.

These observations of M. Tournouër will be shortly published in full in the 'Bulletin' de la Société Linnéenne de Bordeaux, when we shall be better able to appreciate their importance. In the meantime I may venture to point out what strikes me as a very significant fact, viz., the increase of the lacustrine freshwater limestone, and the greater number of its intercalations with marine beds as we recede from the shores of the Atlantic and approach the more elevated regions of the interior. We can here trace the greater amount of oscillation of level to which this country was exposed during the Miocene period in the mountain districts, and we seem, as it were, to catch a glimpse of the causes which finally raised these beds permanently above the level of the sea.

There is another question, too, connected with these upper Tertiaries of France, whether in Touraine or at Bordeaux, to which I would wish briefly to allude. I mean their age relatively to the Crag of England. Although there can be no doubt that the Crag contains a much larger percentage of recent shells,

and particularly of Arctic forms, than the Faluns of Touraine or the beds of Bordeaux and of Dax, there are many facts connected with the physical position of these beds which lead to the inference that the Crag is at least contemporaneous with the uppermost of the French beds, or, at all events, belongs to the same formation.

In the first place, the physical position of all these formations is very similar. Only slightly raised above the level of the sea, they lie in almost perfectly horizontal beds. Secondly, wherever they occur they are the most recent Tertiary marine deposits, and they are all equally associated with great coralline deposits. Thirdly, the upper formations of the series in France, particularly near Dax, contain a large proportion of recent forms, many of them analogous to, if not identical with, forms now living in the Mediterranean. Now if we are told that there is a great difference between the general facies of the Crag fauna and that of the Faluns or the Upper Bordeaux beds, we must remember the vast difference which exists in the present day between the fauna of the coast of England and that of the coast of Portugal, or of the Mediterranean, and particularly of the coast of Africa, many of the forms of which are of a decidedly tropical character. It must also be remembered that it is only with regard to the upper beds of the French series that I would suggest the possibility of a synchronism with our Crag deposits.

More than one distinguished geologist has lately warned us against looking for an identity of forms in the formations of the same period, when separated by a considerable distance. And when we recollect that, according to the views of Prof. Edward Forbes, the separation of England from the Continent of Europe had not yet taken place at the termination of the Miocene period, we at once perceive that the sea, which, during the deposition of the Crag, covered those parts of Norfolk and Suffolk, and other localities on the East of England, could then only be connected with the great Atlantic by the German Ocean and round the North of Scotland; we need not therefore be surprised at the fact that the facies of the Crag fauna should have an Arctic character, and possess so few species in common with those of the Upper French series, the sea of which was so close to the semitropical seas of Northern Africa. How small an amount of identical species could we expect to meet with in two such seas, the one covering the low lands of Touraine, and forming part of the Atlantic, the other being in fact the German Ocean, before the opening of the channel which now connects it immediately with the Atlantic, and when it was evidently only a great gulf extending southwards from the Arctic seas.

With reference to these Tertiary formations of the South-west of France, I may mention that the Rev. Sanna-Solaro has recently published a memoir on the pelvis of *Dinotherium*, the first which has been discovered in the Department of the Haute-Garonne, near Escranecarbe. This gigantic pelvis, which measured,

when the different fragments were put together, nearly six feet across (1.860 metre), was found in a soft marly sand belonging to the Miocene formation, but in which no trace of shells, marine or otherwise, was observed. Having carefully collected all the fragments he could obtain, M. Solaro was surprised to find in a small triangular cavity, situated at the side of the cotyloid cavity, the head of a small bone, which he at once suspected to be a marsupial bone; and on comparing other fragments of a flat angular bone, he found that they all belonged to the head which articulated with the ilium. From this he concluded that the bones belonged to a gigantic marsupial Pachyderm.

He then enters upon the question whether this pelvis really belonged to *Dinotherium*; and from the fact that all the fossil bones found on the spot, and in numerous other localities in the neighbourhood, belonged to that animal, he comes to the conclusion that the pelvis must be that of *Dinotherium*. We thus arrive at this extraordinary result, that this gigantic *Dinotherium* was a marsupial animal; and in allusion to the size of the animal and its habits, he shows why the marsupial bones should have articulated with the ilium, instead of the pubis as in other marsupials.

He also shows that the *Dinotherium* must have been a terrestrial animal and not aquatic, and that it must have exceeded the largest known Elephants of India in size.

M. Pierre de Tchihatcheff has published during the last year an interesting volume on the Bosphorus and Constantinople, and the surrounding districts. The second part of the work is devoted to the Geology of this region. After describing the igneous and basaltic rocks which occur so abundantly on both shores of the Bosphorus, and particularly at its northern extremity, at its entrance into the Black Sea, he notices other instances of eruptions of dioritic porphyry which have burst out through the Devonian beds on both sides of the Bosphorus, particularly in the Giant's Mountain on the Asiatic side, and to the southward, and which are much more frequent than have hitherto been noticed or supposed. This he attributes to the fact of their being so frequently decomposed, in which case it is difficult, without a very minute investigation, to distinguish them from the sedimentary rocks by which they are surrounded, and he believes that all the round bosses (locally called *Tepes* or hills) have for their nucleus a mass of eruptive rock, probably diorite. What makes this hypothesis more probable is, that the Devonian beds which constitute these hills are generally bent and contorted, and that he has frequently found on the surface fragments of crystals of felspar and amphibole, derived, in all probability, from the decomposition of eruptive diorite at no great depth below the surface. Should this be confirmed, it would prove that these diorites represent the last efforts of plutonic action, and that they are consequently of a later age than the dolerites, basalts, and trachytes which occur at the northern extremity of the Bosphorus.

He then proceeds to describe the Devonian rocks of the Bosphorus. These are different on the two shores, and their characters are given in great detail, with the localities where they occur. He also notices the mines of Sangari on the European side, where both copper- and iron-pyrites have been obtained; then he refers to the action of the eruptive rocks in immediate contact with the clay-slates and Devonian limestone. The chief peculiarity of the Asiatic rocks is the greater abundance of quartzites, which are well developed in the hills behind Scutari. The fossil remains are the same as those found on the Asiatic side, and, being more abundant, are described in fuller detail. Proceeding to the northward, it is remarkable that M. de Tchihatcheff again failed to discover organic remains on the Giant's Mountain, though Mr. Strickland and myself found them in great abundance in the argillaceous schists near the summit.

The locality where M. de Tchihatcheff appears to have found the greatest number of fossils is along the northern shore of the Gulf of Ismid, between Kartal and Pendik. This district and the islands in the Sea of Marmora consist of the same formations. We have then a full list of the fossils found by M. de Tchihatcheff, and submitted to M. de Verneuil in 1863, as well as those brought back in 1854. From a careful examination of thirty-eight species, M. de Verneuil comes to the conclusion that they belong to the Lower Devonian, with a slight admixture of Silurian forms, and that consequently M. Rœmer is entirely wrong in referring them to the Upper Devonian; and M. de Tchihatcheff himself brings forward this fact of a small amount of Silurian forms, as *Phacops longicaudatus*, to prove that they belong to the lowest Devonian beds, having their greatest analogy with the Rhenish beds and those of the west of France. The remarks of M. de Verneuil on these fossils will be found more fully given in the 'Bulletin de la Société Géologique de France,' 2nd series, vol. xxi. p. 147.

These remarks apply principally to the fossils derived from the shores of the Sea of Marmora between Kartal and Pendik, and it is admitted that those which are found on the two shores of the Bosphorus may be of a somewhat older age, and may possibly represent the passage from the Upper Silurian to the Lower Devonian.

M. de Tchihatcheff then describes the Tertiary formation in this district, which reposes immediately on the Devonian series. It consists of Nummulitic deposits, having a considerable development, and extending along the shore of the Black Sea as far as Varna, where they have been described by Captain Spratt. These are succeeded by Miocene formations, but the exact limits and lines of junction are difficult to establish. Both are remarkable for their sterile character and almost total want of fresh water. These Miocene rocks appear to be both marine and lacustrine, and are in places overlain by Diluvial or Quaternary deposits, in which thin bands of lignite occur, as, for instance, near the northern entrance of the Dardanelles.

The concluding observations of M. de Tchihatcheff will be found of great interest in explaining the geological features of this district, but I cannot allude to them any further.

Dr. Hartung has published at Leipzig during the last year a geological description of the Islands of Madeira and Porto Santo, with a classified account of the fossil remains from these islands and the Azores, by Dr. Karl Meyer. The names of these two authors are so well known, that anything from them must be valuable. Dr. Hartung, it will be remembered, accompanied Sir Charles Lyell in his visit to Madeira in 1853 and 1854, and he continued his researches in the islands after Sir Charles Lyell returned home; and when, after several years, Sir Charles was unable, in consequence of other occupations, to carry out his intention of publishing a full account of the geology of Madeira and Porto Santo from the materials collected by himself and Dr. Hartung, he returned all the documents to the latter for his own use. The present work is chiefly founded on these materials.

In describing the physical features of the island, Dr. Hartung shows that its present outline is chiefly owing to the action of the waves, that its valleys and ravines, and the long narrow crests and mountain-ridges, are the result of erosion by running water, and not owing to cracks and crevices produced at the time of the upheaval of the island. Tracing back the first formation of the igneous rocks, which form the basis of the island, to submarine eruptions in early geological epochs, Dr. Hartung assumes that the true volcanic formations are subsequent to the commencement of the Tertiary period, the beds of which were deposited on the surface of the already existing eruptive masses. The Upper Miocene beds of Madeira and Porto Santo, the marine organic remains of which have been named and described by Dr. Karl Meyer, afford the best proof of this. But on these marine beds, volcanic rocks, 3000 feet in thickness, are superposed in the centre of the island; and this, together with other appearances in the island, shows that the whole thickness of volcanic products which have been deposited since the formation of the submarine Tertiary beds cannot be less than 5000 feet. Dr. Hartung concludes his portion of the work with some valuable remarks as to the periods when volcanic activity ceased in Madeira itself and in the adjacent islands, as well as with respect to the mode in which the numerous hollows and ravines by which the former island is intersected were hollowed out.

In introducing his description of the marine fossils, Dr. Karl Meyer, who is well known as a first-rate Tertiary conchologist, makes the following remarks respecting the idea of species:—"If some of my determinations should appear incorrect to any palæontologist, this is probably not so much owing to our holding different views respecting species, as to the greater or less completeness of material; for, with regard to the idea of species, I feel that I have adhered to the principle held by most conchologists, according to which two allied individuals, though differing in some

not altogether unimportant characters, or even two series of individuals which constantly differ from each other by one or more decided characters, belong to two species, or at least must be provisionally treated as such. This principle is, in fact, according to my views, the only one which can preserve science from mischievous errors and confusion. But I do not pretend to say that it is founded on the natural idea of species. My own conviction, based on many years' careful study of Tertiary shells, is rather this, that species, at least within the range of natural groups, do not always remain distinct, but rather arise by sometimes slow, sometimes quick (I do not mean sudden) modifications, caused by new conditions of life, by gradual change, and perhaps even by crossing of former species."

In conclusion he calls attention to the very remarkable features of this assemblage of fossil life, consisting of 200 species from ninety-five different genera. It consists of specimens from every zone, littoral and deep-sea, those living on rocks and sea-weed, in bays and estuaries, on mud and sand. It is a mixture of European Miocene species, with recent species of Southern Africa and the East Indies; and considering the short time during which they were collected, he is convinced that they do not represent one half of the real Tertiary fauna of these Atlantic islands.

In addition to his labours on the British Brachiopoda, on which he has been so long engaged, Mr. Davidson has described, in the 'Annals and Magazine of Natural History' (July 1864), seven species of fossil Terebratulæ from the Maltese Islands. This account is given as an appendix to an outline of the geology of these islands by Dr. L. Adams; and, according to the most recent researches, they are considered as portions of an early Miocene, equivalent to the Hempstead beds in England. It is, however, a remarkable fact, that of these seven species, four, namely, *Terebratula minor*, Phil., *Terebratulina caput-serpentis*, Linn., *Megerlia truncata*, Linn., and *Argiope decollata*, Chemn., are now found living in the Mediterranean. In the description of *Terebratula sinuosa*, Brocchi, a well-known large species, some very valuable remarks are introduced respecting the confusion caused by the various synonyms under which it has been described.

Since the time when Mr. Lonsdale gave us so much valuable information respecting fossil corals, no one has worked harder or more successfully in this field of palæontological research than our Secretary, Dr. Duncan. I shall not attempt to give you an analysis of the several interesting papers which he has communicated to us during the past year; but there is one part of the subject on which he has brought forward so much new and important matter, that I must briefly allude to it here*. I refer to that paper in which he describes the process of mineralization which the corals have undergone, and which ends in some cases in such complete silicification that all traces of structure are destroyed, and they are finally reduced to pure homogeneous black

* Quart. Journ. Geol. Soc. vol. xx. p. 358.

flint. After describing the changes which dead corals undergo, and giving a full account of the different forms of mineralization which result therefrom, whether calcareous or siliceous, or one or more combinations of the two, Dr. Duncan states that he does not believe in the hypothesis which attributes the silicification of the West Indian fossil corals to a volcanic outburst which poured siliceous solutions over the depressed reefs of the Miocene age. He shows that this silicification of fossils has been a slow process, having no other origin than in those chemical operations which are still going on, and that their greater or less intensity in certain favourable localities has produced siliceous fossils, even amongst those affected by the calcareous form of mineralization. A kind of chemical transposition takes place under certain circumstances. Silica, it is observed, has an affinity for bodies formerly organized, and often destroys the former tissues. There is a small amount of silica in corals; and in microscopic sections of Antiquan corals, in which silicification is incomplete, the silica is usually seen deposited in molecules in the centre of the calcareous mass, and not on its superficies. The accumulation of the silica is no doubt determined by the persistence of some animal or vegetable organic tissue decomposing more or less slowly, and by which it is attracted, until at last the whole structural details of the coral are destroyed by the deposition of homogeneous black flint. And finally, he observes that every grade of a silicification which destroys the textures of corals, and reduces them at last to pure homogeneous black flint, resembling that of the Upper Chalk, may be distinguished.

M. Charles Martins of Montpellier, recently elected a Foreign Correspondent of this Society, has published, in a recent Number of the 'Revue des deux Mondes' (July 15, 1864), an interesting account of the physical characters of the great Sahara or desert in the province of Constantine. It contains some interesting details of the physical geography of the country, bearing on those geological problems which we are constantly discussing.

Describing the route from El-Kantara to Djebel-el-Mela, with its beds of rock-salt, he says, "We then entered a district composed of grey, blue, yellow, and red marls, associated with conglomerates and limestones, cut up into deep ravines by the torrents which, during the rainy season, descend from the rock-salt mountains. These ravines, from 50 to 60 metres in depth, were so close to each other, that it would have required several days to reach the foot of the mountain, distant only a few kilometres in a straight line, through this labyrinth of gorges separated by sharp narrow ridges. Let those geologists who wish to describe the erosive action of pluvial waters, set aside the wretched examples they quote to illustrate their argument; let them visit Algeria, and gain their inspirations from the ravined district of Djebel-el-Mela and the mountains of the Kabyle. There they will see how the erosive power of water is able, under our very eyes, to transform a level plain into a mass of mountains as varied and broken in their

forms as those which have been caused by the elevation and fracture of strata."

The next passage to which I wish to call your attention is the description of the Sahara itself. M. Martins thus describes it. "It is the examination of a dried-up sea-bottom to which the reader is invited. Geologically speaking, this event is recent; it probably occurred a hundred thousand years ago. But although we cannot tell the number of years, it has a relative date—it is subsequent to the deposition of the Tertiary strata. When it took place the Mediterranean already existed, for we find in the Sahara the shells of the same Mollusca which still live on its shores. The soil is impregnated with salt; it is formed of gypsum or sulphate of lime, probably still deposited in existing seas, and of sands brought down by the rivers which emptied themselves into the Saharan gulf. Now these rivers lose themselves in the desert, and their waters disappear by infiltration in the soil. Salt-lakes, the level of which is some metres lower than that of the Mediterranean, are the last remnants of this inland sea. A series of these leads to the Gulf of the Gabés, the lesser Syrtis of the ancients, on the shores of Tunis. The last of these salt-lakes, the great lake of Fejej, ceases only at 16 kilometres from the sea. Were this isthmus broken through, the Sahara would again become a sea, a Baltic of the Mediterranean." He goes on to compare this with what is now going on in the Gulf of Bothnia, the gradual elevation of the bottom of which will ultimately produce a Sahara between Sweden and Finland.

But the disappearance of the Saharan sea took place without any elevation of its bottom. While constant evaporation was going on, the annual addition of water from the mountains was but small; but these torrents brought down enormous masses of sand and clay and rolled pebbles, which accumulated at the mouth of the Gulf in the Mediterranean, so that under the influence of the then prevalent currents the opening became gradually narrower, until a littoral *cordon* or strip of land, 16 kilometres wide, was interposed between the Mediterranean and its Saharan gulf. No longer in communication with the great sea, the rapid evaporation under an almost tropical sun soon reduced its waters below the present level of the sea, and nothing remained but the salt-lakes which still mark the eastern limit of the Saharan gulf.

Amongst the many discoveries of organic remains made during the last twenty years, few have been more remarkable, both for the number of specimens and the variety of genera and families, than those of the mammalian and other remains at Pikermi in Attica. The first discovery was made by Mr. George Finlay in 1835, and occasional researches have been made with greater or less success in subsequent years. But it was not until M. Albert Gaudry undertook a careful and systematic investigation of these beds in 1855 and 1856, and again in 1860, that it was possible to have even an approximative idea of the remarkable treasures of organic remains contained in these Tertiary deposits of Pikermi.

In 1862 M. Gaudry commenced the publication of his great work on these fossil remains, comprising several species and genera of the Quadrumana, Carnivora, Rodentia, Pachydermata, Ruminantia, Edentata, Birds, and Reptiles, many of which, however, approach very nearly to those of Africa and India, while they are entirely distinct from all the genera, whether living or extinct, of the Continent of America. Many of these vertebrated animals are identical with those which are considered as characteristic of the middle Tertiary epoch. From these facts M. Gaudry draws the conclusion, that at about this epoch the new continent (America) was already separated from the old, and that the great parts of which the latter consists, Europe, Asia, and Africa, were much more closely united than at present in the regions now watered by the Mediterranean.

The first part of the work consists of a description of the fossil Vertebrata of Pikermi. The second part will be devoted to the Geology of Attica. M. Gaudry tells us that in the upper Tertiaries he distinguishes three kinds of deposits:—1st, Marine; 2nd, Freshwater lake-deposits; and 3rd, those which have resulted from the erosion of the mountains, consisting of red loams and conglomerates; the fossiliferous beds of Pikermi are in these red loams, and, as M. Gaudry observes, it will be interesting to ascertain how these animals, which appear to belong to the middle Tertiaries, have been buried in the upper Tertiary formations.

I will only further observe, that during the past year four more livraisons, the 7th, 8th, 9th, and 10th, have been published, containing descriptions of a new species of Mastodon, Dinotherium, three species of Rhinoceros, and two species belonging to the Palæotherium type, namely, *Acrotherium*, *Leptodon Græcus*, a species of *Sus*, and *Camelopardalis Atticus*. The remains already described in the former parts consisted of Quadrumana, one species, with at least twenty skulls; Carnivora, ten species described, and four others of *Felis*, too imperfect to be named; Rodentia, one species; Edentata, one species. There remain still to be described the Horse, Deer, Ox, &c., and the Birds and Reptiles.

Glacial Period.—I now come to that period which is generally considered as immediately preceding the first appearance of man on our planet, I mean the glacial period; and I will briefly allude to some points which have lately been discussed respecting its effects in modifying the surface of our earth. The chief of them has been the effect of glaciers in excavating valleys and scooping out those basins, whether in solid rocks or otherwise, which are now filled with lakes at the foot of the mountains, or at the lower end of the valleys which descend from mountain-chains.

That the extension of glaciers over vast regions of northern and central Europe during this glacial period far exceeded their present limits cannot be questioned; equally so, that their thickness was enormous, and consequently that their power to erode the earth's surface was far greater than that which now prevails. The question I now wish to consider is, whether that power was

so great as to justify the conclusions of those who have attributed to its action the excavation of basins in solid rock many hundred feet in depth, and whether the position of these deep excavations is such as any amount of glacial pressure could have produced under any circumstances.

The principal champion of the theory that the rock-basins in which the Alpine lakes are placed were scooped out by the great glaciers of the icy period, is Professor Ramsay. He has supported his views in three able publications*, with an amount of illustration and argument which might almost be said to carry conviction to his readers; and he has, to a certain extent, found a warm supporter in Professor Tyndall in his paper "On the Conformation of the Alps" in the same Number of the 'Philosophical Magazine.'

Now it must be observed that there are here two questions discussed, 1st, the erosion of the valleys themselves, and 2nd, the scooping out of the rock-basins in which the great lakes have been formed. With the former of these questions I do not propose to interfere. There is much force in Professor Tyndall's argument, drawn from the great regularity of feature which pervades the system of valleys in a mountain-chain, showing the probability that much of this system was the result of the eroding force of water and of ice combined with the general effects of weathering; but it should, I think, be conceded that this agency must have been greatly assisted by the varied nature of the material which was to be eroded, and the extent to which the mountain masses had been previously dislocated and contorted by the many changes—upheavals, depressions, fractures, inversions, and other disturbances, which there is abundant evidence to show they must have undergone in previous geological periods of almost infinite duration. We have only to look at the different configurations of land and sea in Switzerland alone, so graphically described by Professor Heer of Zurich, to be convinced of the truth of this statement.

The question, therefore, to which I mean to confine myself at present is the scooping-out of the rock-basins by glaciers. Professor Ramsay in his paper in the Society's 'Journal,' after disposing of four distinct hypotheses as to the cause of lake-depressions or hollows, namely, a synclinal trough, a line of fracture, an area of subsidence, or an area of aqueous erosion, concludes that the great moulding agency of ice is the *only* other cause by which the form of the ground could have been thus modified. Now it appears to me that Professor Ramsay has too hastily assumed the impossibility of any of these four causes having had anything to do with the formation of lake-basins. It is true that the evidence he brings forward against the operation of any one of these causes in each particular case alluded to may be correct, but it does not therefore follow that he is correct in stating that none of these causes could have operated in any case. It does

* Quart. Journ. Geol. Soc. vol. xviii. p. 185; Physical Geography and Geology of Great Britain; and the Philosophical Magazine, vol. xxviii. p. 293.

not follow, for instance, that because the Lake of Geneva does not lie in a synclinal trough, it may not be in an area of depression, or that because the Lake of Garda is not in an area of depression, it may not be in a line of fracture; and therefore I am of opinion that his conclusion is not warranted, that these Alpine lake-basins must have been caused by the excavating power of a glacier in motion.

Prof. Ramsay says that he does not believe that there are any lakes now occupying yawning fractures consequent, in Switzerland, on post-eocene or post-miocene disturbances; but why does he confine his argument to these Tertiary disturbances? He has himself shown in his paper in the *Phil. Mag.* vol. xxviii. p. 298, "that the great and small outlines of mountain-chains, of valleys, of river-gorges, and of plains are the combined results of an immense number of operations, many of these going back to exceedingly remote periods of geological antiquity, and a great proportion of their details being lost even to probable conjecture." The effect of those operations must have been to cause great inequalities of surface even in these remote periods, partly, no doubt, by producing cracks and crevices; and if during subsequent depressions these cracks and inequalities were filled up by the materials washed into them, the first effect produced by their subsequent emergence would be that this more recent and softer material would speedily be washed out either by torrential water or atmospheric agency, and thus valleys of greater or less depth, and greater or less length would be formed, which, when the glacial period arrived, would afford a ready pathway for the descent of the glaciers, by which no doubt their areas would be considerably enlarged, and much of the loose material still remaining be carried off. For that glaciers descending from lofty mountains down valleys with any considerable amount of inclination would wear away the sides and bottoms of the valleys cannot be questioned.

But this is not the point I am contesting. What appears to me improbable is that a glacier, after emerging from the narrow valley in which it has been confined, and having entered a vast plain where little or no lateral pressure can be exerted, and where it has reached a state of comparative if not absolute rest, should by the mere force of its enormous thickness exercise such a pressure upon the rocks below as to excavate a basin, in the solid rock, of several hundred feet in depth. I am not aware that Prof. Ramsay himself has anywhere stated that, supposing the glacier were at rest, the mere vertical pressure would produce this effect upon the rocks beneath. This statement has, however, been made by Dr. Haast in his account of the glaciers of New Zealand, which has been recently read before this Society.

Let me now, by way of example, inquire into some of the circumstances connected with the Lake of Geneva. It is a locality generally well known, and there will be no difficulty in realizing its geographical position, lying as it does in the great plain of Switzerland, and flanking the northern slope of the Alps as the

Lake of Neuchâtel flanks the southern slope of the Jura. We may at once admit that this region was formerly covered by a mighty glacier, extending from Villeneuve at the mouth of the valley of the Rhone to Geneva, Neuchâtel, Bern, and Solothurn. Descending principally from the valley of the Rhone, this glacier is assumed to have been 2780 feet thick at this spot, and 2200 feet thick where it abutted against the flanks of the Jura near Neuchâtel. But if we add to this the depth of a portion of the Lake of Geneva, the total thickness of the ice was in some places 3764 feet. If, again, we look at the tract of country over which this icy mantle was spread, we find it extending about 100 miles in length, from Geneva to Solothurn, from S.W. to N.E., and upwards of thirty miles in width between the Alps and the Jura. Now the greater portion of this glacier must have come down the valley of the Rhone by Sion, Martigny, and Bex, and this valley, particularly near its termination, cannot be more than two or three miles in width, in many places not so much. The inclination from Sion to Villeneuve is very slight; and although it is probable that the Alpine chain may have had a greater altitude during the glacial period than at present, there is no reason for supposing that the angle of inclination of the main valley down which the great glacier advanced was greater than it is now, although that of the smaller valleys, which also contributed their quota to swell the moving mass, may have had a somewhat steeper inclination.

Admitting then all this, and remembering the thickness of the icy covering in the plain, I am at a loss to understand where we are to look for that powerful agency, that *vis à tergo*, by which this comparatively small mass could push forward at the very lowest imaginable rate, the vast field of ice covering 3000 square miles of the great plain of Switzerland, and yet with such irresistible energy, and in a direction at right angles to its principal line of movement, as to cause it to scoop out the rocky basin in which the Lake of Geneva now lies. In his address to the Royal Geographical Society last year, Sir Roderick Murchison has already pointed out this difficulty, and Prof. Ramsay has endeavoured to meet it by showing (Phil. Mag. p. 300) that this great mass of ice from the Rhone valley was "prodigiously swelled by the great tributary glacier of Chamouni, which, descending from Mont Blanc, filled a valley some fifty miles in length, and joined the Rhone glacier near the lower end of the Lake of Geneva;" and moreover, he adds, that "during the cold of the glacial epoch all the higher region south of the lake must have maintained its glaciers and filled the valleys that run north."

Now, with all due submission to Prof. Ramsay's greater experience, I cannot avoid entertaining the opinion that the immediate effect of this Chamouni glacier, although adding to the accumulation of ice in the great valley of Switzerland, must have had the effect of checking the momentum and progress of the Rhone glacier, if it had any, towards the south-west, and of driving the two together in a line of mean result against the flanks of the Jura. But leav-

ing this digression, is it within the range of physical possibility to suppose that a mass of ice two or three miles in width should have had the power of forcing onwards over an uneven bottom a mass occupying a space of upwards of 3000 square miles, and moreover of scooping out a deep basin in the solid rock to a depth of 900 feet? Are we not rather forced to the conclusion that this vast field of ice, closed in by mountain-ranges on every side, must have been practically stationary, except in so far as the gradual melting away of the ice at the south-western extremity may have caused it gradually to have swelled out into the vacant space by the constant freezing of the infiltrating water, but without exerting much, if any, grinding power? Are we not also forced to the conclusion that, if a certain amount of pressure from above did cause the glaciers to descend the valley from the high Alpine regions, this descending mass, or rather the upper portion of it, on reaching the icy plateau of the plain, which must have resisted its pressure, would rather have flowed over the surface, and have spread itself over the comparatively quiescent portion below?

With regard to this point, Prof. Ramsay says that he "cannot conceive a horizontal fracture of forty miles in length over the area of the Lake of Geneva, clearly dividing two bodies of ice, the lower of which was when thickest nearly 1000 feet, and the upper and sliding stratum must have been nearly 3000 feet thick." Now I am not aware, I certainly have nowhere read, that any one has ever propounded such a doctrine, so contrary, as Prof. Ramsay says, to all our knowledge of the motion of liquid or semiliquid bodies. But, on the other hand, I have no doubt he will admit that the motion of all parts of a liquid or semiliquid body is not always equal. In the case of water, the most fluid of all liquids, we know that the motion is not uniform in the flow of a river. Near the banks, where there is friction, independently of other opposing causes, the motion is less rapid than in the centre. At the bottom, for the same reason, the motion is less rapid than on the surface. And when we apply this argument to ice, a viscous gelatinous body as Prof. Ramsay calls it, the less yielding nature of which makes it more amenable to the laws of friction, we must be all the more convinced that motion could not have been equal throughout all its parts. There appears to me therefore no difficulty whatever in conceiving that while the upper portion of the glacier may have been slowly moving forward, propelled perhaps by the pressure of the more elevated glacier in the valley behind, the lower portion, forming the bottom of the glacier resting on the surface of the ground, may have been either absolutely quiescent, or so nearly so, as to have produced no effect whatever on the rocky surface below; not that this difference of motion was caused by a horizontal fracture separating the moving from the non-moving portion, but by a gradual diminution of motion acting throughout the entire mass from the surface to the bottom.

Thus I am at a loss to conceive where the force could come from which could enable this gigantic glacier, spreading over the

whole vale of Switzerland, to scoop out these rocky basins of Geneva or Neuchâtel. I will not waste your time by stopping to discuss the question whether the mere vertical pressure of the ice, without any forward motion, could have produced this effect; for, to refer to nothing else, how could the material thus abraded be removed?

Although I fear I have too far trespassed on your time already, and am most unwilling to prolong this discussion at present, yet one other argument occurs to me, which I think deserves some consideration, although I am not prepared to say what weight physicists may attach to it. Allow me, therefore, to enunciate it for your consideration. Let us, for the sake of argument, admit that this gigantic glacier-field, covering nearly 3000 square miles, and impelled by some mysterious power, this *vis à tergo* of which we have heard so much, did really move with slow but irresistible motion over the sites of these Alpine and Swiss lakes, pressing upon the rock below with the whole force of the superincumbent weight of a mass of ice 3000 feet in thickness; let me then ask whether the friction caused by the motion, however slow, of such a tremendous weight would not develop such an amount of heat as to reduce the ice in contact with the hard rocks into a liquid state? Would not the ice be melted, and a stratum of water be thus introduced between the ice and the rocky surface? and would not this stratum of water thus intervening act as a kind of cushion to prevent the ice from exerting any abrading power on the rocks beneath? I cannot resist the conviction that some effect of this kind would necessarily be the result of the conditions I have mentioned, but I merely venture to throw out the idea for further consideration, without wishing to press it unduly.

But before leaving this subject, which still requires much local examination, it will perhaps be expected that I should offer some suggestions as to the probable causes of these lake-basins. I might decline the inquiry, as I have never made this question a subject of special investigation on the spot. I therefore shall not allude to the general question. But with reference to the two lakes of Geneva and Neuchâtel, some facts occur to me which I think may throw light on their origin. It is well known, from the researches of Swiss and other geologists, that during the Eocene period and some portion of the Miocene, the greater part of the Alpine and the Jura Mountains were submerged. When at a subsequent period these mountain-ranges were again elevated above the waves, whether rapidly in one or more convulsive throes, or gradually during a long lapse of time, we may assume for certain that violent disturbances both of land and water must have taken place, of which our most vivid imagination will not permit us to form any idea, or even to appreciate the extent. The intervening space between these two regions, although not elevated, must have been violently disturbed, and it is not difficult to suppose the occurrence of one or the other of the two following phenomena. 1. When the Eocene and Miocene formations were

raised up, violently disturbed and abraded, the necessary result must have been great irregularities of surface, great inequalities of ground, here elevated ridges and there corresponding depressions; and what is more probable than that some of these depressions, particularly such as occurred near the northern flank of the Alps and the southern flank of the Jura, became the recipients of those torrential waters which, during and subsequent to this period of convulsion, rushed down the mountain-sides, thus forming those very lakes we are now examining? 2. Might we not expect that the very fact of the elevation of these mountain-ridges, on the very site where from the earliest geological periods mountains and continents and islands are known to have existed, would have produced corresponding depressions parallel with the axis of their line of elevation, and in their immediate neighbourhood. Such a solution appears to me more probable than the scooping-out of rock-basins by glacial action. Of course this explanation does not apply to all Alpine lakes, particularly those on the Italian side, I therefore only venture to offer it as a probable solution in some cases.

While on this subject I wish also to call your attention to an interesting correspondence between MM. Gastaldi, Mortillet, and Omboni in the fifth volume of the 'Atti della Società Italiana di Scienze Naturali.' From this it appears that the two former writers adopt the views of Prof. Ramsay only to a very limited extent. Looking at the excavating powers of glaciers with greater moderation, they do not attribute to them the gigantic task of having hollowed the lake-basins out of the hard rock; but merely that of having forced out, partly by dissolution and partly by pushing forward, the soft alluvium which had been deposited in preexisting valleys and hollows, and which belonged to the preglacial period, when the plain of the Po in Lombardy was formed, and which extended like so many fiords up the Alpine valleys. M. Omboni, who takes another view, considers that these old valleys and basins, into the question of the formation of which he does not enter, were already filled with ice before the deposit of the alluvium of the plains of Lombardy, and that on the introduction of a warmer period the ice melted, and the preexisting hollows became filled with water, the overflow of which cut its way through the terminal moraines. This explanation seems quite satisfactory, as far as the Lake of Garda is concerned.

Postglacial Period.—I find that it is impossible for me to carry out my original intention of referring to the discoveries of Falconer, Prestwich, Evans, and many others, respecting the postglacial period, and those deposits, both in this country and on the continent of Europe, where evidence of man's existence has been found contemporaneous with the remains of animals now extinct, but which appear still to have lived on after his appearance on the earth. I regret this the more as it is by no means an unimportant fact. It adds another link to that chain of evidence by which we are daily becoming more and more convinced that no real natural breaks

exist between the Faunas and the Floras of what we are accustomed to call geological periods. As we have already learnt that the fauna of one period was not destroyed before the creation or introduction of that of the succeeding period, so now we learn that those forms of animal life which roamed over the surface of the earth before man came to exercise dominion over them, were not, as was at one time supposed, destroyed before his arrival, but continued to coexist with him, until the time came when they were to make way for other forms more suited to the new conditions of life and to his requirements.

But I must, however briefly, allude to the papers read before the Royal Society by Mr. Prestwich, and published in the 'Philosophical Transactions' last year, giving us the results of his investigations respecting the geological position and age of the flint-implement-bearing beds, and of the causes to which they are to be attributed. He shows that river-action, as it now exists, could not have excavated the present valleys and spread out the old alluvia. Nor does he admit purely cataclysmic action in cases where the evidences of contemporaneous old land surfaces and of fluviatile beds are so common. But with river-action of greater intensity, and periodical floods imparting a torrential character to the rivers, he considers that the phenomena admit of more ready explanation.

Without attempting to go into the interesting details contained in these papers, I will merely quote one passage which embraces the conclusions at which he has arrived. "I conceive," he says, "that the hypothesis brought forward in this paper gives consistency to the whole subject. It brings down the large mammalia to a period subsequent to that when the extreme glacial conditions prevailed, and closer to our own times; it places all the old river alluvia in the same period, and groups together the previously isolated fluviatile beds of Grays, Brentford, and other places in England, together with the *loess* and various *sables lacustres* and diluviums of French authors; it connects the great platform-terraces of gravel, skirting so many of our river-valleys, with the same period, and makes the connexion between these, and the excavation of the valleys themselves as well as the formation of the loess, dependent upon one prolonged and uniform set of operations, in accordance with the climatal conditions and necessarily resulting from them."

With regard to the geological age of these deposits, Mr. Prestwich shows that they were subsequent to the period of the Boulder-clay deposits, and he concludes his paper with some interesting remarks on the uninterrupted succession of life from this post-pliocene period to our own time, as evidenced by the direct descent of a portion of the old fauna to our day, though he cannot explain why the larger Pachyderms should not also have survived.

Would it be rash to suggest as an answer to this question the possibility of their having been destroyed during the glacial period, and that the bones of Elephants and Rhinoceros now found

in these river-gravels were washed into them out of preexisting beds in which they had been originally entombed, or from off the surface of the land where they had perished, on the commencement of the glacial period?

Miscellaneous.—Amongst recent geological works of a more general character, I have much pleasure in now directing your attention to the new edition published by Sir Charles Lyell of his 'Elements of Geology.' The alterations and amendments in this volume are both numerous and important, but both the time and space at my command will only allow me to notice some of the principal points which a somewhat hasty inspection of the work, comparing it with the previous edition, has enabled me to notice. I may at once mention that not only have many portions of it been entirely rewritten and recast, but that it contains 130 more pages, and above fifty additional woodcuts.

The tabular view of the fossiliferous strata is recast, and chapter 10, on recent and Postpliocene periods, contains much new matter: the latter part is entirely rewritten, as well as a considerable portion of the following chapter on the glacial period. The erosion of lake-basins by ice is discussed in the 12th chapter, and Sir Charles maintains the opinion he had already expressed in the 'Antiquity of Man,' against the views of Prof. Ramsay and others who have adopted the ice-eroding theory, and he recalls attention to the theory of unequal movements of upheaval and subsidence which he then brought forward.

But by far the greatest addition of new matter will be found in the 13th, 14th, 15th, and 16th chapters, which treat of the Tertiary formations, and much of which is entirely rewritten. The author has somewhat modified his views respecting those intermediate beds of Germany and Paris, which are placed by Prof. Beyrich in the Middle Oligocene, including the Mayence-basin and the Fontainebleau sands. This arrangement would make the gypsum of Montmartre the uppermost of the Eocene subdivisions; yet even adopting this view to a certain extent, he shows that the difficulty of drawing a line between Lower Oligocene and Eocene is as great as between Lower Miocene and Eocene; but, as he observes, we are now arriving at that stage of progress when the line, wherever it be drawn, will be only an arbitrary one, or one of mere convenience.

Of all these, however, the 15th contains by far the greatest quantity of new matter of any chapter in the volume. It shows the enormous stride which the Botany of the Tertiary strata has made of late years, owing in a great measure to the successful labours of Prof. Heer of Zurich, according to whose observations it appears that a fossil flora is of much greater importance in enabling us to identify and classify the middle Tertiary strata than has hitherto been generally admitted; and in illustration of this question, Sir C. Lyell gives a full account of the fossil flora of the Upper freshwater Molasse as seen in the valley of Ceningen.

Much interest will also attach to the account here given of the

theory of a Miocene Atlantis. The remarkable resemblance of many of the numerous types which form the fossil Miocene Flora of Switzerland (richer even than the modern flora) to living Western American types, suggested first to Unger, and subsequently to Heer, that the present basin of the Atlantic was once occupied by land, over which the Miocene plants passed freely. This view is combated by Dr. Asa Gray, who argues that it is far more probable that the plants, instead of reaching Europe by the shortest route, over an imaginary Atlantis, emigrated in an opposite direction, and took a course four times as long, across America and the whole of Asia. The objections to the Miocene Atlantis theory are confirmed by the evidence shown by the study of the fossil shells and corals of that period. Mr. J. Carrick Moore has pointed out that certain Tertiary shells of St. Domingo show a great affinity to the Miocene shells of Europe. Dr. Duncan has done the same with regard to the corals, thereby inferring that there was no great barrier of land or Atlantic continent separating the Miocene seas of Europe from those of the West Indies.

If I might be allowed to hazard an opinion on this subject, I would say that, even on the showing of the advocates of the respective theories, there is such a manifest want of a connecting link in the chain of evidence, that both the contending theories must be dismissed from consideration. In the first place, the floras which are compared are not contemporaneous, it is the Miocene flora of Switzerland which is compared with the existing flora of North America, and there is no evidence that the Miocene flora of America was the same as the living one. In the next place, both theories assume that the plants travelled from America to Switzerland, that is to say, from the recent flora to that of the Miocene period—a physical impossibility. Moreover in France we have evidence of an intervening Miocene sea extending to the Atlantic. Again, all that is assumed in comparing the two Floras is rather analogy of type than identity of species. I cannot, therefore, think that either of these theories will be permanently established. Would it not be a more probable solution or explanation of the typical resemblance to suppose that the conditions of climate and of soil were so nearly similar during the Miocene period in Switzerland to that which now prevails on the American continent, that analogous forms were introduced in the respective floras independently of each other, rather than to look upon one as the direct descendant of the other? Such an explanation may not suit the views of those who have adopted the Darwinian theory; but this is not the time to discuss the law of species, or the causes which have led to the creation of new forms.

But I cannot go through the whole of this interesting work, although many other important points remain to be noticed, as in the 31st chapter, where Sir C. Lyell publishes for the first time the results of his own observations and those of others on the Miocene rocks of Madeira and Grand Canary, and on the fossils

which he collected in those islands, and which I have referred to in my notice of the work of Dr. Hartung. I will only observe, in conclusion, that there is not a chapter in the book which does not contain much new and valuable matter.

Herr von Dechen, so well known for the active part he has taken in the preparation of the Geological Map of Germany, has published at Bonn a very important work on the Lake of Laach and its volcanic neighbourhood. The chaotic manner in which volcanic rocks of different ages and of various mineralogical characters are heaped together in this district, renders it a most difficult task to disentangle their history, and we are therefore all the more indebted to Herr von Dechen for the effort he has made to solve the many difficult problems here met with. I will therefore endeavour to point out some of the more important geological conclusions which the author has arrived at.

The products of the volcanos in the neighbourhood of the Lake of Laach are in close contact with the lower division of the Devonian beds which form the far-extending basis of all the other formations in this district; also with the middle Tertiary (Oligocene) deposits, or the Brown-coal formation, which, as a whole, does not extend beyond the limits of this volcanic district, although with interruptions it spreads out far beyond it; and also with the high-level gravels which extend in terraces to the valley and the bed of the Rhine, and with the overlying loam and loess.

The time of volcanic action began before the close of the Oligocene period, and posterior to the period when the Devonian beds had by elevation acquired their present highly inclined position, and its surface had already undergone its most important modifications.

The great hollowing out in the district of the Devonian beds in the neighbourhood of this volcanic region of Coblenz and Bendorf, as far down as Andernach and Fähr, was already in existence before the formation of the Brown-coal deposits.

The formation of the Rhine Valley took place after the deposit of the Brown-coal beds.

Some of the volcanic outbursts, *e.g.*, that which furnished the material for the tufa, with impressions of leaves, near Plaidt, are older than the formation of the valley. Other outbursts, on the other hand, belong to the most recent changes which this district has undergone. The series of volcanic outbursts here comprises a long period of time, during which the formation of the valleys and the gradual development of the form of the surface took place.

On the confines of the volcanic district some basaltic hills appear, the emergence of which, as in the Siebengebirge, probably took place during the formation of the Brown-coal.

The streams of lava which have flowed down the neighbouring valleys prove the previous existence of these valleys, and also that the form of the surface of the whole neighbourhood has undergone no important changes from that time down to the present day.

In a few of these valleys only a slight lowering or excavation of the bottom of them has taken place. The relative age of many of these lava-streams, and of the outbursts by which they were produced, can be fixed. On the Nette the lava-stream from Salzbusch is unquestionably the oldest; in the Brohl valley that of the Kunksköpfe.

The lava-streams lie partly immediately on the upturned edges of the Devonian beds, partly on the clays of the Oligocene or Brown-coal formation, partly on river-gravels, which again overlie both the above-mentioned formations, or on beds of tufa. Many of the lava-streams of this district are covered by the loess, or by beds of pumice-stone and tufa; and they are all older than the loess. These lavas are of very variable mineral character, many resemble basalt, others contain much nepheline. The nepheline lavas are alone used for millstones and other masonry works. The other conclusions are purely mineralogical.

It is satisfactory to observe that the publication of that great work the 'Palæontographica,' under the superintendence of Hermann von Meyer and Dr. Dünker, has progressed rapidly during the past year. Several parts of vols. xi., xii. & xiii. have recently been received. Amongst the more important notices in the 12th volume may be mentioned Professor Göppert's work on the Fossil Flora of the Permian formation. This first portion of the work contains descriptions of species from the following families—*Fungi*, *Algæ*, *Calamariæ*, and Ferns. Professor Ludwig also gives an account of the Pteropods from the Devonian formation in Hessen and Nassau, as well as from the Tertiary clay of the Mayence Basin.

I must also notice the publication of several parts of the 'Paléontologie Française,' containing an account of the Gastropods and Brachiopods of the Jurassic formation, and the Echinidæ of the Chalk.

There is another similar publication on British Palæontology, in the progress and prosperity of which we must take the greatest interest. The Palæontographical Society is our own offspring, and I am happy to state that its publications continue to appear with unabated regularity; indeed I may say that, thanks to the exertions of its past and present Secretaries, the publication of the volumes has of late years been all that could be expected. The Monographs included in the volume published during the last year (the volume for 1862) yield in no degree in interest to those which had preceded it.

The first is by Dr. Wright, on the British fossil Echinodermata from the Cretaceous formations. In this first part of his work, Dr. Wright describes the *Cidaridæ*. He begins with a brief account of the different groups into which the formation has been subdivided, chiefly taken from the Isle of Wight, commencing with the Lower Greensand, followed by the Gault, the Upper Greensand, Chloritic Marl, Lower Chalk and Chalk Marl, and the White Chalk. This is followed by a classification of the

Echinodermata, which are divided into eight orders. But of these the *Sipunculoidea* and *Holothuroidea* are not found in a fossil state; and the *Blastoidea* and *Cystoidea* are peculiar to the Palæozoic rocks; consequently we have here only to consider the remaining four orders, the *Echinoidea*, *Asteroidea*, *Ophiuroidea*, and *Crinoidea*. Dr. Wright then gives a descriptive analysis of the component elements of the test and body of the *Echinoidea*, which consists of three parts: 1st, the test or calcareous envelope, of various forms, and composed of a framework of plates, which are either hexagonal, pentagonal, or polygonal; 2nd, the visceral cavity, containing the different organs; and 3rd, the external spines and tubercles. They are divided into two sections, *E. endocyclica* and *E. exocyclica*, which are subdivided into thirteen natural families, of which the *Cidaridæ* are the first, and to which this first part of the work alone applies. Some idea may thus be formed of the magnitude of the work undertaken by Dr. Wright. Thirteen species are here described, illustrated by eleven plates, of which it is not too much to say that they are probably the most perfectly executed plates published by this or any Society.

The next paper is the commencement of Mr. Salter's Monograph of British Trilobites, with six plates. He commences with a short account of the history or literature of Trilobites and the progress of their discovery, with special allusion to the works of Burmeister, Quenstedt, Emmerich, Barrande, and others, followed by a sketch of their vertical range, structure, and habits, with a provisional classification, in which the *Phacopidæ* are placed as the typical and most perfect group of the order. Forty species are here described and figured, chiefly belonging to the *Phacopidæ* and *Cheiruridæ*.

The third paper is by Mr. Davidson, on the British Devonian Brachiopoda. It is the first portion of the 6th part of his great work on British Fossil Brachiopoda. I have already to-day alluded to the great claims on your approbation which Mr. Davidson has acquired by the manner in which, for the last thirteen years, he has laboured with unvarying zeal and diligence at this important work. I shall therefore now only briefly allude to the contents of this portion. In the preliminary remarks, Mr. Davidson refers to the remarkable break which exists in Devonshire between the Devonian and Silurian rocks, and possibly in other regions, and quotes Professor Ramsay as stating that of several hundred Upper Silurian forms, only about six occur in the Lower Devonian rocks. He then refers to the observations of Mr. Pengelly, Professor de Koninck, Ramsay, Salter, and others. In Morris's 'Catalogue of British Fossils' ninety-four species of British Devonian Brachiopods have been enumerated; many of these Mr. Davidson considers as only synonyms; but there is great difficulty in identifying some of these so-called species, partly from the want of sufficiently perfect material, and at times also from insufficiency of description and illustration. For the present Mr. Davidson reserves what he may have to say with reference to those spe-

cies which are common to the Silurian, Devonian, Carboniferous, and Permian systems, which will be treated of in the concluding portion of his Monograph. He then proceeds to describe the following species:—*Terebratula*, 4; *Rensselæria*, 1; *Stringocephalus*, 1; *Athyris*, 4; *Merista*, 1; *Retzia*, 1; *Uncites*, 1; *Spirifera*, 14; *Spiriferina*, 2; *Cystina*, 3; and *Atrypa*, 3; several of which are now for the first time added to the British lists. They are illustrated by nine plates, all of which have been drawn on stone by Mr. Davidson himself, a fact which adds materially to their value, by vouching for their correctness. For when an author who has himself described the species is also able to figure them on stone, we are sure of having those typical features brought out which might escape the notice of the professional draftsman, who is not enough of a conchologist to seize upon the characteristic points.

The next Monograph is by Mr. Searles Wood, on the Bivalves of the Eocene Mollusca. I must here remind you that the illustration of the Eocene Mollusca was originally undertaken by Mr. F. E. Edwards, who had commenced with the Univalves, and had already published three parts, with thirty-three plates. When, however, the state of his health prevented Mr. Edwards from going on with his work, Mr. Searles Wood, sensibly alive to the disappointment felt by many Palæontologists who were anxiously looking to the completion of this important Monograph, undertook the task himself. Hoping, however, that Mr. Edwards might in time be able to resume his work on the Univalves, Mr. S. Wood began with the Bivalves, which was commenced in the volume for 1859, with thirteen plates. In the present volume he has given us seven plates, with an accurate description of the following species:—*Modiola*, 5; *Arca*, 18; *Cucullæa*, 1; *Pectunculus*, 10; *Limopsis*, 2; *Trigonocelia*, 2; *Nucula*, 23; *Leda*, 9; and *Unio*, 7; of which a very considerable number are new species.

The last work in this volume is by Professor Owen, and consists of Supplements II. & III. to his Monograph of the fossil Reptilia of the Cretaceous formations, with ten plates. The first Supplement (No. II.) contains descriptions and additional particulars of *Plesiosaurus planus*, Owen; *Pl. Bernardi*, Owen; *Pl. Neocomiensis*, Campiche, and *Pl. latispinus*, Owen. The second Supplement (No. III.) gives an account of the left ramus of the lower jaw of a young Iguanodon from Brixton, Isle of Wight, including the entire series of alveoli, fifteen in number. From a comparison of this jaw with those of larger specimens, of greater length, and with a greater number of alveoli, Professor Owen draws this interesting conclusion, that the Iguanodon possessed the mammalian character of increasing the number of teeth and sockets longitudinally, according to its age, like the true molars of mammals, in new and distinct alveoli, behind those in place; whereas in the Crocodiles and other existing reptiles the number of teeth and sockets does not vary with age, thus showing the greater affinity of the Iguanodon to the warm-blooded mammalia.

I will merely add one remark, which I trust geologists will

bear in mind, namely, that notwithstanding the growing importance of the publications of the Palæontographical Society, the number of subscribers has not increased of late years to the extent which is desirable. With a larger number of subscribers, a still more valuable volume might be annually published.

Prof. Theobald, of Chur, has published an important work on Swiss geology, entitled 'Geological Description of the North-eastern Mountains of Graubünden' (Grisons). The district is one of the most mountainous in Switzerland, lying on both sides of the Upper and Lower Engadin. The difficulty of any scientific inquiry in these elevated regions, amidst glaciers and fields of snow, is, as Prof. Theobald observes, increased by the peculiar nature of the Alpine rocks and their disturbed stratification, where overturns, displacements, and contortions are the most ordinary occurrences, so that for great distances the superposition of the older to the younger rocks becomes the rule. Moreover, the highly developed metamorphism of the beds, in consequence of which the same rock appears under the most varied and dissimilar forms, and the want of well-preserved fossils throughout the greater part of the district, greatly increase the difficulty.

It is now generally known that the Alps do not consist so much of one mountain-chain as of a series of central masses, round which the younger or newer formations are grouped. These central masses consist chiefly of gneiss and its associated crystalline schists, as hornblende and mica-schist. Hollows or deep depressions filled with sedimentary rocks lie between these central masses, and separate them from each other. But these central masses are often broken up, and with the surrounding sedimentary rocks form a series of undulations, instead of single centres of elevation.

These crystalline central masses have not only burst the overlying capping of sedimentary rocks and pushed them on one side, but even appear themselves as burst or broken domes of two distinct characters. Either the layers of the crystalline schists fall away in an anticlinal direction on both sides of the central point or central line, or they are still more lifted up, have separated in a fan-shaped manner, and have been thrown over at their extremities, so that they overlie the sedimentary rocks which have been equally turned over. In both cases massive crystalline rocks generally rise up in the middle, but not always; and the non-crystalline rocks surround them in long lines called undulations of elevation; they have undergone their greatest amount of elevation near the central masses, where they have also been most destroyed, whereas they gradually become more horizontal towards the plain. The force which has raised these central masses has not been sudden or spasmodic, but slow and gentle and constantly operating. True eruptive rocks have sometimes burst through the broken-up covering and completed what the metamorphic elevation had commenced. This metamorphism, however, is not confined to the true crystalline rocks, but many of

the sedimentary rocks also have been affected by it—a process which is still going on.

The author then proceeds to describe the physical features of the different mountain-masses in the district under consideration, and describes in detail the order of stratification and their disturbances, changes, and metamorphisms in the twelve different groups examined. It is impossible to give even a slight sketch of the various complications, upheavals, inversions of stratification, and distortions which these sedimentary rocks have undergone during the oft-repeated elevatory action, as well as the corresponding subsidences, to which they have been subjected. I will only observe that the sedimentary rocks here treated of consist of all the known formations of the Alps, from the Triassic system upwards to the Flysch. It is, however, suggested that the Verrucano, which overlies the Casanna and hornblende-schists, may possibly be of Permian age.

The description of each group or central mountain-mass is followed by an account of the results arrived at by its examination.

The first group described is the Rhæticon, and the following are some of the results at which the author has arrived.

All its formations lie in zones around the central nucleus, which consists of the outlier of the Selvretta mass towards the west. The northern Trias-liassic zone, which, following the Ill and the Arlberg road as far as the Inn, forms the north side of the Selvretta mass, has been already alluded to, but it does not belong to the district under consideration.

The crystalline rocks show a decided fan-shaped structure towards their flanks, and overlie the sedimentary rocks, so that the formations appear inverted.

This crystalline nucleus consists of gneiss and hornblende-schist, so that the former appears to form the true nucleus, and the latter the outer layers, although internally they alternate, and mica-schist alternates with both. The boundary towards the sedimentary rocks consists everywhere of Casanna-schist, which passes into the former or crystalline rock.

The sedimentary rocks participate in this inversion even where the crystalline rocks are not seen, or at least not in large masses.

The Verrucano is seen along the whole line, but very variably developed. In one place it forms a broad zone of red conglomerate, in another it is reduced to thin bands of quartzite and variegated schists.

The middle formations are much less strongly developed along the whole southern base of the Rhæticon than on the north side, so that it is difficult to distinguish the separate members, particularly as they have been much altered by the proximity of the crystalline formations, and fossils are wanting.

The most persistent is the Virgloria limestone. The lower Rauchwacke only appears on the Saaser Alp. Towards Monbiel the whole zone thins out completely, and is replaced by thin slaty limestone beds.

The principal dolomite also thins out towards the Plassegger Pass. It is uncertain whether the dolomite of Monbiel belongs here; or is an altered Dachstein-limestone.

The Kœssen beds do not appear to occur eastwards of the Geiss-spitze, on the Ofentobel.

The following are some of the principal results of the examination of the Selvretta-stock, not far from Cernetz, in the Lower Engadin.

1. The whole central mass consists of crystalline rocks: gneiss, mica-schist, and hornblende-schist; on its outer flanks first appear Casanna-schists and sedimentary rocks; no granite or eruptive rock is visible in this mass, only on the southern flank on the borders of the sedimentary rocks in Lower Engadin, and rather in the strike of the anticlinals.

2. The chief mass of the Selvretta is an exploded or burst dome or saddle, the elevation of which was probably caused by the metamorphism of the rocks; the narrow ridges with their flaggy beds are the scattered crusts or outer layers of this dome-shaped mass: the inner points are not the most elevated; but the main line or centre of elevation is marked by a depression, on each side of which the strata or beds dip outwards from this line.

On the western side the elevating force must have been repeated with greater intensity, as the crystalline rocks are here forced in a fan-shaped form *over* the sedimentary rocks.

The boundary of this mass towards the Fluela Scaletta Mountain, which also forms a portion of the whole central mass, is not accidental, but is caused by the coincidence or combination of the action of two centres of elevation which operated with less intensity on the line between Klosters and Lavin, marked by the valleys of Vareina and Sagliains, whilst, owing to a greater intensity of force, the burst dome of the Selvretta rose up on the one side, and the fan-shaped mass of the Scaletta on the other. The beds between the two were pressed together and crumpled up, but here the two crystalline masses are not separated by any line of sedimentary rocks.

These two instances will serve to show how Prof. Theobald has executed the laborious task he has undertaken, without troubling you with an account of the other central masses which he has described. When similar observations shall have been made on other portions of the Alps—a task which has already been done to some extent by Prof. Studer—we shall have a clearer view of the gigantic operations of nature which have led to the elevation and structure of this typical region.

Prof. E. Desors has also published a work on the structure of the Alps, in which he endeavours to show the laws and causes which have led to the development of their present forms. These outward forms depend on two conditions, the nature of the rocks of which they are composed, and the intensity of the force by which they were elevated. Recent investigations have upset the ancient theories that all the highest points consisted of crystalline rocks,

and that no sedimentary rocks formed high mountains. Again, it was formerly supposed that the crystalline rocks, particularly granite, owed their origin to igneous action. Now it is well known that these granites are chiefly arranged in layers and, as it were, stratified, as those of the Finster Aarhorn and of St. Gothard. The granite passes into gneiss, and the gneiss into mica-schist and talc-schist, and this is again closely connected with the green and grey slates; and it is well known that many of these rocks formerly considered as plutonic, are really metamorphosed sedimentary rocks. Like Prof. Theobald, the author adopts Studer's view that the Alps, instead of consisting of a central chain with several parallel lateral chains, are composed of a number of mountain-groups forming so many elliptical central masses of crystalline rocks, the intervening spaces or troughs being occupied generally by the sedimentary rocks.

He then describes these various central masses, thirty-five in number, having their respective belts of sedimentary rocks variously contorted and disturbed, and often inverted, wrapping round them. This is followed by an account of the sedimentary rocks themselves, the erratic appearances in the Alps, and an explanation of the Alpine lakes, showing that the valleys and depressions in which these lakes lie were owing to causes existing before the glacial period; amongst these causes not only the accidental form of the surface is to be noted, but also the nature and constitution of the ground and soil.

With regard to the striking difference in the features of the Italian lakes and those in the interior of Switzerland, he considers that, while the former owe their existence to longitudinal cracks or crevices in the mountain-chains at right angles to their direction, the Swiss lakes are for the most part washed-out or excavated lakes; and this excavation he attributes to mighty floods, caused by the elevation of the Alps, rushing against and tearing away the softer material of the Molasse and other Tertiary deposits, against which they were directed; for previously to the last elevation of the Alps these Tertiary formations were covered by the waters of the sea. This excavation took place before the glacial period, but could not have been caused by the action of rivers, such as they now are. He does not admit that they are the result of local depressions, although this is the view taken of their origin by Prof. Studer. And the reason why they were not filled up by the gravel and other material washed down from the Alps during the glacial period was that they were covered by glaciers over which these materials as well as the Alpine boulders were carried, and which afterwards melted away, leaving the lake-basins in the same condition as they were in before.

Another important work on Swiss geology, published during the past year, is that of Prof. Heer of Zurich, entitled 'The Primeval World of Switzerland' ('Die Urwelt der Schweiz'). You will remember that in the year 1862 the Council awarded the balance of the proceeds of the Wollaston Fund to Prof. Heer to assist him

in his important investigations into the fossil botany of the Tertiary strata; and the work which I am now noticing will, I think, be a satisfactory proof of the correctness of the views of the Council in having thus appreciated the labours of the distinguished botanist of Zurich. I will endeavour as briefly as possible to give you some idea of the grand generalizations accompanying the graphic pictures by which he illustrates the geological phenomena of Switzerland. The first chapter commences with the following words:—“In the mountainous region of our country is represented the history of the earth. In the lofty cliffs and deep chasms, in the wonderfully contorted masses of rocks, and the manifold convolutions of mountain-chains are manifested the mighty revolutions which have affected the earth's surface; and in the numerous plants and animals, the remains of which are imbedded in these rocks, we see the periods of peaceable development.” This first chapter gives an account of the Carboniferous strata, the oldest stratified rocks in Switzerland, some of which belong to the Anthracitic period. The author then treats of its remarkable vegetation, a subject to which his botanical knowledge gives additional interest. He shows that, without an exception, the plants were all cryptogamous, the seeds or spores of which are so microscopically minute that they are easily wafted by the winds or other agencies from one country to another, developing themselves wherever favourable conditions of life occur. He thus accounts for the remarkable resemblance between the fossil flora of Europe and America during the Carboniferous period, assisted by those peculiar climatological conditions which then prevailed. The plants themselves lived on a moist and marshy soil; the earth was probably surrounded by a thick mass of clouds, since with the higher temperature of the ground there must have been more moisture in the air than now. The influence of the sun must consequently have been less, and the climate was chiefly regulated by the high temperature of the earth. The author then compares the flora of the Carboniferous period with that of the present day, which is mainly phanerogamous, and varies greatly in different regions, owing partly to the greater variations of climate, which is now more dependent on the local variations of the sun's power, and partly also to the fact that the seeds of these plants, being generally larger, are not so easily wafted from place to place.

In the account he gives of the history of coal, from the newest peat to the anthracite of Wales, he maintains its vegetable origin against a modern theory by which it is considered as a kind of petroleum collected in hollows and depressions. He believes that the real coal-formations have been formed *in situ* by the slow change of decayed vegetation, which, gradually losing the greater part of its oxygen and a small proportion of hydrogen, comes to consist at last in its anthracitic state of 94 per cent. of carbon.

He gives the following as the two extremes of its chemical composition:—

	Carbon.	Hydrogen.	Oxygen.
Woody fibre	52·65	5·25	42·10
Brown coal.....	66·41	5·46	28·13
Anthracite (Welsh) .	94·04	3·38	2·58

And after describing the mode of formation of the bed of clay or chalk which generally underlies a Carboniferous deposit, he shows that in those old periods the atmosphere must have contained a much larger proportion of carbonic acid gas than now, a favourable circumstance for the growth of plants, but injurious to that of air-breathing animals, and he suggests that by the deposit of the carbon in the earth, the air was purified and prepared for the growth of a higher class of animal life.

Although Switzerland itself is ill provided with coal, there is enough to show that even in these early days of our planet a continent must have existed towards the line of the Central Alps, and that it was clothed with vegetation. The rocks, however, which contain its remains have been so often disturbed by the convulsions which have repeatedly altered the appearance of the country, that they now form a portion of the loftiest mountains of Switzerland. They are in many places so caught-up and buried amidst younger rocks, that several distinguished geologists have been thereby deceived, and have attributed to them too recent a date.

Dr. Heer then endeavours to form some calculation as to the length of time during which the Coal-period lasted; and after calculating the average annual growth of peat-moors, and the thickness of peat necessary to form a given thickness of coal, he comes to the conclusion that a bed of coal 44 feet thick would have required 20,000 years for its formation. Probably, however, under more favourable circumstances the growth of the peat was more rapid than at present; at the same time, however, it must not be forgotten that, in calculating its age, the beds of sandstone, clay, and limestone which accompany the coal must also be considered, and these are of enormous thickness in some places. In Switzerland alone the carboniferous beds have occasionally a thickness of 6000 and 7000 feet. What an enormous period of comparative quiet they represent!

But this period of calm was at length disturbed by convulsions which introduced the Permian period, characterized in many parts of Germany by vast deposits of red sandstone, and in many places by outbursts of porphyritic and other igneous rocks. Prof. Heer also observes that this formation is remarkable for containing most of the copper which has been obtained both in Europe and in North America.

The second chapter is devoted to an account of the formation of salt-deposits in Switzerland, and to a description of the Triassic rocks, consisting of Bunter Sandstein, Muschelkalk, and Keuper. He alludes to the occurrence of the *Avicula-contorta* beds in some parts of Switzerland, and refers them to the upper beds of the Keuper, with which he thinks their fossils have the greatest analogy.

The third chapter is devoted to the Lias formation, and com-

mences with a detailed account of a peculiar and local series of Marl-beds on the left bank of the Reuss, near its junction with the Aare, to which the local name of Schambelen or Tschembelen has been given. It rests immediately on the Keuper dolomite, and is overlain by Gryphæa-limestone full of *Ammonites*, *Belemnites*, and *Gryphæa* (*G. obliqua*); its total thickness is about 35 feet, but it consists of twenty-one different beds, and, as Prof. Heer states, it forms a most important document respecting the organic nature of the country, and tells a wonderful episode in the earth's history.

After carefully describing the different fossil contents of each bed, in order to give a specimen of the manner in which the rocks of this country were gradually formed, and to show how their fossils tell their history, he states that the upper and lower marls, forming about 15 feet of the whole, are absolutely unfossiliferous; the six lowest beds are purely marine; land-insects appear in the seventh and ninth, but are most numerous in the eleventh; they then gradually diminish upwards, and are no more seen after the eighteenth, which, like the seventh, contains marine animals which had almost entirely disappeared since the deposition of the tenth bed.

From all these facts Dr. Heer concludes that these strata must have been deposited in a quiet arm of the sea, protected by a reef of rocks, or a long promontory, from the disturbing action of the waves. Thus only can we account for the excellent preservation of the remains of organic life which were quietly covered up by the deposit of silt. That dry land existed close by is proved by the abundance of land-insects, which are so well preserved that they could not have been drifted from a distance. They must also have been rapidly covered up, consequently the water which washed them down, probably a river, must have held much earthy matter in suspension. The commencement of these insect-remains in the seventh bed, and the total disappearance of marine life in the eleventh, combined with the fact of its reappearance in the thirteenth, shows that the earth was at first gradually rising, until at the time of the deposition of the eleventh bed the salt water was entirely excluded. At this period a change took place, the ground again began to sink, the sea burst in, the insect-remains become scarcer and scarcer, and the marine shells and other forms of life rapidly reappeared in the reversed order to that in which they had disappeared, and at last we find the same unfossiliferous marls. By the continued sinking of the ground, the mainland retired to such a distance that its productions no longer reached this spot; and at length the depth became so great that the conditions of life were no longer suitable to the existence of marine animals. The author concludes with a comparison of the marine portion of this series of beds with his observations on an analogous protected Gulf on the coast of Madeira which he had often visited.

Comparing the insect-forms of the Schambelen with those of the Lias in England, particularly between Charmouth and Lyme Regis, he shows that the sketch of organic life which he has here given is not purely local, but that it represents the natural state

of a great world-epoch, and that the same climatological conditions existed in England as in Switzerland.

The following chapter (fourth) gives us an equally interesting and graphic description of the great Jurassic sea, its depths and its shallows; the latter generally shown by the greater abundance of organic life, its coral-reefs and atolls, and the tortoise banks of Solothurn, &c. Dividing the Jurassic formation into the northern and the Alpine, the author points out that the former, from its greater abundance of fossil contents, was formed in a shallow sea full of coral reefs, while the latter, generally unfossiliferous, was deposited in a much deeper ocean; and he thus accounts for the constant difference in colour between these two formations. The brown colour of the limestone of the deeper sea is owing to the carbon probably derived from marine Algæ; and he calls in as illustrations the Sargasso region of the Atlantic, and a remark of Darwin's respecting the Keeling Atoll, that wherever masses of sea-weed had attached themselves to the Coral-limestone, the calcareous deposits, instead of being perfectly white, were invariably coloured by the vegetable matter mixed up with them.

The fifth chapter describes the Chalk, with its seas and continents, and their respective Flora and Fauna, all of which are laid before us in the same graphic manner as the earlier formations. The Eocene formations of Switzerland occupy the sixth chapter; amongst the oldest of them are the slates of Matt and other places in Canton Glarus, remarkable for fossil fish, of which fifty-three species are known, besides two of *Chelonia* and two of Birds. This also is shown to have been a deep-sea formation; the climate and all the fish are peculiar to this locality, and are probably of an older epoch than those of Monte Bolca. The Flysch formation is next described, with its granite boulders, the origin of which has not yet been ascertained; its fossil contents are confined to fucoids, a very remarkable fact; and this absence of organic life, except the fish of the Matt slates and the fucoids of the Flysch, renders it very difficult to determine whether these beds belong to the Upper Chalk or Lower Eocene, although the latter is most probable. The Flysch is shown to be in close connexion with the Nummulitic formation, which is found in the same district, and respecting the age of which there can be no doubt. It occurs on the Titlis and the Surenen Pass, and appears to form the summit of the Tödi; and both Studer and Escher von der Linth look upon it as older than the Flysch. To this Eocene period is also referred the Bohnerz formation, in which the remains of numerous Vertebrata have been found, one half of which belong to the Pachydermata.

The Molasse formation of Switzerland is described in the seventh chapter. This is divided by the author into five formations, representing the Lower, Middle, and Upper Miocene.

I. The Lower Miocene is chiefly a freshwater formation, consisting of, 1st, Tongrian, or marine molasse of Basle, Pruntrut, and Delsberg; 2nd, Lower Brown-coal formation and Red Molasse; 3rd, Grey Molasse.

II. The Middle Miocene is a marine deposit, divided into the Subalpine Molasse and the Muschel Sandstein.

III. The Upper Miocene is again freshwater, consisting of the Upper Brown-coal and the Eningen beds.

The various local changes produced by the different upheavals and subsidences of the land are carefully described; the courses of the different rivers of this old-world period, and the distribution of land and sea at different epochs, are also given; and it is shown that both the Alpine chain and the Jura, though in a very modified condition, existed as dry land at the time of the deposit of the marine beds of the Molasse.

But I can only hint at the contents of the following chapters. The eighth contains an account of the Flora, and the ninth of the Fauna of the Molasse. In the tenth chapter special Miocene localities, as Lausanne, Eningen, &c., are described. The Eningen deposit is most remarkable; it contains 475 species of plants, and 922 species of animals, of which 826 are insects. It is therefore highly probable that the vegetation of the surrounding country must have been rich and luxuriant, and that the climate, which is treated of in the next chapter (the eleventh), must have been subtropical, although not quite so warm as in the earlier periods of the Molasse formation, thereby indicating a gradual diminution of temperature.

The next chapter (twelfth) gives an account of the Slate-coal of Utznach and Dürnten. The fossil contents of the beds are entirely different from those of the Molasse. They greatly resemble those of the present day; and the great gap which intervenes between these two periods probably represents the Pliocene age.

The thirteenth chapter is devoted to an account of the Glacial period, the phenomena by which it was accompanied, the commencement and extent of the glaciers, their effects on the soil, and the long period during which they endured. This epoch is divided into two periods, and the interglacial epoch between them is supposed to represent the time when the schistose or slaty coal of Utznach was formed. I must pass over the interesting remarks respecting the flora of this period, and the effects which the glacial epoch had in modifying and destroying that subtropical flora which existed during the Miocene age, but which was replaced by the appearance of man on the earth towards the close of the diluvial period.

The next chapter (fourteenth) gives a brief retrospective view of the great changes which the earth's surface has undergone from the age of the metamorphic rocks to the present day, and of the different formations which have been successively deposited, and then broken up and overturned, modifying the general appearance of the country and giving it its present form.

The fifteenth and last chapter, which treats of the general considerations respecting the formation and modification of the country, is divided into two parts. The first refers to inorganic nature, the second to organic. The first part is again subdivided into the three following heads:—

I. Formation of mountains and valleys by elevation and subsidence of the land. Science has not yet come to any conclusion as to the causes which have led to these phenomena. The hypotheses which have been imagined to explain these mighty operations of nature are connected with the views respecting the formation and the original condition of the earth; and the contest which has been going on for 2000 years, whether fire or water has had the greatest share in it, is not yet decided. But the mode of operation is visible in a thousand ways; and the author proceeds to show how the endless variety of mountain-forms and valleys has been the result of the elevations and subsidences of the previously horizontally-bedded strata, influencing the surface-distribution of water as well as the contour of the land. He describes the various risings and sinkings of the land which have taken place in Switzerland, and which were generally of a very gradual character; but this remark does not apply to the last Pliocene elevation of the Alps.

II. By the effect of water. The streams which flow from the mountains received their first direction from the forms of the mountains themselves and the disturbed strike of the stratified rocks, although in the course of thousands of years they have deepened their beds and widened their channels. It would only occur to the wildest Neptunist to maintain that such gorges as the *Via Mala* and others have been excavated by the Rhine, &c., although undoubtedly these streams, flowing through original cracks and crevices, have gradually widened and deepened them. It is otherwise in the Molasse country, where the valleys and river-beds are generally the work of erosion. These began in the Pliocene period during the elevation of the Alps; and when afterwards the glaciers descended from the mountain-tops, they filled up the valleys and lake-basins with ice, and thus protected them from being filled up by the gravel and other materials which they brought down from the mountains.

III. Modification of the surface of the land by the climates of the different periods. Amongst other causes of a change of climate, Professor Heer again refers to the probability that during the Miocene period a great Atlantic continent extended from the western shores of Europe to the east coast of America, stretching, in the form of a promontory, from Iceland in the north to the Atlantic Islands in the south. Thus we can understand how the Tulip-tree existed in Ireland and in Switzerland, while many other phenomena both in the Flora and Fauna of the Miocene age are accounted for in the same way. But I must refer you to the work itself for the interesting observations contained in this chapter respecting the change in the configuration of the European continent and the surrounding region, which took place during the Pliocene age, and the diluvial period which followed it. These are becoming daily of more importance in connexion with those recent changes which accompanied man's first appearance, and led to the present configuration of the earth's surface.

The second part of this chapter refers to organic nature. The author shows that there are no sharply defined lines of separation

between the animal and vegetable creations of the different periods in the earth's history. They pass gradually into one another at the limits of each period, like the natural regions into which the mountains are divided when we wish to describe their natural products. At the same time we find everywhere a gradual approach to the forms and types of the present day. In the same way, as we look back to former ages of the world, we find forms more and more peculiar, and different from those of the present creation; but all stand in a certain relation to each other, they are constructed on the same plan. Looking at the various periods in which different forms of animal and vegetable life appear, the author says that we may consider the Primary period as that of the flowerless plants (Cryptogamia) and fish, the Secondary as that of Monocotyledons and Reptiles, the Tertiary as that of the Dicotyledonous and Mammalia, and adds, "We therefore perceive in the appearance of plants and animals in the different ages of the world a progressive law of development, from the lower and more simply constructed to the higher organized beings, and since the time when this course of development terminated in man, no new species has been introduced." But this does not imply that the earlier forms were not in themselves perfect. They were adapted to the then existing conditions of life, and as these became more varied and changed, new forms were gradually introduced while others died out. This dying-out of forms on the cessation of favourable conditions of life is simple and easy to be understood. Not so the law of the introduction of new forms. The author then considers the Darwinian theory, and points out where it is not in accordance with the facts which have been observed. He shows that there has been no gradual fusion of forms, but a transition by steps or jumps, a kind of recasting of the forms of life, within short periods of time. Of the way in which this takes place we can form no idea, but we must assume, in connexion with the great changes in the form of the earth after long periods of rest, that there were also certain periods of creation, in which the types of life were recast, as well as a first period in which a creation of species took place. I fear I have dwelt too long on this interesting work, and yet, in justice to its merits, I could not do less than indicate the contents as briefly as possible.

The second volume of M. d'Archiac's work, '*Cours de Paléontologie Stratigraphique*,' has been published at Paris during the past year. The first volume had given us the history of Stratigraphical Palæontology, and contained the whole literature of the subject, from the earliest period of antiquity down to the present time, as treated of in the different countries of Europe and America. The second volume refers rather to geological principles, and to that special knowledge which should precede the study of Palæontology, and the organic phenomena of the present day which are connected with it: subjects of great diversity, but all of which may elucidate and complete it, and help to explain the past by the knowledge of the present.

His principal attention, as he himself observes, has been directed to the physical condition of the globe, and to everything which in one way or another is connected with biological phenomena. These questions are often neglected by naturalists, who, devoting themselves too exclusively to the examination of species, lose sight of those external causes which even at the present time, either on the surface of the continents, or in the depths of seas and lakes, act directly on the functions and characters of organs, and consequently on those of the animals and vegetables themselves.

But, interesting as is the whole work, I think the two first chapters are particularly deserving our attention, but I can only briefly indicate the subjects of which they treat. The first chapter discusses the origin and development of organic beings, and their successive forms. The author shows that the organization of the most ancient forms with which we are acquainted, as preserved in the oldest sedimentary rocks, as well as those of the present day, entirely destroys the hypothesis that the more perfect forms were derived, by secular modifications, from preexisting and less-developed species. The succession of these forms indicates a constant progress and a uniform plan, which cannot be the mere result of chance; and whether we look at the great assemblages of forms in any given period, or the appearance and extinction of species in time, we must recognize a law which regulates their relative position, and maintains a certain equilibrium. And although we may never arrive at the perfect knowledge of the law which regulated the creation and the existence and final dying out of many forms, we can trace many of the physical changes in the conditions of life which have influenced the existence of organic beings. He then discusses the three principal kinds of causes which mainly influenced the conditions of life before the present epoch, namely, chemical, physical, and meteorological.

The second chapter is devoted to the discussion of the question of species. Varied are the opinions on this subject. It is the great stumbling-block of naturalists. M. d'Archiac endeavours to point out and to discuss the principal opinions which have been enunciated, the grounds by which they have been supported, and to justify those which appear to him most tenable. After giving the general views of the most distinguished naturalists on this subject, the author proceeds to discuss in more detail the works of Mr. Darwin and of M. Godron, particularly the former. This is done with great fairness, although he cannot adopt his conclusions; for M. d'Archiac declares himself a full believer in the immutability of species, and having declared himself against the doctrine of variability or transmutation of species, first brought forward, on scientific grounds, by Lamarck, he maintains that the balance of all observations proves that the idea of fixity of species is founded on the study of nature. This must be distinguished from their perpetuity. They die out and are succeeded by others; but we have yet to learn the laws which have regulated

the successive creations of organic life, according to the conditions in which they were to live.

The publication of various papers in the different scientific journals of Italy gives us the pleasing assurance that the progress of geological discovery in that interesting and classic land is satisfactory. I have already alluded to some of them, and additional evidence of this fact will be found in the publication of a new work by Major Crescenza Montagna, entitled 'Generazione della terra,' of which the first three *fasciculi* have already appeared. It combines what may be called both the elements and principles of geology, and is remarkable for sound and cautious views and great originality of thought on many of those subjects which now occupy the attention of geologists. As far as can be judged from the parts which have as yet appeared, it promises to be a valuable addition to Italian geological literature.

The civil war which has been so long raging in the United States has, no doubt, greatly interfered with the progress of geological investigation amongst our transatlantic fellow-workers; yet the pages of Silliman's Journal show us that they have not been altogether idle. I have also received information that Mr. Whitney has been very energetic in the survey of California, and has published the first part of his report, with some very good plates drawn on stone, in Philadelphia.

But the subject which, notwithstanding the importance of the war, appears to have chiefly engrossed public attention in some of the States is the discovery of Petroleum, and the rapid development of measures to obtain it from the oil-wells, and the daily increasing quantity obtained. The extent of country over which these oil-wells are now worked, and that to which they are supposed to reach, is enormous; the activity and enterprise they have called forth is almost incredible, and the quantities obtained verge upon the fabulous. The richest district now worked is Venango County and part of Crawford County, Pennsylvania; but it is supposed by some to extend from the southern portion of the Ohio Valley to Georgian Bay of Lake Huron in Upper Canada, and from the Alleghanies in Pennsylvania to the western limits of the bituminous coal-fields in the vicinity of the Missouri River.

With regard to the amount of enterprise developed, I will only mention, that independent of all private speculations, I find in one Number of the 'Philadelphia Coal-oil Circular,' a list of 483 companies, chiefly located in Philadelphia and New York, formed for the purpose of sinking oil-wells, and not half of which are yet in operation, while the produce already obtained is stated to exceed 10,000 barrels a day.

With reference to this subject, I may mention an interesting paper by Mr. Lesley in the 'Proceedings of the American Philosophical Society,' on a Petroleum vein in North-western Virginia. The substance, which is remarkably pure asphaltum, fills a crack several feet thick and of great extent, cutting through the rocks of the country almost at right angles to their stratification. It is sup-

posed to be hardened Petroleum, the solidification of which must have taken place at a very early geological period.

In the 'Bulletin' of the Geological Society of France (2nd ser. vol. xxi. p. 132) is an account of the geology of Nebraska, by M. Jules Marcou. His object was to connect his observations on Lake Superior with those which he had made on the banks of the Rio Grande del Norte. He describes the sections, seen to great advantage in the Bluffs, on the banks of the Upper Missouri, and particularly in the neighbourhood of Nebraska city. The base of the section consists of red arenaceous marls, sometimes micaceous and slightly schistose, becoming green in the upper part, and containing thin plates of red sandstone, and nodules of marly limestone containing fine specimens of a *Productus* allied to *P. Cancrini*, but larger. These are overlain by cream-coloured and slightly dolomitic limestones, with many stems of Encrinites, alternating with bands of black clay containing thin seams of coal. The only other fossils in this division are a new species of *Spirifer* and a new *Allorisma*. The next division (C) is 34 feet in thickness, and very fossiliferous. In the lower portion a new *Productus* is very abundant, also a small *Spirifer*, and a *Terebratula* allied to *T. subtilita*. Above this is a bed of mottled plastic clay, containing a vast abundance of fossils, perfectly preserved, and of a delicacy rather resembling that of Tertiary fossils than of those of the age of the New Red Sandstone. Most of these are new, and belong to the genera *Edmondia*, *Aucella*, *Avicula*, *Leda*, *Myalina*, *Monotis*, *Bakewellia*, *Pecten*, *Lima*, *Apiocrinites*, *Stenopora*, and *Synocladia*. There are also two species of Brachiopods, very abundant, one of which appears to be identical with *Spirifer Clannyanus*, King, and the other with *Chonetes mucronata*, Meek. Other fossils also occur rather higher up. The whole assemblage is considered by M. Marcou as resembling the Dyassic fauna of Saxony, and he considers the beds of Nebraska city as belonging to, and representing in America, the upper portion of the Dyas of Europe.

Another locality, rich in these same fossils, is the immediate neighbourhood of a town called Plattesmouth, near where the river Platte falls into the Missouri, twenty-five miles to the north of Nebraska city. The beds are all different from those of Nebraska city, and belong to the lower portion of the Dyas. The fauna of these lower beds, although eminently a New Red Sandstone fauna, nevertheless resembles that of the Carboniferous beds which lie below, and are considered by M. Marcou as a marine equivalent of the Rothliegende of Germany and Russia. Five miles off, near Bellevue, the Carboniferous Limestone is brought up, having a slightly different dip and inclination, namely, 6° to the west instead of about 4° to the south-west. This Dyas formation is described as lapping round the masses of Carboniferous Limestone, which probably existed as islands or reefs in the Dyassic sea.

After describing other localities where he found a fauna in the Carboniferous series identical with that which he had found in the Mountain-limestone rocks of Pecos and Tigras, and on the top of

Rocky Mountain, near Albuquerque, in New Mexico, he describes the Cretaceous beds which he found higher up the right bank of the Missouri, at De Soto and Cuming City. There is here a remarkable hill, called Pilgrim's Hill, deserving particular attention. It is not above 100 feet high. The base consists of blue clays 30 or 40 feet thick, overlain by 30 or 40 feet of sandstone, partly friable, partly compact. M. Marcou says, "In the clays I found no fossils; but in the sandstone there is a rich and well-preserved flora of plants which are almost all dicotyledonous, as laurels, poplar, sassafras, walnut, oak, willow, tulip-tree, &c., a flora which M. Heer considers Miocene, and which, in fact, appears to be rather Upper Miocene or even Pliocene than Lower Tertiary. And yet this flora is not even Tertiary, but Upper Cretaceous." M. Marcou cannot adopt the views of M. Heer, because he found on the banks of the Big Sioux River beds of chalk containing *Inoceramus problematicus* and *Ostrea congesta*, &c. overlying the rocks with the dicotyledonous leaves, without indication of faults or disturbances of any kind. Moreover, on the summit of Pilgrim's Hill he found the *Inoceramus problematicus* in great abundance; and in the leaf-bed below a great quantity of a freshwater bivalve, *Cyrena Nova-Mexicana*, Marcou, which he had already found in New Mexico; and he subsequently recognized the whole Cretaceous series which he had formerly seen in the neighbourhood of Galisteo; from which he concludes that this freshwater formation and the *Inoceramus*-beds of Nebraska are of the same age as, and in fact the prolongation of, the formation of White Chalk of the neighbourhood of Galisteo.

From these observations he concludes that the laws and rules of Palæophytology hitherto adopted must be greatly modified, since we here find a flora considered as Miocene in Europe at the bottom of the Chalk. It is hardly necessary to remind you that, notwithstanding the extent to which Prof. Heer has availed himself of the fossil floras to assist him in his determination of geological periods, it has long been the opinion of many distinguished geologists that evidences derived from a fossil flora are not so certain or so trustworthy as those derived from a fossil fauna.

The Geological Survey of India under Prof. Oldham has also progressed during the past year, and I have now before me two works, forming the 2nd part of vol. iii. and the 2nd part of vol. iv. of the 'Memoirs,' in which much interesting information is given. The first of these publications gives an account of the geological structure and relations of the southern portion of the Himalayan ranges between the rivers Ganges and Ravee, by H. B. Medlicott, F.G.S. The subjects treated of in this memoir are, first, a general description of the area and the rocks, referring principally to the Eastern Himalaya, essentially the Snowy Mountains of Hindostan. They present as a whole three well-marked regions: 1. the range of peaks; 2. a broad band of hills commonly spoken of as the Lower or Outer Himalaya; and 3. to the South, a narrow fringing band of much lower hills, for which the name of Sub-Himalaya is appro-

priate, and of which the Siwâlik Hills are the type. The Himalaya or peak-range consists of metamorphic and unmetamorphic rocks, while to the westward of the Beas River there is no equivalent of the Lower Himalayan region. The Sub-Himalayan series is divided into the Subathu group, containing Nummulites, therefore probably Eocene, and the Nahun and Siwalik groups, which may be Miocene, although these terms are not used by the author. The memoir concludes with a description of the post-Siwalik or Gangetic formation, which is most distinctly separated from that of the Siwalik Hills, without any approach to shading off or passing from one into the other.

The second memoir to which I have alluded, is on the geological structure of parts of the districts of Salem, Trichinopoly, Tanjore, and South Arcot in the Madras Presidency (being the area included in Sheet 79 of the Indian Atlas, by Messrs. King and Foote of the Geological Survey of India). One of the most remarkable features in this district are the beds of magnetic iron-ore which occur amidst the metamorphic gneiss-rocks, and the supply of which seems to be practically inexhaustible. They are, moreover, of great interest and value to the geologist, as they, more than any of the other strata, enable him to decipher the great contortions and flexures which have tended in great measure to produce the existing form of the surface in these regions.

Two classes of rocks, of igneous or quasi-igneous origin, are also represented in this region, namely, trap-rocks and granites. The latter is principally developed in the Trichinopoly district, where it forms a band of considerable extent, and from four to six miles wide, apparently intruded between the planes of bedding of the gneiss. But there appear to have been, at least, three periods of intrusion of granite into the rocks which now constitute the gneissic series, two of which are probably much older than the third.

The superficial deposits and soils are next described, consisting of Laterite, Cotton soil, and Kunkur. With the exception of a few fossils, as a cast of a *Terebratula*, a species of *Lithophagus*, a Coral, and a *Cidaris*, found in the Cuddalore Sandstones, which are considered to be post-cretaceous, fossils do not appear to be abundant in this district. The laterite is generally found on the top of the grit series. It is a brown ferruginous deposit, and occurs in two forms in the district, as a regular aqueous deposit of great extent, or as the effects of decomposition *in situ* of highly ferruginous rocks. In the latter form it is called Lithomarge, and it is essentially a decomposed gneiss *in situ*. The true laterite consists of an agglomeration of small rounded particles cemented together by a ferruginous sandy clay, the nodules consisting of the same ferruginous sandy clay, with a concretionary structure. The Kunkur is a greyish-white calcareous deposit, similar in structure to the laterite, and occurring as little grains or concretions. It is also either the result of deposition from water, or of the decomposition of rocks *in situ*.

The general results of the Novara Expedition, undertaken by

the Austrian Government, have been for some time before the public. We have now before us two specific works on the geology of New Zealand which deserve notice, as well as a geological and topographical atlas of New Zealand, prepared by Dr. F. Hochstetter and Dr. Petermann. As, however, we may hope to receive shortly the results of the Geological Survey of New Zealand, which has been undertaken by our own Government, and as the collections made by Dr. Hochstetter during his comparatively short residence on the island were necessarily imperfect, I shall only briefly allude to them at present.

The first of these memoirs is by Dr. C. Zittel on the Fossil Mollusks and Echinoderms of New Zealand. The oldest fossiliferous beds which occur in New Zealand are referred to the Trias, on account of the great preponderance of two characteristic shells, *Monotis salinaria* and *Halobia Lommeli*. There is, however, some slight evidence of the occurrence of Palæozoic forms, as *Spinigera undata*, Defr., of the Spirifer Sandstone; these occur in the southern (middle) Island in the neighbourhood of Nelson.

On the west coast of the northern island are dark-coloured calcareous marls containing numerous Belemnites and a few Ammonites. It is difficult to assign its exact position to this formation. The Belemnites would lead to the inference that its proper place was Jurassic, whereas the Ammonites and a large *Inoceramus* show a greater resemblance with Cretaceous forms.

The Tertiary formations which occur in various localities are referred to two periods. 1. The older formation. With the exception of *Waldheimia lenticularis*, Desh., this formation contains no species now living in the neighbourhood, indeed they belong almost exclusively to extinct species. A list of the localities where it occurs is also given. 2. The younger formation. This shows a very remarkable contrast to the former, and is closely connected with the molluscan Fauna of the present day. These beds appear to have been deposited during, and to belong to, a period in which climate and the conditions of life, as well as the geographical distribution of animals, were generally the same as at present.

Full descriptions of the fossils are then given, accompanied by ten plates of illustrations.

The second work contains an account of the Foraminifera of the Tertiary green sandstone of Orakei Bay near Auckland, by Felix Karrer, with one plate of illustrations. The general conclusion at which the author arrives is, that as *Globigerina*, *Miliolidea*, and *Rhabdoidea*, inhabitants of deep water, are on the one hand almost entirely wanting, and *Rotalia* and *Amphistegina* found at a moderate depth are the prevailing forms, the deposit must have been formed at no great depth; and as Bryozoa are also very rare, he refers it to the lowest portion of the Amphistegina-zone. Of the twenty-one species here described, the majority are new.

The Atlas, which is preceded by an explanatory notice by Dr. Petermann on the progress of the cartographical knowledge of New Zealand, consists of six maps. Dr. Hochstetter adds a special

description of each of these maps, with an account of the geological features which they represent.

In the eighth volume of the 'Bulletin de la Société Linnéenne de Normandie' is an account of some of the geological features of New Caledonia, which has been more or less explored since its occupation by the French. M. Eugène Deslongchamps, having collected all the information he could obtain from various sources, concludes with the following remarks:—"The little we yet know of the geology of our colony proves, by the variety of old metamorphic rocks (granite, porphyry, diorite, serpentine, &c.), that the soil is of very ancient origin, and that it was long ago raised above the surface of the ocean; the Silurian, Carboniferous, and Triassic rocks, which are now well known to exist there, also confirm this statement, and lead to the inference that we now only see, as it were, the backbone of a region formerly much more extended, represented by its most elevated ridges. The Loyalty Islands, arranged in a line parallel to the axis of New Caledonia, probably represent the tops of a Secondary and less elevated mountain-chain. Cretaceous or Tertiary deposits have not yet been noticed. If they do not exist in this region, it would confirm this view, and prove that the land has sunk since the Jurassic period, and that the deposits of the shores of those periods are now under water. In that case New Caledonia would represent the ruins of a more extensive region which preceded the appearance of man on our planet."

M. Deslongchamps also calls attention to the fact that the rocks collected from the neighbouring Isle of Hugon show the great analogy existing between the formations of this island and those of the other great Australian regions, as New Zealand and New Holland, where the same Triassic rocks have also been recently noticed. In describing these specimens, he particularly alludes to those from the Isle of Hugon, amongst which is a limestone full of a small bivalve which cannot be distinguished from the *Avicula salinaria*, Goldf., and particularly var. *Richmondiana*, Zittel. This analogy with the rocks of the Upper Trias of the Alps at Dorrenberg, where the *Avicula salinaria* occurs by thousands, induces the author to look upon the limestone of the Isle of Hugon as belonging to the upper series of the Trias, but, as M. Zittel remarks, with an antipodial character. Other fossils are also described, and figures are given of some of the most remarkable forms.

In conclusion, it only remains for me, while thanking you for the attention with which you have listened to me, to request your forbearance for the crude and somewhat disconnected form in which these observations have been made. I am aware that I have omitted many subjects, and have neglected reference to many works which ought to have been noticed, whilst, on the other hand, I may perhaps have introduced much which, to some of you, may appear unnecessary. I will not attempt to justify what I have done, but will only ask you to believe that I have endeavoured to do my best.

THE
QUARTERLY JOURNAL
OF
THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS
OF
THE GEOLOGICAL SOCIETY.

NOVEMBER 9, 1864.

Frederick Braby, Esq., 28 Osnaburgh Street, Regent's Park, was elected a Fellow.

The following communications were read:—

1. *A Notice of the GEOLOGY of JAMAICA, especially with reference to the DISTRICT of CLARENDON; with DESCRIPTIONS of the CRETACEOUS, EOCENE, and MIOCENE CORALS of the ISLANDS.* By P. MARTIN DUNCAN, M.B. (Lond.), Sec. G.S., and G. P. WALL, Esq., F.G.S., late of the Geological Survey of the West Indies.

[PLATES I. & II.]

CONTENTS.

1. Introduction.
2. Notice of the Relations of the Jamaican Strata.
3. List of the Species of Corals.
4. Description of the Species.
5. General remarks on the affinities of the Species, and on the Correlation of the Cretaceous, Eocene, and Miocene strata of Jamaica with those of Europe.

1. *Introduction.*

THE Corals from Jamaica hitherto described came from the inclined white limestones, and from the shales and sands subordinate to them; their Mid-tertiary age has been demonstrated, together with that of the Shells and *Foraminifera*; and the general succession of the Ter-

tiary strata has been brought several times before the Society*. All the Corals, moreover, which have been described from the other islands of the Caribbean Sea were derived from strata of a Miocene age. But this communication refers to the Cretaceous and Eocene as well as to the Miocene fauna of Jamaica, and it offers the first palæontological proofs of the existence of the Eocene formation in the West Indian Islands†.

To do justice to those engaged in the geological survey of Jamaica, it is necessary to bear in mind that there is no good map of the island, no perfect trigonometrical survey, that dense vegetation covers everything, and that the physical difficulties are very great. Hence it has arisen that the geology of the island is still in its infancy. The general features of the country have been determined, and the relations of the series of formations also, but their palæontology has not been much studied.

After the publication of Sir H. De la Beche's memoir on Jamaica, little was done for many years in the geology of the island, and the first important communication on it was a diagram of the succession of the strata, which was drawn by the late Mr. Barrett, and which introduced to notice the Cretaceous rocks with their Hippurites, an *Acteonella*, a *Nerinea*, and an *Orbitoides*. The age of the Cretaceous rocks was suggested by Mr. Barrett, and was confirmed by Dr. S. P. Woodward by the discovery of a shell resembling *Acteonella levis*, D'Orb., and by his admirable paper on the nature of the *Barrettia monilifera*, Woodw.; that of the Plant-bearing dark shales above the Hippurite rocks was, from stratigraphical reasons, asserted to be Eocene by Mr. Barrett, whose determination of the Miocene age of the coralliferous sands and shales at the base of the great inclined limestone was proved to be correct by those who examined the fossils. The great disturbance of all the strata, the existence of porphyries beneath the sedimentary rocks, and the association of cupriferous granite with the Tertiary strata have been determined by the survey and noticed in the Quarterly Journal of this Society‡.

2. Notice of the Relations of the Jamaican Strata.

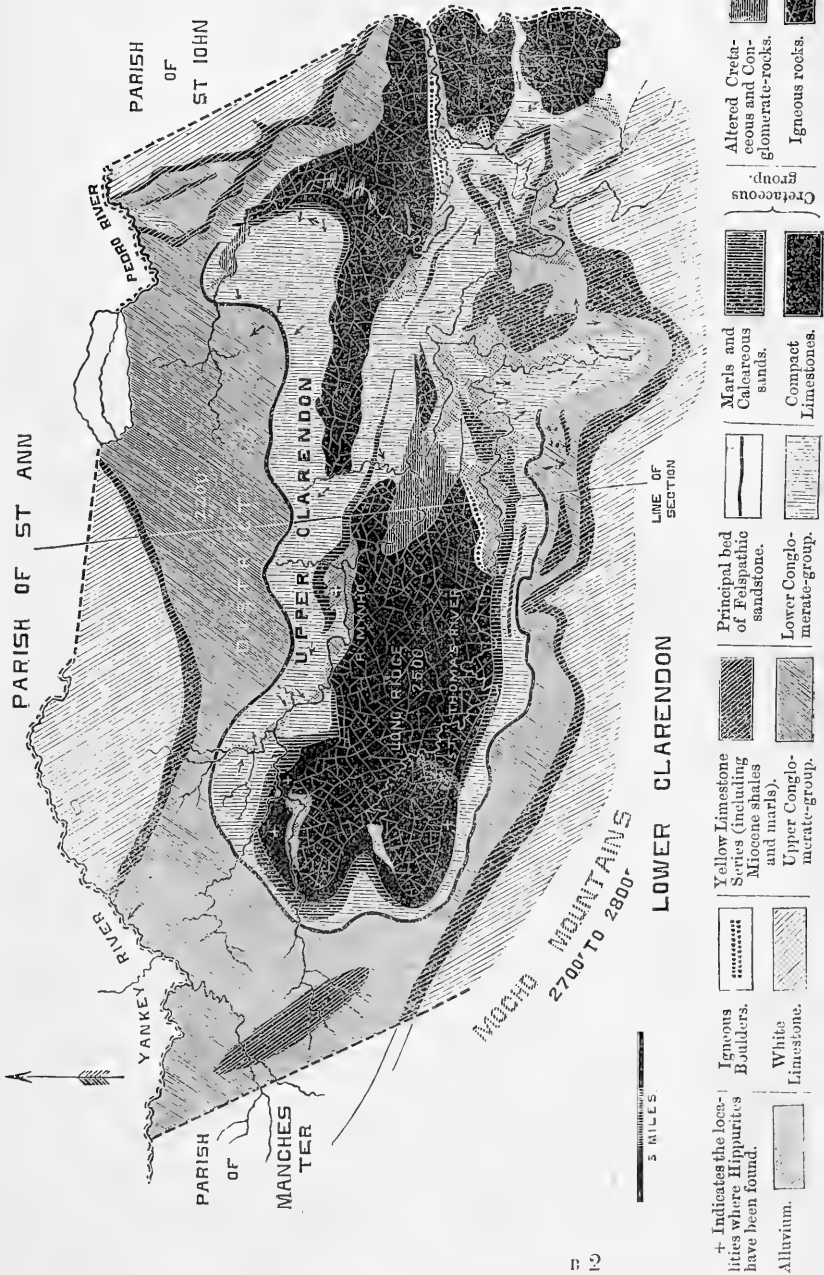
The original surface of Jamaica appears to have been composed of crystalline schists; but they have long since disappeared, and the only traces of such rocks hitherto observed consist of fragments of mica-schist and gneiss, associated with masses of granite, in some of the conglomerates in the neighbourhood of Port Maria.

* J. C. Moore, Quart. Journ. Geol. Soc. vol. xix. p. 510. T. R. Jones, Quart. Journ. Geol. Soc. vol. xix. p. 515. L. Barrett, Quart. Journ. Geol. Soc. vol. xvi. p. 324. P. M. Duncan, Quart. Journ. Geol. Soc. vol. xix. pp. 406, 513; vol. xx. pp. 20, 358. See also S. P. Woodward, 'Geologist' for 1863, p. 372.

† The fossils about to be described by me were collected by Mr. Wall; and the following notice of the general relations of the Cretaceous, Eocene, and Miocene strata is the result of our correspondence. Mr. Wall has furnished the sections and the Map of Clarendon.—P. M. D.

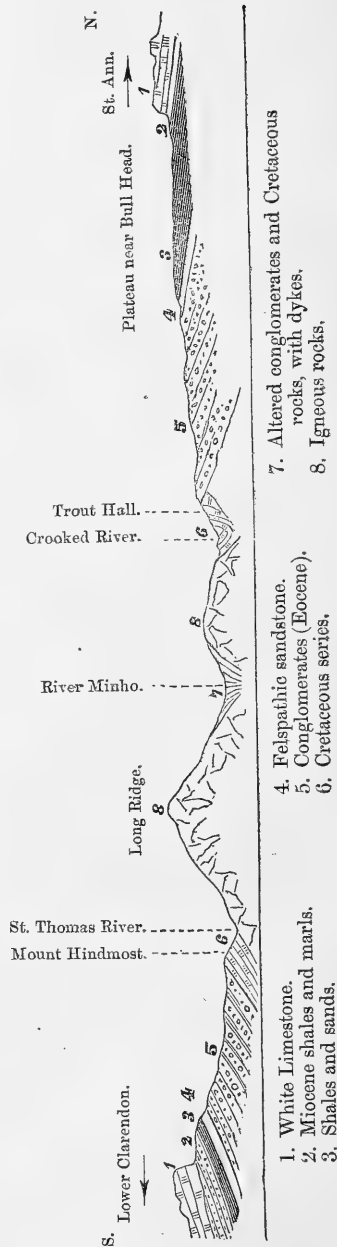
‡ J. G. Sawkins, Quart. Journ. Geol. Soc. vol. xix. p. 35. Prof. Owen has described a fossil Mammal from the inclined limestone (Quart. Journ. Geol. Soc. vol. xi. pp. 532, 541).

Fig. 1.—Geological Sketch-map of the District of Upper Clarendon, Jamaica.



In the Blue Mountain district, where the hills rise to about 7350 feet, and present a most broken surface, the strata are so excessively disturbed, so traversed and semi-metamorphosed by dykes of syenite, and mixed up with porphyritic masses, that it is impossible to resolve the intricacies of the stratification, or to determine the sequence of the beds *inter se*, without a lengthened and detailed investigation. But in the parish of Clarendon it is manifest that igneous rocks, presenting many interesting phases, but all appertaining to the porphyritic type, form the base of the stratified series. On such rocks the Cretaceous beds are deposited, and are often found raised to an angle of from 40° to 50° . The lowest member of the Cretaceous series frequently consists of a thin bed of conglomerate formed of the harder materials of the porphyries. It is succeeded by massive compact limestones enclosing fossils of the Hippurite family (*Barrettia monilifera*, Woodw.), so solidly imbedded as to prohibit simple extraction. The limestones are succeeded by marls and calcareous sandstones, from which most of the Hippurites, Corals, *Orbitoides*, *Acteonella*, &c., have been obtained. The Hippurites are the only abundant organic remains. It is uncertain whether these strata should form a single series, or be divided into an inferior and superior group. Their combined thickness may amount to 500 or 800 feet. Extensive disturbances have almost invariably broken up

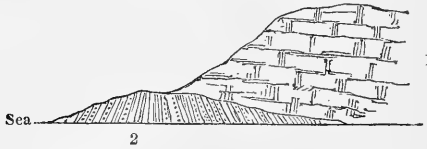
Fig. 2.—Section through Upper Clarendon, Jamaica.



the Cretaceous beds previous to the

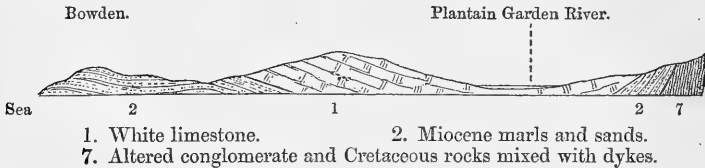
fossils distinguish this series, and the Shells, Foraminifera, and Corals have been already in part described*.

Fig. 4.—Section on the coast of Vere.



1. White limestone.
2. Miocene shales, sands, and marls, highly disturbed.

Fig. 5.—Section from Bowden to the Blue Mountain Region, near Bath.



1. White limestone.
2. Miocene marls and sands.
7. Altered conglomerate and Cretaceous rocks mixed with dykes.

The beds of Bowden, Vere, and Upper Clarendon, whence the Corals about to be described were derived, are included in this formation. Although less disturbed than the preceding Cretaceous and Eocene groups, still the Miocene strata have not escaped the great movements which have affected the island. Thus this fossiliferous group may be observed on the coast of Vere in a vertical position, with the white limestone resting almost horizontally upon it. A thickness of less than from 500 to 600 feet can scarcely be attributed to this series. The White Limestone (a great succession of beds, or rather masses, of friable, compact or semicrystalline limestone) covers by far the greater part of Jamaica; it is at least 2000 feet thick, and is in some places highly inclined, in others horizontal, in some conformable to the sands and marls, in others not so, whilst frequently it rests on a base of igneous rock, without the intervening Cretaceous, Conglomerate, and Lower Miocene strata. The White Limestone contains but few fossils, and these are often in the state of casts. It would appear that, after the emission of great masses of porphyry, beds of the Hippurite-cretaceous age were formed, elevated, and broken up, and often metamorphosed by contact with dykes of syenite †. During the latter period great masses of conglomerate were

* J. C. Moore, P. M. Duncan, and T. R. Jones, *Quart. Journ. Geol. Soc.* vol. xix. p. 510.

† As regards the influence of the proximity of igneous dykes and masses upon the stratified rock, it is to be observed that it is at first to obliterate or confuse the evidence of their sedimentary or detrital origin, and eventually to induce a more or less crystalline texture. Thus in many rocks which were originally conglomerates, the distinction between the matrix and the included boulders has quite disappeared, a homogeneous texture being presented resembling a fine-grained porphyry, or even certain varieties of trachyte. The calcareous rocks are

in course of formation from the fragments of the pre-existing rocks; shales and sands, with few organic remains, were deposited on the conglomerate, which in its turn was subject to disturbance and metamorphism. The violence of these phenomena appears to have subsided when the Miocene sands and shales were deposited, nevertheless they are represented in the occasionally vertical condition of the strata. The great White Limestone suffered from granitic intrusions, and from the final series of movements which affected the whole of the sedimentary rocks and gave the island its present outline.

3. List of the Species.

I. LOWER CRETACEOUS.

- | | |
|---|--|
| 1. <i>Diploria crassolamellosa</i> , Edwards & Haime. | 3. <i>Heliastrea cyathiformis</i> , spec. nov. |
| 2. <i>Heliastrea exsculpta</i> , Reuss, sp. | 4. <i>Cyathoseris Haidingeri</i> , Reuss. |
| | 5. <i>Porites Reussiana</i> , spec. nov. |

II. EOCENE.

- | | |
|---|---|
| 6. <i>Paracyathus</i> , sp. | 9. <i>Stylocænia emarciata</i> , var., Lamarck, sp. |
| 7. <i>Stylophora contorta</i> , Leymerie, sp. | |
| 8. ———, var. nov. | |

III. MIOCENE.

- | | |
|---|--|
| 10. <i>Flabellum exaratum</i> , spec. nov. | 14. <i>Thysanus elegans</i> , spec. nov. |
| 11. <i>Placotrochus costatus</i> , spec. nov. | 15. <i>Stylophora granulata</i> , spec. nov. |
| 12. <i>Placocyathus Moorei</i> , spec. nov. | 16. <i>Antillia Walli</i> , spec. nov. |
| 13. <i>Trochocyathus obesus</i> , Michelin, sp. | 17. <i>Siderastrea crenulata</i> , var., Blainville, sp. |

The following species have been already described from the Miocene strata, but are mentioned to complete the fauna as at present known* :—

- | | |
|---|--|
| 18. <i>Placocyathus Barretti</i> , Dunc. | 24. <i>Cyphastræa costata</i> , Dunc. |
| 19. <i>Placotrochus alveolus</i> , Dunc. | 25. <i>Antillia ponderosa</i> , Edwards & Haime, sp. |
| 20. <i>Trochocyathus profundus</i> , Dunc. | 26. <i>Alveopora Dædalæa</i> , var. <i>regularis</i> , Blainville, sp. |
| 21. <i>Thysanus excentricus</i> , Dunc. | 27. <i>Trochocyathus abnormalis</i> , Dunc. (doubtful). |
| 22. <i>Astrocænia decaphylla</i> , Edwards & Haime. | |
| 23. <i>Siderastrea grandis</i> , Dunc. | |

4. Descriptions and Notices of the Species.

1. *DIPLORIA CRASSOLAMELLOSA*, Edwards & Haime.

Localities: Trout Hall and Upper Clarendon, Jamaica; Gosau, Europe.

usually much silicified, and in some instances a considerable extent of serpentine is developed, which almost invariably retains some evidences of stratification.

A true foliated schistose structure is never presented; but there are some instances of shales and calcareous slates which, when near the eruptive centre, manifest a tendency to the arrangement of separate minerals in parallel layers; but in the most advanced degree it only amounts to an incipient stage of that foliated condition characterizing true crystalline schists, such as mica-slate and gneiss.

* P. M. Duncan, *op. cit.*

2. *HELIASTRÆA EXSCULPTA*, Reuss.

Localities: Mount Hindmost, Trout Hall, and Cupuis, Jamaica; Gosau and St. Wolfgang, Europe.

3. *HELIASTRÆA CYATHIFORMIS*, spec. nov. Pl. I: fig. 1 *a*, 1 *b*.

The corallum is cyathiform, and flat on the upper surface. The calices, which are small and often placed in regular lines, cover all the surface; they are distant, have shallow fossæ, and are slightly prominent. The septa are small, consisting of three cycles in six systems; the primary have a paliform tooth, and are larger than the secondary, whilst the tertiary are very small. The columella is small and papillary. The costæ are subequal, frequently long, and often touch those of other calices; they are occasionally flexuous, and generally granular in the intercalicular spaces. Intercalicular spaces large, and covered by large granules. Diameter of calices from $\frac{1}{12}$ to $\frac{1}{10}$ inch.

Locality: Trout Hall, Jamaica.

4. *CYATHOSERIS HADINGERI*, Reuss.

Localities: Upper Clarendon district, Jamaica; Gosau, Europe.

5. *PORITES REUSSIANA*, spec. nov. Pl. I. fig. 2.

The corallum is in more or less cylindrical branches, which leave the stem at an acute angle, and are often flattened and always rugged and gibbous. The calices are large, irregular in size, and shallow. The columella is small, and there are sometimes more than the six distinct pali. The septa are from eight to twenty-four in number. Diameter of calices often $\frac{1}{10}$ inch; that of the branches from $\frac{6}{10}$ to $\frac{3}{10}$ inch.

Locality: Upper Clarendon district, Jamaica.

6. *PARACYATHUS*, sp.

The specimens are fragmentary, but appear to belong to *P. caryophyllus*, Lamarck, sp., of Sheppey and Bracklesham. Yallahs Valley Black Shale, Jamaica.

7. *STYLOPHORA CONTORTA*, Leymerie, sp.

A common coral in the Black Shale of Port Maria, Jamaica. It also occurs at La Palarea and in Sinde.

8. *STYLOPHORA CONTORTA*, var.

A variety with thick septa is found at Port Maria.

9. *STYLOCENIA EMARCIATA*, Lamarck, sp.

The specimen has a greater resemblance to those from Sinde than from elsewhere. Localities: Bracklesham, Paris Basin, La Palarea, Sinde, and Port Maria, Jamaica.

10. *FLABELLUM EXARATUM*, spec. nov. Pl. I. fig. 3.

The coral is simple, flabelliform, slightly curved in the plane of

the major axis, much compressed, and has the remains of a flat and curved pedicel, which does not present any traces of former adherence. The calicular margin is long, compressed centrally, and expanded at the ends; its long axis is on a much lower plane than the short. The lateral costæ are not more prominent than the others, which are all delicately lamellar and projecting near the calice. The intercostal spaces are wide and distinct. The costæ radiate from the pedicel, many being formed low down by a single series of papillæ, but higher up by laminae which are finely granular laterally, and bluntly dentate on the free margin; some costæ extend halfway down, others one quarter, and those which correspond to the highest orders of septa a very short distance from the calicular margin. The angle formed by the sides at the pedicel is about 118° . The septa are numerous, crowded, unequal, slightly exsert, larger at the wall than elsewhere, generally straight, but often bent, and on the whole delicate. There are six cycles in six systems, a few of the higher orders being deficient. The laminae are faintly granular, and extend deeply into the coral, bounding a very deep fossula. The columella exists in some parts in a very rudimentary condition, and is formed by trabeculae from the septal ends. The wall is stout. There is a trace of epitheca close to the pedicel, but otherwise it is wanting. Length of the calice $2\frac{4}{10}$ inches. Height of the coral $1\frac{4}{10}$ inch; greatest width $1\frac{1}{10}$ inch. Depth of fossa $\frac{7}{10}$ inch.

Locality: Miocene of Vere, Jamaica.

11. *PLACOTROCHUS COSTATUS*, spec. nov. Pl. I. fig. 4a, 4b.

The coral is short, pedicellate, compressed, conical, and deltoid; it is longer than broad, and has a very open and large calice. The calice is in the shape of a long ellipse; its margins are slightly everted and not quite straight; its long axis is on a lower plane than the short; and it has a wide shallow fossa, with a deep and narrow fossula. The costæ are very marked structures in the upper two-thirds of the coral, and less so in the lower third. The largest are subcrestiform, with an irregular and wavy edge, which is faintly dentate near the calice; lower down the costæ are more granular and less prominent, being not at all so on the pedicel. The sides of the lamellæ of the costæ are granular. The smallest costæ are very rudimentary, and extend but a short distance. The costæ, as they radiate from the pedicel, are granular, then linear, and subcrestiform near the calice; one lateral crest is more prominent than the others. The pedicel is small, and presents a trace of former adherence. The septa are numerous, delicate, granular, and extend to and bound the fossula; they are in six systems of five cycles, and one large septum is followed by a set of three smaller, of which two are rudimentary, and the central less than the first of the series. The columella is long, linear, and lamellar. Epitheca very scanty, and only existing near the pedicel. Length of the coral $1\frac{1}{10}$ inch; height $\frac{7}{10}$ inch; breadth of calice $\frac{5}{10}$ inch. In young specimens the costæ are beautifully granular.

Locality: Bowden, Jamaica.

12. *PLACOCYATHUS MOOREI*, spec. nov. Pl. II. fig. 1 *a-c*.

The coral is short, very much compressed, and narrow; it has a short and flat pedicel, and sides which rapidly expand laterally. The calice is long, narrow, shallow on an even plane, and its margins are not everted, but are slightly sinuous. The fossula is narrow and deep. The costæ are delicate, very distinct when uncovered by epitheca, and are parallel near the calice; they then curve either towards the lateral costæ or to the pedicel. The larger costæ are slightly prominent near the calice, where they are not granular; but as they become covered by epitheca they lose their lamellar character and become a series of granules; near the pedicel they again become lamellar. The smaller costæ are granular near the calice, and are generally recognized as lines of simple granules, lamellar here and there. The external and lateral costæ are granular, and generally the larger costæ are succeeded by a smaller. The septa are numerous, unequal, delicate, granular, exsert, rounded above, and crenulate, straight at the inner margin, where they bound the fossula. The pali are large, thin, tall, and rounded, and are attached to the small septa, which are placed between the smallest. The columella is very long, thin, lamellar, and sharp superiorly; it is ridged laterally for the attachment of the septa and pali. The epitheca is well developed, pellicular, and reaches high up, to $\frac{2}{10}$ or $\frac{3}{10}$ inch from the calicular margin. Height of coral $1\frac{2}{10}$ inch; length $4\frac{2}{10}$ inch; breadth $\frac{7}{10}$ inch. There are 24 septa in $\frac{1}{2}$ inch.

Locality: Bowden, Jamaica.

13. *TROCHOCYATHUS OBESUS*, Michelin, sp.

A small specimen of this well-known form is in a collection from a Pteropod-marl on Navy Island, off Port Antonio, sent to England by the late Mr. Barrett. It is identical with the species drawn by Michelin. European locality, Tortona.

14. *THYSANUS ELEGANS*, spec. nov. Pl. II. fig. 2 *a, 2 b*.

This coral resembles *T. excentricus*, nobis, in form; but its costæ are equal and more decidedly dentate, the septa are finely toothed inferiorly, and every other one has a blunt, thick, granular, and prominent paliform tooth. Locality: Bowden, Jamaica.

15. *STYLOPHORA GRANULATA*, spec. nov. Pl. II. fig. 3.

The corallum is ramose; the branches are nearly cylindrical, often flattened on one side, and leave the stem at an acute angle. The calices are placed irregularly, and are separated by a cœnenchyma, which is sharply granular, and which has very rarely any grooves or continuous ridges on its surface. The calices are circular, not inclined, very deep, and are surrounded by a raised ring formed by the septa and costæ. The columella is situated deeply; it is cylindrical below, and sharp where free, but it does not reach the level of the calicular margin; it is delicate, and six large septa are attached to it low down. The septa are in two sets. The superficial septa are

from eighteen to twenty in number; six are continuous with the large septa, and the rest taper finely internally and externally, the spindle-shaped process being one-half septum and the rest costa. The processes are close, radiate, and horizontal. Diameter of calices $\frac{1}{30}$ inch.

Localities: Bowden and Vere, Jamaica.

16. *ANTILLIA WALLI*, spec. nov. Pl. II. fig. 4 a-c.

The corallum is compressed laterally, and slightly curved inferiorly, in the plane of the major axis; it is much broader than long, has a pedicel, and is indented anteriorly, but is convex posteriorly. The pedicel is mammilliform and bluntly pointed, and the corallum expands rapidly above it on either side.

The calice is elliptical, and has a sinuous margin. The wall is very stout and appears to be double, the space between the true and false wall being occupied by part of the septa and dissepiments. The portions of septa between the walls are much thinner than their continuations, and a dissepiment divides the space between the walls into quadrangular cells. The inner wall is denser towards the base of the corallum, and consists of endotheca. The costæ are very distinct where uncovered by epitheca, and diminish in width as they approach the pedicel; many are lost after passing downwards a little distance, and all are marked by one series of distinct papillæ hardly amounting to dentations. The septa are numerous, crowded, unequal, often curved; and their inner margin is perpendicular, long, and dentate. The laminae are slightly stouter internally than externally, and are marked with radiating lines of papillæ. There are five cycles and a few septa of the sixth in six systems. The columella is spongy, long, narrow, and deeply seated. The endotheca is abundant, and the dissepiments are often inclined, especially when they form the inner false wall. The exotheca is feebly developed; the epitheca is strong and membraniform. Length $1\frac{6}{10}$ inch; breadth $\frac{9}{10}$ inch.

Locality: Bowden, Jamaica.

17. *SIDERASTRÆA CRENULATA*, Blainville, sp. Var. *ANTILLARUM*, nobis.

The remaining species have been described in a former communication*.

5. *General Remarks on the Affinities of the Species, and on the Correlation of the Cretaceous, Eocene, and Miocene Strata of Jamaica with those of Europe.*

The Cretaceous strata of Mount Hindmost and Trout Hall, in the parish of Upper Clarendon, have afforded numerous determinable specimens of corals, a few of which cannot be specifically identified with any forms already described. The majority have a very decided facies, one which is familiar to the student of European Lower Cretaceous *Zoantharia*, and suggestive of a close alliance with the great coral-fauna of Gosau in the eastern Alps. *Heliastrea exsculpta*, Reuss,

* Quart. Journ. Geol. Soc. vol. xix. pp. 437, 513.

Diploria crassolamellosa, Edw. & Haime, and *Cyathoseris Haidingeri*, Reuss, of the Upper Clarendon Chalk, are common forms in the Kriedensmerle, which, with its associated Hippurite-limestone, was first brought before the notice of geologists in the classical essay on the Eastern Alps by Professor Sedgwick and Sir Roderick Murchison, and the organic remains of which have been so ably described and figured by Reuss, of Vienna. The minority have yielded a species allied to the small-caliced *Heliastrea*s of Gosau, and a species of *Porites* which is the oldest on record. There is a community of species of corals between the Lower Chalk of Gosau and Piesting and the French Hippurite-limestone at Martigues, the Corbières, and Uchaux. It is clearly this assemblage of forms which is represented in Jamaica; and it is an interesting fact that the specimens from Gosau, Mount Hindmost, and Trout Hall present the same mineral aspect; in fact, the specimens are barely to be distinguished.

This Lower Cretaceous coral-fauna is very rich in species, almost equalling the Miocene; it is peculiar to the horizon of the Lower Chalk with *Hippurites*, and its forms determine the age of the Clarendon strata as significantly as their *Rudistes*. The strata yielding the corals are of the same horizon as those which first yielded the *Barrettia* and the *Acteonella*, although great masses of intrusive rocks and some distance separate them. It is very probable that the Hippuritic limestone exists in the neighbouring island of San Domingo; and it will be found in a former communication that corals were noticed in Miocene strata there with very decided Lower Cretaceous affinities, as well as in Jamaica*. The *Astrocenia decaphylla*, a well-known coral of the European Lower Chalk, was noticed as having been found by Mr. Barrett in the Jamaican Miocene; and *Phyllocenia sculpta*, an equally well-known species from Gosau and Uchaux, was found in the Nivajé shale of San Domingo: moreover, four other species, whose affinities are decidedly Turonian, were described from this last locality. Some of the specimens of these erratic species are so mineralized as to lead to the belief that they are *derived* fossils, whilst others resemble those of unquestionably Mid-tertiary age. The derived appearance is much more decided in the San-Domingan specimens than in those from Jamaica; and as the Lower Chalk is present in the latter island, it is very probably to be found in the former. The formation would appear to be present in the island of St. Thomas, where Dr. S. P. Woodward asserts that the shell *Acteonella levis* was found; but as yet it has not been recognized in any other of the Antilles, neither has it been discovered on the mainland. The Cretaceous formation of Trinidad is identical with that of the adjacent part of South America; it is of Neocomian age, and is subordinate to an immense Mid-tertiary series †. In North America, where the Upper Greensand and the Upper Chalk exist, the Lower Chalk has not yet been found.

It follows that the Hippuritic and Coral-bearing limestone of

* "West Indian Fossil Corals," Quart. Journ. Geol. Soc. vol. xix. p. 406.

† R. Etheridge, in Geol. Surv. of Trinidad, by G. P. Wall & J. G. Sawkins, 1860, p. 161.

Jamaica is separated from its known equivalent formations by the Atlantic, and that those which, according to the ordinary rules of palæontology, must be associated with it, as regards contemporaneity and relative position, are the Hippurite-limestone of North Africa (in the Province of Constantine, for instance); that of Portugal at Alcantara; that of Spain in Leon; that of South-Western and South-Eastern France, in the Departments of Lot et Garonne, Charente Inférieure, Loire et Cher, Aude, Bouches du Rhône, Vaucluse, and Var; and that of Austria, at Gosau and Piesting. The English Lower Chalk belongs to a special natural-history province, and doubtless is of the same age as the Jamaican, due regard being allowed for the limits of the notion of geological contemporaneity. The discovery of forms common to Europe and the West Indies in the Cretaceous strata furnishes another to the many examples of the wide dispersion of species which occurred formerly; and it is interesting to observe that the genera so well represented in the Lower Chalk are equally well represented in the present Caribbean Sea. The brainstone-corals, the stony compound corals, and the porose *Porites* are the commonest in the reefs around the Antilles, and their near allies appear to have luxuriated at Gosau and amongst the French Hippurites. When the dependence of coral-life on very definite physical conditions is considered (and there are few series of facts better made out than those which illustrate that dependence), the identity of climate, purity of sea-water, absence of fresh water, and equivalent depth of sea between the old chalk-reefs and the modern are forcibly suggested.

The Eocene shales and dark-coloured sands which represent the conglomerate in some localities, or which constitute its upper part in others, yield corals in no very great number. The specimens from Port Maria are either dark and carbonaceous-looking, or are encrusted on a fine dark-purple conglomerate: all are very significant of the horizon, and recall the puny development of the species of the London Clay. The *Paracyathus* from Yallahs valley resembles that of the London Clay, being even stained black, like the Sheppey specimens: the *Stylocœnia emarciata* is a well-known form in British, French, Italian, and Sindian early Tertiary collections, and the *Stylophora contorta* also. The *Stylocœnia* and *Stylophora* are characteristic Corals, and denote an Eocene horizon; and they indicate, when unaccompanied by other species, the existence of physical conditions not favourable for coral-growth.

The existence of strata of Eocene age in Jamaica was asserted by the late Mr. Barrett, and their position was marked on his diagram of the succession of the strata of the island; but it does not appear that he has communicated any reasons for thus naming the plant-bearing and other dark shales subordinate to the Miocene sands and shales, except those referring to stratigraphy. That he was correct there can now be no doubt, and an important member of the Tertiary series is thus added to the formations represented in the West Indies. Its equivalents are as yet unknown in the other islands; but it is not probable that a great conglomerate resembling the Flysch in magni-

tude should be unrepresented in the larger islands. The characteristic corals of the Eocene strata of the Southern States are not amongst those from Port Maria.

The corals obtained from Vere, Bowden, and Navy Island, off Port Antonio, have no general resemblance to those from the Eocene and Cretaceous strata, but present the appearance of the common specimens of the various Miocene shales and marls of San Domingo and the European Miocene; and all are absent from the existing coral-fauna of the West Indies. The new species of *Flabellum* is unlike that of the Nivajé shale, and its genus is unknown in the Caribbean Sea. The existence of the genus in every other coral-sea, and its discovery in the Miocene of the Antilles, have already been noticed in a former communication. The genus *Placotrochus* is represented by a second species in the Jamaican Miocene; it has no species in the Caribbean Sea, but several occur in Oceania; and its fossil species are found in the Australian* and San-Domingan Tertiaries. The *Placotrochus costatus* is a very interesting form, for it is mimetic of the new species of *Flabellum* just mentioned. *Placotrochus* differs from *Flabellum* in having a lamellar columella; but the genera are closely allied, and their habits are very much alike: it happens, moreover, that several sets of species resemble each other, except in the prominent generic peculiarity, and are mimetic.

The *Placocyathus* which I have ventured to name after Mr. Carrick Moore is allied to *P. Barretti*, nobis; and the new *Thysanus* adds another species to that beautiful genus.

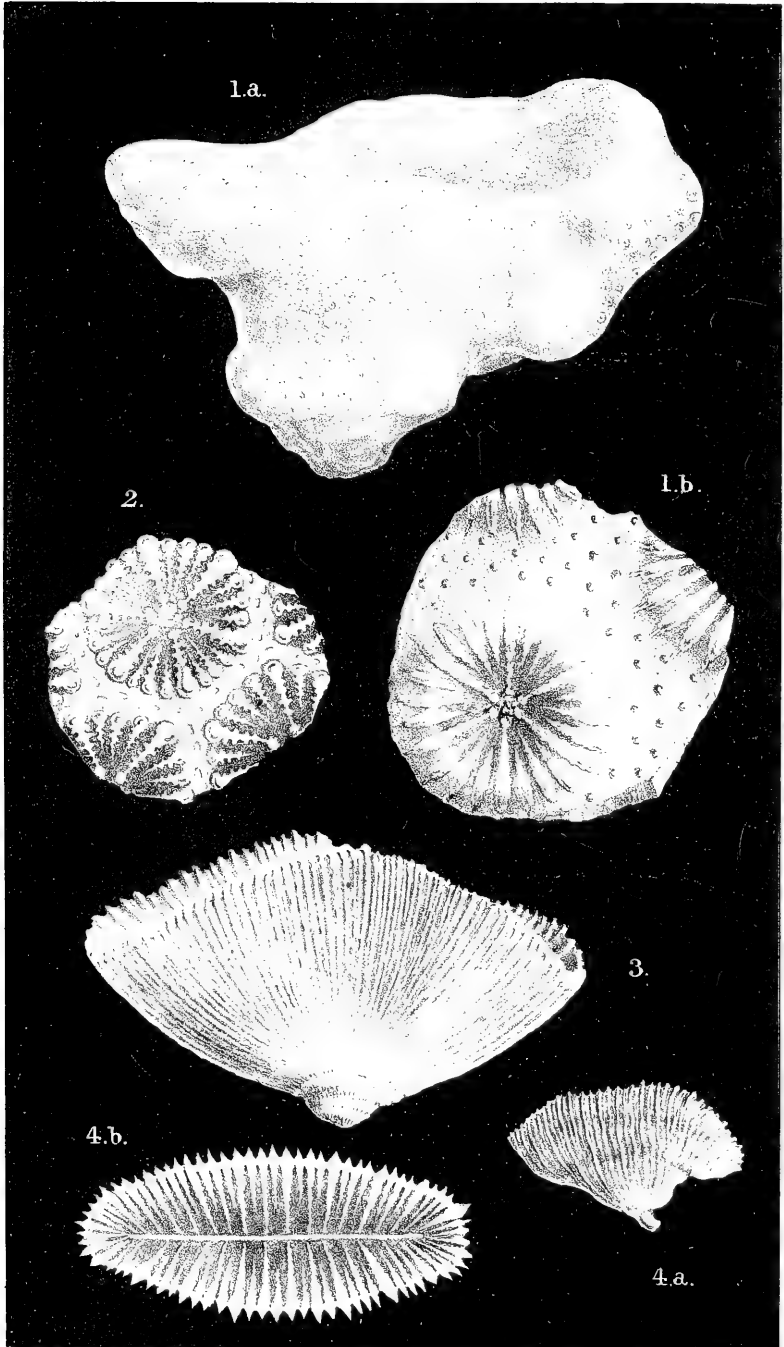
The comparative absence of compound corals from the Jamaican Miocene is very remarkable; and equally interesting, in reference to the deep-sea nature of a part of the coral-fauna, is the abundance of Foraminifera, which crowd amongst and fill up the interstices of the specimens. The reef-coral *Alveopora*, however, exists in the White Limestone, and there is, therefore, a proof of some variation in the depth of the sea during the deposition of the Jamaican Miocene.

The general correlation of the Jamaican Mid-tertiary marls, sands, and limestones with the Nivajé and Esperanza shales and the limestone of San Domingo has been noticed in a former communication. These Miocene deposits are the equivalent formations to the Newer Parian of Trinidad and the mainland, to the three sets of strata in Antigua, and to the calcareous bed of Barbuda, &c. †; their coral-faunæ have much in common, and bear but slight affinity to that existing in the Caribbean Sea, but a well-marked resemblance to the Australian, Oceanian, and East Indian coral-fauna; moreover, they are closely related by identity of species with the fauna of the Faluns, of the Turin Miocene, of the Vienna basin, and of the lowest Maltese limestone.

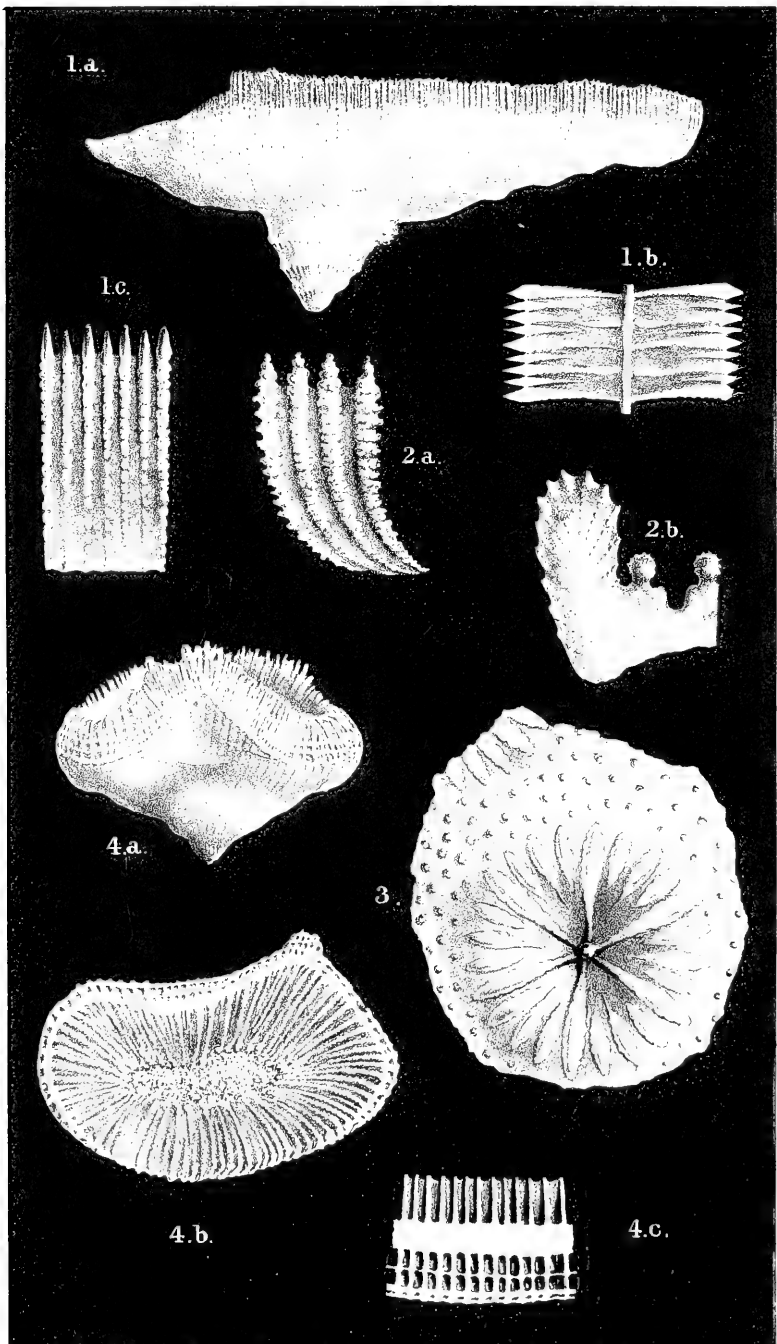
* P. M. Duncan, Ann. & Mag. Nat. Hist. vol. xiv. 1864, p. 161.

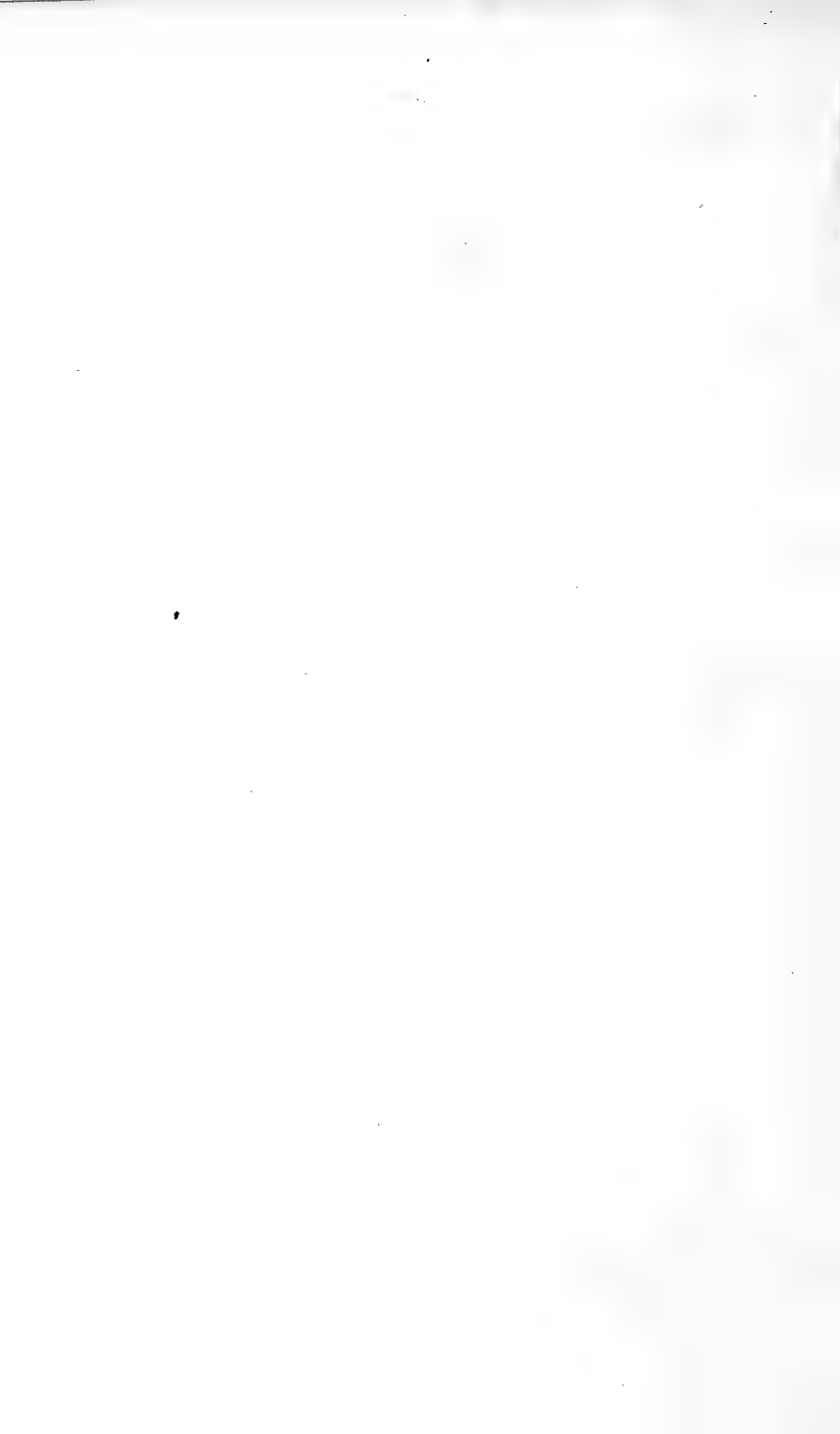
† The small island off Port Antonio contains a Pteropod-marl, according to the late Mr. Barrett, and the *Trochocyathus obesus* was derived from it.











EXPLANATION OF PLATES I. & II.

Illustrative of the Fossil Corals of Jamaica.

PLATE I.

- Fig. 1. *Heliastrea cyathiformis*: *a*, corallum, natural size; *b*, calice and intercalicular spaces, magnified 4 diameters.
 2. *Porites Reussiana*: calices, magnified 4 diameters.
 3. *Flabellum exaratum*: side view, natural size.
 4. *Placotrochus costatus*: *a*, corallum, natural size; *b*, the calice of a young specimen, magnified 3 diameters.

PLATE II.

- Fig. 1. *Placocyathus Moorei*: *a*, corallum, natural size; *b*, septa, pali, and columella, magnified 2 diameters; *c*, costæ, magnified 4 diameters.
 2. *Thysanus elegans*: *a*, costæ, magnified 6 diameters; *b*, large paliform tooth on a dentate septum, magnified 6 diameters.
 3. *Stylophora granulata*: calices, magnified 6 diameters.
 4. *Antillia Walli*: *a*, side view, natural size; *b*, calicular view, natural size (the specimen is fractured); *c*, the structure of the wall, endotheca, and epitheca, magnified 2 diameters.

2. On the CORRELATION of the CRETACEOUS FORMATIONS of the NORTH-EAST of IRELAND. By RALPH TATE, Esq., F.G.S.

[PLATES III.-V.]

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I. INTRODUCTION.

IN a former communication I described "The Rhætic and Lower Liassic Rocks of the neighbourhood of Belfast" *, and I now propose to continue the subject with a description of the strata which surmount the Liassic series, namely, the Upper Cretaceous rocks in part.

An incentive to study these formations was the knowledge that the results of the labours of the late Robert McAdam, Esq., F.G.S., had been anxiously looked for by many geologists †, who hoped that

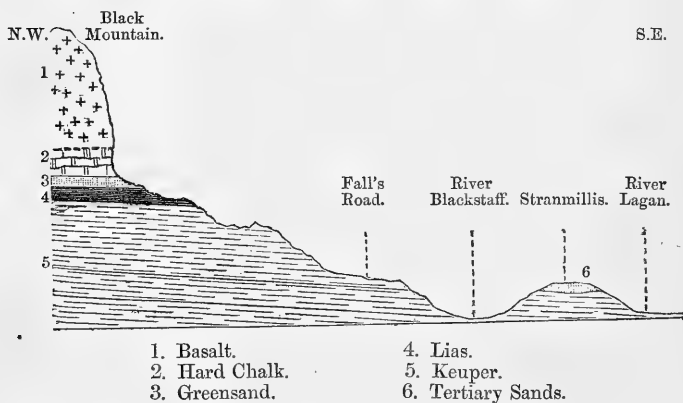
* Quart. Journ. Geol. Soc. vol. xx. p. 103.

† Oldham, Journ. Geol. Soc. Dublin, Annual Address, vol. iv. p. 97; Haughton, *ibid.* vol. ix. p. 319; Forbes, Quart. Journ. Geol. Soc., Annual Address, vol. x. p. 1v; Huxley, *ibid.* vol. xviii. p. xxxviii; Salter, Quart. Journ. Geol. Soc. vol. xiii. p. 84.

the true relationship of the Irish Cretaceous beds would have been satisfactorily determined by him from the study of his own collection of local fossils. That geologist has passed away from amongst us without having accomplished these researches; and as his collection has not been applied to the furtherance of the much-desired object up to the present time, I have undertaken the task he may have intended to perform. During a residence of two years and a half in Belfast, I have worked assiduously in collecting fossils from the Irish Cretaceous strata, and in studying their lithology and stratigraphical characters, with the hope that these materials would enable me to correlate them satisfactorily; and I shall now endeavour to show that they belong to the so-called Upper Greensand and to the Upper Chalk.

The general features of the disposition of the Neozoic rocks in the neighbourhood of Belfast may be understood by reference to the accompanying section.

Fig. 1.—Section from the River Lagan to Black Mountain.



II. ABSENT FORMATIONS.

1. *Oolitic Strata*.—In the foregoing section, the Cretaceous beds are represented as overlying the Liassic, without the interposition of any Oolitic deposit. Conybeare was the first to notice this feature*; he observes that “The numerous beds of coarse calcareous Oolites, which in England succeed this green sandstone, are entirely wanting in Ireland, and the *Mulatto* reposes immediately on the *Lias limestone*.”

Subsequent writers on this subject have not been free from error; for instance, Sir R. Griffith remarks†, in 1838, that “we may be said to possess portions of the whole upper series of the Secondary rocks of England, with the exception of the Oolite, though traces even of that formation have been discovered on the coast, near Larne,” while

* Trans. Geol. Soc. 1st ser. vol. iii. p. 130.

† Outline of the Geology of Ireland, 1838, p. 20.

Bryce*, in 1852, more cautiously states that “indications of a rudimentary development of some Oolitic strata have indeed been noticed near Larne; but as they have not been clearly made out, we may pass them over here.”

Again, McAdam †, in 1852, observed that “at Larne a bed of oolitic structure rests upon Lias, and in it are found *Avicula contorta*, *Lima proboscidea*,” &c.; while Professor King ‡ (1863) similarly particularizes the position of the quasi Oolitic formation, introducing in his table oolitic beds probably of the age of the Bath Oolite, and said to contain obscure impressions of *Cardium*, &c., as occurring near Larne.

The beds which have been regarded as of Oolitic age by the above writers, excepting, perhaps, Professor King, are to be seen in a fine cliff-section on the coast south of Waterloo, Larne. They consist of two beds, each about 5 feet in thickness, overlying indurated marls, containing *Avicula contorta*, *Cardium Rhæticum*, &c. The lower bed is simply an indurated marl with disseminated calcareous grains, and presents an oolitic structure. The upper bed is made up of spheroids of marl of the size of large peas. The marls that are associated with these pseudo-oolitic beds belong to the Rhætic series, and are surmounted by true Lower Lias, containing *Gryphæa incurva*, *Lima tuberculata*, Terquem (*L. proboscidea*), &c. I have also seen similar beds of the same age at Cave Hill, Belfast §.

The ‘Larne mixed fossil-bed’ of Professor King is without doubt that of Ballycraig, near Larne, a specimen of which, in the museum of the Natural History Society of Belfast, is labelled “Oolite, Ballycraig.” This specimen at first appears to be an oolitic limestone; but on a careful examination it proves to be only a fine-grained siliceous rock, with a light-coloured calcareous cement. The block bears an impression of the flat valve of *Pecten quinquecostatus*, and was evidently obtained from a bed which occurs above the basement-bed of the Upper Greensand, and is a part of the upper series of that formation. It is in fact the ordinary rock of that member (which is a siliceo-chloritic rock with a calcareous paste), wanting in the disseminated chloritic ingredient. The presence of *P. quinquecostatus* is sufficient to prove its age without other evidence. Therefore, with Professor Jukes || (1862), I contend that “the only beds belonging to the Oolitic (Jurassic would have been more strictly correct) series in Ireland are some black Liassic shales.”

2. *Lower Greensand and Gault*.—The majority of the writers on the age of the Irish Cretaceous beds have referred them to Upper Chalk, Lower Chalk, and Upper Greensand, altogether or in part; yet a few have departed from such determinations.

Bryce ¶ (1837) is one of the few authors who has regarded some portion of the Cretaceous series as a probable equivalent of the Lower

* Geol. Notices, Environs of Belfast, p. 10.

† Rep. Brit. Assoc., Trans. of Sect. p. 54.

‡ Synoptical Table of British Aqueous Rocks, 5th edit.

§ Quart. Journ. Geol. Soc. vol. xx. p. 108.

|| Manual of Geology, p. 589.

¶ Trans. Geol. Soc. 2nd ser. vol. v. pt. 1. p. 79.

Greensand; but, as observed by D'Archiac*, "no part represents the *Grès-vert inférieur*, as supposed by Bryce;" while Professor Oldham† comes to the same conclusion, on the authority of McAdam, "who has found no representative of the Lower Greensand in that district."

Portlock‡ (1843), mistaking the age of the fossils, states that "the true Lower Greensand, containing *Pecten quinquecostatus*, *P. æquicostatus* var. *longicollis*, *Inoceramus Hamiltoni*, &c., is found on the eastern chalk-escarpment in the county of Antrim."

Professor Forbes§ thought that the Upper Greensand of Ireland was more nearly allied to the Gault by its fossils. As regards the Glauconitic Sands, such was also my opinion|| until recently, but my reasons for abandoning this view are given at p. 22.

III. REVIEW OF THE WRITINGS OF PREVIOUS AUTHORS.

The Cretaceous beds of Ireland may be divided into the following lithological zones in descending order; but, convenient as they are, they do not accord, as will be shown in the sequel, with the palæontological horizons.

Lithological Divisions of the Cretaceous Beds.

1. "White Limestone" with flints.
2. Chloritic Sandstone and Sands—"Mulatto Stone."
3. Yellow Sandstones and Marls.
4. Glauconitic Sands.

Whitehurst¶ (1786) was the first to regard the White Limestone as "similar in appearance to a stratum of *chalk*."

Hamilton** (1790) observes that "the White Limestone in colour resembles chalk, but, in hardness, exceeds it: like chalk, it abounds in irregular nodules of flint." He further very accurately defined the boundaries of this formation, and gave important observations upon the imbedded flints.

Sampson†† (1814) further, though confusedly, recognized a sandstone below the White Limestone.

Conybeare‡‡ (1816) more clearly exhibited the order of succession of the Cretaceous strata, and referred the Mulatto sandstone underlying the Chalk to the horizon of the Upper Greensand. "It agrees altogether in its character and fossils with green sandstone, which occurs in a similar geological position underlying the Chalk in England" (p. 130). He, however, referred the White Limestone to the age of the Lower Chalk, thus:—"It agrees exactly with the lower beds of the English Chalk."

* *Histoire des Progrès*, vol. iv. p. 8.

† *Journ. Geol. Soc. Dublin*, vol. x. p. 97.

‡ *Report Geol. of Londonderry, &c.*, pp. 109 and 139.

§ *Jukes's Manual of Geology*, 1st edit. p. 514.

¶ *Quart. Journ. Geol. Soc.* vol. xx. pp. 103, 108, &c.; *Geologist*, 1863, p. 444.

** *Original State, &c., of the Earth*, 2nd edit. pp. 248, 259, and pl. 6. fig. 2.

†† *Letters, Northern Coast of Antrim*, part i. pp. 3, 5, 6; part ii. pp. 93-98.

‡‡ *Expl. Chart and Survey, co. Derry*, p. 84.

‡‡ *Trans. Geol. Soc.* vol. iii. pp. 129-131, 167-173.

Allan* (1821) noticed the prevalence of the White Limestone in the north-eastern angle of Ireland, and its uniformly resting on the Greensand or Mulatto stone. He also pointed out the extent and position, as well as the general characters of the limestone, and those of its altered portions.

Boué† still later referred the Mulatto sandstone to the *Craie tuffeau* of France, and the superior beds to the *Craie blanche*.

Griffith‡ (1838) has referred to the relations of the Secondary rocks of the co. Antrim, and described their position, characters, and area.

Bryce§ (1837) added some further details, especially as regards the relation of the Chalk to the Mulatto and underlying formations, and the variation and thinning-out of the Mulatto in its progress northwards.

Of the labours of General Portlock|| (1843) I have only to notice, for my present purpose, that he made the first attempt to particularize the palæontological characters of the Cretaceous beds. The fossils, to the number of seventy-eight, he distributed into three subdivisions of the "Chalk," as follows:—

- “ 1st, Arenaceous, or glauconous, or ‘ Greensand.’
- 2nd, The Lower Chalk.
- 3rd, The Upper Chalk.”

The first division comprises the loose grey sandy beds referred to at p. 110, and are evidently the Glauconitic sands and yellow sandstones of my section, here introduced for the first time.

The second division he elsewhere designates as the Chloritous Chalk (p. 109) and indurated Greensand, or the so-called Mulatto stone (p. 110); and as such it accords with my lithological zone No. 2 at p. 18.

The lithological divisions of the Cretaceous beds, as given by Mr. Bryce (1852) in the following quotation, are the same that I have employed, though his paper was not known to me until after the preparation of this communication:—

“The Cretaceous system is represented by the Upper Greensand and Chalk, the Lower Greensand and Gault being absent. This Upper Greensand consists of three beds: the lowest is a slightly cohering sandy bed of a green colour, a true greensand; the second is a buff-coloured calcareous sandstone; the uppermost is a greyish-white impure limestone, pervaded by chloritic grains. The upper portions of this bed are often conglomerate, pebbles of quartz being imbedded. To these upper chloritous beds the workmen have given the name of ‘ Mulatto,’ which is often used to designate the whole series in Ireland.” He gives no further details, but adds (and here I essentially differ from him), “Hard white chalk, apparently the representative of the lower part of the Chalk series in England.”

* “Formation of the Chalk,” &c., Trans. Royal Soc. Edinb. vol. ix. p. 393.

† Essai Géologique sur l’Ecosse, p. 379.

‡ Outline of the Geology of Ireland, p. 19.

§ Trans. Geol. Soc. 2nd ser. vol. v. pp. 78–80.

|| *Loc. cit.* p. 749.

Sharpe* (1853) regarded the White Limestone as of the age of the Upper Chalk.

Jukes† (1862) refers the White Limestone to the Upper Chalk, and regards the "Mulatto" stone as of Upper Greensand age.

King‡ (1863) parallels the "Antrim Mulatto stone" with Upper Greensand, and the "Antrim White Limestone" with the Dover Lower Chalk.

Those authors who have compared the Irish Cretaceous fossils with those of the English Cretaceous beds have referred the former to the Upper Greensand and the Upper Chalk, very properly disregarding the hiatus existing between them. Others, guided only by stratigraphical succession, have referred the beds overlying the Upper Greensand to the Lower Chalk, the same being the next above, in the order of superposition.

IV. DESCRIPTIONS OF THE FORMATIONS.

1. *Preliminary remarks.*—From the foregoing *résumé* of previous memoirs, it is apparent that there still remains much to be done for the correct identification of the Cretaceous beds of the north-east of Ireland, which are invested with additional interest on account of their occupying an isolated area, being the most north-westerly Cretaceous deposits in Europe. "The most northerly point in the whole earth, in which Chalk has yet been found, is in the vicinity of Thistedt in Jutland, 57°, or in that of Aberdeen; the last appears in the south coast of the Island of Rathlin"§, off the coast of the county of Antrim. The most westerly points in Ireland where Chalk is found *in situ* are Benyevenagh and near Dungiven, co. Londonderry, in long. 6° 55'.

2. *Hibernian Greensand.*—I propose this name for the Cretaceous beds underlying the Upper Chalk of Ireland, the term Upper Greensand, as used in England, not being sufficiently comprehensive, as the Irish strata may more perfectly be correlated with the "étage Cénomanién" of D'Orbigny.

The Hibernian series forms three lithological zones, each with its own suite of organic remains; but the upper part of the third, or highest, zone, though agreeing lithologically with the lower portion, I associate with the Upper Chalk. With this reservation, I purpose, first, to describe the series according to its lithological divisions, and afterwards to notice its fossils.

The Hibernian Greensand may conveniently be studied in most of the glens of the Antrim Hills; and I have selected as a type-section that naturally exposed in the Woodburn stream, by the Priest's Hole, on the Carrickfergus Commons.

a. *The Glauconitic Sands.*—These sands are of a dark-green colour, and consist of glauconitic and arenaceous grains in a slightly argillaceous paste. Throughout the district they present the same

* Monograph of Cretaceous Mollusca, p. 47.

† Manual of Geology, p. 622.

‡ Synoptical Table, 5th edit.

§ Quart. Journ. Geol. Soc. vol. vi. pt. 2. p. 22.

general aspect, becoming towards the west, as at Carmoney, more argillaceous, when the streak is of a dull yellowish green. It is the

Woodburn Section.

Formations.	Lithological Zones of p. 18.	No. of Bed.	Lithology.	Thickness. feet, in.	Fossils.
Upper Chalk.	White Limestone, Zone 4.	1.	White limestone.		
	Sandstones. Zone 3. Chloritic Sandstones. Chloritic Sandstone, less calcareous and more incoherent than No. 4. A shell-bed especially marked by fragments of <i>Inoceramus</i> .	2.	Chloritic white limestone, fragmentary, its lower portion charged with Sponges	0	3	Cephalites fungiformis, Ventriculites radiatus.
3.		Chloritic white limestone, darker in colour than No. 2, with a persistent band of <i>Ananchytes</i> at the base	2	0	Ananchytes ovatus, A. gibbus.
4.		Chloritic calcareous sandstone, slightly compact	1	7	{ Pecten quinquecostatus, Ostrea canaliculata, O. semiplana, Inoceramus Crispi, Terebratulina striata, Terebratula carinea, Rhynchonella robusta, R. latissima, Catopygus carinatus.
5.		Calcareo-chloritic sandstone, less calcareous and more incoherent than No. 4. A shell-bed especially marked by fragments of <i>Inoceramus</i>	0	3	
6.		Similar to No. 5; few fossils.	1	0	
7.		Greyish marls, with chert-nodules, passing into dark-green sands of No. 8	2	3	Interlacing casts of Sponges in a green siliceous sandstone.
8.		Glauconitic compact sands, slightly argillaceous	3	9	
9.		Fossil-bed with phosphatic nodules	0	2	{ Belemnites attenuatus, Exogyra conica, Pecten orbicularis, P. Dutemplei, P. virgatus, Aricula lineata, Terebratula squamosa, Gryphaca incurva, Cardinia ovalis.
10.		Similar to No. 9, resting on	4	0	
Lower Lias.				Black argillaceous shales

most persistent of the divisions, preserving a uniform thickness of about 8 feet, and maintaining the same characters and fossils. It is, however, wanting beyond Colin Glen.

The fossils are confined to the bed of *Exogyra conica*; this fossiliferous band preserves a medial position in the zone, as indicated in the foregoing section (No. 9), throughout the district. Using this band as a safe guide, I have traced the Glauconitic Sands from Larne, around the Island Magee to Whitehead, Woodburn, Carmoney, &c., to Colin Glen—a line-section of twenty-four miles.

The rock is not used economically, though the employment of the sands as a dressing for lands has been suggested. The phosphatic nodules in the bed occur in too small a quantity to be available for the purpose that such concretions are usually applied to; they occur rather as a substratum to the fossil-bed, yet many of the organic remains are of the nature of casts in the phosphatic material.

It is a water-bearing deposit, though few springs of any importance arise upon it.

This zone has yielded thirty-six species, which, with very few exceptions, are confined to it. Most of them were obtained at Whitehead, during the construction of the railway to Larne; the other localities, excepting Woodburn, are apparently less fossiliferous, probably because they have not been wrought to such an extent, on account of the difficulty of exploiting the bed.

This lithological zone is without doubt the "Glauconous Sand" of Portlock, and the fossils of it are indicated in his list by G_3 ; these are identical with those I have found in this stratum in the neighbourhood of Belfast.

In the following list are some of the more important species, placed according to their value:—

<i>Exogyra conica</i> , var. <i>lævigata</i> , <i>Sow.</i>	<i>Arca carinata</i> , <i>Sow.</i>
<i>Pecten orbicularis</i> , <i>Mant.</i>	<i>Belemnites ultimus</i> , <i>D'Orb.</i>
— <i>Dutemplei</i> , <i>D'Orb.</i>	<i>Ammonites varians</i> , <i>Sow.</i>
<i>Avicula lineata</i> , <i>Roem.</i>	<i>Pecten virgatus</i> , <i>Nils.</i>
<i>Pecten quinquecostatus</i> , <i>Sow.</i>	<i>Ditrupa deformis</i> , <i>Lamarck.</i>

The Glauconitic Sands I formerly regarded as of the age of the Gault, rather from their marked persistency and restricted organic contents than from the affinity of their species to those of the Gault. These sands pass up into grey marls at Woodburn and elsewhere. I find the same lithological features to appertain to the basement-beds of the "étage Cénomancien" in Normandy, having observed the glauconite-sands underlying grey and brown marls dashed with green grains, the lower passing up into the higher, from Cap de la Hève to Auberville. This similarity is further increased by the fossil contents. I am therefore justified in concluding that no representative of the Gault occurs in Ireland.

b. *The Grey Marls and Yellow Sandstones with Chert.*—The marls of Woodburn (see section, p. 21) have the same characters as far westwards as Cave Hill; they contain but few species of fossils, and are of limited thickness. To the east of Woodburn, as at Whitehead and around the shores of Island Magee, they are brownish-yellow argillaceous sandstones with cherty masses. In the western part of the district, from Carr's Glen to Colin Glen (see section, p. 25), the

arenaceous element prevails, and they assume the character of yellow sandstones abounding in chert; they are also comparatively fossiliferous and of great thickness. The characteristic fossils of the yellow sandstones of Colin Glen, Black Mountain, &c., are, *Ostrea carinata*, *Pecten æquicostatus*, *P. quadricostatus*, *Rhynchonella latis-sima*, and *Vermicularia quinquecarinata*, Roem.

The argillaceous sandstones of Whitehead and Island Magee contain in abundance *Ditrupea deformis*, Lamarck, *Discoidea sub-uculis*, *Micrabacia coronula*, and *Vermicularia quinquecarinata*.

c. *The Chloritic Sands and Sandstones.*—This division includes part of the “Mulatto” of the workmen, and part of the “Chloritic Chalk” of Portlock. Several authors have referred it to the Upper Greensand.

In the Woodburn section there is some slight evidence of un-conformability between this zone and the underlying grey marls; that is to say, Bed No. 6 reposes upon a slightly undulated surface of Bed No. 7 (see section, p. 21).

The beds between the Grey Marls and the White Limestone are generally siliceous sands in a calcareous paste, and contain disseminated chloritic grains. The compactness of this zone varies with the locality. On the whole, I find that, in ascending the bed, it becomes more and more compact, by the predominance of the calcareous paste, and the siliceous and chloritic elements become less and less in amount, finally passing up insensibly into the condition of a white compact limestone. These general features are seen especially in the eastern localities.

Despite the greater or less uniformity in the lithological characters of this stratum, a study of the fossils has led me to refer the upper portion of it, to which I apply the term “Chloritic Chalk,” as met with in the eastern escarpment of the Cretaceous area, to the Upper Chalk. The band with *Ananchytes ovatus* I regard as the lower limit of the Upper Chalk, though no line of demarcation exists further than the appearance of the calcareous element in greater force. In the Woodburn section (p. 21) it embraces Beds Nos. 2, 3, and 4.

The relations of the Chloritic Chalk to the Chloritic Sandstones are shown in the following sections, in which also is noted the local variation in their composition.

Section on the East Coast of Island Magee.

		Thickness.	
		ft. in.	
Upper Chalk.	{ Chloritic Chalk.	1. White limestone.	
		2. White limestone with chloritic grains increasing downwards.....	1 10
		3. Ventriculite-bed (<i>Cephalites fungiformis</i> , &c.)	0 3
Hibernian Greensand.	{ Chloritic Sands.	4. Slightly compact green sands, with <i>Cyphosoma Cc- nomanense</i> , <i>Serpula filiformis</i> , <i>Ostrea canaliculata</i> , &c.	

Section at Whitehead.

		Thickness.	
		ft. in.	
Upper Chalk.	{ Chloritic Chalk.	1. White limestone.	
		2. White limestone with chloritic grains, yielding <i>Ventriculites</i>	1 6
		3. Soft chloritic calcareous sandstone in nodules	1 8
		4. Band of <i>Ananchytes ovatus</i>	0 2
Hibernian Greensand.	{ Chloritic Sands.	5. Soft greenish sands.....	3 9
		6. Fossil-bed marked by fragments of <i>Inoceramus Crispi</i>	0 1
		7. Soft green sands, &c.	

The fossils of the Chloritic Sands are principally derived from the band characterized by *Inoceramus Crispi*, which is a conspicuous horizon in the eastern area. The characteristic species, arranged in the order of their frequency, are:—

Inoceramus Crispi.	Spondylus spinosus.
Ostrea semiplana.	Heteropora cryptopora.
Terebratula obesa.	Catopygus carinatus.
— carnea.	Serpula filiformis.
Rhynchonella robusta.	Pleurotomaria perspectiva.
— latissima.	Cidaris vesiculosa.
Ostrea canaliculata.	Epiaster distinctus.
Pecten quinquecostatus.	

On tracing the Chloritic Sands to the west, some lithological differences appear, accompanied by almost a new fauna. Thus to the west of the Cave Hill the Chloritic Sands are generally represented by compact siliceo-chloritic sandstones, with intervening bands of soft sands. These sands are the fossiliferous portions *par excellence*, the dominant species being *Exogyra columba*.

These beds are exposed at the Black Mountain, Hanna's Town, and near the bridge in Colin Glen. Succeeding a great development of the yellow sandstones at the last-named locality, there occur compact chloritic sandstones of a light-green colour, with two fossil-bands in a softer sandstone, one below especially charged with *Vermicularia concava*, the other with *Exogyra columba*, with which are associated *Cucullæa fibrosa*, *Trigonia Dædalea*, *Pecten æquicostatus*, *Waldheimia Hibernica*, *Ostrea semiplana*, *Ammonites Lewesiensis*, *Corax falcatus*, *Otodus appendiculatus*, *Ptychodus mammillaris*, *Anatina Royana*, *Cardium gibbosum*, *Inoceramus striatus*.

In the last-mentioned localities the Chloritic Chalk is wanting, and the passage from the Chloritic Sandstones to the White Limestone is abrupt. This is seen in a fine section by the waterfall in Colin Glen, about half a mile above the bridge, the Chloritic Sandstones exhibiting in so short a distance a remarkable variation in composition and fossils.

Section in Colin Glen.

Upper Chalk.		White Limestone, resting on—		Thickness.	
				ft.	in.
Hibernian Greensand.	Chloritic Sandstones.	{	1. Compact dark chlorito-siliceous sandstone	6	6
			2. The same with Crustacea (<i>Callianassa</i> , sp.)	3	0
			3. The same, but unfossiliferous, as No. 1.	6	0
	Yellow Sandstones.	{	4. Yellow sandstone with nodular cherty masses, becoming blackish and shaly below, and yielding <i>Pecten æquicostatus</i> , <i>P. quadricostatus</i> , and <i>Vermicularia quinquecarinata</i>	30	0
			5. Glauconitic Sands with <i>Exogyra conica</i> , &c.....	8	6
				54	0

This section presents the maximum thickness attained by each zone of the Hibernian Greensand.

3. *Upper Chalk*.—a. *Chloritic Chalk*, or *Basement-bed of the White Limestone*.—The lithological characters and relative position of this stratum have been already referred to. It is essentially a local development, becoming attenuated towards the west, and at Cave Hill is represented only by a bed of *Ananchytes ovatus* and a few *Ventriculites* interposed between the White Limestone and the Chloritic Sandstone. It is entirely wanting further to the west, and then the White Limestone rests abruptly upon the Hibernian series, whereas in the eastern districts the Chloritic Chalk passes upwards into the state of a white limestone, and downwards into that of a chloritic sandstone.

Its fossil contents are chiefly Sponges and *Ananchytes ovatus*. The former characterize a distinct palæontological zone reposing upon that of the *Ananchytes*.

With *Ananchytes ovatus*, type, and *A. gibbus*, I found only *Galerites albogalerus*, type and tumid variety.

In the Spongarian zone the following species are characteristic:—*Camerospongia fungiformis*, Goldf., *Ventriculites alternans*, *V. decurrens*, and *Etheridgia mirabilis*, spec. nov.

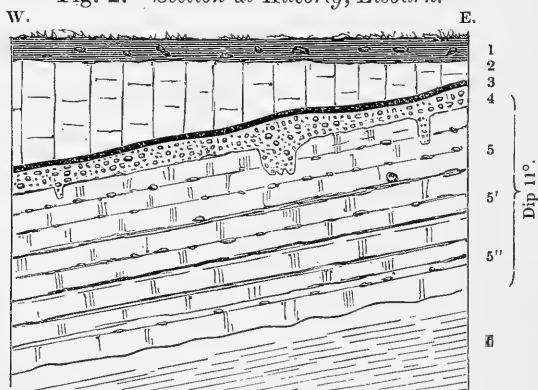
b. *White Limestone or Hard Chalk*.—This stratum has been so accurately described by previous writers that I need only repeat their descriptions, so far as they are applicable to the stratum as developed around Belfast.

The rock is an imperfectly bedded white compact limestone, with a splintery fracture, and containing layers of flints throughout. It is overlain by the Basalt, and rests either upon the Chloritic Chalk or the Hibernian Greensand; from beyond Colin Glen, by Kilcorig, near Lisburn, to Moira, it is seen resting directly on the New Red Marls. It bears abundant evidences of alteration, namely, in its crystalline structure where in contact with the basaltic dykes, and in the shattered condition of the flints in their vicinity. Furthermore, the limestone is throughout the district capped by a layer of flints imbedded in an ochreous clay; all these flints are of a deep bright-red

colour, and are encrusted by a calcareous cement, those of the limestone being of the usual brown or grey tint,—the original heat of the basaltic lavas having altered the degree of oxidation of the iron, constituting the colouring-matter of the flint, by which the brown was converted into a red.

The White Limestone bears evidence of great denudation, firstly, in its variable thickness, attaining a maximum of about 100 feet at Whitehead and Cave Hill, and dwindling down to a few feet in Colin Glen and Woodburn, and being even absent in the lower section in the Woodburn River; secondly, in the flint-gravel bed which is interposed between it and the basalt, which is a constant accompanying feature throughout the district. A fine exposure of the gravel is to be seen in the White Limestone quarries at Kilcorrig, near Lisburn, as represented in the following section.

Fig. 2.—Section at Kilcorrig, Lisburn.



	Thickness.	
	ft.	in.
1. Superficial drift, a stiff clay with imbedded blocks of basalt	4	0
2. Basalt, rudely columnar, attenuated on the eastern part of the section to	6	0
3. Bituminous band, averaging	0	9
4. Gravel-bed, composed of altered chalk-flints in an ochreous paste, filling up the hollows of the denuded White Limestone, and with an average thickness of	3	0
5. White Limestone (Upper Chalk?) with numerous layers of flints and few fossils	21	0
5'. 'Flinty flag,' a highly splintery limestone, irregularly crowded with flints, its upper surface covered with branching Sponge-remains imbedded in a glauconitic paste. Very fossiliferous.	1	0
5''. Two bands of limestone separated by	1	3
a glauconitic layer	0	9
White Limestone, with flints	13	0
6. Variegated marls of the Keuper formation.	37 0	

The White Limestone is very extensively quarried in the county Antrim, it being the only rock available for lime-burning within a very extensive area; generally that obtained from the basement-beds yields the best lime for building-purposes, notably so in the quarries at Kilcorrig; the lime obtained from beds below the "flinty flag" sets more rapidly than that yielded by the stone higher in the quarry. It is not used as a building-stone, as it very readily splits along the planes of bedding on exposure.

The fossils of the White Limestone are by no means plentiful, excepting some ubiquitous species, as *Belemnitella mucronata*, *Terebratula carnea*, and *Rhynchonella octoplicata*; most of the species in my list were obtained from the "flinty flag," at Lisburn, the higher zones rarely yielding a single species; elsewhere the fossils were derived from the lower portion of the zone, the higher parts of it being apparently but slightly fossiliferous.

The characteristic species are—

Ammonites Gollevillensis.
 Belemnitella mucronata.
 Turritella unicarinata.
 Cinulia catenata.
 Ostrea vesicularis.
 Pholadomya cordata.
 ——— Stewarti.
 Pecten nitidus.
 Terebratula carnea.
 Rhynchonella octoplicata.

Megerlia lima.
 Anachytes ovatus, *type and*
var. pyramidatus.
 Cardiaster anachytis.
 Galerites abbreviatus.
 Cyphosoma corollare.
 Paramilia centralis.
 Guettardia stellata.
 Paramoudra Bucklandi.

The above list of fossils not only indicates that the White Limestone is of the age of the Upper Chalk, but points to its representing a high stage in that formation, suggesting, in fact, its parallelism to the Norwich Chalk.

The lowermost portion of the White Limestone being thus known to me as an equivalent of the highest portion of the Upper Chalk of England, *i. e.* of the Norwich Chalk, I endeavoured to obtain fossils from the upper part of it; but I have not been enabled to bring forward direct proofs of a less antiquity than that just inferred for any portion of our Irish Chalk, although the restriction of the fossils to the lower part leads me to hope that the following opinion of Professor Forbes may yet be substantiated, though it can only be so for the upper portion of the White Limestone. He writes*, "The equivalents of the Upper Chalk, of which *Cardiaster granulatus* is a guiding fossil, may be seen at Cipleby and near Maestricht underlying the Yellow Chalk with *Hemipneustes radiatus*, *i. e.* the 'Craie supérieure' of Hébert. I have never seen in England any beds which could satisfactorily be assigned to the last-mentioned series, but think it extremely probable that the Chalk of Antrim, which assuredly should be regarded in its greater part as equivalent to our English Upper or Norwich Chalk, will be found to include equivalents of Maestricht or Yellow Chalk of the Continent."

* Quart. Journ. Geol. Soc. vol. x. p. lv.

V. TABLE SHOWING THE DISTRIBUTION OF THE CRETACEOUS SPECIES IN THE IRISH ZONES, AND THEIR OCCURRENCE IN THE ENGLISH AND CONTINENTAL FORMATIONS.

EXPLANATION OF ABBREVIATIONS.

v.c. very common; c. common; r. rare; v.r. very rare; x. species not common, or its frequency unobserved. G. Gault; G.S. Greensand of Blackdown; U.G.S. Upper Greensand of Warminster, &c.; Chl. M. Chloritic Marl; Ch. M. Chalk Marl; G.Ch. Grey Chalk; L.Ch., U.Ch. Lower and Upper Chalk; U.C., M.C., L.C., Upper, Middle, and Lower Cénomanien; T. Turonien; S. Sénonien.

List of Species.	Distribution.					England and Continent.
	Irish.					
	Hibernian Greensand.			Upper Chalk.		
	Glaucouitic Sands.	Yellow Sands & Marls.	Chloritic Sandstone.	Chloritic Chalk.	White Limestone.	
Class REPTILIA.						
Plesiosaurus, vertebra of	x.	...	...	...	...
Class PISCES.						
Corax falcatus, <i>Ag.</i>	x.	...	?x.v.r†	G.Ch.
Lamna acuminata, <i>Ag.</i>	x. c.	...	...	G.Ch.
Otodus appendiculatus, <i>Ag.</i>	px.	...	x.	...	x†	G.Ch.
Gyrodus cretaceus, <i>Ag.</i>	x. c.	...	...	G.Ch.
Ptychodus mammillaris, <i>Ag.</i>	x.	...	...	G.Ch.
— polygyrus, <i>Ag.</i>	x.	...	...	G.Ch.
Notidanus microdon, <i>Ag.</i>	x†	U.Ch.
Beryx, sp.	x†	
Oxyrhina Mantelli, <i>Ag.</i>	x.	M.Ch.
Class CEPHALOPODA.						
Ammonites varians, <i>Sow.</i>	x.	...	...	...	...	U.G.S.—G.Ch., C.
— Lewesiensis, <i>Mant.</i>	x.	...	...	G.Ch.
— Gollivillensis, <i>d'Orb.</i>	x. v.c.	S. <i>A. colligatus</i> , Binkhorst, Maestricht Ch. is probably this species.
— ocellus, n. sp.	x.	Allied to <i>A. Forbestianus</i> , U.Ch., India.
Scaphites elegans, n. sp.	x.	
Helicoceras Hibernicum, n. sp.	x.	
Hamites Carolinus, <i>d'Orb.</i>	x.	S. Mendon.
Nautilus lævigatus, <i>d'Orb.</i>	x. c.	G.Ch.—U. Ch.
— radiatus, <i>Sow.</i>	x.	G.Ch., C.
— Deslongchampsianus, <i>d'Orb.</i>	x.	...	...	G.Ch., C.
Belemnites ultimus, <i>d'Orb.</i>	x.	...	...	...	...	G.—G.Ch., C.
Belemnitella mucronata, <i>Schloth.</i>	x.	x. v.c.	U.Ch., S.
Class GASTEROPODA.						
Fusus Royanus, <i>d'Orb.</i>	x.	S.
Rostellaria, sp.	x.	
Turritella uncarinata, <i>Woodw.</i>	x. v.c.	U.Ch., Norwich.
Scalaria albæ-creta, n. sp.	x.	
Littorina rotundata, <i>Sow.</i>	x.	...	...	...	...	G.S.
Solarium ornatum?, <i>Sow.</i>	x.	...	...	...	...	G.
Trochus cirrus, <i>Woodw.</i>	x. v.c.	U.Ch., Norwich.
— Basteroti, <i>Brong.</i>	x. c.	S. Mendon, C.
— sp.	x.	
Turbo Zekeli, <i>Binkhorst.</i>	x. r.	S. Limbourg.
Pleurotomaria Thomsoni, <i>Tate.</i>	x.	
— Mailleana, <i>d'Orb.</i>	x.	...	...	U.G.S.; C.
— perspectiva, <i>Mant.</i>	x.	...	...	Ch.M.; L.Ch.

† Coll. Mr. Galloway.

TABLE (continued).

List of Species.	Distribution.					England and Continent.
	Irish.					
	Hibernian Green-sand.			Upper Chalk.		
	Glauconitic Sands.	Yellow Sands & Marls.	Chloritic Sandstone.	Chloritic Chalk.	White Limestone.	
<i>Pleurotomaria disticha</i> ?, <i>Goldf.</i> .....	...	...	...	...	X	S.
—, sp. ....	...	...	...	...	X	
<i>Calyptrea Grayana</i> , n. sp. ....	...	...	...	...	X	
<i>Patella orbis</i> , <i>Roemer</i> .....	...	...	...	...	X	S.
<i>Cinulia avellana</i> , <i>Brong.</i> , sp. ....	...	...	X	...	...	U.G.S., L.Ch.; C.
— <i>catenata</i> , n. sp. ....	...	...	...	...	X	
Class CONCHIFERA.						
<i>Ostrea vesicularis</i> , <i>Lamk.</i> .....	...	...	...	...	X v.c.	U.Ch.; S. C.; Ch.M. (a small form).
— <i>carinata</i> , <i>Lamk.</i>	X v.r.	X c.	...	...	...	U.G.S.—G.Ch., C.
— <i>canaliculata</i> , <i>Sow.</i>	X	...	X v.c.	...	...	U.G.S., G.S.; C.
— <i>semiplana</i> , <i>Sow.</i> .....	...	...	X v.c.	...	...	U.Ch., S.
<i>Exogyra columba</i> , <i>Lamk.</i> .....	...	...	X c.	...	...	C.; G.S., Lyme.
— <i>conica</i> , var. <i>laevigata</i> , <i>Sow.</i>	X v.c.	...	...	...	...	C.
—, var. <i>plicata</i> , <i>Sow.</i>	X	X	...	...	...	C.
— <i>halioidea</i> ,	X	X	...	...	...	C.; G.S.; U.G.S.
— <i>laciniata</i> , <i>Nils.</i> .....	...	...	X v.r.	...	...	G.Ch.
<i>Pecten orbicularis</i> , <i>Mant.</i>	X v.c.	X v.r.	...	...	...	U.G.S.; Ch.M.; G.Ch.
— <i>asper</i> , <i>Lamk.</i>	X	X	...	...	...	G.S.; U.G.S.
— <i>Dutemplei</i> , <i>d'Orb.</i>	X v.c.	X v.r.	X v.r.	...	...	U.G.S.; C.
— <i>glauconeus</i> , n. sp.	X	...	...	...	...
—, sp.	X	...	...	...	...
— <i>cometa</i> , <i>d'Orb.</i>	X	...	...	...	...	C.
— <i>virgatus</i> , <i>Nils.</i>	X	...	...	...	...	C.
— <i>quadrucostatus</i> , <i>Sow.</i> .....	...	X r.	X r.	...	? X †	U.G.S.; C.
— <i>quinquecostatus</i> , <i>Sow.</i>	X c.	X	X v.c.	...	...	U.G.S.—L.Ch.; C.
— <i>sexcostatus</i> , <i>Woodw.</i> .....	...	...	...	...	? X †	U.Ch., Norwich.
— <i>sepicostatus</i> , <i>Lamk.?</i>	? X	X	X	...	...	G.Ch.; U.G.S.
— <i>nitidus</i> , <i>Mant.</i> .....	...	...	...	...	X	U.Ch.
<i>Lima elegans</i> , <i>Nils.</i> .....	...	...	...	...	X	U.Ch., Sweden; Ch. hints, Aberdeen.
— <i>Hoperi</i> , <i>Mant.</i> , sp. ....	...	...	...	...	X †	S.; U.G.S., L.Ch.
— <i>semiornata</i> , <i>d'Orb.</i> .....	...	...	X	...	...	C.; U.G.S.
— <i>simplex</i> , <i>d'Orb.</i> .....	...	...	X	...	...	C.
<i>Spondylus spinosus</i> , <i>Sow.</i> , sp. ....	...	...	X v.c.	...	X	U.Ch.
— <i>striatus</i> , <i>Sow.</i> , sp. ....	...	...	X	...	...	U.G.S.
<i>Plicatula deltoidea</i> , n. sp.	X	...	...	...	...
<i>Avicula sublineata</i> , <i>d'Orb.</i>	X v.c.	...	...	...	...	Untere Kreide; G.S., Farrington.
<i>Inoceramus Crispi</i> , <i>Mant.</i> .....	...	...	X v.c.	...	...	G.Ch.
— <i>striatus</i> , <i>Mant.</i> .....	...	...	X	...	...	G.Ch.
<i>Pinna subtetragona</i> , <i>d'Orb.</i> .....	...	...	X	...	...	G.S., U.G.S.
<i>Mytilus subfalcatus</i> , <i>d'Orb.</i> .....	...	...	X	...	...	C.
<i>Cucullæa carinata</i> , <i>Sow.</i>	X	...	...	...	...	G., G.S., U.G.S.
— <i>Ligeriensis</i> , <i>d'Orb.</i> , sp. ....	...	...	X	...	...	C.
—, 2 sp.	X	...	...	...	...
<i>Area albæ-cretæ</i> , <i>Tate</i> .....	...	...	...	...	X	
—, sp. ....	...	...	X	...	...
<i>Chama inæquirostrata</i> , <i>Woodw.</i> .....	...	...	...	...	X	U.Ch., Norwich.
<i>Cardium gibbosum</i> , n. sp. ....	...	...	X	...	...
<i>Lucina orbicularis</i> , <i>Sow.</i>	X	...	...	...	...	G.S., C.
<i>Astarte lenticularis</i> , <i>Sow.</i> .....	...	...	...	...	X	
<i>Isocardia cretacea</i> , <i>Goldf.</i> .....	...	...	...	...	X	S.
<i>Cypriocardia trapezoidalis</i> , <i>Roem.</i> .....	...	...	...	...	X	S.
<i>Cardita dubia</i> , <i>Sow.</i> , sp. ....	...	...	X	...	...	Ch.M., C.
<i>Venus caperata</i> ?, <i>Sow.</i>	X	...	...	...	...	U.G.S.; G.S.
— <i>subparva</i> , <i>d'Orb.</i> .....	...	...	...	X (c.)	...	S.
<i>Cytherea</i> , 2 sp. ....	...	...	X	...	...

TABLE (continued).

List of Species.	Distribution.					England and Continent.
	Irish.					
	Hibernian Green-sand.			Upper Chalk.		
	Glanconitic Sands.	Yellow Sands & Marls.	Chloritic Sandstone.	Chloritic Chalk.	White Limestone.	
<i>Thetis major</i> , Sow.	x	...	...	...	...	G.S., U.G.S.
<i>Cercomya Royana</i> , d'Orb.	x	...	...	T.
<i>Pholadomya cordata</i> , n. sp.	x	
— <i>obliquissima</i> , n. sp.	x	
— <i>Stewarti</i> , n. sp.	x	
<i>Myacites læviscula</i> , Sow.	x	...	...	...	...	U.G.S.
— <i>mandibula</i> , Sow.	x	...	...	...	...	U.G.S.; C.
<i>Trigonia crenulata</i> , Lamk.	x	...	...	C.
— <i>Dædalea</i> , Park.	x	...	...	G.S.; U.G.S.; C.
—, 2 sp.	x	...	x	...	...
—, sp.	x	...	...	...	...
Class BRACHIOPODA.						
<i>Crania Ignaburgensis</i> , Retz.	x	Ch.
<i>Terebratulina striata</i> , Wahl.	x	...	x	U.G.S.—U.Ch.
— <i>Defrancei</i>	x	S.
<i>Terebratula carnea</i> , Sow.	x. v.c.	...	x. v.c.	[G.S.—Ch.
— <i>obesa</i> , Sow.	x. v.c.	...	x. (r. a	nd very large.) U.
— <i>biplicata</i> ?, <i>Brocchi</i>	x	...	...	G.—Ch.M.; S.
— <i>squamosa</i> , Mant.	x	...	...	...	...	U.G.S.—Ch.M.
— <i>semiglobosa</i> , Sow.	x. v.r.	U.G.S.—Ch.
— <i>abrupta</i> , n. sp.	x	
<i>Waldheimia Hibernica</i> , n. sp.	x	...	...	[Ch., Norwich.
<i>Megerlia lima</i> , Sow.	x	U.G.S.—U.Ch.; U.
<i>Rhynchonella limbata</i> , Schloth., var. <i>lenticiformis</i> , Woodw.	x	Up.Ch. This is most certainly the young of <i>R. octoplicata</i> , Sow., but not of <i>R. plicatilis</i> .
—, var. <i>robusta</i> , nov.	x. v.c.	...	...
— <i>latissima</i> , Sow.	x	...	...	...	U.G.S.
—, var.	x.(v.c.)	...	...	A form of <i>R. latissima</i> that closely approaches to <i>R. plicatilis</i> , Sow.
— <i>nuciformis</i> , Sow.	x	...	...	...	!	U.G.S.—Chl.M.
— <i>plicatilis</i> , Sow.	x. v.c.	U.Ch.
— <i>octoplicata</i> , Sow.	x. v.c.	U.Ch.
Class POLYZOA.						
<i>Desmeopora cylindrica</i> , Roem.	x	...	...	U.Ch.
— <i>aculeata</i> , Mich.	x	...	...	C., Mans, Villiers.
<i>Retepora clathrata</i> ?, Goldf.	x	...	...	U.G.S.
— <i>ramosa</i> , d'Orb.	x	...	S., Meudon, &c.
<i>Pustulipora pustulosa</i> , Goldf.	x	...	...	U.Ch.
<i>Proboscina ramosa</i> , Mich.	x	...	...	U.Ch., S.
<i>Semieschara Normaniana</i> , d'Orb.	x	...	S.
<i>Diastopora Oceani</i> , d'Orb.	x	...	...	C.
— <i>tubulosa</i> , d'Orb.	x	...	...
<i>Heteropora cryptopora</i> , Goldf.	x	x	...	U.G.S.—U.Ch.
<i>Holostoma contingens</i> ?, <i>Lonsdale</i>	x	
<i>Membranipora Parisiensis</i> , d'Orb.	x	S.
<i>Zonopora variabilis</i> , d'Orb.	x	...	...	S.
Class CRUSTACEA.						
<i>Callianassa</i> , sp.	x. c.	...	...
<i>Scalpellum trilineatum</i> ?, <i>Darw.</i>	x	...	...	...	T. and Ch.
— <i>maximum</i> , Sow.	x	U.Ch.
<i>Pollicipes glaber</i> , <i>Roem.</i>	x	...	...	...	T. and U.Ch.
<i>Loricula McAdami</i> , Thomson	x.†	...	...

† Coll. late R. MacAdam, F.G.S.

TABLE (continued).

List of Species.	Distribution.					England and Continent.
	Irish.					
	Hibernian Green-sand.			Upper Chalk.		
	Glauconitic Sands.	Yellow Sands & Marls.	Chloritic Sandstone.	Chloritic Chalk.	White Limestone.	
Class ANNELIDA.						
<i>Vermicularia concava</i> , <i>Sow.</i>	x. v.c.	..	..	U.G.S.
— <i>quinquecarinata</i> , <i>Roem.</i>	x.	x. v.c.	..	..	..	'Hilsthon,' Bohemia.
<i>Vermilia ampullacea</i> , <i>Sow.</i>	x.	x.	..	..	U.G.S.—U.Ch.
<i>Ditrupa deformis</i> , <i>Lamk.</i>	x.	x. v.c.	x.	..	..	U.G.S.; Ch.M.; C.
— <i>cretacea</i> , <i>Hébert</i>	x.	S., Meudon.
<i>Serpula filiformis</i> , <i>Sow.</i>	x. v.c.	..	..	G.; U.G.S.
— <i>plexus</i> , <i>Sow.</i>	x.	..	..	U.G.S.—Ch.
— <i>lævis</i> , <i>Goldf.</i>	x.	..	..	..
— <i>vibicata</i> ?, <i>Münst.</i>	x.	..	..	..
— <i>antiquata</i> , <i>Sow.</i>	x.	..	..	..	..	G.—U.G.S.
— <i>planus</i> , <i>Woodw.</i>	x.	U.Ch.
Class ECHINODERMATA.						
<i>Cidaris vesiculosa</i> , <i>Goldf.</i>	x.	..	..	U.G.S.; G.Ch.
— <i>Sorigneti</i> , <i>Desor</i>	x.	..	..	C. (If distinct from
—, sp.	x.	[<i>C. clavigera</i>].)
<i>Cyphosoma corollare</i> , <i>Park.</i>	x.	U.Ch.
— <i>Cenomanense</i> , <i>Cott.</i>	x.	..	..	L.C.
<i>Echinocoelus abbreviatus</i> , <i>Lamk.</i>	x.	U.Ch.
— <i>subrotundus</i> , <i>Mant.</i>	x.	..	..	G.Ch.
— <i>conicus</i> , <i>Breynius</i>	x.	x.	U.Ch.
—, var. <i>tumidior</i> , <i>Forbes</i>	x.	..	U.Ch.
<i>Discoidea subuculus</i> , <i>Klein</i>	x.	..	..	..	U.G.S.; Ch.M.; G.Ch.
— <i>cylindrica</i> ?, <i>Lamk.</i>	x.	..	..	Ch.M.; G.Ch.
<i>Cardiaster ananchytis</i> , <i>Leske</i>	x.	U.Ch.; S. (<i>C. granulosa</i> , <i>Goldf.</i>)
<i>Micraster cor-anginum</i> , <i>Klein</i>	x.	U.Ch.
<i>Epiaster distinctus</i> , <i>Agass.</i>	x.	x.	..	..	L.C.
— <i>crassissimus</i> , <i>Defr.</i>	x.	..	..	L.C.
<i>Holaster pilula</i> , <i>Lamk.</i>	x.	U.Ch.
<i>Catopygus columbarius</i> , <i>Ag.</i>	x. c.	..	..	U.G.S.—G.Ch.
<i>Echinocorys sulcatus</i> , <i>Goldf.</i>	x. v.r.	U.Ch.
— <i>vulgaris</i> , <i>Breyn.</i> (type)	x. v.c.	x.	U.Ch.
— var. <i>γ. pyramidata</i> , <i>Portl.</i>	x.	..
— <i>gibbus</i> , <i>Lamk.</i>	x. c.	..	S.; U.Ch.
<i>Bourguetierinus ellipticus</i> , <i>d'Orb.</i>	?x.	..	x.	G.Ch.—U.Ch.
<i>Goniaster</i> , sp.	x.	..	..	..
Class ACTINOZOA.						
<i>Cœlosmilia laxa</i> , <i>Edw.</i>	x. (r.)	U.Ch.
<i>Cyathina lævigata</i> , <i>Edw.</i>	x. (r.)	U.Ch.
<i>Parasmilia centralis</i> , <i>Mant.</i>	x.	U.Ch.
<i>Stelloria sulcata</i> , <i>Mich.</i>	x.	..	..	C.
<i>Synastrea superposita</i> , <i>Mich.</i>	x.	..	..	C.
<i>Micrabacia coronula</i> , <i>Goldf.</i>	x. (c.)	..	..	..	U.G.S.
Class RHIZOPODA.						
<i>Orbitolina concava</i> , <i>Lamk.</i>	x.	..	..	U.G.S.
Class SPONGIDA.						
<i>Ventriculites decurrens</i> , <i>Smith</i>	x.	..	U.Ch.
— <i>tessellatus</i> , <i>Sm.</i>	x.	..	U.Ch.
— <i>alternans</i> , <i>Roem.</i>	x.	x.	U.Ch.
— <i>radiatus</i> , <i>Mant.</i>	x.	x.	U.Ch.; S.
— <i>Murchisoni</i> , <i>Goldf.</i>	x.	..	..
<i>Cephalites Bennettii</i> , <i>Mant.</i>	x.	..	U.Ch.; S.
<i>Camerospongia fungiformis</i> , <i>Goldf.</i>	x. (v.c.)	..	S.
<i>Etheridgeia mirabilis</i> , n. sp.	x. (c.)	..	..
<i>Brachiolites protensus</i> , <i>Sm.</i>	x.	..	..	..	L.Ch.

TABLE (continued).

List of Species.	Distribution.					England and Continent.
	Irish.					
	Hibernian Greensand.			Upper Chalk.		
	Glauconitic Sands.	Yellow Sands & Marls.	Chloritic Sandstone.	Chloritic Chalk.	White Limestone.	
<i>Coscinopora infundibuliformis</i> , Goldf.	x	...	S.
<i>Guettardia stellata</i> , Mich.	x (c.)	S.
<i>Cœloptychium furcatum</i> , n. sp.	
— <i>Belfastiense</i> , n. sp.	x	
<i>Cœloscyphia sulcata</i> , n. sp.	x	...	
— <i>Paramoudra</i> , Buckl., sp.	x	U.Ch., Norwich.
<i>Hippalimus</i>	x	...	
<i>Siphonia</i>	x	
<i>Amorphospongia globularis</i> , Reuss.....	x, v. c.	x (c.)	Ch.
— <i>perreticulatum</i> , Portl.....	x	...	
— <i>ramosa</i> , Mant., sp.	x	Ch.
<i>Cliona cretacea</i> , Portl.....	x	x	U.Ch.
<i>Talpina dendrina</i> , Quenst.	x	U.Ch.

Table of Species occurring in the Cretaceous Beds of the North of Ireland, not yet found in the Neighbourhood of Belfast.

<i>Ammonites Portlocki</i> , Sharpe ...	...	...	...	...	...	White Limestone.
— <i>Jukesi</i> , Sh. ...	...	...	...	...	...	"
— <i>Griffithsi</i> , Sh. ...	...	...	...	...	...	"
— <i>Oldhami</i> , Sh. ...	...	...	...	...	...	"
<i>Baculites anceps</i> , Lam. ...	...	...	...	...	...	"
— <i>Faujasi</i> , Lam. ...	...	...	...	...	...	"
— <i>obliquatus</i> , Sow. ...	...	...	...	...	...	"
<i>Emarginula cancellata</i> , Sow. ...	...	...	...	...	...	"
<i>Trochus regalis</i> , Roem. ...	...	...	...	...	...	"
<i>Pyrula rapulum</i> , Sow. ...	...	...	...	...	...	"
<i>Dentalium planicostatum</i> , Hébert (<i>Pseudobelus striatus</i> , Blainville) ...	...	...	...	...	...	"
<i>Gervillia angusta</i> ?, Goldf. ...	...	...	...	...	...	"
<i>Inoceramus Hamiltoni</i> , Portl. ...	...	...	...	...	...	Hibernian Greensand.
— <i>involutus</i> ?, Sow. ...	...	...	...	...	...	"
<i>Gryphaea vesiculosa</i> , Sow. (as <i>G. MacCullochi</i> , Sow.) ...	...	...	...	...	...	"
<i>Lima semisulcata</i> ...	...	...	...	...	...	White Limestone.
<i>Salenia Portlocki</i> , Woodw. (<i>Cidaris acrocidaris</i> , Portl.) ...	...	...	...	...	...	"
<i>Holaster Sandoz</i> , Ag. ...	...	...	...	...	...	"
<i>Siphonia cervicornis</i> , Goldf. ...	...	...	...	...	...	"

The above list contains several species given by Portlock in his lists, with some corrections by me; and the new species of *Ammonites* has been determined and described by Sharpe—the *Salenia* of Woodward. The two lists include all the Cretaceous species of Ireland that are known.

VI. PALÆONTOLOGICAL SUMMARY.

In the Glauconitic Sands, which may be further designated the "Zone of *Exogyra conica*," 36 species have been observed; of these 12 species, or 34 per cent., pass up into the higher zone, 7 of them appearing in the Chloritic Sandstones. With but two or three exceptions, the species that rise upwards are of rare occurrence in the superior zones into which they extend, and similarly those that pass down into the Glauconitic Sands from higher zones are rare in them.

In the "Grey Marls and Yellow Sandstones," which may further be called the "Zone of *Ostrea carinata*," 19 species have been met with, 7 are confined to it, 10 occur also in the Glauconitic Sands below, and 8 are common to it and the Chloritic Sandstones.

In the Chloritic Sandstones and Sands, which embrace two zones—the Zone of *Inoceramus Crispi* and that of *Exogyra columba*,—78 species have been discovered, 59 of which, or 78·2 per cent., are peculiar to them; 10 occur in the lower zones, and 9 extend into the White Limestone: the majority of these are Brachiopods; the only anomalous species is, perhaps, *Spondylus spinosus*, which, however, is rare in the White Limestone, though exceedingly abundant in the Zone of *Inoceramus Crispi* (?).

The species of the Zone of *Exogyra columba* are, with some five or six exceptions, distinct from those of the Zone of *Inoceramus Crispi*.

In the Chloritic Chalk 24 species and varieties have been found. The majority of the *Spongiadae* are peculiar to it, *Belemnitella mucronata*, *Turritella unicarinata*, and the *Echinodermata* appearing also in the White Limestone.

The White Limestone has yielded 83 species, 68 of which are peculiar.

These figures show that each palæontological zone has a distinctive character; that the Zones of *Exogyra conica*, *Ostrea carinata*, *Inoceramus Crispi*, and *Exogyra columba* are more closely related one to the other than they are severally to the zones of the Upper Chalk; that, of these, the fauna of the Zone of *Exogyra conica* presents a striking contrast to that of the Zones of *Inoceramus Crispi* and *Exogyra columba*, the hiatus being bridged over by the species in the intermediate zone, which, however, are more closely related to those of the Zone of *Exogyra conica*.

So, again, the fossils of the Upper Chalk present marked points of contrast to those of the Hibernian Greensand; and its subdivisions, as employed, are good horizons both as regards their palæontological and their lithological characters.

VII. CONCLUSIONS.

1. The Cretaceous rocks of Ireland are referable to two formations—the Hibernian Greensand and the Upper Chalk.

2. The Hibernian Greensand is divisible into well marked lithological and palæontological zones, and is the equivalent in miniature of the Étage Cénomanién of D'Orbigny.

3. The Zone of *Exogyra conica* represents the basement-beds of

Comparative Table of the Upper Cretaceous

Formations.	FRANCE.		ENGLAND.
		Zones of	
Maestrichtien.	Craie supérieure.		Upper part of Norwich Chalk?
Sénonien*.	Craie blanche, ou Craie à <i>Belemnitella mucronata.</i>	<i>Belemnitella mucronata.</i>	Upper Chalk.
		<i>Belemnitella quadrata.</i>	
	Craie marneuse, ou Craie à <i>Spondylus spinosus.</i>	<i>Micraster cor- anguinum.</i>	
		<i>Micraster cor- testudinarum.</i>	
Turonien.	Group of <i>Inoceramus problematicus.</i>	<i>Inoceramus labiatus.</i>	Lower Chalk.
		<i>Ammonites peramplus.</i>	
		<i>Rhynchonella Cuvieri.</i>	
Cénomanién.	Group of <i>Ammonites navicularis.</i>	<i>Terebratula Carontonensis.</i>	(Without fossils.)
		<i>Ostrea biauriculata.</i>	Lower Chalk.
	Group of <i>Pecten asper.</i>	<i>Rhynchonella compressa.</i>	Chalk Marl.
		<i>Turrilites costatus.</i>	Upper Greensand.
		<i>Pygurus lampas.</i>	
		<i>Turrilites tuberculatus.</i>	
<i>Ostrea vesiculosa.</i>			
Albien.			Gault.

* The subdivision and Zones of the "Étage Sénonien" are those of Professor

Formations in France, England, and Ireland.

	IRELAND.
Upper Chalk.	Upper part of White Limestone?
	White Limestone. } Rhynchonella octoplicata, Terebratula carnea, Ananchytes ovatus, Belemnitella mucronata, Holaster pilula.
	Spongarian Zone. } Ventriculites radiatus, Etheridgia mirabilis, Cephalites.
	Zone of <i>Ananchytes gibbus</i> .—Echinoconus conicus.
Absent.	
Hibernian Greensand.	Zone of <i>Exogyra columba</i> . { Inoceramus striatus, Corax falcatus, Trigonion Dædalea, Ammonites Lewesiensis, Ptychodus mammillaris, Anatina Royana, Exogyra laciniata.
	{ Zone of <i>Inoceramus Crispi</i> . { Pleurotomaria perspectiva, Ostrea flabelliformis, O. canaliculata, Cato-pygus columbarius, Orbitolina concava, Cidaris vesiculosa.
	{ Zone of <i>Ostrea carinata</i> . { Exogyra haliotoidea, Pecten æquicostatus, Ditrupa deformis, Micraster distinctus, Discoidea subuculus, Micrabacia coronula. Zone of <i>Exogyra conica</i> . { Pecten asper, P. quinquecostatus, P. Duplei, Myacites mandibula, Ammonites varians.
Absent.	

Hébert; those of the Turonien and Cénomaniens are M. Triger's.

the Étage Cénomanién of the French geologists, and is approximately équivalent to the Greensand of Blackdown.

4. The Zone of *Ostrea carinata* represents most certainly a portion of the Upper Greensand of England and the Lower Cénomanién of Normandy.

5. The Chloritic Sands and Sandstones have, on the whole, a fauna possessing an Upper Greensand facies, many species, however, pointing to higher zones.

It is very probable that the Chloritic Sands of Woodburn (the "Zone of *Inoceramus Crispi*?") may be inferior to the Chloritic Sandstones of Colin Glen—the "Zone of *Exogyra columba*." These two zones, however, never come in contact.

6. The Upper Chalk contains three subdivisions:—

a. Zone of *Ananchytes gibbus*.

b. Spongarian Zone.

c. White Limestone, or the Zone of *Ammonites Gollevillensis*.

The White Limestone certainly represents the Upper Chalk of Norwich and the 'Craie de Meudon'; and some of its fossils point even to a higher parallel—that of the Maestricht Chalk.

These conclusions are represented in the comparative Table of the Upper Cretaceous formations at pp. 34 & 35.

VIII. DESCRIPTIONS OF SPECIES.

1. AMMONITES OCCLUSUS, spec. nov. Pl. III. figs. 1a, 1b.

Shell inflated, with obscure ribs, which are continued over the rounded back; umbilicus imperforate, impressed. Outer whorl embracing all the others, slightly compressed, and gradually increasing so as to form a wide elliptical dilated aperture.

Dimensions.—Diameter $1\frac{6}{10}$ inch; diameter of outer whorl 1 inch; median thickness of outer whorl $\frac{7}{10}$ inch.

Affinities and Differences.—In the disposition of the lobes and saddles of this species, *A. oclusus* bears a great resemblance to *A. Gollevillensis*, D'Orb., *A. Oldhami*, Sharpe, *A. Levesiensis*, Sow., and *A. colligatus*, Binkhorst; but it cannot be regarded as the young of any of these, for in them the umbilicus is open and not imperforate. In its general form, impressed and imperforate umbilicus, and in the general character of its sutural markings, it is closely related to the species constituting the section *Heterophylli*; among the Cretaceous species it has affinities with *A. Rouyanus*, D'Orb., *A. Forbesianus*, D'Orb. (*A. Rouyanus*, D'Orb., Forbes), and *A. picturatus*, D'Orb. From *A. picturatus* it is at once distinguished by its more angular sutural lobes. The nearest known ally is *A. Forbesianus*. I have compared *A. oclusus* with the Indian species in the collection of the Geological Society, and the general facies of the two are most certainly different. In *A. Forbesianus* the back is more inflated, and the sides slope gradually down to the imperforated umbilicus. In *A. oclusus* the last whorl is not so convex, is somewhat flattened from side to side, and the imperforate umbilicus is

markedly more abruptly impressed; the lobes also are more angular and complex.

From *A. inornatus*, D'Orb., to which species Portlock referred his specimens of *A. oculus*, it is distinguished by its closed umbilicus.

Locality.—Rare in the White Limestone of Kilcorig, Lisburn. The specimens in the Museum of Practical Geology were collected from the Upper Chalk of Dungiven.

2. *HELICOCERAS HIBERNICUM*, spec. nov. Pl. III. fig. 2.

As the fragment figured is the largest portion of this species that I have found, a description of the shell from such materials would be imperfect; but the sutural markings, which differ markedly from those of any known species, afford a good specific distinction.

Locality.—Kilcorig, Lisburn, in the White Limestone (Upper Chalk); it is rare.

3. *SCAPHITES ELEGANS*, spec. nov. Pl. III. fig. 3.

Projecting part of the shell with flattened sides and convex back. The sides with an inferior and superior row of spinous tubercles. Three sets of curved costæ decorate the shell: one set, few in number, arise on the inner margin and pass between the tubercles over the back, while the other two sets arise from the tubercles and are similarly continued over the back.

Locality.—Rare at Lisburn. Several specimens are in the Irish Collection deposited in the Museum of Practical Geology, from the White Limestone (Upper Chalk) of Dungiven, co. Londonderry.

4. *PLEUROTOMARIA THOMSONI*, spec. nov.

Turbo? bicarinatus, Sow., in Portlock's Geol. Rep. Londonderry, &c., p. 421; not *P. bicarinata* (*Trochus*, Sow.), Morris, Cat. p. 271.

White Limestone (Upper Chalk), Lisburn; Tamlaght, co. Derry. I dedicate this species to Mr. G. Thomson, who has largely augmented the list of species of the Hibernian Greensand of Woodburn.

5. *TURRITELLA UNICARINATA*, Woodward, sp. Pl. III. fig. 7.

Cerithium unicarinatum, Woodward, Geol. Norfolk, pl. 6. f. 21.

Turritella unicarinata, Woodward; Portlock, Geol. Rep. p. 421, (non Quenstedt).

Nerinea unicarinata, Woodward; Morris, Cat. p. 264.

Shell turreted, elongated, without an umbilicus, many-whorled; whorls convex, angular below; upper surface ornamented with about thirty fine, crenulated, longitudinal, equidistant ribs, with often smaller ones interposed; lower surface similarly ornamented. Inner surface of the whorl with a medial longitudinal sulcus, which is not impressed to the exterior as a band. Suture impressed. Cast smooth, with a single medial longitudinal band on the upper part of each whorl.

This species has hitherto been known only from a cast, and has been referred to three genera, of which I would retain that of *Turritella*. The mouth of the shell, though somewhat angular below, is neither notched nor produced into a canal, and cannot therefore be either a *Cerithium* or a *Nerinea*. The band on the mould is the cast of the internal sulcus, and has no relation to the plaits of a *Nerinea*.

Dimensions.—Total length 3 inches; height of last whorl $\frac{1}{2}$ inch.

Locality.—It is one of the most ubiquitous species in the White Limestone (Upper Chalk) of Ireland. I have also found it, though rarely, in the Spongarian Zone (Upper Chalk) at Woodburn. Specimens with the test preserved are very rare, and the same is true of the majority of the Mollusca.

Casts of *T. unicarinata* occur in the Upper Chalk of Norwich.

6. *SCALARIA ALBÆ-CRETÆ*, spec. nov. Pl. III. fig. 6.

Shell turreted; whorls about ten, contiguous, separated by a linear suture; ornamented transversely by oblique, flexuous, bluntly carinated ribs; interspaces with narrow sulci coincident with the curvature of the ribs. Mouth circular; umbilicus minute. Body-whorl with an anterior keel, furnished with fifteen ribs.

Dimensions.—Length $1\frac{1}{4}$ inch; height of last whorl $\frac{1}{4}$ inch.

Affinities and Differences.—*S. albæ-cretæ* bears a close resemblance to *S. canaliculata*, D'Orb., and *S. albiensis*, D'Orb., both from Neocomian strata; but it differs from them more particularly in the almost entire obliteration of the sutures and in the less obtuse character of the ribs.

Locality.—A few specimens were obtained from the "flinty flag" at Kilcorrig, Lisburn. White Limestone (Upper Chalk).

7. *CALYPTRÆA GRAYANA*, spec. nov. Pl. III. figs. 8a, 8b.

Shell oval, conical, elevated; summit slightly recurved. Ornamented by numerous angular raised ribs, decussated by flexuous and inequidistant lines of growth.

Dimensions (of largest specimen).—Height $\frac{9}{24}$ inch; diameters $\frac{1}{2}\frac{3}{4}$ and $\frac{1}{2}\frac{2}{0}$ inch.

Locality.—Rare in the White Limestone (Upper Chalk) of Kilcorrig, Lisburn.

I dedicate this species to my friend Mr. W. Gray.

8. *CINULIA CATENATA*, spec. nov. Pl. III. figs. 4a-4c.

Shell oval, ventricose, very globose, thick; spire composed of four whorls, of which the last is higher than broad, and occupies nearly the total length. It is ornamented with about thirty longitudinal, smooth, flat ribs, which increase in breadth from the base to the suture of the body-whorl. The narrow sulci between the ribs are occupied by elliptical, somewhat confluent punctations in chain-like rows. Mouth large; lip thick and reflected, provided with numerous equal denticulations; columella with a single plait inferiorly.

Affinities and Differences.—This species is allied by its form to

C. cassis, D'Orb., and some others, but is easily distinguished by its chain-like punctations in the narrow sulci between the flat and broad longitudinal ribs. It is closely allied to *C. Archiaciana*, D'Orb., from which it is distinguished by the absence of the fine striæ upon the ribs, which characterize that species. There is also a marked difference in the form of the punctations; in *C. catenata* they are elliptical and large, in *C. Archiaciana* minute and circular. *C. catenata* is also a much larger and more globose shell.

The cast shows the broad flattened ribs, which enable one to distinguish it even in that condition from *C. cassis*, *C. incrassata*, and others.

Dimensions.—Length $\frac{5}{8}$ inch; height of last whorl $\frac{1}{2}$ inch.

Locality.—This species is not uncommon at Kilcorig, Lisburn, in the "flinty flag" of the White Limestone (Upper Chalk).

9. *PLICATULA DELTOIDEA*, spec. nov. Pl. III. figs. 5a, 5b.

Shell ovato-triangular, oblique, very depressed, nearly equivalve; superior valve nearly flat, inclined to convex, with numerous imbricated lamellæ coincident with the contour of the valve; inferior valve slightly convex, ornamented with concentric lamellæ, which are produced into spines, the spines disposed in seven rays, with one or two intercalated towards the margin. Adherent by the apex.

Affinities and Differences.—This shell in its depressed form is allied to *P. clathrata*, E. Deslong.; but it differs from that species in the character of its ornamentation. *P. clathrata* is furnished with numerous radiating dichotomous ribs, which are not spinous. In the character of the spinous rays of the lower valve, *P. deltoidea* resembles *P. radiola*, Lam., and *P. gurgitis*, Pictet & Roux. From these species it is distinguished by the absence of the rounded, very slightly elevated, feebly spinous rays of the upper valve, and by being depressed; for in these species the superior valve is concave, and the inferior very convex.

Locality.—This species I obtained from the Glauconitic Sands at Whitehead, during the construction of the railway. It is very rare.

10. *CARDIUM GIBBOSUM*, spec. nov. Pl. IV. fig. 6.

Shell equilateral, oblong, compressed, remarkably inflated at the umbones; ornamented by about twenty flat radiating ribs; the sulci about equal in breadth to the ribs; interspaces between the ribs crossed with transverse bars.

The remarkably gibbous character of this shell is very distinctive, and the oblong form further distinguishes it from any other species.

Dimensions.—Length $\frac{7}{16}$ inch; height $\frac{5}{16}$ inch.

Locality.—I am acquainted with only five specimens of this species, all from the Zone of *Exogyra columba* of the Hibernian Greensand of Colin Glen.

11. *PECTEN GLAUCONEUS*, spec. nov. Pl. IV. fig. 5.

Shell equivalve, equilateral, ovate-orbicular, slightly convex; ornamented with from fifteen to twenty convex and elevated radi-

ating ribs, with distant, imbricated, squamose plates. Ears small, equal.

Dimensions.—Length $\frac{5}{16}$ inch; height $\frac{3}{8}$ inch.

Affinities and Differences.—*P. glauconeus* is very closely allied to *P. subaratus*, Nilsson, an Upper Chalk species of Sweden and Germany, from which, however, it may be distinguished by its more regularly rounded form, its fewer and thicker ribs, and the less number of squamose asperities. From *P. imbricatus*, Desh., and *P. subimbricatus*, Münster, it is distinguished by its circular form and fewer ribs.

Locality.—The Glauconitic Sands of Woodburn and Whitehead, where it is rare. Zone of *Exogyra conica*, Hibernian Greensand.

12. *ARCA ALBÆ-CRETÆ*, spec. nov.

A. radiata, Sow., in Portlock's Geol. Rep. Londonderry, &c., p. 442; non *A. radiata*, Münster, 1838.

Locality.—Rare at Lisburn; "not rare in the Tamlaght Chalk." Upper Chalk.

13. *PHOLADOMYA OBLIQUISSIMA*, spec. nov. Pl. IV. fig. 3.

Shell oblique, arcuate; umbones very far forward, elevated, and approximate; anterior side very short, nearly obsolete; posterior extremity very much produced, arcuate, and subtruncated. Lunule small, slightly cordate; hinge-area large, open, and deeply impressed. Surface covered by numerous straight longitudinal ribs, decussated by well-marked lines of growth and intermediate striæ.

Dimensions.—Total length $3\frac{5}{8}$ inches; greatest depth $2\frac{1}{8}$ inches; height $2\frac{1}{2}$ inches; length of anal side $3\frac{1}{8}$ inches.

Affinities and Differences.—The above species is closely allied to *P. Esmarki*, Nilss., from which it may be distinguished by its more flattened and oblique anterior side and by its less arcuate posterior extremity. *P. obliquissima* is much higher proportionally to its transverse length than *P. Esmarki*, as seven to six, and is of less depth, in the proportion of three to four.

Locality.—Not uncommon in the White Limestone (Upper Chalk), Kileorig, Lisburn, co. Antrim, and Dungiven, co. Derry.

14. *PHOLADOMYA CORDATA*, spec. nov. Pl. IV. figs. 1 a, 1 b.

Shell oblique, subtrigonal, anterior margin keeled and curved; lunule largely cordate, produced, enclosing between it and the keeled margin a deep concave area becoming shallower and more expanded towards the front. Radiating ribs numerous, the anterior ones coincident with the curvature of the keel, crossed by thick, concentric, inequidistant lines of growth; umbones incurved.

Dimensions.—Total length $2\frac{1}{2}$ inches; height $2\frac{1}{4}$ inches; length of anal side 2 inches, depth $1\frac{3}{4}$ inch.

Affinities and Differences.—*P. cordata* bears a great resemblance to *P. decussata*, Phill.; but the anterior extremity in that species is flat, and the radiating ribs on the sides are straight in consequence, and not curved as in *P. cordata*. The greatest diameter of *P. decus-*

sata is close to the flat anterior side; in *P. cordata* it is at about one-third of the breadth of the shell from the anterior margin. In *P. decussata* the lunule is not defined.

Locality.—It is not uncommon in the White Limestone (Upper Chalk), at Kilcorrig, Lisburn, and also at Dungiven.

15. PHOLADOMYA STEWARTI, spec. nov. Pl. IV. fig. 2.

Shell oblong, inequilateral; umbones prominent; length of anterior side about one-third of the length of the shell; margin rounded; posterior side truncated, with a keel proceeding from the umbo to the lower posterior margin, enclosing between it and the hinge-line a smooth area. Ornamented by about ten straight radiating ribs, which are thickened where crossed by the prominent lines of growth.

Dimensions.—Total length $1\frac{5}{8}$ inch; height 1 inch; length of anal side $1\frac{1}{8}$ inch.

Affinities and Differences.—Allied to the young of *P. Royana*, D'Orb., in its form and ornamentation, but differs from it in its truncated posterior margin. *P. Stewarti* has constantly the dimensions given.

Locality.—One of the most common bivalves in the White Limestone (Upper Chalk) of Lisburn, &c.

I have much pleasure in dedicating this species to Mr. S. A. Stewart, a valued friend and pupil, who has contributed much to the palæontology and botany of the north of Ireland.

16. TEREBRATULA ABRUPTA, spec. nov. Pl. V. figs. 1 a, 1 b.

Shell elongated, oval, much longer than wide; greatest breadth at the middle, whence the shell tapers rapidly towards the front and beak, marked with inequidistant concentric lines of growth and faint longitudinal striæ; shell-structure punctated. Valves nearly equally convex; imperforate valve most convex near the umbonal region; ventral valve biplicated; beak very short, prolonged and transversely truncated by a circular foramen of large dimensions; beak-ridges ill defined; deltidium inconspicuous, from the aperture being contiguous to the umbo of the dorsal valve; hinge-area remarkably declinous.

Dimensions.—Length 2 inches; breadth $1\frac{4}{10}$ inch; depth 1 inch.

Affinities and Differences.—This biplicated *Terebratula* cannot well be confounded with any of the Cretaceous species. It, however, resembles *T. obesa* and *T. biplicata*, from which it is readily distinguished by its transversely truncated beak, which is produced but very slightly beyond the plane of the umbo of the dorsal valve. In both of these species the beak is incurved; the more spindle-shaped appearance of *T. abrupta* is a very distinctive character. The largely truncated beak and foramen contiguous to the umbo distinguish this species from biplicated examples of *T. longirostris*, and of certain Belgian Cretaceous forms, which in other respects bear some resemblance to it.

Locality.—I have collected this species at Lisburn and at Moira, where it is rare. Specimens in the Portlock Collection, in the Museum of Practical Geology, are from Dungiven, co. Londonderry.

At all the localities it has been found in the White Limestone (Upper Chalk).

17. *Terebratula* (*Waldheimia*) *Hibernica*, spec. nov. Pl. V. figs. 3*a*–3*c*.

Shell somewhat longitudinally ovate, or orbicular, slightly depressed; surface marked by numerous faint concentric striæ; shell-structure largely punctated. Valves nearly equally convex. Margin subobtuse, flexuous; the imperforated valve with a very shallow longitudinal depression and a tendency to bifurcation. Beak incurved and obliquely truncated by an elliptical foramen, surrounded and separated from the hinge-line by a deltidium of two pieces. Beak-ridges moderately incurved, rather obtuse.

Dimensions.—Length $\frac{3}{8}$ inch; breadth $\frac{5}{16}$; depth $\frac{3}{16}$.

Affinities and Differences.—It is most nearly allied to *W. tamarindus*, Sow., from which it differs in its more oblong form, bifurcation of the upper valve, smaller foramen, greater development of the deltidium-plates, and more obtuse beak-ridges, and in the presence of numerous fine concentric striæ. It is also a smaller species, and never becomes obovate like many specimens of *W. tamarindus*, Sow. *W. Celtica* is at once distinguished from *W. Hibernica* by its remarkably elongated form.

At present I am unacquainted with the character of the loop; but the general form of the shell warrants me in referring it to the above subgenus.

Locality.—It is common in a compact chloritic sandstone in Colin Glen, of the Zone of *Exogyra columba* of the Hibernian Greensand.

18. *Terebratulina* *Defrancei*, Brong. Pl. IV. fig. 4.

The fragment of this conspicuous species, or adult variety, as it may be, of *T. striata*, Wahl., is the first indication of the occurrence of this form in the British Isles. Being a new and interesting addition to British palæontology, it is here figured.

The figured fragment is the only one known; it was obtained by me from the flinty flag (Upper Chalk), at Kilcorig, Lisburn.

19. *Rhynchonella* *limbata*, Schloth., var. *robusta*, var. nov. Pl. V. figs. 2*a*–2*c*.

This well-marked variety of *R. limbata* is very distinct on account of the exceeding gibbosity of the shell; it is moreover of larger dimensions than specimens of *R. limbata* usually are. It is exceedingly common in the Zone of *Inoceramus Crispi*, at Woodburn, Whitehead, and Island Magee. It is not found in any other zone.

ETHERIDGIA, gen. nov.

Characters.—Conoid, summit truncated and pierced by a relatively large opening communicating with the interior. Base rather flat, provided with radiceform processes of attachment, disposed inframarginally and centrally. The external surface of the cone is provided with larger circular oscules, with an irregular biserial arrangement, between which are minute pores.

Affinities.—*Etheridgia* bears some general resemblance to *Camer spongia*, D'Orbigny. The general form of the species of that genus is that of two cones opposed by their bases, the inferior one with irregularly disposed oscules, more or less elongated, and attached by the extremity. The upper cone or head, which is very conspicuous and unmistakable, is smooth, depressed, and truncated.

I dedicate this genus to my friend Robert Etheridge, Esq., F.G.S., F.R.S.E., of the Geological Survey, from whom I have received much assistance and encouragement in the prosecution of my geological studies and investigations.

20. *ETHERIDGIA MIRABILIS*, spec. nov. Pl. V. figs. 4a, 4b.

Locality.—Very common in the Spongarian Zone (Upper Chalk); Island Magee, Whitehead, and Woodburn especially.

CÆLOSYPHIA, gen. nov.

Polycælia, E. de From., 1860 (not of King, 1849).

M. E. de Fromentel, in the 'Mémoires de la Société Linnéenne de Normandie' (vol. xi. p. 32), describes the characters of a natural section of the genus *Scyphia* of Goldfuss, under the generic name of *Polycælia*; Dr. A. F. Roemer, in Dunker's 'Palæontographica' (vol. xiii. p. 30, 1864), adopts De Fromentel's genus. But this term had been already used by Professor W. King, in 1849, for a new genus of *Zoantharia* (see also Morris's Cat. p. 62, 1854). Therefore the generic term *Polycælia* being thus preoccupied, I propose that of *Cæloscyphia* for that group of Sponges associated under the generic title *Polycælia* by De Fromentel and by Roemer.

21. *CÆLOSYPHIA SULCATA*, spec. nov. Pl. V. fig. 5.

Compound, trifold. Spongite cylindrical, short, and proportionately of great diameter, truncated transversely; opening, with a diameter half that of the spongite, surrounded by a deeply crenulated border. Walls of spongite deeply folded, with from 10–13 rounded ribs.

Locality.—Rare in the Spongarian Zone (Upper Chalk), Island Magee.

22. *CÆLOPTYCHIUM FURCATUM*, spec. nov. Pl. V. fig. 6.

Expanded circular disk (only part known) ornamented with ten rounded elevated ribs, which radiate from a common centre to the circumference of the disk, and which bifurcate near their commencement and again at about half the length of the ribs. A few scattered oscules appear on the ribs.

Locality.—In the Spongarian Zone (Upper Chalk), Whitehead. The figured specimen is unique.

23. *CÆLOPTYCHIUM BELFASTIENSE*, spec. nov. Pl. V. fig. 7.

Disk circular, with fifteen broad flattened radiating ribs, which bifurcate near their commencement, and increase in breadth as they proceed to the circumference.

Locality.—The specimen figured was obtained in the White Limestone (Upper Chalk), at the Cave Hill, Belfast, by Mr. S. A. Stewart.

24. *DITRUPA DEFORMIS*, Lamarck.

This is a well-known species in the Upper Cretaceous rocks of Normandy and Belgium, and as it has been unnoticed up to the present time by English collectors, I am induced to give its synonymy, with references to published figures.

1815. *Dentalium deforme*, Lamk. Animaux sans Vert. vol. v. p. 344, no. 6.

1825. — *septangulare*, Fleming, Edinburgh Phil. Journ. p. 240, pl. 12. f. 9.

1839. *Serpula septemsulcata*, Geinitz, Charac. der Schicht. p. 66, pl. 22. f. 6.

1847. — *sulcataria*, D'Archiac, Fossiles du Tourtia, p. 30, pl. 14. f. 11.

1848. — ? *clavata*, Kner, Kreidem. von Lemberg, pl. 5. f. 13.

1850. *Ditrupe deformis*, De Ryckholt, apud Lamarck, Mélanges Paléontologiques, p. 123.

1850. *Dentalium*? *difforme*, Sow. in Dixon's Geol. Sussex, pl. 29. f. 10.

EXPLANATION OF PLATES III.-V.

Illustrative of the Fossils of the Irish Cretaceous Strata.

PLATE III.

Fig. 1. *Ammonites oculusus*, nat. size: *a*, side view with septal suture; *b*, back view.

Fig. 2. *Helicoceras Hibernicum*: *a*, fragment with septal suture.

Fig. 3. *Scaphites elegans*, nat. size.

Fig. 4. *Cinulia catenata*: *a*, enlarged 2 diameters; *b*, portion of shell, magnified; *c*, sectional view of shell.

Fig. 5. *Plicatula deltoidea*, nat. size: *a*, upper valve; *b*, lower valve.

Fig. 6. *Scalaria albæ-cretæ*, nat. size.

Fig. 7. *Turritella unicarinata*, nat. size; upper portion representing the mould, with a mesial band.

Fig. 8. *Calyptrea Grayana*, enlarged 2 diameters: *a*, view from above; *b*, side view.

PLATE IV.

Fig. 1. *Pholadomya cordata*, nat. size smallest specimen: *a*, side view; *b*, front aspect.

Fig. 2. — *Stewarti*, nat. size.

Fig. 3. — *obliquissima*, nat. size.

Fig. 4. *Terebratulina Derancei*: *a* dorsal valve, nat. size. (This figure represents the specimen turned half round.)

Fig. 5. *Pecten glauconeus*, enlarged 2 diameters.

Fig. 6. *Cardium gibbosum*, enlarged 2 diameters.

PLATE V.

Fig. 1. *Terebratula abrupta*, nat. size: *a*, seen from above; *b*, side view.

Fig. 2. *Rhynchonella limbata*, var. *robusta*, nat. size: *a*, viewed from the front; *b*, side view; *c*, seen from above.

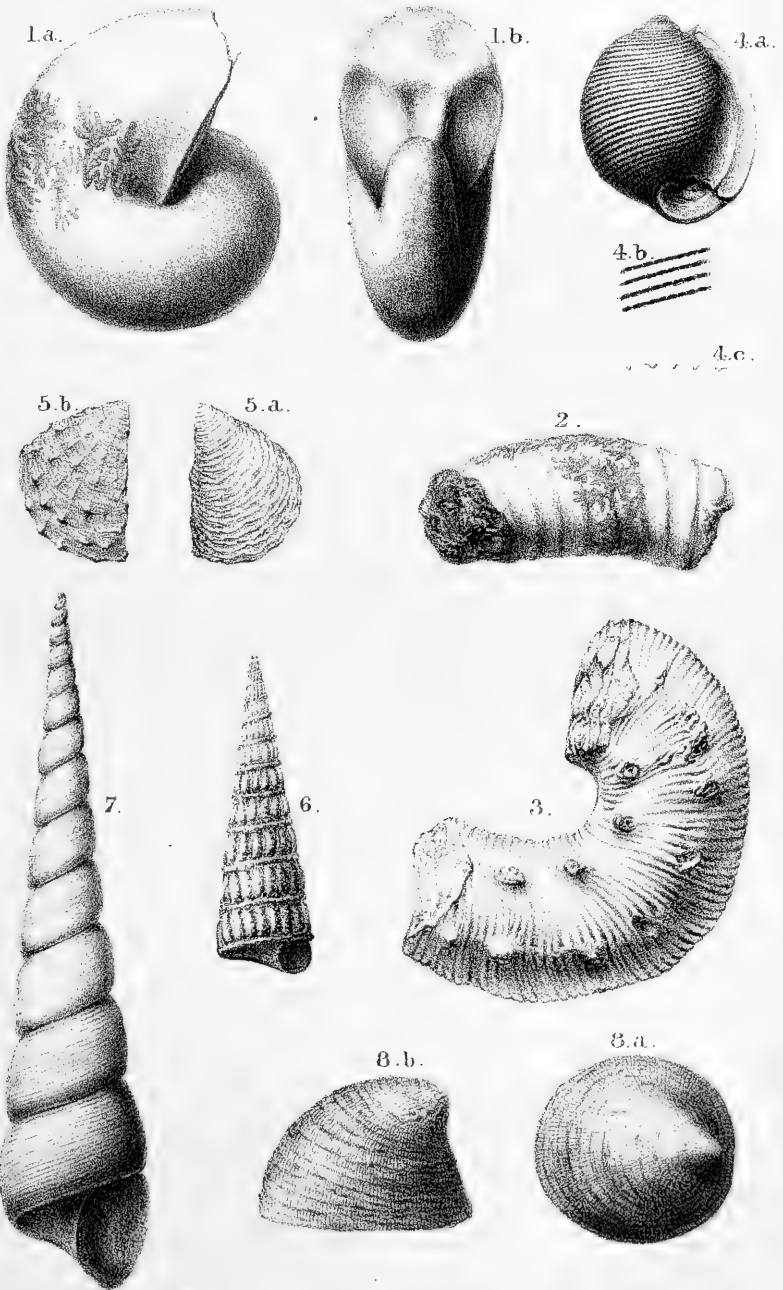
Fig. 3. *Terebratula (Waldheimia) Hibernica*: *a*, *b*, enlarged 2 diameters; *c*, a fragment of the beak, enlarged.

Fig. 4. *Etheridgia mirabilis*, nat. size: *a*, side view; *b*, under surface, showing the radiciform processes.

Fig. 5. *Cæloscyphia sulcata*, nat. size.

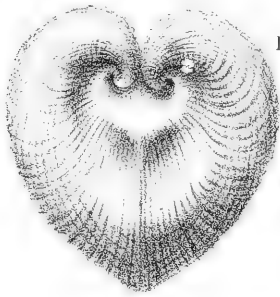
Fig. 6. *Cæloptychium furcatum*, reduced one-half.

Fig. 7. — *Belfastiense*, nat. size.

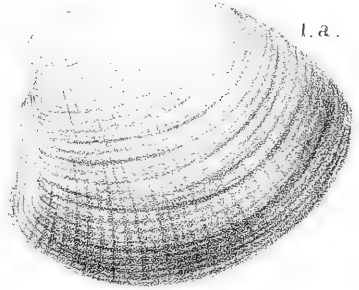


Edwin M. Williams, Sc

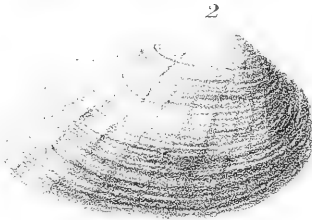
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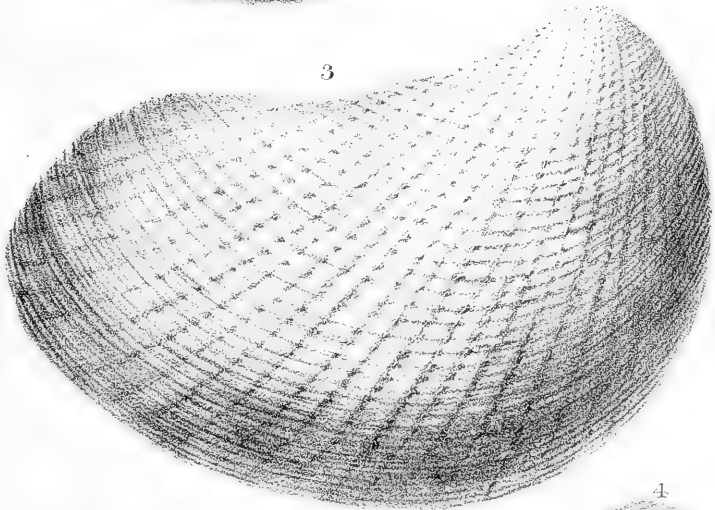
1.b.



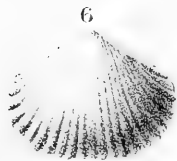
1.a.



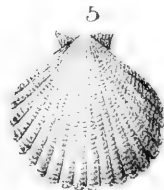
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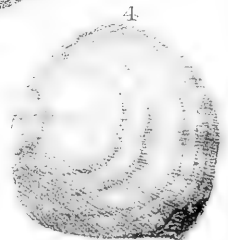
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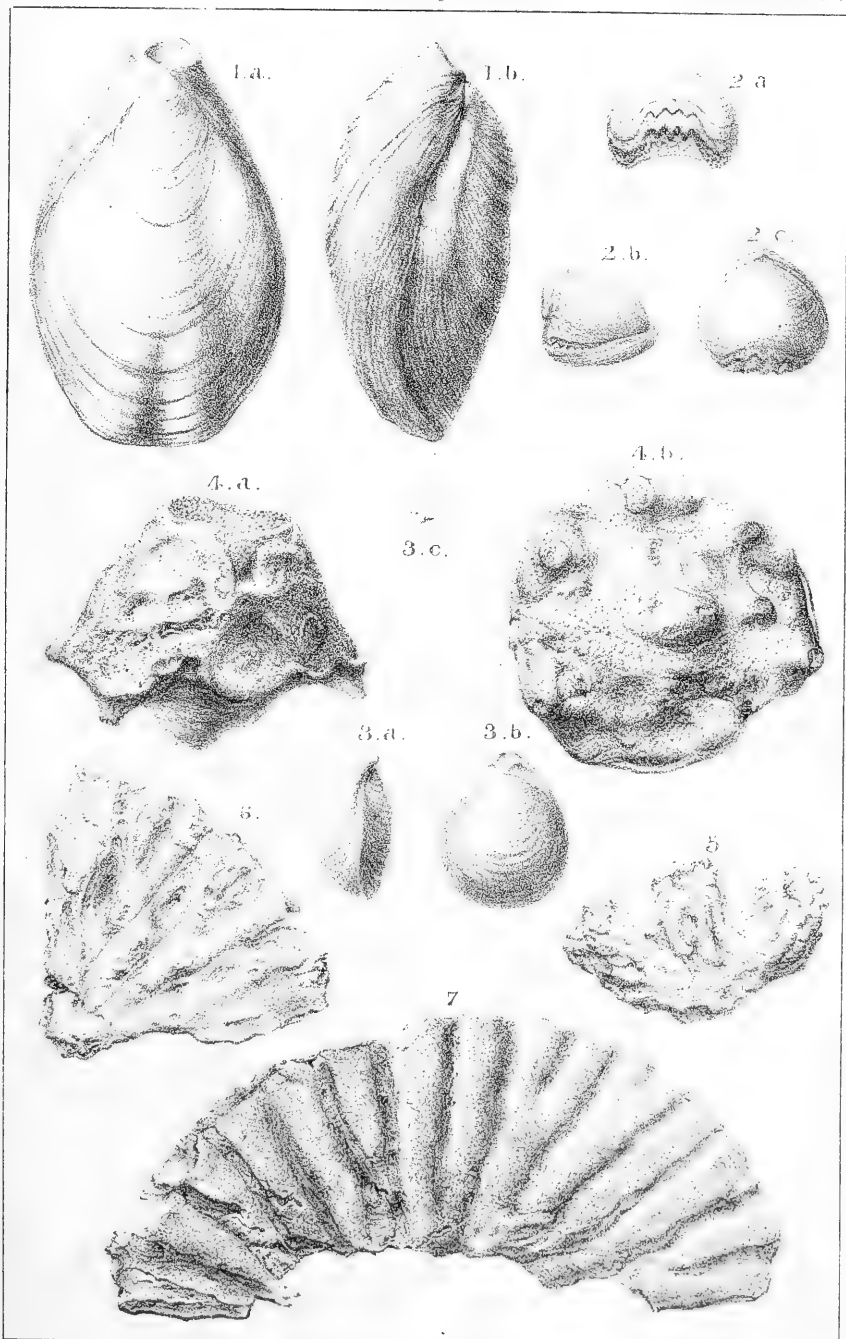
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3. *On the RECENT EARTHQUAKE at ST. HELENA.*
By GOVERNOR SIR C. ELLIOT, K.C.B.

[Communicated by the Colonial Secretary through Sir C. Lyell, Bart.,
F.R.S., F.G.S.]

[Abstract.]

THIS earthquake, which is stated to be the fourth that has occurred during the two centuries that we have been in the occupation of the Island, occurred at about 4h. 10m. A.M. on July 15th, and in this paper Sir C. Elliot described the nature of the shock and the circumstances attending it.

NOVEMBER 23.

William Stephen Mitchell, Esq., of Gonville and Caius College, Cambridge, was elected a Fellow.

The following communications were read:—

1. *On the OCCURRENCE of ORGANIC REMAINS in the LAURENTIAN ROCKS of CANADA.* By Sir W. E. LOGAN, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Canada.

THE oldest-known rocks of North America are those which compose the Laurentian Mountains in Canada and the Adirondacks in the State of New York. By the investigations of the Geological Survey of Canada, they have been shown to be a great series of strata, which, though profoundly altered, consist chiefly of quartzose, aluminous, and argillaceous rocks, like the sedimentary deposits of less ancient times. This great mass of crystalline rocks is divided into two groups, and it appears that the Upper rests unconformably upon the Lower Laurentian series.

The united thickness of these two groups in Canada cannot be less than 30,000 feet, and probably much exceeds it. The Laurentian of the West of Scotland also, according to Sir Roderick Murchison, attains a great thickness. In that region the Upper Laurentian, or Labrador series, has not yet been separately recognized; but, from Mr. McCulloch's description, as well as from the specimens collected by him, and now in the Museum of the Geological Society of London, it can scarcely be doubted that the Labrador series occurs in Skye. The labradorite and hypersthene-rocks from that island are identical with those of the Labrador series in Canada and New York, and unlike those of any formation at any other known horizon. This resemblance did not escape the notice of Emmons, who, in his description of the Adirondack Mountains, referred these rocks to the hypersthene-rock of McCulloch, although these observers on the opposite sides of the Atlantic looked upon them as unstratified. In the 'Canadian Naturalist' for 1862, Mr. Thomas McFarlane, for

some time resident in Norway, and now in Canada, drew attention to the striking resemblance between the Norwegian primitive gneiss formation, as described by Naumann and Keilhau, and observed by himself, and the Laurentian, including the Labrador group; and the equally remarkable similarity of the lower part of the primitive slate formation to the Huronian series, which is a third Canadian group. These primitive series attain a great thickness in the north of Europe, and constitute the main features of Scandinavian geology.

In Bavaria and Bohemia there is an ancient gneissic series. After the labours in Scotland, by which he was the first to establish a Laurentian equivalent in the British Isles, Sir Roderick Murchison, turning his attention to this central European mass, placed it on the same horizon. These rocks, underlying Barrande's Primordial zone, with a great development of intervening clay-slate, extend southward in breadth to the banks of the Danube, with a prevailing dip towards the Silurian strata. They had previously been studied by Gümbel and Crejci, who divided them into an older reddish gneiss and a newer grey gneiss. But, on the Danube, the mass which is furthest removed from the Silurian rocks being a grey gneiss, Gümbel and Crejci account for its presence by an inverted fold in the strata, while Sir Roderick places this at the base, and regards the whole as a single series, in the normal fundamental position of the Laurentian of Scotland and of Canada. Considering the colossal thickness given to the series (90,000 feet), it remains to be seen whether it may not include both the Lower and Upper Laurentian, and possibly, in addition, the Huronian.

This third Canadian group (the Huronian) has been shown by my colleague, Mr. Murray, to be about 18,000 feet thick, and to consist chiefly of quartzites, slate-conglomerates, diorites, and limestones. The horizontal strata, which form the base of the Lower Silurian in Western Canada, rest upon the upturned edges of the Huronian series, which, in its turn, unconformably overlies the Lower Laurentian. The Huronian is believed to be more recent than the Upper Laurentian series, although the two formations have never yet been seen in contact.

The united thickness of these three great series may possibly far surpass that of all the succeeding rocks, from the base of the Palæozoic series to the present time. We are thus carried back to a period so far remote, that the appearance of the so-called Primordial fauna may by some be considered a comparatively modern event. We, however, find that, even during the Laurentian period, the same chemical and mechanical processes which have ever since been at work disintegrating and reconstructing the earth's crust were in operation as now. In the conglomerates of the Huronian series there are enclosed boulders derived from the Laurentian, which seem to show that the parent rock was altered to its present crystalline condition before the deposit of the newer formation, while interstratified with the Laurentian limestones there are beds of conglomerate, the pebbles of which are themselves rolled fragments

the Laurentian series, seemed to be an evidence of the existence of vegetation, since no one disputes the organic character of this mineral in more recent rocks. My colleague, Dr. T. Sterry Hunt, has argued for the existence of organic matters at the earth's surface during the Laurentian period from the presence of great beds of iron-ore, and from the occurrence of metallic sulphurets; and, finally, the evidence was strengthened by the discovery of supposed organic forms. These were first brought to me, in October 1858, by Mr. J. McCulloch, then attached, as an explorer, to the Geological Survey of the province, from one of the limestones of the Laurentian series, occurring at the Grand Calumet, on the River Ottawa.

Any organic remains which may have been entombed in these limestones would, if they retained their calcareous character, be almost certainly obliterated by crystallization; and it would only be by the replacement of the original carbonate of lime by a different mineral substance, or by an infiltration of such a substance into all the pores and spaces in and about the fossil, that its form would be preserved. The specimens from the Grand Calumet present parallel or apparently concentric layers, resembling those of *Stromatopora*, except that they anastomose at various points. What were at first considered the layers are composed of crystallized pyroxene, while the then supposed interstices consist of carbonate of lime. These specimens, one of which is figured in the 'Geology of Canada,' page 49, called to memory others which had, some years previously, been obtained from Dr. James Wilson, of Perth, and were then regarded merely as minerals. They came, I believe, from masses in Burgess, but whether in place is not quite certain; and they exhibit similar forms to those of the Grand Calumet, composed of layers of dark-green silicate of magnesia (loganite), while what was taken for the interstices are filled with crystallized dolomite. If the specimens from both these places were to be regarded as the result of unaided mineral arrangement, it appeared to me strange that identical forms should be derived from minerals of such different composition. I was therefore disposed to look upon them as fossils, and as such they were exhibited by me at the meeting of the American Association for the Advancement of Science, at Springfield, in August 1859. In 1862 they were shown to some of my geological friends on this side of the Atlantic; but no microscopic structure having been observed belonging to them, few seemed disposed to believe in their organic character, with the exception of my friend Professor Ramsay.

One of the specimens had been sliced and submitted to microscopic examination, but unfortunately it was one of those composed of loganite and dolomite. In these, minute structure rarely occurs. The true character of the specimens thus remained in suspense until last winter, when I accidentally observed indications of similar forms in blocks of Laurentian limestone which had been brought to our museum by Mr. James Lowe, one of our explorers, to be sawn up for marble. In this case the forms were composed of serpentine

and calcspar; and slices of them having been prepared for the microscope, the minute structure was observed in the first one submitted to inspection. At the request of Mr. Billings (the palæontologist of our Survey), the specimens were confided for examination and description to Dr. J. W. Dawson, of Montreal, our most practised observer with the microscope, and the conclusions at which he has arrived are appended to this communication. He finds that the serpentine, which was supposed to replace the organic form, really fills the interspaces of the calcareous fossil. This exhibits in some parts a well-preserved organic structure, which Dr. Dawson describes as that of a Foraminifer, growing in large sessile patches after the manner of *Polytremia* and *Carpenteria*, but of much larger dimensions, and presenting minute points which reveal a structure resembling that of other Foraminiferal forms, as, for example, *Calcarina* and *Nummulina*. Dr. Dawson's description is accompanied by some remarks by Dr. Sterry Hunt on the mineralogical relations of the fossil. He observes that, while the calcareous septa which form the skeleton of the Foraminifer in general remain unchanged, the sarcode has been replaced by certain silicates which have not only filled up the chambers, cells, and septal orifices, but have been injected into the minute tubuli, which are thus perfectly preserved, as may be seen by removing the calcareous matter by an acid. The replacing silicates are white pyroxene, serpentine, loganite, and pyralolite or renselaerite. The pyroxene and serpentine are often found in contact, filling contiguous chambers in the fossil, and were evidently formed in consecutive stages of a continuous process. In the Burgess specimens, while the sarcode is replaced by loganite, the calcareous skeleton, as has already been stated, has been replaced by dolomite, and the finer parts of the structure have been almost wholly obliterated. But in the other specimens, where the skeleton still preserves its calcareous character, the resemblance between the mode of preservation of the ancient Laurentian *Foraminifera* and that of the allied forms in Tertiary and Recent deposits (which, as Ehrenberg, Bailey, and Pourtales have shown, are injected with glauconite) is obvious.

The Grenville specimens belong to the highest of the three already mentioned zones of Laurentian limestone, and it has not yet been ascertained whether the fossil extends to the two conformable lower ones, or to the calcareous zones of the overlying unconformable Upper Laurentian series. It has not yet either been determined what relation the strata from which the Burgess and Grand Calumet specimens have been obtained bear to the Grenville limestone or to one another. The zone of Grenville limestone is in some places about 1500 feet thick, and it appears to be divided for considerable distances into two or three parts by very thick bands of gneiss. One of these occupies a position towards the lower part of the limestone, and may have a volume of between 100 and 200 feet. It is at the base of the limestone that the fossil occurs. This part of the zone is largely composed of great and small irregular masses of white crystalline pyroxene, some of them twenty yards in

length by four or five wide ; and they appear to be confusedly placed one above another, with many ragged interstices and many smooth-worn, rounded, large and small pits and subcylindrical cavities, some of them pretty deep. The pyroxene, though it appears compact, presents a multitude of small spaces, consisting of carbonate of lime, and many of these show minute structures similar to that of the fossil. These masses of pyroxene may characterize a thickness of about 200 feet, and the interspaces among them are filled with a mixture of serpentine and carbonate of lime. In general a sheet of pure dark-green serpentine invests each mass of pyroxene, the thickness of the serpentine, varying from the sixteenth of an inch to several inches, rarely exceeding half a foot. This is followed in different spots by parallel, waving, irregularly alternating plates of carbonate of lime and serpentine, which become gradually finer as they recede from the pyroxene, and occasionally occupy a total thickness of five or six inches. These portions constitute the unbroken fossil, which may sometimes spread over an area of about a square foot, or perhaps more. Other parts, immediately on the outside of the sheet of serpentine, are occupied with about the same thickness of what appear to be the ruins of the fossil, broken up into a more or less granular mixture of calcespar and serpentine, the former still showing minute structure ; and on the outside of the whole a similar mixture appears to have been swept by currents and eddies into rudely parallel and curving layers, the mixture becoming gradually more calcareous as it recedes from the pyroxene. Sometimes beds of limestone of several feet in thickness, with the green serpentine more or less aggregated into layers, and studded with isolated lumps of pyroxene, are irregularly interstratified in the mass of rock ; and less frequently there are met with lenticular patches of sandstone, or granular quartzite, of a foot in thickness and several yards in diameter, holding in abundance small disseminated leaves of graphite.

The general character of the rock connected with the fossil produces the impression that it is a great Foraminiferal reef, in which the pyroxenic masses represent a more ancient portion, which having died, and having become much broken up and much worn into cavities and deep recesses, afforded a seat for a new growth of *Foraminifera*, represented by the calcareo-serpentinous part. This in its turn became broken up, leaving in some places uninjured portions of the general form. The main difference between this Foraminiferal reef and more recent coral-reefs seems to be that, while with the latter are usually associated many shells and other organic remains, in the more ancient one the only remains yet found are those of the animal which built the reef.

2. *On the STRUCTURE of certain ORGANIC REMAINS in the LAURENTIAN LIMESTONES of CANADA.* By J. W. DAWSON, LL.D., F.R.S., F.G.S., Principal of McGill University, Montreal.

[PLATES VI. & VII.]

At the request of Sir William E. Logan, I have submitted to microscopic examination slices of certain peculiar laminated forms, consisting of alternate layers of carbonate of lime and serpentine, or of carbonate of lime and white pyroxene, found in the Laurentian Limestones of Canada, and regarded by Sir William as possibly fossils*. I have also examined slices of a number of limestones and serpentines from the Laurentian Series, not showing the external forms of these supposed fossils.

The slices were prepared by the lapidary of the Survey, and were carefully examined under ordinary and polarized light, with objectives made by Ross and Smith & Beck, and also with good French objectives.

The specimens first mentioned are masses, often several inches in diameter, presenting to the naked eye alternate laminæ of serpentine, or of pyroxene, and carbonate of lime. Their general aspect, as remarked by Sir W. E. Logan (*Geology of Canada*, 1863, p. 49), reminds the observer of that of the Silurian Corals of the genus *Stromatopora*, except that the laminæ diverge from and approach each other, and frequently anastomose or are connected by transverse septa.

Under the microscope the resemblance to *Stromatopora* is seen to be in general form merely, and no trace appears of the radiating cells characteristic of that genus. The laminæ of serpentine and pyroxene present no organic structure, and the latter mineral is highly crystalline. The laminæ of carbonate of lime, on the contrary, retain distinct traces of structures which cannot be of a crystalline or concretionary character. They constitute parallel or concentric partitions of variable thickness, enclosing flattened spaces or chambers frequently crossed by transverse plates or septa, in some places so numerous as to give a vesicular appearance, in others occurring only at rare intervals (Pl. VI., Pl. VII. fig. 1). The laminæ themselves are excavated on their sides into rounded pits, and are in some places traversed by canals, or contain secondary rounded cells apparently isolated (Pl. VII. fig. 2). In addition to these general appearances, the substance of the laminæ, where most perfectly preserved, is seen to present a fine granular structure, and to be penetrated by numerous minute tubuli, which are arranged in bundles of great beauty and complexity, diverging in sheaf-like forms, and in their finer extensions anastomosing so as to form a network (Pl. VII. figs. 3*a*, 4). In transverse sections and under high powers, the tubuli are seen to be circular in outline and sharply defined (Pl. VII. fig. 5). In longitudinal sections they sometimes present a beaded or jointed appearance. Even where the tubular

* *Canadian Naturalist and Geologist*, 1859, p. 49.

structure is least perfectly preserved, traces of it can still be seen in most of the slices, though there are places in which the laminae are perfectly compact, and perhaps were so originally.

Faithful delineations of these structures have been prepared by Mr. Horace Smith, the artist of the Survey, which will render them more intelligible than any verbal description.

With respect to the nature and probable origin of the appearances above described, I would make the following remarks:—

1. The serpentine and pyroxene which fill the cavities of the calcareous matter have no appearance of concretionary structure. On the contrary, their aspect is that of matter introduced by infiltration or as sediment, and filling spaces previously existing. In other words, the calcareous matter has not been moulded on the forms of the serpentine and augite, but these have filled spaces or chambers in a hard calcareous mass. This conclusion is further confirmed by the fact, to be referred to in the sequel, that the serpentine includes multitudes of minute foreign bodies, while the calcareous matter is uniform and homogeneous. It is also to be observed that small veins of carbonate of lime occasionally traverse the specimens, and, in their entire absence of structures other than crystalline, present a striking contrast to the supposed fossils.

2. Though the calcareous laminae have in places a crystalline cleavage, their forms and structures have no relation to this. Their cells and canals are rounded, and have smooth walls, which are occasionally lined with films apparently of carbonaceous matter. Above all, the minute tubuli are different from anything likely to occur in merely crystalline calcespar. While in such rocks little importance might be attached to external forms simulating the appearances of corals, sponges, or other organisms, these delicate internal structures have a much higher claim to attention. Nor is there any improbability in the preservation of such minute parts in rocks so highly crystalline, since it is a circumstance of frequent occurrence in the microscopic examination of fossils that the finest structures are visible in specimens in which the general form and the arrangement of parts have been entirely obliterated. It is also to be observed that the structure of the calcareous laminae is the same, whether the intervening spaces are filled with serpentine or with pyroxene.

3. The structures above described are not merely definite and uniform, but they are of a kind proper to animal organisms, and more especially to one particular type of animal life, as likely as any other to occur under such circumstances; I refer to that of the Rhizopods of the order *Foraminifera*. The most important point of difference is in the great size and compact habit of growth of the specimens in question; but there seems no good reason to maintain that *Foraminifera* must necessarily be of small size, more especially since forms of considerable magnitude referred to this type are known in the Lower Silurian. Prof. Hall has described specimens of *Receptaculites* 12 inches in diameter; and the fossils from the calciferous formation of Labrador, referred by Mr. Billings to the genus *Archæocyathus*, are examples of *Protozoa* with calcareous skeletons, scarcely inferior

in their massive style of growth to the forms now under consideration.

These reasons are, I think, sufficient to justify me in regarding these remarkable structures as truly organic, and in searching for their nearest allies among the *Foraminifera*.

Supposing then that the spaces between the calcareous laminae, as well as the canals and tubuli traversing their substance, were once filled with the sarcode body of a Rhizopod, comparisons with modern forms at once suggest themselves.

From the polished specimens in the Museum of the Canadian Geological Survey, it appears certain that these bodies were sessile by a broad base, and grew by the addition of successive layers of chambers separated by calcareous laminae, but communicating with each other by canals or septal orifices sparsely and irregularly distributed. Small specimens have thus much the aspect of the modern genera *Carpenteria* and *Polytrema*. Like the first of these genera, there would also seem to have been a tendency to leave in the midst of the structure a large central canal, or deep funnel-shaped or cylindrical opening, for communication with the sea-water. Where the laminae coalesce, and the structure becomes more vesicular, it assumes the "acervuline" character seen in such modern forms as *Nubecularia*.

Still the magnitude of these fossils is enormous when compared with the species of the genera above named; and from the specimens in the larger slabs from Grenville, in the Museum of the Canadian Survey, it would seem that these organisms grew in groups which ultimately coalesced and formed large masses penetrated by deep irregular canals, and that they continued to grow at the surface while the lower parts became dead and were filled up with infiltrated matter or sediment. In short, we have to imagine an organism having the habit of growth of *Carpenteria*, but attaining to an enormous size, and by the aggregation of individuals assuming the aspect of a coral-reef.

Mr. Billings has described two remarkable species from the Calcareous formation at Mingan, referred by him to the new genus *Archæocyathus*, which he places, with doubt, among *Protozoa*. If, as I believe, correctly referred to this group, their calcareous-chambered skeletons would place them with *Foraminifera* rather than with Sponges. The mode of growth of *Archæocyathus* is cylindrical or inverted conical, with a hollow axis. In one of the species, *A. Minganensis*, this hollow cylinder is very wide, and the chambers are arranged in a radiating manner. In the other, *A. atlanticus*, the central canal is narrower, and the chambers have thick walls and are more irregularly disposed. These fossils, in the general arrangement of their parts, appear like gigantic representatives of *Nubecularia* and *Dactylopora*, though different in details. They are evidently generically distinct from the Laurentian fossils; but if, as I think probable, calcareous Rhizopods, they resemble the specimens now under consideration in the development of such structures into coral-like forms and dimensions, and this at an early, if less remote, geological period.

The complicated systems of tubuli in the Laurentian fossils indicate, however, a more complex structure than that of any of the forms mentioned above. I have carefully compared these with the similar structures in the "supplementary skeleton" (or the shell-substance that carries the vascular system) of *Calcareina* and other forms*, and can detect no difference except in the somewhat coarser texture of the tubuli in the Laurentian specimens. It accords well with the great dimensions of these, that they should thus thicken their walls with an extensive deposit of tubulated calcareous matter; and, from the frequency of the bundles of tubuli, as well as the thickness of the partitions, I have no doubt all the successive walls as they were formed were thickened in this manner, just as in so many of the higher genera of more modern *Foraminifera*.

It is proper to add that no spicules, or other structures indicating affinity to the Sponges, have been detected in any of the specimens.

As it is convenient to have a name to designate these forms, I would propose that of *Eozoön*, which will be specially appropriate to what seems to be the characteristic fossil of a group of rocks which must now be named *Eozoic* rather than *Azoic*. For the species above described, the specific name of *Canadense* has been proposed. It may be distinguished by the following characters:—

Eozoön CANADENSE, gen. et spec. nov. Pls. VI. & VII.†

General form.—Massive, in large sessile patches or irregular cylinders, growing at the surface by the addition of successive laminae.

Internal structure.—Chambers large, flattened, irregular, with numerous rounded extensions, and separated by walls of variable thickness, which are penetrated by septal orifices irregularly disposed. Thicker parts of the walls with bundles of fine branching tubuli.

These characters refer specially to the specimens from Grenville and the Calumet. There are others from Perth, Canada West, which show more regular laminae, and in which the tubuli have not yet been observed; and a specimen from Burgess, Canada West, contains some fragments of laminae which exhibit, on one side, a series of fine parallel tubuli like those of *Nammulina*. These specimens may indicate distinct species; but, on the other hand, their peculiarities may depend on different states of preservation.

With respect to this last point, it may be remarked that some of the specimens from Grenville and the Calumet show the structures of the laminae with nearly equal distinctness whether the chambers have been filled with serpentine or pyroxene, and that even the minute tubuli are penetrated and filled with these minerals. On the other

* I desire to express my obligations to the invaluable memoirs of Dr. Carpenter on the *Foraminifera*, in the 'Transactions' of the Royal Society and in the publications of the Ray Society, and without which it would have been impossible satisfactorily to investigate the structure and affinities of *Eozoön*. I have also to acknowledge the kindness of Dr. Carpenter in furnishing me with specimens of some of the forms described in his works.

† Plates VIII. & IX., illustrating the following paper by Dr. Carpenter, further elucidate the structure of *Eozoön*.—ED.

hand, there are large specimens in the collection of the Canadian Survey, in which the lower and older parts of the masses of *Eozoön* are mineralized with pyroxene, and have to a great extent lost the perfection of structure which characterizes the more superficial parts of the same masses, in which the chambers have been filled with a light-green serpentine. Dr. Sterry Hunt has directed his attention to the conditions of deposit of these minerals, and will, I have no doubt, be able satisfactorily to explain the manner in which they may have been introduced into the chambers of the fossils without destroying the texture of the latter.

It is due to Dr. Sterry Hunt to state that, as far back as 1858, in a paper published in the Quarterly Journal of the Geological Society*, he insisted on certain chemical characters of the Laurentian beds as affording "evidence of the existence of organic life at the time of the deposition of these old crystalline rocks," and that he has zealously aided in the present researches.

I may also state that Mr. Billings, the palæontologist of the Survey, has joined in the request that I should undertake the examination and description of the specimens, as being more specially a subject of microscopical investigation.

Before concluding this part of the subject, it is proper to observe that the structures above described can be made out only by the careful study of numerous slices, and in some instances only with polarized light. Even in the more perfect specimens of *Eozoön*, as those accustomed to such researches will readily understand, the accidents of good preservation and the cutting of the slices in the proper place and direction must conspire in order to a clear definition of the more minute structures.

It is also to be observed that the specimens present numerous remarkable microscopic appearances, depending on crystallization and concretionary action, which must not be confounded with organic structure. It would be out of place to give any detailed description of them here, but it is necessary to caution observers unaccustomed to the examination of mineral substances under the microscope, as to their occurrence. I may also mention that the serpentine presents many curious varieties of structure, especially when associated with apatite, pyroxene, and other minerals, and that it affords magnificent objects under polarized light, when reduced to sufficiently thin slices.

In connexion with these remarkable remains, it appeared desirable to ascertain, if possible, what share these or other organic structures may have had in the accumulation of the limestones of the Laurentian series. Specimens were therefore selected by Sir W. E. Logan, and slices were prepared under his direction. On microscopic examination, a number of these were found to exhibit merely a granular aggregation of crystals, occasionally with particles of graphite and other foreign minerals, or a laminated mixture of calcareous and other matters, in the manner of some more modern sedimentary

* Vol. xv. p. 493.

limestones. Others, however, were evidently made up almost entirely of fragments of *Eozoön*, or of mixtures of these with other calcareous and carbonaceous fragments which afford more or less evidence of organic origin. The contents of these organic limestones may be considered under the following heads:—(1) Remains of *Eozoön*; (2) Other calcareous bodies probably organic; (3) Objects imbedded in the serpentine; (4) Carbonaceous matters; (5) Perforations or worm-burrows.

1. The more perfect specimens of *Eozoön* do not constitute the mass of any of the larger specimens in the collection of the Survey; but considerable portions of some of them are made up of material of similar minute structure, destitute of lamination and irregularly arranged. Some of this material gives the impression that there may have been organisms similar to *Eozoön*, but growing in an irregular or “acervuline” manner without lamination. Of this, however, I cannot be certain, and on the other hand there is distinct evidence of the aggregation of fragments of *Eozoön* in some of these specimens. In some they constitute the greater part of the mass. In others they are imbedded in calcareous matter of a different character, or in serpentine or granular pyroxene. In most of the specimens the cells of the fossils are more or less filled with these minerals, and in some instances it would appear that the calcareous matter of fragments of *Eozoön* has been in part replaced by serpentine.

2. Intermixed with the fragments of *Eozoön* above referred to, are other calcareous matters apparently fragmentary. They are of various angular and rounded forms, and present several kinds of structure. The most frequent of these is a strong lamination, varying in direction according to the position of the fragments, but corresponding, as far as can be ascertained, with the diagonal of the rhombohedral cleavage. This structure, though crystalline, is highly characteristic of Crinoidal remains when preserved in altered limestones. The more dense parts of *Eozoön*, destitute of tubuli, also sometimes show this structure, though less distinctly.

Other fragments are compact and structureless, or show only a fine granular appearance; and these sometimes include grains, patches, or fibres of graphite. In Silurian limestones, fragments of corals and shells which have been partially infiltrated with bituminous matter show a structure like this. On comparison with altered organic limestones of the Silurian system, these appearances would indicate that, in addition to the débris of *Eozoön*, other calcareous structures, more like those of Crinoids, Corals, and Shells, have contributed to the formation of the Laurentian limestones.

3. In the serpentine filling the chambers of a large portion of *Eozoön* from Burgess, C. W., there are numerous small pieces of foreign matter, and the serpentine itself is laminated, indicating its sedimentary nature. Some of the included fragments appear to be carbonaceous, others calcareous; but no distinct organic structure can be detected in them. There are, however, in the serpentine many minute rounded grains of a bright-green siliceous colour, re-

sembling greensand-concretions ; and the manner in which these are occasionally arranged in lines and groups suggests the supposition that they may possibly be casts of the interior of minute Foraminiferal shells. They may, however, be concretionary in their origin.

4. In some of the Laurentian limestones submitted to me by Sir W. E. Logan, and in others which I collected some years ago at Madoc, Canada West, there are fibres and granules of carbonaceous matter, which do not conform to the crystalline structure, and present forms quite similar to those which in more modern limestones result from the decomposition of Algæ. Though retaining mere traces of organic structure, no doubt would be entertained as to their vegetable origin if they were found in fossiliferous limestones.

5. A specimen of impure limestone from Madoc, in the collection of the Canadian Geological Survey, which seems from its structure to have been a finely laminated sediment, shows perforations of various sizes, somewhat scolloped at the sides, and filled with grains of rounded siliceous sand. In my own collection there are specimens of micaceous slate from the same region, with indications on their weathered surfaces of similar rounded perforations, having the aspect of *Scolithus*, or of worm-burrows.

I would observe, in conclusion, that the researches detailed in this paper must be regarded as merely an introduction to a most interesting and promising field of research. The specimens to which I had access were for the most part collected by the explorers of the Survey merely as rocks, and without any view to the possible existence of fossils in them. It may be hoped, therefore, that other and more perfect specimens may reward a careful search in the localities from which those now described have been obtained. Further, though the abundance and wide distribution of *Eozoön*, and the important part it seems to have acted in the accumulation of limestone, indicate that it was one of the most prevalent forms of animal existence in the seas of the Laurentian period, they do not imply the non-existence of other organic beings. On the contrary, independently of the indications afforded by the limestones themselves, it is evident that in order to the existence and growth of these large Rhizopods, the waters must have swarmed with more minute animal or vegetable organisms on which they could subsist. On the other hand, though this is a less certain inference, the dense calcareous skeleton of *Eozoön* may indicate that it also was liable to the attacks of animal enemies. It is also possible that the growth of *Eozoön*, or the deposition of the serpentine and pyroxene in which its remains have been preserved, or both, may have been connected with certain oceanic depths and conditions, and that we have as yet revealed to us the life of only certain stations in the Laurentian seas.

Whatever conjectures we may form on these more problematic points, the observations above detailed appear to establish the following conclusions :—First, that in the Laurentian period, as in subsequent geological epochs, the Rhizopods were important agents in the accumulation of beds of limestone ; and, secondly, that in this early period these low forms of animal life attained to a development,

in point of magnitude and complexity, unexampled, in so far as yet known, in the succeeding ages of the earth's history. This early culmination of the Rhizopods is in accordance with one of the great laws of the succession of living beings ascertained from the study of the introduction and progress of other groups; and, should it prove that these great Protozoans were really the dominant type of animals in the Laurentian period, this fact might be regarded as an indication that in these ancient rocks we may actually have the records of the first appearance of animal life on our planet.

Since the above was written, thick slices of *Eozoön* from Grenville have been prepared, and submitted to the action of hydrochloric acid until the carbonate of lime was removed. The serpentine then remains as a cast of the interior of the chambers, showing the form of their original sarcode-contents. The minute tubuli are found also to have been filled with a substance insoluble in the acid, so that casts of these also remain in great perfection, and allow their general distribution to be much better seen than in the transparent slices previously prepared. These interesting preparations establish the following additional structural points:—

1. That the whole mass of sarcode throughout the organism was continuous, the apparently detached secondary chambers being, as I had previously suspected, connected with the larger chambers by canals filled with sarcode.

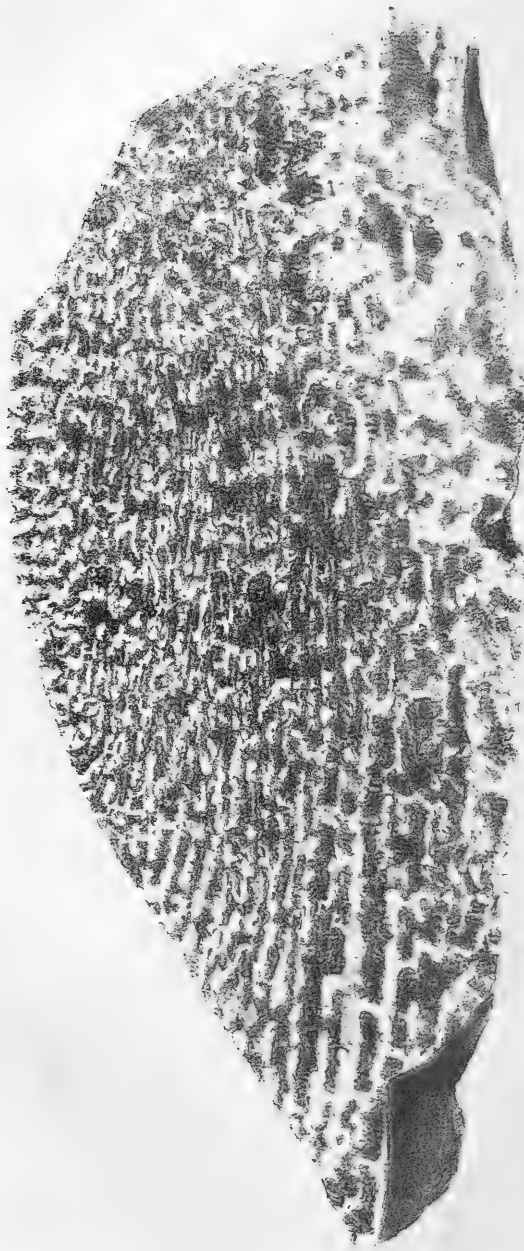
2. That some of the irregular portions without lamination are not fragmentary, but due to the acervuline growth of the animal; and that this irregularity has been produced in part by the formation of projecting patches of "supplementary skeleton," penetrated by beautiful systems of tubuli. These groups of tubuli are in some places very regular, and have in their axes cylinders of compact calcareous matter. Some parts of the specimens present arrangements of this kind as symmetrical as in any modern Foraminiferal shell.

3. That all except the very thinnest portions of the walls of the chambers present traces, more or less distinct, of a tubular structure.

4. These facts place in more strong contrast the structure of the regularly laminated specimens from Burgess, which do not show tubuli, and that of the Grenville specimens, less regularly laminated and tubulous throughout. I hesitate, however, to regard these as distinct species, in consequence of the intermediate characters presented by specimens from the Calumet, which are regularly laminated like those of Burgess, and tubulous like those of Grenville. It is possible that in the Burgess specimens tubuli originally present have been obliterated; and in organisms of this grade, more or less altered by the processes of fossilization, large suites of specimens should be compared before attempting to establish specific distinctions.

Some additional specimens, from a block consisting principally of serpentine, differ from the ordinary Grenville specimens in the more highly crystalline character of the calcareous spar and serpentine, in the development of certain minute dendritic crystallizations, and in the apparent compression and distortion of the fossils. These ap-



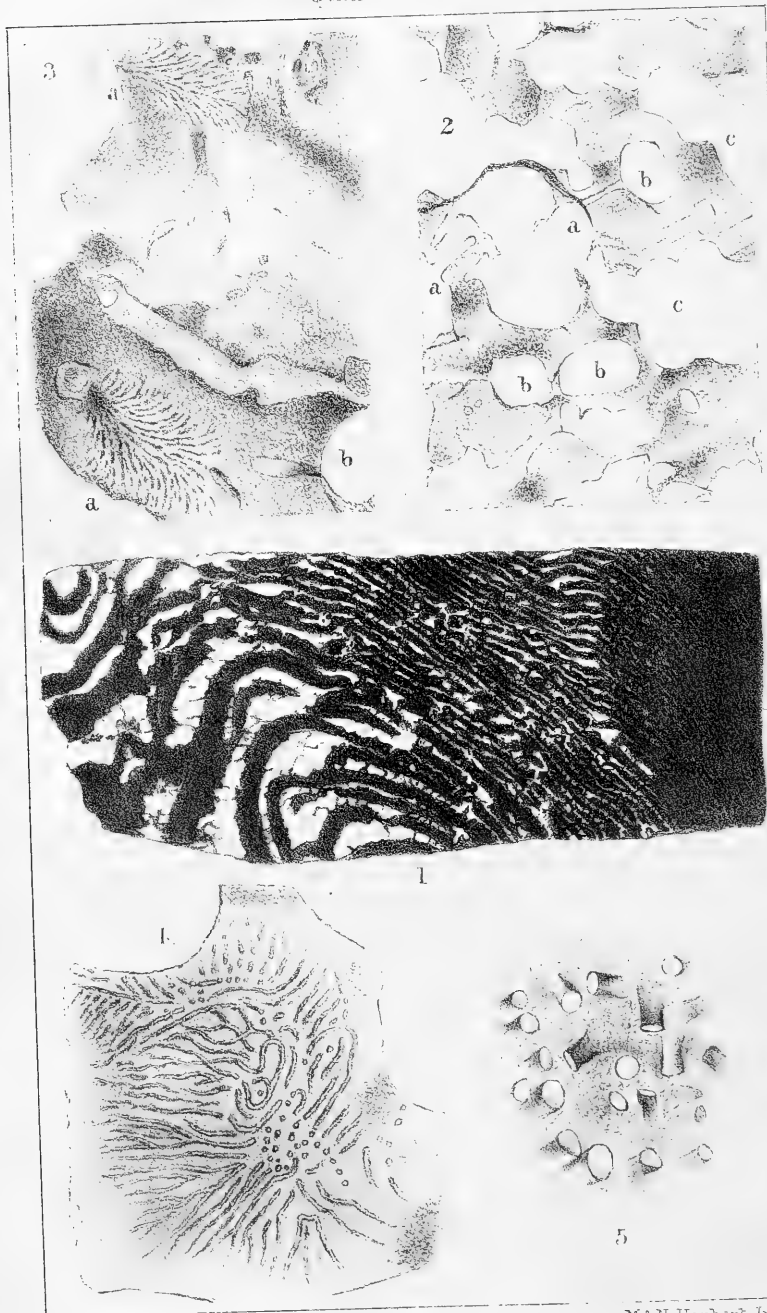


G. West, lith.

M & N. Hanhart, imp.

EOZOON CANADENSE, Dawson.





G. West, lith.

M & N. Hanhart, imp.

EOZOON CANADENSE, Dawson.

pearances I regard as due to the mode of preservation rather than to any original differences, certain portions less altered than the others presenting the ordinary typical characters.

Two slices of limestone from the British Islands, and supposed to be Laurentian, have been compared with the Canadian limestones above noticed. One is a serpentine marble from Tyree. It appears to be fragmental, like some of the Laurentian limestones of Canada, and may contain fragments of *Eozoön*. The other is from Iona (?). It presents what I regard as traces of organic structure, but not, in so far as can be made out, of the character of *Eozoön*. Both of these limestones deserve careful microscopic examination.

EXPLANATION OF PLATES VI. & VII.

Illustrating the Structure of Eozoön.

PLATE VI.

Specimen from Grand Calumet. Natural size. The white layers are carbonate of lime; the dark layers are whitish pyroxene.

PLATE VII.

- Fig. 1. Specimen from Burgess. Natural size. The white layers are dolomite; the black layers are dark-green loganite.
2. Transverse section of *Eozoön* from Grenville, magnified 25 diameters: (a) tubuli; (b) septal orifices, &c.; (c) large chambers.
 3. Horizontal section of *Eozoön* from Grenville, magnified 25 diameters: (a) systems of tubuli; (b) secondary chamber.
 4. One of the systems of tubuli cut transversely, magnified 100 diameters.
 5. Part of a system of tubuli cut transversely, magnified 200 diameters.

3. ADDITIONAL NOTE on the STRUCTURE and AFFINITIES of EOZOÖN CANADENSE. By W. B. CARPENTER, M.D., F.R.S., F.G.S.

[In a Letter to Sir William E. Logan, LL.D., F.R.S., F.G.S.]

[PLATES VIII. & IX.]

THE careful examination which I have made—in accordance with the request you were good enough to convey to me from Dr. Dawson, and to second on your own part—into the structure of the very extraordinary fossil which you have brought from the Laurentian rocks of Canada*, enables me most unhesitatingly to confirm the sagacious determination of Dr. Dawson as to its Rhizopod characters and Foraminiferal affinities, and at the same time furnishes new evidence of no small value in support of that determination. In this examination I have had the advantage of a series of *sections* of the fossil much superior to those submitted to Dr. Dawson; and also of a large series of *decalcified specimens*, of which Dr. Dawson had only the opportunity of seeing a few examples after his memoir had been written. These last are peculiarly instructive; since, in conse-

* The specimens submitted to Dr. Carpenter were taken from a block of *Eozoön* rock, obtained in the Petite Nation Seigniory, too late to afford Dr. Dawson an opportunity of examination. They are from the same horizon as the Grenville specimens.—W. E. L.

quence of the complete infiltration of the chambers and canals, originally occupied by the sarcode-body of the animal, by mineral matter insoluble in dilute nitric acid, the removal of the calcareous shell brings into view not only the internal casts of the chambers, but also casts of the interior of the "canal-system" of the "intermediate" or "supplemental skeleton," and even casts of the interior of the very fine parallel tubuli which traverse the proper walls of the chambers. And, as I have remarked elsewhere*, "such casts place before us far more exact representations of the configuration of the animal body and of the connexions of its different parts, than we could obtain even from living specimens by dissolving-away their shells with acid; its several portions being disposed to heap themselves together in a mass when they lose the support of the calcareous skeleton."

The additional opportunities I have thus enjoyed will be found, I believe, to account satisfactorily for the differences to be observed between Dr. Dawson's account of the *Eozoön* and my own. Had I been obliged to form my conclusions respecting its structure only from the specimens submitted to Dr. Dawson, I should very probably have seen no reason for any but the most complete accordance with his description: while if Dr. Dawson had enjoyed the advantage of examining the entire series of preparations which have come under my own observation, I feel confident that he would have anticipated the corrections and additions which I now offer.

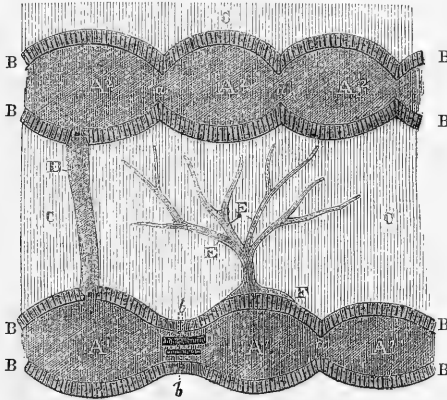
Although the *general plan of growth* described by Dr. Dawson, and exhibited in his photographs of vertical sections of the fossil (Pl. VI., Pl. VII. fig. 1), is undoubtedly that which is typical of *Eozoön*, yet I find that the *acervuline* mode of growth, also mentioned by Dr. Dawson, very frequently takes its place in the more superficial parts, where the chambers, which are arranged in regular tiers in the laminated portions (Pl. VIII. fig. 1), are heaped one upon another without any regularity, as is particularly well shown in some decalcified specimens which I have myself prepared from the slices last put into my hands (Pl. IX. fig. 2). I see no indication that this departure from the normal type of structure has resulted from an injury; the transition from the regular to the irregular mode of increase not being abrupt, but gradual. Nor should I be disposed to regard it as a monstrosity; since there are many other *Foraminifera* in which an originally definite plan of growth gives place in a later stage to a like acervuline piling-up of chambers.

In regard to the *form and relations of the chambers*, I have little to add to Dr. Dawson's description. The evidence afforded by their internal casts (Pl. IX. fig. 1) concurs with that of sections, in showing that the segments of the sarcode-body, by whose aggregation each layer was constituted, were but very incompletely divided by shelly partitions; this incomplete separation (as Dr. Dawson has pointed out) having its parallel in that of the secondary chambers in *Carpenteria*. But I have occasionally met with instances in which the

* Introduction to the Study of the Foraminifera, p. 10.

separation of the chambers has been as complete as it is in Foraminifera generally; and the communication between them is then established by several narrow passages (Pl. VIII. fig. 2) exactly corresponding with those which I have described and figured in *Cycloctypeus* *.

Diagram illustrating the Structure of Eoozön.



A', A', A'. Three chambers of one layer, communicating with each other directly at *a*, and by three passages through a shelly partition at *b*.

A², A², A². Three chambers of a more superficial layer.

B, B, B. Proper wall of the chambers, composed of finely-tubular shell-substance.

C, C, C. Intermediate or supplemental skeleton, traversed by D, D, a stolon of communication between two chambers of different layers, and by E, E, canal-system originating in the lacunar space F.

The mode in which each successive layer originates from the one which has preceded it, is a question to which my attention has been a good deal directed; but I do not as yet feel confident that I have been able to elucidate it completely. There is certainly no regular system of apertures for the passage of stolons giving origin to new segments, such as are found in all ordinary Polythalamous Foraminifera, whether their type of growth be rectilinear, spiral, or cyclical; and I am disposed to believe that where one layer is separated from another by nothing else than the proper walls of the chambers,—which (as I shall presently show) are traversed by multitudes of minute tubuli giving passage to pseudopodia,—the coalescence of these pseudopodia on the external surface would suffice to lay the foundation of a new layer of sarcodic segments. But where an intermediate or supplemental skeleton, consisting of a thick layer of solid calcareous shell, has been deposited between two successive layers, it is obvious that the animal body contained in the lower layer of chambers must be completely cut off from that which occupies the upper, unless some special provision exist for their mutual

* *Op. cit.* p. 294.

communication. Such a provision I believe to have been made by the extension of bands of sarcode, through canals left in the intermediate skeleton, from the lower to the upper tier of chambers. For in such sections as happen to have traversed thick deposits of the intermediate skeleton, there are generally found passages distinguished from those of the ordinary "canal-system" by their broad flat form, their great transverse diameter, and their non-ramification. One of these passages I have distinctly traced to a chamber, with the cavity of which it communicated through two or three apertures in its proper wall (Pl. VIII. fig. 3 *c*); and I think it likely that I should have been able to trace it at its other extremity into a chamber of the superjacent tier, had not the plane of the section passed out of its course. Riband-like casts of these passages are often to be seen in decalcified specimens, traversing the void spaces left by the removal of the thickest layers of the intermediate skeleton (Pl. IX. fig. 3).

But the organization of a new layer seems to have not unfrequently taken place in a much more considerable extension of the sarcode-body of the pre-formed layer; which either folded back its margin over the surface already consolidated (in a manner somewhat like that in which the mantle of a *Cypræa* doubles back to deposit the final surface-layer of its shell), or sent upwards wall-like lamellæ, sometimes of very limited extent, but not unfrequently of considerable length, which, after traversing the substance of the shell like trap-dykes in a bed of sandstone, spread themselves out over its surface. Such, at least, are the only interpretations I can put upon the appearances presented by decalcified specimens. For, on the one hand, it is frequently to be observed that two bands of serpentine (or other infiltrated mineral) which represent two layers of the original sarcode-body of the animal, approximate each other in some part of their course, and come into complete continuity; so that the upper layer would seem at that part to have had its origin in the lower. Again, even where these bands are most widely separated, we find that they are commonly held together by vertical lamellæ of the same material, sometimes forming mere tongues, but often running to a considerable length. That these lamellæ have not been formed by mineral infiltration into accidental fissures in the shell, but represent corresponding extensions of the sarcode-body, seems to me to be indicated not merely by the characters of their surface, but also by the fact that portions of the canal-system may be occasionally traced into connexion with them.

Although Dr. Dawson has noticed that some parts of the sections which he examined present the fine tubulation characteristic of the shells of the *Nummuline* Foraminifera, he does not seem to have recognized the fact, which the sections placed in my hands have enabled me most satisfactorily to determine,—that the proper walls of the chambers everywhere present the fine tubulation of the *Nummuline* shell (Pl. VIII. figs. 3, 4), a point of the highest importance in the determination of the affinities of *Eozöön*. This tubulation, although not seen with the clearness with which it is to be discerned in recent

examples of the Nummuline type, is here far better displayed than it is in the majority of *fossil* Nummulites, in which the tubuli have been filled up by the infiltration of calcareous matter, rendering the shell-substance nearly homogeneous. In *Eozoön* these tubuli have been filled up by the infiltration of a mineral different from that of which the shell is composed, and therefore not coalescing with it; and the tubular structure is consequently much more satisfactorily distinguishable. In decalcified specimens, the free margins of the casts of the chambers are often seen to be bordered with a delicate white glistening fringe; and when this fringe is examined with a sufficient magnifying power, it is seen to be made up of a multitude of extremely delicate *aciculi*, standing side by side like the fibres of asbestos (Pl. IX. fig. 4). These, it is obvious, are the internal casts of the fine tubuli which perforated the proper wall of the chambers, passing direct from its inner to its outer surface; and their presence in this situation affords the most satisfactory confirmation of the evidence of that tubulation afforded by thin sections of the shell-wall.

The successive layers, each having its own proper wall, are often superposed one upon another without the intervention of any *supplemental* or *intermediate skeleton*, such as presents itself in all the more massive forms of the Nummuline series; but a deposit of this form of shell-substance, readily distinguishable by its homogeneousness from the finely tubular shell immediately investing the segments of the sarcode-body, is the source of the great thickening which the calcareous zones often present in vertical sections of *Eozoön*. The presence of this "intermediate skeleton" has been correctly indicated by Dr. Dawson; but he does not seem to have clearly differentiated it from the proper wall of the chambers. All the tubuli which he has described belong to that *canal-system*, which, as I have shown*, is limited in its distribution to the "intermediate skeleton," and is expressly destined to supply a channel for its nutrition and augmentation. Of this "canal-system," which presents most remarkable varieties in dimensions and distribution, we learn more from the *casts* presented by decalcified specimens, than from *sections* which only exhibit such parts of it as their plane may happen to traverse. Illustrations from both sources, giving a more complete representation of it than Dr. Dawson's figures afford, have been prepared from the additional specimens placed in my hands (Pl. VIII. fig. 5, Pl. IX. fig. 5).

It does not appear to me that the "canal-system" takes its origin directly from the cavity of the chambers. On the contrary, I believe that, as in *Calcarina* (which Dr. Dawson has correctly referred to as presenting the nearest parallel to it among recent *Foraminifera*), they originate in lacunar spaces on the outside of the proper walls of the chambers, into which the tubuli of those walls open externally; and that the extensions of the sarcode-body which occupied them were formed by the coalescence of the pseudopodia issuing from those tubuli †.

* *Op. cit.* pp. 50, 51.

† *Op. cit.* p. 221.

It seems to me worthy of special notice, that the "canal-system," wherever displayed in transparent sections, is distinguished by a yellowish-brown coloration, so exactly resembling that which I have observed in the canal-system of recent *Foraminifera* (as *Poly-stomella* and *Calcarina*) in which there were remains of the sarcod-body, that I cannot but believe the infiltrating mineral to have been dyed by the remains of sarcode still existing in the canals of *Eozoön* at the time of its consolidation. If this be the case, the preservation of this colour seems to indicate that no considerable metamorphic action has been exerted upon the rock in which this fossil occurs. And I should draw the same inference from the fact that the organic structure of the shell is in many instances even more completely preserved than it usually is in the Nummulites and other *Foraminifera* of the Nummulitic limestone of the early Tertiaries.

To sum up,—That the *Eozoön* finds its proper place in the Foraminiferal series, I conceive to be conclusively proved by its accordance with the great types of that series in all the essential characters of organization,—namely, the structure of the shell forming the proper wall of the chambers, in which it agrees precisely with *Nummulina* and its allies; the presence of an "intermediate skeleton" and an elaborate "canal-system," the disposition of which reminds us most of *Calcarina*; a mode of communication of the chambers when they are most completely separated, which has its exact parallel in *Cyclo-clypeus*; and an ordinary want of completeness of separation between the chambers, corresponding with that which is characteristic of *Carpentaria*.

There is no other group of the Animal Kingdom to which *Eozoön* presents the slightest structural resemblance; and to the suggestion that it may have been of kin to *Nullipore* I can offer the most distinct negative reply, having many years ago carefully studied the structure of that stony *Alga*, with which that of *Eozoön* has nothing whatever in common.

The objections which not unnaturally occur to those familiar with only the ordinary forms of *Foraminifera*, as to the admission of *Eozoön* into the series, do not appear to me of any force. These have reference in the first place to the great size of the organism; and in the second, to its exceptional *mode of growth*.

1. It must be borne in mind that all the *Foraminifera* normally increase by the continuous gemmation of new segments from those previously formed; and that we have, in the existing types, the greatest diversities in the extent to which this gemmation may proceed. Thus in the *Globigerinæ*, whose shells cover to an unknown thickness the sea-bottom of all that portion of the Atlantic Ocean which is traversed by the Gulf-stream, only *eight* or *ten* segments are ordinarily produced by continuous gemmation; and if new segments are developed from the last of these, they detach themselves so as to lay the foundation of independent *Globigerinæ*. On the other hand, in *Cyclo-clypeus*, which is a discoidal structure attaining $2\frac{1}{4}$ inches in diameter, the number of segments formed by continuous gemmation must be many thousand. Again, the *Receptaculites* of the Canadian

Silurian rocks, shown by Mr. Salter's drawings* to be a gigantic Orbitolite, attains a diameter of 12 inches; and if this were to increase by vertical as well as by horizontal gemmation (after the manner of *Tinoporus* or *Orbitoides*) so that one discoidal layer would be piled on another, it would form a mass equalling *Eozoön* in its ordinary dimensions. To say, therefore, that *Eozoön* cannot belong to the *Foraminifera* on account of its gigantic size, is much as if a Botanist who had only studied plants and shrubs were to refuse to admit a tree into the same category. The very same continuous gemmation which has produced an *Eozoön* would produce an equal mass of independent *Globigerinæ*, if, after eight or ten repetitions of the process, the new segments were to detach themselves.

It is to be remembered, moreover, that the largest masses of *Sponges* are formed by continuous gemmation from an original Rhizopod segment; and that there is no *à priori* reason why a *Foraminiferal* organism should not attain the same dimensions as a *Poriferal*,—the intimate relationship of the two groups, notwithstanding the difference between their skeletons, being unquestionable.

2. The difficulty arising from the Zoophytic plan of growth of *Eozoön* is at once disposed of by the fact that we have in the recent *Polytrema* (as I have shown, *op. cit.* p. 235) an organism nearly allied in all essential points of structure to *Rotalia*, yet no less aberrant in its plan of growth, having been ranked by Lamarek among the *Millepores*. And it appears to me that *Eozoön* takes its place quite as naturally in the *Nummuline* series as *Polytrema* in the *Rotaline*. As we are led from the typical *Rotglia*, through the less regular *Planorbulina*, to *Tinoporus*, in which the chambers are piled up vertically, as well as multiplied horizontally, and thence pass by an easy gradation to *Polytrema*, in which all regularity of external form is lost, so may we pass from the typical *Operculina* or *Nummulina*, through *Heterostegina* and *Cycloclypeus*, to *Orbitoides*, in which, as in *Tinoporus*, the chambers multiply, both by horizontal and by vertical gemmation; and from *Orbitoides* to *Eozoön* the transition is scarcely more abrupt than from *Tinoporus* to *Polytrema*.

The general acceptance, by the most competent judges, of my views respecting the *primary* value of the characters furnished by the *intimate structure of the shell*, and the *very subordinate* value of *plan of growth*, in the determination of the affinities of *Foraminifera*, renders it unnecessary that I should dwell further on my reasons for unhesitatingly affirming the *Nummuline* affinities of *Eozoön* from the microscopic appearances presented by the proper wall of its chambers, notwithstanding its very aberrant peculiarities; and I cannot but feel it to be a feature of peculiar interest in geological inquiry, that the true relations of by far the earliest fossil yet known should be determinable by the comparison of a portion which the smallest pin's head would cover, with organisms at present existing.

I need not assure you of the pleasure which it has afforded me to

* First Decade of Canadian Fossils, pl. x.

be able to cooperate with Dr. Dawson and yourself in this development of my previous researches; but I may venture to add the anticipation that the discovery of *Eozoön* is the first of many discoveries in the Laurentian series, which will vastly add to our knowledge of the primæval life of our globe. And I am strongly inclined also to concur in the belief expressed by Dr. Dawson in a private letter to myself, that a more thorough examination of some of the Silurian fossils (such as *Stromatopora*) hitherto ranked among *Corals* and *Sponges*, will prove that they are really, like *Eozoön* and *Receptaculites*, gigantic *Foraminifera*.

EXPLANATION OF PLATES VIII. & IX.

Illustrating the Structure and Affinities of Eozoön.

PLATE VIII.

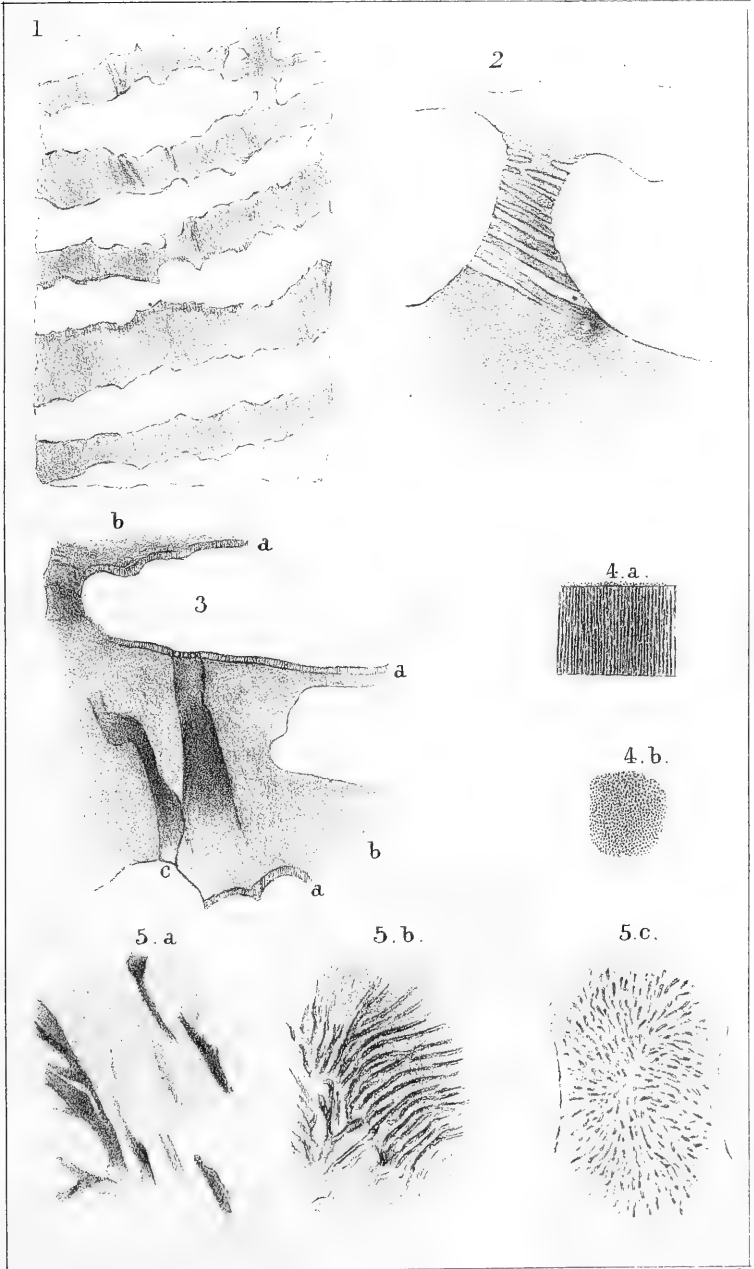
[The figures in this plate are all taken from *transparent sections* of specimens in which the original Shell has been well preserved, and its minutest cavities infiltrated with Serpentine.]

- Fig. 1. Vertical section of regularly stratified portion, showing the ordinarily continuous connexion of the chambers of each stratum: magnified 10 diameters.
2. Occasional mode of communication between two distinct chambers of the same series: magnified 40 diameters.
3. Portions of two chambers of different layers, showing at *a*, *a* the proper walls of their chambers, at *b*, *b* the intermediate skeleton, and at *c*, *c* a stoloniferous passage: magnified 25 diameters.
4. Portions of the proper wall of the chambers, showing its Nummuline tubulation, as seen at *a* in longitudinal, and at *b* in transverse section: magnified 100 diameters.
5. Sections of intermediate skeleton, showing portions of canal-system of different dimensions,—*a*, large, *b*, medium, *c*, small: magnified 25 diameters.

PLATE IX.

[The figures in this plate are all taken from decalcified specimens, and represent the appearances presented by the *internal casts* of the cavities, tubes, &c., as seen by reflected light.]

- Fig. 1. Portion of chambered layer, showing the continuous connexion of its segments: magnified 10 diameters.
 2. Portion of acervuline structure, showing the irregular connexions of its segments: magnified 10 diameters.
 3. Casts of flattened stolons communicating between successive layers of chambers: magnified 25 diameters.
 4. Acicular casts from Nummuline wall of chamber: magnified 100 diameters.
 5. Casts of interior of canal-system:—*a*, portion of large, magnified 25 diameters; *b*, entire group of the same, magnified 10 diameters; *c*, medium, *d*, small, magnified 25 diameters.
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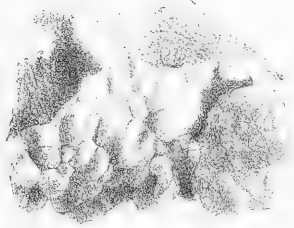


G. West, lith.

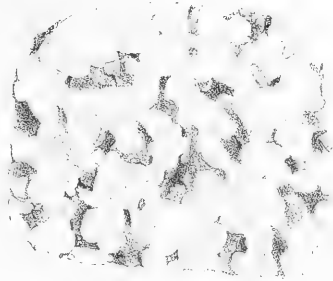
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EOZOON CANADENSE Dawson.

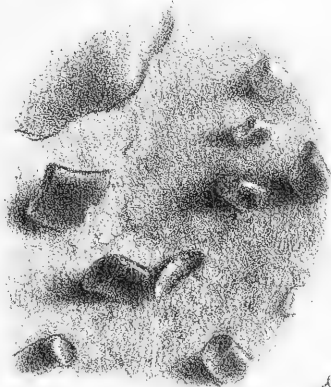
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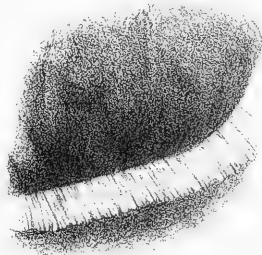
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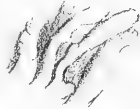
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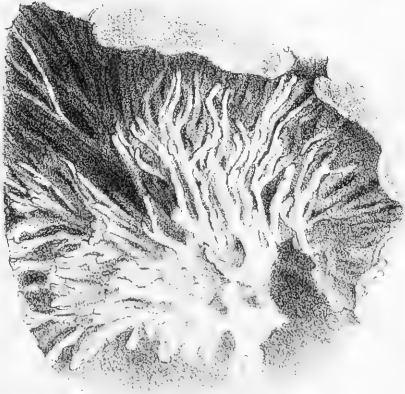
5.a.



5.d.

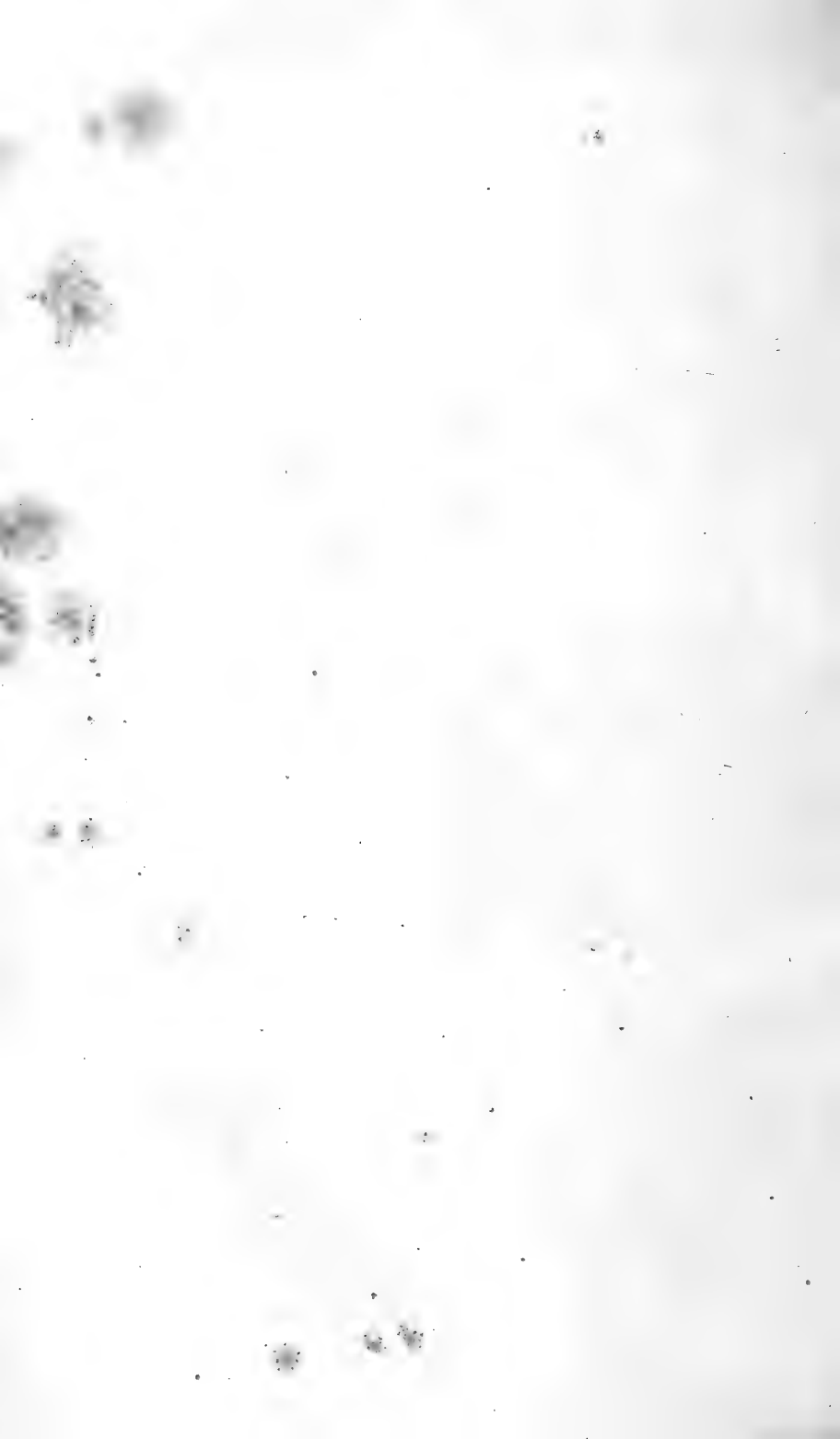


5.b.



5.c.





4. *On the MINERALOGY of CERTAIN ORGANIC REMAINS from the LAURENTIAN ROCKS of CANADA.* By T. STERRY HUNT, Esq., M.A., F.R.S.

[Communicated by Sir W. E. Logan, LL.D., F.R.S., F.G.S.]

THE remains of *Eozoön Canadense*, a Foraminiferal organism recently discovered in the Laurentian limestones of Canada, present an interesting subject of study, both to the mineralogist and the geologist. For a zoological description of this organic form the reader is referred to the preceding description by Dr. Dawson.

The details of structure have been preserved by the introduction of certain mineral silicates, which have not only filled up the chambers, cells, and canals left vacant by the disappearance of the animal matter, but have in very many cases been injected into the tubuli, filling even their smallest ramifications. These silicates have thus taken the place of the original sarcode, while the calcareous septa remain. It will then be understood that when the replacement of the *Eozoön* by silicates is spoken of, this is to be understood of the soft parts only, since the calcareous skeleton is preserved, in most cases, without any alteration. The vacant spaces left by the decay of the sarcode may be supposed to have been filled by a process of infiltration, in which the silicates were deposited from solution in water, like the silica which fills up the pores of wood in the process of silicification. The replacing silicates, so far as yet observed, are a white pyroxene, a pale-green serpentine, and a dark-green aluminomagnesian mineral, which is allied in composition to chlorite and to pyrosclerite, and which I have referred to loganite. The calcareous septa in the last case are found to be dolomitic, but in the other instances are nearly pure carbonate of lime. The relations of the carbonate and the silicates are well seen in thin sections under the microscope, especially by polarized light. The calcite, dolomite, and pyroxene exhibit their crystalline structure to the unaided eye; and the serpentine and loganite are also seen to be crystalline when examined with the microscope. When portions of the fossil are submitted to the action of an acid, the carbonate of lime is dissolved, and a coherent mass of serpentine is obtained, which is a perfect cast of the soft parts of the *Eozoön*. The form of the sarcode which filled the chambers and cells is beautifully shown, as well as the connecting canals and the groups of tubuli; these latter are seen in great perfection upon surfaces from which the carbonate of lime has been partially dissolved. Their preservation is generally most complete when the replacing mineral is serpentine, although very perfect specimens are sometimes found in pyroxene. The crystallization of the latter mineral appears, however, in most cases to have disturbed the calcareous septa.

Serpentine and pyroxene are generally associated in these specimens, as if their deposition had marked different stages of a continuous process. At the Calumet, one specimen of the fossil exhibits the whole of the sarcode replaced by serpentine; while, in another one from the same locality, a layer of pale-green translucent serpentine occurs in immediate contact with the white pyroxene.

The calcareous septa in this specimen are very thin, and are transverse to the plane of contact of the two minerals; yet they are seen to traverse both the pyroxene and the serpentine without any interruption or change. Some sections exhibit these two minerals filling adjacent cells, or even portions of the same cell, a clear line of division being visible between them. In the specimens from Grenville, on the other hand, it would seem as if the development of the *Eozoön* (considerable masses of which were replaced by pyroxene) had been interrupted, and that a second growth of the animal, which was replaced by serpentine, had taken place upon the older masses, filling up their interstices.

The results of the chemical examination of these fossils from different localities may now be given:—I. A specimen of *Eozoön* from the Calumet, remarkable for the regularity of its laminated arrangement, gave to warm acetic acid 27.0 per cent. of soluble matter, consisting of carbonate of lime 97.1, carbonate of magnesia 2.9=100. II. Another specimen of the fossil, from Grenville, replaced by pyroxene, yielded in the same way 12.0 per cent. of soluble matter, which was composed of carbonate of lime 98.7, carbonate of magnesia 1.3=100. III. In this specimen of the fossil, which adjoined the last, serpentine was the replacing mineral. The soluble portion from this equalled 47.0 per cent., and consisted of carbonate of lime 96.0, carbonate of magnesia 4.0=100. It thus appears that the septa in these specimens of *Eozoön* are nearly pure carbonate of lime. The somewhat larger proportion of magnesia from the last is due to the use, as a solvent, of dilute nitric acid, which slightly attacked the serpentine.

The pyroxene of the above specimens is a very pure silicate of lime and magnesia; that from I. gave, by analysis, silica 54.90, lime 27.67, magnesia 16.76, volatile matter 0.80=100.13. A partial analysis of the pyroxene from II. yielded lime 28.3, magnesia 13.8. This specimen was interpenetrated with serpentine, amounting to about 10.0 per cent., which was first removed by the successive action of heated sulphuric acid and dilute soda-ley. The serpentine from III. yielded silica 42.85, magnesia 41.68, protoxide of iron 0.67, water 13.89=99.09. As already mentioned, this serpentine had lost a little magnesia from the action of nitric acid; a similar serpentine from the Calumet, associated with the *Eozoön*, gave silica 41.20, magnesia 43.52, protoxide of iron 0.80, water 15.40=100.92. These serpentines from the Laurentian limestones are remarkable for their freedom from iron-oxide, for their large amount of water, and their low specific gravity*.

Specimens of *Eozoön* from Burgess differ from the foregoing in the composition both of the replacing material and the septa. The latter consist of a somewhat ferriferous dolomite, the analysis of which was made upon portions mechanically separated from the enclosed silicate; it yielded carbonate of magnesia 40.7, carbonate of lime, with a little peroxide of iron, 59.0=99.7. The septa of the

* See my descriptions, 'American Journal of Science,' 2nd ser. vol. xxvi. p. 236.

specimen from this locality are in some parts more than 3·0 millimetres in thickness, and exhibit the chambers, cells, and septal orifices; but no tubuli are seen. The replacing material has the hardness of serpentine, for which it was at first mistaken. Its colour is blackish-green, but olive-green in thin sections, when it is seen by transmitted light to be crystalline in texture. Its fracture is granular, and its lustre feebly shining. It is decomposed by heated sulphuric acid, and was thus analyzed, yielding the result I. The centesimal composition of the soluble portion is given under II.

	I.	II.	III.
Silica.....	33·75	35·14	36·50
Alumina	9·75	10·15	10·80
Magnesia	30·24	31·47	28·20
Protoxide of iron ..	8·19	8·60	9·54
Water	14·08	14·64	14·62
Insoluble sand	2·50	—	—
	<hr/>	<hr/>	<hr/>
	98·51	100·00	99·66

The silicate which here takes the place of the pyroxene and serpentine observed in the other specimens of *Eozoön* is one of frequent occurrence in the Laurentian limestones, and appears to constitute a distinct species, which I long since described under the name of loganite, and which occurs at the Calumet in dark-brown prismatic crystals*. I have since observed a similar mineral in two other localities besides the one here noticed. The result III., which is placed by the side of the analysis of the Burgess fossil, was obtained with a greenish-grey sparry prismatic variety from North Elmsley, having a hardness of 3·0, and a specific gravity of 2·539 †. These hydrous aluminomagnesian silicates, which I have there included under the name of loganite, are related to chlorite and to pyrosclerite in composition, but are distinguished by their eminently foliated micaceous structure.

When examined under the microscope, the loganite, which replaces the *Eozoön* of Burgess, shows traces of cleavage-lines, which indicate a crystalline structure. The grains of insoluble matter found in the analysis, chiefly of quartz-sand, are distinctly seen as foreign bodies imbedded in the mass, which is moreover marked by lines apparently due to cracks formed by a shrinking of the silicate, and subsequently filled by a further infiltration of the same material. This arrangement resembles on a minute scale that of septaria. Similar appearances are also observed in the serpentine which replaces the *Eozoön* of Grenville, and also in a massive serpentine from Burgess resembling this, and enclosing fragments of the fossil. In both of these specimens also grains of mechanical impurities are detected by the microscope, which are, however, rarer than in the loganite of Burgess.

From the above facts it may be concluded that the various sili-

* Phil. Mag. 4th ser. vol. ii. p. 65.

† For a description of this and similar silicates, see 'Geology of Canada,' p. 491.

cates which now constitute pyroxene, serpentine, and loganite were directly deposited in waters in the midst of which the *Eozoön* was still growing or had only recently perished, and that these silicates penetrated, enclosed, and preserved the calcareous structure precisely as carbonate of lime might have done. The association of the silicates with the *Eozoön* is only accidental, and large quantities of them, deposited at the same time, include no organic remains. Thus, for example, there are found associated with the *Eozoön*-limestones of Grenville massive layers and concretions of pure serpentine; and a serpentine from Burgess has already been mentioned as containing only small broken fragments of the fossil. In like manner large masses of white pyroxene, often surrounded by serpentine, both of which are destitute of traces of organic structure, are found in the limestone at the Calumet. In some cases, however, the crystallization of the pyroxene has given rise to considerable cleavage-planes, and has thus obliterated the organic structure from masses which, judging from portions visible here and there, appear to have been at one time penetrated by the calcareous plates of *Eozoön*. Small irregular veins of crystalline calcite, and of serpentine, are found to traverse* such pyroxenic masses in the *Eozoön*-limestone of Grenville.

As already mentioned in Sir W. E. Logan's description, it appears that great beds of the Laurentian limestones are composed of the ruins of the *Eozoön*. These rocks, which are white, crystalline, and mingled with pale-green serpentine, are similar in aspect to many of the so-called primary limestones of other regions. In most cases the limestones are non-magnesian, but one of them from Grenville was found to be dolomitic. The accompanying strata often present finely crystallized pyroxene, hornblende, phlogopite, apatite, and other minerals. These observations bring the formation of siliceous minerals face to face with life, and show that their generation was not incompatible with the contemporaneous existence and the preservation of organic forms. They confirm, moreover, the view which I some years since put forward, that these silicated minerals have been formed, not by subsequent metamorphism in deeply buried sediments, but by reactions going on at the earth's surface†. In support of this view, I have elsewhere referred to the deposition of silicates of lime, magnesia, and iron from natural waters, to the great beds of sepiolite in the unaltered Tertiary strata of Europe, to the contemporaneous formation of neolite (an alumino-magnesian silicate related to loganite and chlorite in composition), and to glauconite, which occurs not only in Secondary, Tertiary, and Recent deposits, but also, as I have shown, in Lower Silurian strata‡. This hydrous

* Recent examinations have shown that some of these masses encrusted with *Eozoön*, replaced by serpentine, consist of crystalline pyralolite (rensselaerite), which seems, like the other silicates, to have replaced the organic matter of the Rhizopod. Further examinations, aided by the microscope, are however needed to determine with certainty the relations of the *Eozoön* to these masses of pyralolite.

† Amer. Journ. Science, 2nd ser. vol. xxix. p. 284; vol. xxxii. p. 286. Geology of Canada, p. 577.

‡ Amer. Journ. Science, 2nd ser. vol. xxxiii. p. 277. Geology of Canada, p. 487.

silicate of protoxide of iron and potash, which sometimes includes a considerable proportion of alumina in its composition, has been observed by Ehrenberg, Mantell, and Bailey, associated with organic forms in a manner which seems identical with that in which pyroxene, serpentine, and loganite occur with the *Eozoön* in the Laurentian limestones. According to the first of these observers, the grains of greensand, or glauconite, from the Tertiary limestone of Alabama are casts of the interior of Polythalamia, the glauconite having filled them by "a species of natural injection, which is often so perfect that not only the large and coarse cells, but also the very finest canals of the cell-walls and all their connecting tubes are thus petrified and separately exhibited." Bailey confirmed these observations, and extended them. He found in various Cretaceous and Tertiary limestones of the United States, casts in glauconite, not only of *Foraminifera*, but of spines of *Echinus* and of the cavities of Corals. Besides, there were numerous red, green, and white casts of minute anastomosing tubuli, which, according to Bailey, resemble casts of the holes made by burrowing Sponges (*Cliona*) and Worms. These forms are seen after dissolving the carbonate of lime by a dilute acid. He found, moreover, similar casts of *Foraminifera*, of minute Mollusks, and of branching tubuli, in mud obtained from soundings in the Gulf-stream, and concluded that the deposition of glauconite is still going on in the depths of the sea*. Pourtales has followed up these investigations on the recent formation of glauconite in the Gulf-stream waters. He has observed its deposition also in the cavities of *Milleepores*, and in the canals in the shells of *Balanus*. According to him the glauconite-grains formed in *Foraminifera* lose after a time their calcareous envelopes, and finally become "conglomerated into small black pebbles," sections of which still show under a microscope the characteristic spiral arrangement of the cells†.

It appears probable from these observations that glauconite is formed by chemical reactions in the ooze at the bottom of the sea, where dissolved silica comes in contact with iron-oxide rendered soluble by organic matter; the resulting silicate deposits itself in the cavities of shells and other vacant spaces. A process analogous to this, in its results, has filled the chambers and canals of the Laurentian *Foraminifera* with other silicates; from the comparative rarity of mechanical impurities in the silicates, however, it would appear that they were deposited in clear water. Alumina and oxide of iron enter into the composition of loganite as well as of glauconite; but in the other replacing minerals, pyroxene and serpentine, we have only silicates of lime and magnesia, which were probably formed by the direct action of alkaline silicates, either dissolved in surface-waters or in those of submarine springs, upon the calcareous and magnesian salts of the sea-water. Experiments undertaken with the view of determining the precise conditions under which these and similar silicates may thus be formed are now in progress.

* Amer. Journ. Science, 2nd ser. vol. xxii. p. 280.

† Rep. Amer. Coast-Survey, 1858, p. 248.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPER.

On the GEOLOGICAL STRUCTURE of the MALVERN HILLS and ADJACENT DISTRICTS. By HARVEY B. HOLL, M.D., F.G.S.

[Read June 8, 1864*.]

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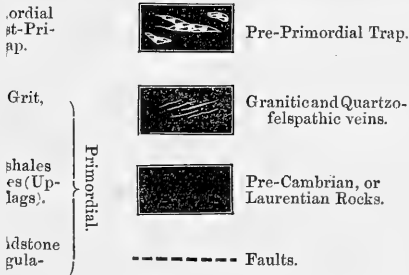
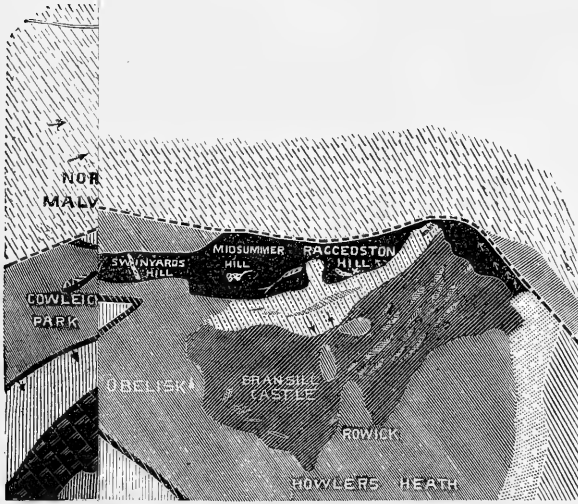
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I. INTRODUCTION.

In a short communication which was read at the last meeting of the British Association (1863), "On the Geology of the Malvern Hills," I expressed my belief that the rocks which had hitherto been treated of as syenite, and supposed to form the axis of the hills, were in reality of metamorphic origin, and belonged to the Pre-Cambrian, Azoic, or Laurentian age †.

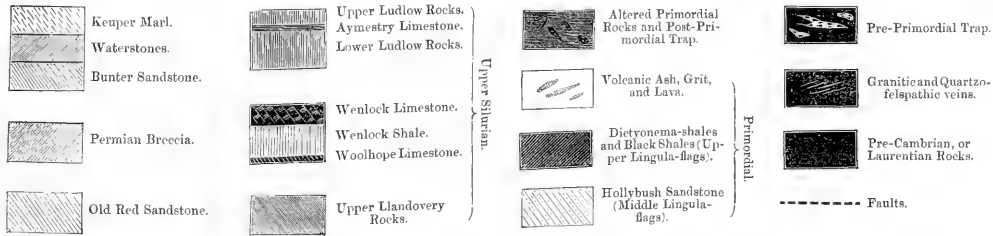
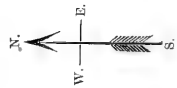
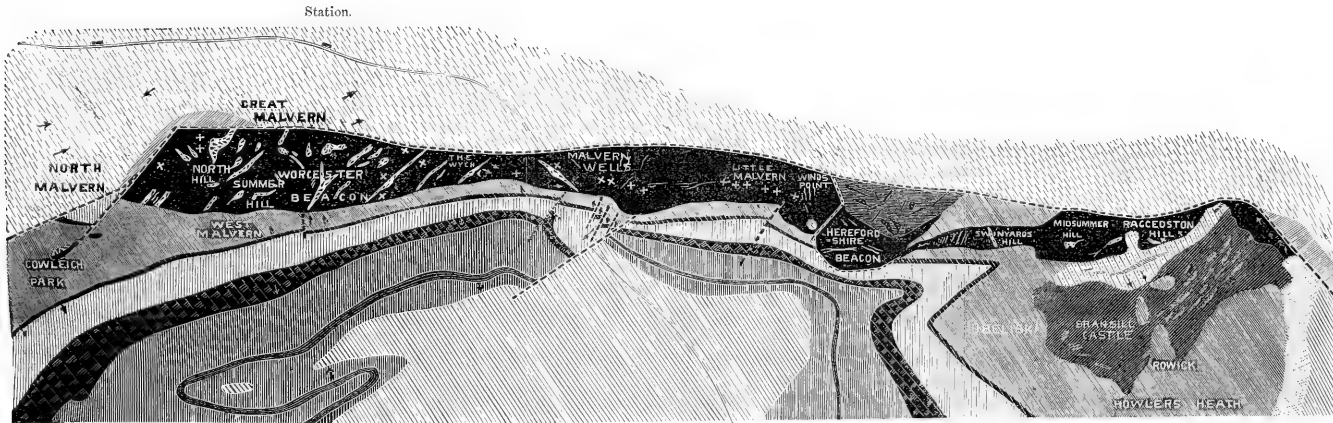
* For the other communications read at this Evening-meeting, see Quart. Journ. Geol. Soc. vol. xx. p. 396.

† Excluding the Huronian rocks, which are now believed to belong to a more recent age, the Azoic rocks of the American geologists include the Laurentian gneiss of Sir W. Logan, and are equivalent to the Pre-Cambrian rocks of Prof. Jukes. They are, therefore, synonymous terms, employed to designate all those metamorphic rocks *which are known* to be older than the Cambrian system. By whatever name they may be distinguished, however, they are parts of the old Pre-Cambrian continents, of which the metamorphic rocks north of the River St. Lawrence, of the Hebrides, the Malverns, Scandinavia, Bohemia, Brittany (?), &c., and probably of Charnwood Forest and Donegal, &c., are uncovered areas. In the absence of organic remains, and in the insufficiency of mineral characters, we have no means of correlating the local subdivision of these very ancient rocks; we must, therefore, be content to take them as a whole.



Scale 1 inch to the mile.

Geological Sketch-map of the Malvern Hills.



+ Strike of beds.

Dip. →

Scale 1 inch to the mile.

In that communication I also intimated that I should enter into further details at no distant date ; but the completion of the paper has been delayed by circumstances which were unavoidable. In the meantime, I have been enabled to clear up certain points on which I was not then altogether satisfied, and to avail myself of some recent researches of my friend the Rev. J. H. Timins, of West Malling, into the chemical constitution of many of these rocks, which have a bearing upon the subject of this memoir, as will be seen in the sequel*.

The objects of this communication are the following:—(1) to discuss the structure and origin of the crystalline rocks of the Malvern Hills ; (2) to give the result of an examination of the superimposed Palæozoic strata immediately adjacent ; and (3) to endeavour to show the chronological relationship of the several events in their geological history.

II. METAMORPHIC ROCKS.

It will be preferable to commence the description at the southern extremity of the hills, where older deposits are seen resting upon the metamorphic rocks than in the northern part of the chain.

1. *Keys-end Hill*.—Some quarries at the southern extremity of this hill, near Bromesberrow Park, exhibit thinly bedded gneissic rocks dipping east. In one of these quarries the gneiss is micaceous ; in the other two it is chiefly hornblendic, with some interstratified thinner beds of dark micaceous gneiss, and a few bands of hornblende-schist. Nearer to the central parts of the hill there is some dark-coloured hornblende- and felspar-rock traversed by a few small quartzo-felspathic veins, and beyond this, forming its northern half, are rocks which consist principally of imperfectly formed hornblendic gneiss, with much greyish and greenish amorphous or semicrystalline rock, very much divided by joints, but breaking with a smooth slaty fracture in the plane of the bedding. Sometimes this rock is nearly homogeneous in appearance, or has a minutely foliated structure ; at other times it has rounded grains of felspar, and more rarely of quartz, scattered more or less abundantly through its substance, frequently in a somewhat linear arrangement. The bedding is best seen in the quarries at the southern extremity of the hill, near the park, the strike being west of north and south of east, and the dip easterly. In the other quarries it is almost entirely obscured by the numerous joints and cross-joints which intersect the rocks, and cause them to break readily into more or less rhomboidal fragments, so that fresh surfaces are difficult to obtain. These jointage-planes are much coated by peroxide of iron, and exhibit abundance of slickensides. Small quartzo-felspathic veins traverse the rocks in different parts of the hill, and a fault, indicated by a narrow band of brecciated rock, is seen in one of the quarries at its southern extremity.

* Mr. Timins has now made more than two hundred analyses of the Malvern rocks, and his results will, I trust, be made known at no distant date.

2. *Ragged-stone Hill*.—The next or Ragged-stone Hill consists of two ridges, divided by a deep excavation which first runs south-south-east and then south-east, the western spur being prolonged further to the south than the eastern one. On the north the hill is similarly divided by a shallower excavation into two spurs, the summits being united by a short transverse ridge.

The mineral structure of these two crests or ridges is somewhat different. In the quarry at the southern extremity of the eastern ridge are beds of thinly laminated and crumpled mica-schist, sometimes rather quartzose, interstratified with greenish-brown and dark greenish-grey schistose rock having a minutely foliated structure*. The beds have a north-west and south-east strike, and dip to the north-east; but a little further along the ridge, after passing over much brecciated white quartz, the strike is altered to north-north-east and south-south-west. Beyond the quartz is some silvery mica-schist, which is followed by dark-grey rock similar to that in the quarry, but more granular in structure; and, nearer to the summit, a still coarser variety shows the commencing separation into hornblende and felspar. These darker-coloured beds alternate repeatedly, and are regularly interstratified, with beds of minutely granular reddish-grey felspathic rock, containing often microscopic spangles of mica, at other times minute dark specks of some easily fusible mineral allied to hornblende. Some of this felspathic rock contains a large quantity of silica, together with some lime and soda. In the transverse ridge which connects the two summits, this rock becomes more argillaceous, and presents a speckled red and grey appearance and a foliated structure, and has associated with it dark-green imperfectly laminated rock passing into hornblende-schist. The northern slope of this ridge is crossed by a fault running north-north-west and south-south-east, beyond which are gneiss and mica-schist.

In the large quarry at the southern extremity of the western spur, near the little hamlet of White-leaved Oak, the lowest beds exposed consist of greenish friable schist, which resembles steatite-schist in appearance, although differing considerably in its chemical composition†. Above these are gneissic rocks of the same ill-developed character as those seen in the quarries towards the southern extremity of the Keys-end Hill, some beds containing mica and others hornblende; but neither of these minerals are cleanly or distinctly crystallized. The dip is to the north of east at a high angle, and against their upturned edges the Hollybush sandstone is seen resting, and dipping also at a high angle in the opposite direction. Beyond the quarry, nearly to the summit of the hill, the rocks consist of greyish-green crumpled schists, either uncrystallized

* It is difficult to find distinctive names for all the varieties of the Malvern rocks. Professor Phillips, in alluding to these dark-coloured bands, speaks of them as "a sort of greenstone or serpentinous trap, more or less laminated, and often veined" (Memoirs of the Geological Survey, vol. ii. pt. 1. p. 27).

† This schist was examined by the Rev. J. H. Timins, and found to contain, silica 41·82, alumina and metallic oxides 35·90, lime 1·40, magnesia 7·81, &c. There is, therefore, too little silica for steatite or talc, and too little magnesia for serpentine. (Timins, *in literis*.)

or more or less altered into mica-schist. Both mica-schist and hornblende-schist occur at the summit, immediately beyond which there is a trap-dyke *. This dyke encircles the north-western side of the summit, and then runs a short distance along the western side of the ridge, a little below the crest. Beyond the trap-rock, on the northern slope of the hill, is slaty hornblende-rock, and at its base near the turnpike road are gneissic rocks and mica-schist †.

Besides the fault already mentioned, the Ragged-stone Hill is traversed by at least two other faults. One of these crosses the crest which connects the summits, and, running down the hollow between the two ridges towards the south, is met by an oblique fault directed north-east and south-west, which cuts off the southern extremities of both ridges, and alters the dip to the north-east.

The Ledbury and Tewkesbury turnpike-road passes between this hill and the next. The rocks on either side of it, uncovered by the Hollybush sandstone, are narrow alternating beds of hornblendic and micaceous gneiss; and opposite the hollow, midway between the northern spurs of the hill, the road is crossed by a trap-dyke.

3. *Midsummer Hill*.—The next hill is divided in a similar manner to the last, by a deep excavation directed towards the south, into an eastern and a western spur, and the summit of the hill is surrounded by the fosse of a supposed Danish encampment. The rocks are best exposed along the western ridge. At its southern extremity are narrow alternating bands of micaceous and hornblendic gneiss. These are succeeded by thickly bedded, rather coarse-grained hornblende- and felspar-rock; a little quartz, and more rarely a little mica, being added in some of the beds. Beyond this is somewhat massive gneissic rock, in part rather poor in quartz, the mica being sometimes of a dark-brown or nearly black, and sometimes of a deep-green colour, and some beds contain epidote. Both the hornblendic and the gneissic rocks are traversed obliquely near their junction by a trap-dyke which there crosses the ridge, and is probably the same as that seen in the turnpike-road. Beyond the thick-bedded gneiss is mica-schist, then some beds of massive gneiss containing dark-coloured mica, and occasionally a little hornblende in addition, which

* The term "trap" is here restricted to igneous intrusive rocks composed of augite and felspar, and is not employed in the more extended sense in which it is sometimes used to designate the more crystalline rocks of the hills generally, especially those rich in hornblende.

† In his description of the rocks of this hill, Professor Phillips observes, "In no part of the Malvern Hills are the trap-rocks more varied in character than in the Raggedstone; nowhere do they depart more widely from the syenitic type, and approach more nearly to the ordinary aspect of eruptive trap, abounding in compact felspar. Consistently with this fact is the observation, that in no part of the Malvern chain is there so much of a metamorphic character in the adjacent Palæozoic strata, and these are the lowest clearly sedimentary deposits which appear in the district" (*op. cit.* p. 26). It should be observed, however, that since the above passage was written, the line of actual contact between the crystalline rocks and the Hollybush sandstone has been exposed in several places, showing the latter quite unaltered.

is succeeded by thinner-bedded gneiss as far as the fosse, and for a short distance beyond it*.

Between the fosse and the summit of the hill there is a large irregular mass of erupted trap, which sends a branch southward into the hollow between the two spurs. This trap rock is precisely similar to that of the summit of the Ragged-stone Hill, and, as will be seen hereafter, to all the other traps associated with the crystalline rocks. In the immediate vicinity of the trap the rocks are chiefly fine-grained gneiss, partly micaceous and partly hornblende. On the north side of the summit, the hill is composed entirely of thin-bedded gneiss and mica-schist, containing dark-brown mica, and ranging from north-west and south-east to west-north-west and east-south-east nearly, and either vertical or inclined at a high angle †.

In the eastern ridge the rocks are not well exposed. A quarry at its southern extremity shows some grey mica-schist, and at its northern end are gneissic rocks having a nearly north and south strike. Some coarsely crystallized hornblende- and felspar-rock protrudes through the turf near the central parts of the hill, and the fragments lying about show the rocks generally to be of the same gneissic character as those of the western ridge.

4. *Swinyards Hill*.—In the narrow hill which succeeds to the last, called Swinyards Hill, the strike of the beds is for the most part east and west; but in the quarry at the southern extremity, near Fair Oaks, there is some contortion of the beds, with a general south-easterly dip; and towards the northern extremity of the hill, the strike of the beds becomes north-west and south-east. The hill is flanked on either side by the higher beds of the May Hill Sandstone, those on its eastern side occupying part of Castle Moreton Common, and separating the crystalline rocks from the Trias, which has hitherto been in close proximity to them ‡.

The following section taken along the crest of the hill, commencing at its southern extremity, although slightly generalized, and not perhaps entirely correct in all its details, inasmuch as there may be minor bands which are not exposed, nevertheless gives a sufficiently accurate notion of the structure of the hill §.

	feet.
1. Micaceous schist and fine-grained gneissic rocks, with a few subordinate bands of hornblende-schist	665

* In noticing the laminated structure of some of these rocks, Professor Phillips observes, "Sometimes the felspar and mica, or felspar, hornblende, and mica, are so arranged as to produce vertical lamination. It is difficult in that case to refuse the rock the title of gneiss" (*op. cit.* p. 28).

† See also Professor Phillips, *op. cit.* p. 28, in which the laminated structure of these rocks is especially noticed.

‡ By some error in the colouring of the Ordnance Map, the May Hill Rock on the east of this hill is represented as Hollybush sandstone. In the skeleton-maps of Professor Phillips (*op. cit.* pp. 60, 84) it is correctly entered as May Hill Sandstone (Upper Caradoc).

§ Owing to the inequality of the ground, and the difficulty of drawing clear lines of demarcation between the beds, the thicknesses given can only be regarded as approximative.

	feet.
2. Fine-grained red granulite	95
3. Fine-grained gneissic rocks and mica-schist, with a few narrow bands of hornblende-schist.....	565
4. Hornblende-schist	15
5. Mica-schist	15
6. Unseen	85
7. Trap-rock, partly brecciated	65
8. Micaceous and hornblendic schists, not well exposed ..	260
9. Fine-grained gneissic rocks with subordinate bands of hornblende-schist	330
10. Diorite *, rich in hornblende, with small quartzo-felspathic veins	22
11. Schist	3
12. Diorite *, rich in hornblende, with many quartzo-felspathic veins	25
13. Schist and interval	12
14. Felspar and hornblende-rock, with quartzo-felspathic veins	18
15. Granite-vein	4
16. Granitoid and gneissoid rocks with small granite-veins not well exposed	14
17. Granite, probably a vein	21
18. Not exposed	20
19. Granite, probably a vein	45
20. Granitoid rocks with small granite-veins	84
21. Granitoid rocks not well exposed; some beds contain epidote and chlorite.....	275
22. Granite-vein?.....	15
23. Granitoid rocks, some bands containing epidote and chlorite.....	30
24. Granite-vein?	3
25. Gneissoid and granitoid rocks	120
26. Hornblendic gneiss and schist, with band of diorite 2 ft. thick, and some small granite-veins	36
27. Granite	14
28. Granitoid and gneissoid rocks, some bands containing epidote	75
29. Granite	3
30. Granitoid and gneissoid rocks.....	95
Overlap of May Hill sandstone †.	

The granite-bands at the northern extremity of the hill are certainly some of them veins, if not all. They contain deep-red potash-felspar, whereas the felspar of the other rocks is of light colours,

* Hornblende and oligoclase, or andesine.

† The laminated and bedded structure of some of the rocks of this hill, and the east and west strike of the beds, are particularly noticed by Professor Phillips (*op. cit.* p. 29); nevertheless he does not appear to regard them in the light of metamorphic rocks. Their schistose-structure is also noticed by Horner, *op. cit.* § 40. p. 301.

and contains both soda and lime. They appear to pursue, for the most part, a north-west and south-east course, and so far to correspond to the general direction of the strike.

5. *Herefordshire Beacon*.—This, which is the second highest eminence in the range, is surrounded near its summit by the entrenchments of an old British camp; and it is only the portion of the hill on which the camp is situated, and a narrow strip to the south of it, that belong to the system of rocks I am now considering, its eastern buttresses and the off-standing hill near Little Malvern being composed of altered rocks of an entirely different age.

Immediately north of Swinyards Hill, and between it and the excavation in the hill-side below the cave, are gneissic rocks having apparently a north-west and south-west course. In the principal mass of the hill, however, on the north side of this excavation, the direction of the strike is from the east of north to the west of south. On the hill-slope, below the south-eastern extremity of the camp, is some uncrystallized hornblendic rock, which has an imperfectly schistose structure, and, from its curved slickenside surfaces, has the appearance of having been squeezed. North-west of this are gneissic rocks, chiefly hornblendic, beyond which is a second band of uncrystallized hornblendic rock, similar to the preceding, which runs very obliquely across the hill, from the western side of the camp near its middle to the northern extremity of the hill at the Wind's Point. Beyond this, and forming the north-western slopes of the hill, are again hornblendic and micaceous gneiss, hornblende-schist, and some mica-schist*.

Two large granite-veins cross the southern half of the camp from north-east to south-west nearly, sending out branches in different directions; and a third vein, also a large one, running nearly north and south, occurs on the eastern side of the summit, between it and the lowest fosse of the encampment, splitting up at each extremity into smaller veins. These granite-veins, like those of Swinyards Hill, are conspicuous from the red colour of their orthoclase-felspar.

6. *Between the Wind's Point and the Wych*.—Similar rocks to those of the Herefordshire Beacon are well exposed at the Wind's Point, in the quarry west of Mr. Johnson's house, and along the side of the turnpike-road leading to Malvern Wells. Mica-schist is here overlain by thick-bedded, dark-coloured, schistose, hornblendic rock, and this again by hornblendic gneiss, rendered ochreous by the decomposition of its hornblende. These are succeeded by alternations of micaceous and hornblendic gneiss, beds of uncrystallized hornblendic rock, and thinly bedded reddish-coloured granulite. Beyond these is much amorphous or semicrystallized hornblendic rock, and then similar rock alternating with hornblendic and micaceous gneiss, and some mica-schist. Quartzo-felspathic veins are numerous, some of them of large size; especially two by the road-side, which can be traced for some distance up the hill. In the

* See also Phillips, *op. cit.* p. 30.

quarry the beds are much disturbed; but in the section along the roadside they have a slightly undulating dip to the north-east.

Along the crest of the ridge, at its southern extremity, the same beds occur, but not so well exposed. In the depression opposite the Roman Catholic Chapel, over which the pathway passes, and in the hill beyond it, overlooking Brand Lodge, the rocks are chiefly hornblende gneiss and schist, with much rather coarse-grained hornblende and hornblende- and felspar-rock traversed by several granitic and quartzo-felspathic veins. In the hollow and hill beyond, as well as in the depression which succeeds it, are fine-grained micaceous gneissic rocks, the strike of the beds being a little to the east of north and west of south. Ascending the southern slope of the next or principal eminence, overlooking Malvern Wells Church, we find diorite and hornblende-schist traversed by several granitic veins; but at the summit, and on its northern declivity, the rocks are entirely gneissic, with hornblende bands and greyish-coloured uncrystallized schist interstratified, the direction of the strike being from north to south.

The ridge here makes a slight bend, and in the narrow part which connects this hill with the succeeding one, overlooking the Holy Well, there is some brecciated and much disturbed rock, indicating a line of fault. The hill beyond consists of micaceous gneiss, with a few bands of hornblende gneiss and some contemporaneous fine-grained granulite. Similar granulite also occurs in the depression beyond.

Ascending the southern slopes of the next hill, we pass over gneissic rocks interstratified with a few narrow bands of schist, beyond which are granitoid or gneissoid rocks interbedded with finer-grained gneiss, until we reach the summit. There is then an interval of about eighty yards, in which the rocks are not exposed *in situ*, but which appear to be gneissoid or granitoid*, traversed by granite-veins. Beyond the summit are gneissic rocks with narrow bands of uncrystallized schist, and some brecciated hornblende rock, then again gneissic and schistose rocks, and further down the northern slope, a trap-dyke, about thirty or thirty-five yards in width, having a north-east and south-west course. This is followed by gneiss and mica-schist as far as the tunnel.

Between the tunnel and the Wych the rocks consist of gneiss and mica-schist, with narrow bands of greenish-grey uncrystallized schist and some hornblende-schist interstratified. Close to the Wych there is a small trap-dyke.

In the hill south of the tunnel the strike is north-east and south-west; but between the tunnel and the Wych the ridge is crossed by three faults, and the strike varies from east and west to north-west and south-east.

The quarries and exposures on the flanks of the hills exhibit thinly bedded rocks, similar to those along the crest of the ridge †.

* The felspar is either andesine or an allied species.

† The bedded structure of the rocks in this part of the chain, and the oblique direction of the strike as regards the axis of the range, seen between Malvern Wells and the Wych, are especially noticed by Professor Phillips, *op. cit.* p. 32.

7. *North of the Wych.*—Beyond the narrow cutting through the hills known as the Wych the intrusions of trap-rock become more numerous. The rocks generally assume a more massive character, owing to the greater prevalence of granitoid rock and of coarse-grained diorite*, and the bedding is for the most part obliterated. The strike can then be inferred only by observing the manner in which these more massive beds occur, lying in narrow belts in the plane of other more distinctly stratified rocks. In the diorite especially, the bedding is either obliterated or obscured by joints. The granite is often gneissoid, and graduates laterally into true gneiss, from which it is inseparable.

Immediately north of the Wych is some granitoid rock, crossed obliquely from north-west to south-east by a trap-dyke. This granite has been quarried on the eastern side of the hills behind some cottages, and also on the crest of the hills north of the dyke. It is partly a coarse-grained rock, rich in red orthoclase-felspar, partly of finer texture, and is generally deficient in mica. The trap-rock is much jointed, and breaks readily into small rhomboidal fragments. Near the surface it is partly decomposed, and, as is the case with many of these traps, it presents in parts more or less of a brecciated structure—a circumstance which will be alluded to hereafter. Some gneiss separates this belt of granite from a second precisely similar one, beyond which, and immediately south of a place known as the “Gold Pit,” is a bed of mica with a little green felspar, and occasionally some large crystals of imbedded hornblende. On the northern edge of this bed is red granite, and beyond this a small trap-dyke. A quarry below this part of the ridge on the west side, and near to the road, shows a confused mixture of gneissoid rocks and hornblendic schists, intersected in various directions by many small quartzo-felspathic veins.

Beyond the Gold Pit, and between it and the rounded eminence midway to the summit of the Worcestershire Beacon, we pass successively over the following belts of rock which cross the ridge in a north-west and south-east direction:—

Diorite	about 10 yards †.
Felspar and mica rock, the latter dark-coloured	„ 23 „
Granitoid rocks	„ 20 „
Trap-dyke, which also appears on the Wych road, south of the turnpike-gate	„ 25 „
Diorite	„ 6 „
Gneissic rocks and mica-schist	„ 90 „
Diorite, coarse-grained and traversed by granite-veins	„ 55 „
Gneiss and hornblende-schist, with many quartzo-felspathic veins	„ 35 „
Gneiss and mica-schist	„ 36 „
Gneiss and hornblende-schist	„ 15 „

* Basic hornblende and felspar rock.

† The distances were only paced off.

Schist	about	4	yards.
Gneissic rocks	”	28	”
Interval	”	20	”
Granitoid rocks, massive and coarse-grained . .	”	90	”
Gneissic and gneissoid rocks, both thickly and thinly bedded	”	37	”
Diorite	”	1	”
Gneissic rocks, with coarse-grained massive beds	”	77	”
Gneissic rocks with hornblendic bands	”	75	”
Trap-dyke and fault	”	30	”

The massive and rugged aspect of the granitoid rocks is partly due to weathering; for when viewed in artificial sections, as along the road from Malvern to the Wych, it has a more gneissic appearance*.

Beyond the rounded summit are gneissic rocks, followed by granite, then some diorite, again granite followed by gneissic rocks, and on the west of the ridge a trap-dyke; then granite, which is again succeeded by gneissic rocks to the summit of the Beacon, where the hill is crossed by a large trap-dyke. Some narrow bands of hornblende- and mica-schist, and a bed of talc, are included in the gneissic rocks at the summit.

The trap-dyke may be traced in a north-westerly direction to the quarry by the side of the high road, at the bottom of the ravine which separates the Beacon from Summer Hill. Below the summit of the Beacon, on its eastern side, it divides into two branches, one of which runs down the ravine above Lady Huntingdon's Chapel, while the other pursues a south-westerly course. Another large mass of trap-rock occurs further down the same ravine, and four others are seen in the ravines between Ellersley and the town reservoirs, a little above the Wych road. They occupy the slopes and bottoms of the hollows, the ridges being formed by the granitoid and gneissic rocks, and, near the roadside, by mica-schist. In the ravine above the reservoir, about halfway up the hills, there is some diorite passing into syenite.

A belt of coarse-grained granite is in contact with the northern margin of the trap-dyke which crosses the summit of the Beacon, beyond which are other bands of more gneissoid granite, separated by gneissic rocks, all having the same north-west and south-east course. A bed of coarse-grained diorite, rich in hornblende, crosses the rounded hill between the Beacon and St. Ann's Well, and on the eastern side of this hill there is another eruption of trap, and a second on its western slope. Other trap-dykes occur in the vicinity of St. Ann's Well, and two more at the southern extremity of Summer Hill.

The largest mass of granite in the whole range occupies the southern half of Summer Hill, directly east of the trap-rock, and the northern slopes of the hill last mentioned, immediately west of St. Ann's Well, and overlooking the pathway leading from Malvern to West Malvern. It has the same coarse-grained structure, but is

* See also Phillips, *op. cit.* p. 33.

less gneissoid than in many other parts of the hills, and it appears on the east to pass into a finer-grained rock with much mica and little quartz, while on the western slopes of Summer Hill the mica in part of the rock is replaced by a brownish-coloured paste, rich in peroxide of iron. The want of exposures precludes the opportunity of ascertaining exactly its mode of occurrence with respect to the other rocks, but on the opposite side of the ravine, along the pathway leading to North Malvern, it is seen passing into gneissic rocks*.

Near the centre of Summer Hill, beyond the granite, is a rather coarse-grained hornblende and white felspar rock, in some parts of which a very small proportion of quartz is added. Beyond this is again granite; and, at the constricted part of the hill, beneath the pathway to West Malvern is another trap-dyke, which sends out a long branch in the direction of the Westminster Arms Hotel.

In the three remaining hills, namely, the North Hill, with the Sugar-loaf Hill on the west, and the Terminal Hill to the north of the latter, hornblende enters more generally into the constitution of the rocks than it does in the Worcestershire Beacon. A long trap-dyke crosses the North Hill from north-west to south-east below the south-west side of the summit, and terminates on the north side of the ravine leading from Malvern to West Malvern. Two smaller masses occur a little to the north of this, near the pathway to North Malvern, and a much larger one on the eastern slope of the hill above Hollymount House. Two smaller ones occur higher up the hill overlooking Trinity Church, and another at the summit, which is prolonged south-easterly and occupies the upper portion of the excavation in the hill-side facing the town. On the south-west side of the first-mentioned dyke, the rocks are chiefly gneissoid granite with some diorite, the latter occasionally containing a little quartz in addition to the felspar and hornblende†. On the north side of the dyke the greater portion of the rocks consists of hornblende and felspar, or of small-grained felspar and mica rock, with little or no quartz. Sometimes a little quartz is added to the former, and occasionally a little hornblende to the latter. At other times the rock is a quaternary mixture of felspar, hornblende, quartz, and mica. Rocks of this variable character especially prevail about the summit. On the eastern slopes some narrow bands of coarser-grained granite are interstratified, some of which, facing the town, alternate with beds of syenite; and, towards its north-eastern face, there is much rather coarsely crystallized hornblende and felspar rock, in which the latter is partly pinkish and translucent, and partly of a dead white colour, and has the constitution of a basic felspar. Towards the point of the hill, at North Malvern, the rocks are chiefly thick-bedded gneiss, often containing much dark-green mica, and occa-

* Alluding to this granite or granitoid rock, Mr. Horner observes, the materials are in some places so disposed as to give the rock somewhat the appearance of gneiss (Trans. Geol. Soc. § 26. p. 295).

† The rock might then be called syenite, but the quartz appears to be only a local and inconstant addition to the hornblende and felspar.

sionally epidote and chlorite. The beds are for the most part massive, but have nevertheless a foliated structure*.

The general direction of the strike is from the north-west to the south-east.

The rocks of the two remaining hills are similar to those of the North Hill. In the Sugar-loaf Hill they are not well exposed. Massive gneissic rocks, and thick-bedded rather fine-grained hornblende and felspar rock, with occasionally a little quartz, occur above the Westminster Arms. Coarse-grained diorite is exposed on the western slopes of the hill, near a trap-dyke, and granitoid rock with much oxide of iron in a quarry below, near the roadside. At the north-eastern part of the hill the same thick-bedded rock, rich in hornblende, occurs as that about the summit of the North Hill; and beyond this, at the constriction between this and the Terminal Hill, is a disintegrated granitoid rock.

The rocks of the Terminal Hill closely resemble those of the North Hill, and are, perhaps, the north-westerly extension of the same beds. At the southern extremity of the hill they are chiefly thick-bedded gneissic rocks, composed of felspar and mica, or hornblende, or both, with sometimes the addition of quartz. Near the centre of the hill is seen coarse-grained hornblende and white-felspar rock (diorite), and towards its northern extremity it is crossed from the north-west to the south-east by two trap-dykes. Beyond these; and on its northern slopes, is a massive rock composed of felspar, quartz, and much green mica, very unequally distributed, which gives to the rock a patchy and more or less foliated structure†.

Three small outlying bosses of the Malvern crystalline rocks protrude through the Llandovery rocks of Cowleigh Park. They consist partly of trap and partly of gneissic rocks containing both mica and hornblende‡. Further to the north, near Martley, there is another boss of these rocks.

8. *General considerations.*—The great instability in the mineral aspects of these rocks, even within very limited distances, renders it impossible to avoid some generalization in the description of them. The schistose portions show various intermediate stages between the amorphous and semicrystalline condition and true micaceous and hornblendic schist. In like manner, between the dark-greenish uncrystallized rock of the Ragged-stone Hill and Wind's Point and the coarsely crystallized black and white diorite§ of the northern part

* The bedded structure of these rocks is noticed by Horner, *op. cit.* § 25. p. 294. See also Phillips, *op. cit.* p. 35.

† Epidote, more or less abundant in many parts of the range, is especially so in this hill.

‡ The peculiar appearance of the May Hill Sandstone along the line of fault on the east of the southernmost of these bosses is probably due, as suggested by Professor Phillips (*op. cit.* p. 37), to the chemical agency of water holding silica in solution, which has also caused the filling-in of the fault with quartz: it is certainly not due to the action of heat, as similar appearances are visible along the line of fault north of Ankerdine, near which there are no crystalline rocks.

§ This rock is the syenite of Prof. Haughton and some German writers;

of the range, there is every possible intermediate form. The schistose hornblendic rocks are for the most part deficient in quartz, although slaty hornblende and quartz rock occurs in the hollow north of the hill overlooking Brand Lodge, and on the western slope of the Worcestershire Beacon. For the most part, however, they are hornblende and felspar schists, or slaty hornblende rocks. In some of the thick-bedded and finer-grained hornblendic rocks of the northern part of the range, quartz or mica, or both, are sometimes added to the felspar and hornblende; but these additions are local, and by no means characterize the rock.

This variability in mineral composition, and the occasional presence of quartz, distinguish the metamorphic from the erupted diorite, and are quite consistent with its probable origin from argillaceous deposits. It is not improbable, also, that some of these metamorphic hornblendic rocks may be lava-beds that were interstratified with the other sedimentary deposits of the epoch, and that have been altered by the same influences.

The gneissic rocks which make up the larger portion of the range are for the most part thinly bedded, and often highly foliated, especially the finer-grained varieties which occur at the northern end of Midsummer Hill, the southern half of Swinyards Hill, and between the Wind's Point and the Wych*. The foliation, however, is often more obvious in the hornblendic varieties of the gneiss, which, although not so thinly bedded, often presents a finely ribboned appearance. For the most part these fine-grained gneissic rocks are rather deficient in quartz, which is frequently altogether absent. When the felspar and quartz prevail, the beds are usually thicker, and the rocks sometimes gneissoid or granitoid. The bedding is massive or obliterated in the southern half of Midsummer Hill, the northern extremity of Swinyards Hill, and north of the Wych. In the gneissoid and granitoid rocks, including the granite, felspar is usually the dominant mineral, but not always so, some rocks near St. Ann's Well being rich in mica, with little or no quartz, and without any obvious gneissic structure. The granitoid varieties are, for the most part, coarse-grained, and weather very rugged on the surface, as is the case about the Worcestershire Beacon. Between the extremes there are many varieties, dependent on the relative proportion of its constituent minerals and on their state of crystallization.

The granite never appears moulded upon the other rocks, as is the case with erupted rocks, as for instance the traps. It does not, like

I prefer, however, restricting the name syenite to granitoid rock having hornblende in lieu of mica.

* Professor Phillips admits the probable metamorphic origin of some of these gneissic rocks (*op. cit.* p. 50); but he appears unwilling to allow to the more massive granitoid and hornblendic rocks a similar derivation, and regards the banded and ribboned structure which he notices "as accompanying most of the syenitic rocks of the Malvern Hills as indications of crystallization under restraint" (p. 46), although elsewhere he observes that we may perhaps admit for some of these bedded hornblendic and laminated felspathic rocks a similar origin and more considerable metamorphosis corresponding to the easier fusibility of the hornblendic element (p. 48). See further, pp. 46 and 49.

them, exhibit that change in its crystalline condition (at the line of contact with other rocks) which is produced by more rapid cooling; nor does it give off any veins into adjacent rocks, all the granite-veins of the hills being posterior to it in age. It lies in the plane of the bedding of the other rocks, and not unfrequently its mica assumes more or less of a linear arrangement, approaching that of gneiss. This gneissoid structure is often better seen in the fresh surfaces of quarried blocks than in the rock *in situ*. Sometimes a belt of granite is subdivided by narrow bands of gneissic rock into several beds, as may be seen in a rock on the north side of the ravine above Lady Huntingdon's Chapel, not far from the upper road*.

Besides the common orthoclase or potash-felspar, there occurs in many parts of the Malvern hills, especially in the rocks containing hornblende, and in the syenite of the North Hill, another form of felspar, which is either white or slightly tinged with yellow or pink, and is usually more or less vitreous and translucent. It is less easily cleaved than orthoclase, and sometimes exhibits striated surfaces like oligoclase. This felspar has been found by the Rev. Mr. Timins to contain too little silica for orthoclase or albite, and to be analogous in its constitution to andesine†. The importance of this determination is greater than may at first sight appear. As this felspar occurs in rocks which contain uncombined silica in the form of quartz, as well as in those that do not, and as the ratio of its soda and lime, alumina, and silica is as 1 : 1 : 3, nearly, we are justified, I think, in concluding that it could never have coexisted in a completely melted condition along with free silica also in a state of fusion, or it would have entered into combination with the latter to form a felspar like albite or orthoclase, in which the ratio is as 1 : 1 : 4; and we have thus confirmatory evidence that these rocks are not eruptive.

Mr. Timins's researches also go to show that in some, if not all, of the orthoclase-felspar, part of the potash is replaced by soda, lime, and magnesia; and that in the chemical constitution of the minerals which compose many of these rocks there is often a wide departure from the theoretical formula—a fact quite consistent with their metamorphic character‡.

* Although, therefore, the rock might sometimes be called, lithologically, a granite, it is, petrologically, only an extreme form of gneiss. See also Horner (*op. cit.* p. 285), who calls attention to the difference in the appearance of the Malvern granite from what he calls the "granite of Alpine countries."

† The constitution of this felspar, as determined by Mr. Timins, at my request, is as follows:—

Silica	59·31
Alumina	23·95
Oxide of iron (determined as Fe ₂ O ₃)	2·66
Oxide of manganese	0·40
Oxide of copper	0·15
Lime	3·66
Magnesia	0·36
Alkalies (determined as difference) ...	8·51
Water ...	1·00
	100·00

‡ The Rev. Mr. Timins's MS.

The quartzo-felspathic and granitic veins are abundant throughout the range, especially at the northern extremity of Swinyards Hill, in the Herefordshire Beacon, opposite Malvern Wells, and in the Worcestershire Beacon. Some of the larger veins are granitic in part of their course. Usually, however, they contain but little mica, and often it is altogether absent. They have a common character in the red colour of their orthoclase-felspar, which in some occurs in large cleavable masses; in others the quartz and felspar form a granular mixture, often minutely so. They traverse all the rocks indifferently, with the exception of the traps, which are posterior to them in date.

The source of these veins is not very clear, unless we adopt Prof. Dana's views as to their mode of formation*.

The situations of the principal protrusions of trap, of which there are upwards of forty, have been already indicated in the general description of the rocks of the hills. These traps have everywhere a very uniform lithological character, and consist of aluminous augite and a felspar allied to labradorite, usually of a brownish colour †, their relative proportions varying only within narrow limits. In two of the dykes in the Terminal Hill, at the northern point of the range, the rock contains, in addition, some iron in a low state of oxidation. Where most highly crystallized, as in the central portions of the masses, the rock has a dotted appearance; but nearer to the margins it becomes fine-grained, and at the line of contact with other rocks, and in the short prolongations some of these masses send forth, it is always compact and homogeneous.

These trap-rocks are all highly jointed, especially the more compact portions, and break readily into small rhomboidal or cubical fragments, so that fresh surfaces are often difficult to obtain. None of the quartzo-felspathic or granitic veins which traverse the metamorphic rocks penetrate the trap masses; on the contrary they always end against them abruptly, and in this respect the traps differ from the dioritic rocks, in which such veins are more or less abundant. The traps are, therefore, posterior in date to the veins. They are anterior, however, to the elevation of the range, as may be inferred from the brecciated appearance which they frequently present, showing that they have partaken in its movements. We may infer it also from the impossibility of a chasm crossing a ridge being filled to the summit with a fluid mass, which would necessarily flow out at the base on either side. The brecciated structure has been produced by the displacement of the small highly jointed fragments, in the upheavals and depressions to which the range has been subjected subsequent to their ejection, and by the faulting which has affected them in common with the other rocks ‡. It is quite possible, also, that these movements may have commenced at a period before

* Manual of Geology, pp. 712 *et seq.*

† The Rev. Mr. Timins's MS. This is the constitution of diabase, or true trap-rock.

‡ Professor Phillips takes a similar view respecting the manner in which this brecciated structure has been produced (*op. cit.* p. 44).

the trap-rocks were consolidated to the entire depth of the fissures, and while, therefore, they were yet weak points in the earth's crust.

Besides the brecciated structure exhibited by some of the trappean masses already mentioned, especially towards their margins, there occur in many parts of the hills narrow bands of breccia formed by the filling up of fissures with fragments from the various adjacent rocks. These long narrow bands indicate lines of fault, and affect the traps as well as the other rocks; in the former, in fact, the brecciated structure is often better displayed than elsewhere. They occur throughout the range, especially in the three southernmost hills, near the Wind's Point, and in the vicinity of the Wych. One of them may be seen crossing the pathway immediately to the west of St. Ann's Well, and a much larger one, nearly nine yards in width, by the roadside leading to the Wych, opposite Furze Bank. This latter traverses the range from south-east to north-west, and has been well exposed in the cutting-back of the hill to widen the road. The great longitudinal fault, which extends the entire length of the range on its eastern side, is filled up with similar fragments derived from the rocks of the hills, and in some parts attains a width of many yards.

These faults, although of very frequent occurrence, can rarely be traced to any distance, owing to the want of exposures; but, where no line of breccia occurs, we may still often ascertain the existence of a fault by the abrupt change in the direction of the strike of the beds. They probably belong to various epochs; some of them are certainly posterior in age to the traps, while others are subsequent to the Upper Silurian period, and the one at the eastern foot of the range is more recent than the Lias.

Some of these fissures, whether filled with trap-rock forming dykes or with breccia, lie in the plane of the bedding, for the reason, probably, that these schistose rocks fractured more readily in that direction than across it.

III. UPPER CAMBRIAN ROCKS.

1. *Hollybush Sandstone*.—The oldest fossiliferous beds resting upon the crystalline rocks of the Malvern hills are a series of sandstones, for the most part of olive and brownish-green colours, which have been long known to contain *Trachyderma antiquissima*, but which has hitherto been supposed to be their only fossil; and hence the exact position of these sandstones in the geological scale has been somewhat uncertain. At the base of the series there is a conglomerate of rounded pebbles of quartz, felspar, &c., which is visible on the south side of the turnpike-road, near a cottage at the foot of the western spur of the Ragged-stone Hill*; and about halfway up, there are some beds of contemporaneous volcanic lava, which form lenticular intercalations nearly, though not quite, on the same geological horizon. Between these two points the beds consist partly of light-coloured felspathic sandstones and of speckled sandstone containing

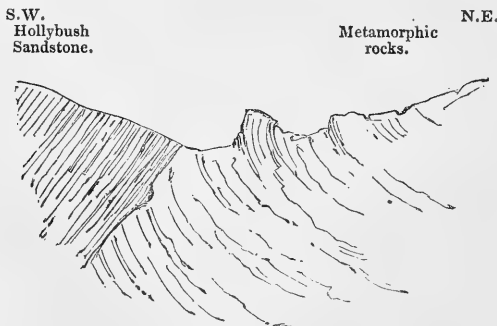
* Noticed also by Phillips, *op. cit.* p. 52.

bright-green grains, both of which are fossiliferous, and partly of olive-coloured slightly micaceous and rather massive sandstone, in which no fossils have yet been detected, and which is well seen in an old quarry at the base of the northern extremity of the Ragged-stone Hill, near the turnpike-road; but the exact order of superposition among the different beds is not determinable for want of more numerous exposures. Above the volcanic rocks are greenish sandstones containing *Serpulites*, and overlying these are thicker beds abounding in *Trachyderma antiquissima*, Salt.

Of the lava-beds, two of them constitute hillocks on the south-west side of Midsummer Hill, in one of which, nearest to the road, a small quarry has been opened. The rock consists of an intimate mixture of felspar and augite, and is of a brownish or reddish-brown colour, uncrystallized, and has occasionally small specks of augite* (?) disseminated through it. A larger but similar bed of lava occurs on the western slope of the Ragged-stone Hill. The northern extremity of this bed was cut through in making the turnpike-road, and it extends southwards from the road nearly three-eighths of a mile. Part of it on the hill-side is nearly black, and almost entirely augitic; but the greater portion of it is a brownish and reddish-brown felspathico-augitic rock similar to the other two †. Further to the south, in the Valley of the White-leaved Oak, and abutting against the metamorphic rocks of the north-eastern extremity of the Keys End Hill, there is a fourth lava-bed interstratified with the sandstones, which differs from the former in its darker colour, owing to the larger proportion of augite it contains, and in having some imperfectly formed crystals of hornblende sparingly scattered through its substance.

In the quarry at the southern extremity of the Ragged-stone Hill, previously alluded to when speaking of the metamorphic rocks, these

Fig. 2.—Sketch showing the Junction of the Hollybush Sandstone with the Metamorphic rocks as exhibited at Ragged-stone Hill ‡.



* Or hornblende.

† "Felspathic trap," Phillips (*op. cit.* p. 52).

‡ By J. W. Salter, Esq., F.G.S.

sandstones are seen resting against the edges of highly inclined gneissic and schistose beds, and dipping in an opposite direction. The lowest strata consist of sandy shales with worm-tracks*. Above these is a bed of dark-purple or purplish-black sandstone, about 3 or 4 feet in thickness, and, still higher up, a bed of light-blue calcareous sandstone, about 6 or 8 feet in thickness, divided in the middle by a narrow band of hard pale-bluish limestone. This is followed by some more or less thinly laminated micaceous sandstone, which graduates upwards into massive beds of an olive-green colour.

These beds appear to come in below the horizon of the lava, and, although here resting upon the crystalline rocks, are evidently above the lower beds seen at the northern extremity of the hill, in the Hollybush Pass, which they cover up by overlap.

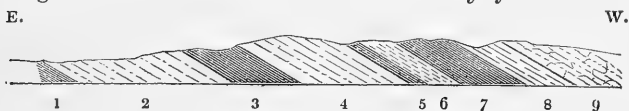
These sandstones have been estimated by Prof. Phillips† to have a thickness of 600 feet on the turnpike-road from Eastnor to Tewkesbury; but in the Valley of the White-leaved Oak, less than three-quarters of a mile to the south, their thickness is little more than 200 feet, owing to overlap of the overlying black shales.

The fossils of the sandstones, with the exception of worm-tracks, are rare, and for the most part small. The following are all that are at present known.

Scolithus.	|	Obolella Phillipsii, <i>spec. nov.</i>
Trachyderma antiquissima, <i>Salt.</i>		Obolella, sp.
Serpulites fistula, <i>spec. nov.</i>		Obolella, sp.
Lingula squamosa, <i>spec. nov.</i>		Small bivalve shell.
Lingula, sp.		

2. *The Black Shales.*—The sandstones just described are overlain unconformably by black and pale-greenish shales, which have a

Fig. 3.—Section across the northern extremity of Coal Hill.



1. Shale.	ft. in.
2. Volcanic grit	2 10
3. Grey indurated shale	1 2
4. Volcanic grit	1 8
5. Shale	0 4
6. Slightly calcareous felspathic ash	0 7
7. Light-brown shale.....	1 0
8. Slightly calcareous lava	0 8
9. Dark-greyish felspathico-augitic lava.....	35 0

The beds dip a little south of west at an angle of 20 to 25 degrees.

* In the foot-note to page 75, allusion is made to the opinion at one time entertained that these sandstones showed signs of metamorphism at their line of junction with the crystalline rocks. It does not appear, however, that Professor Phillips himself took this view, and it is now clearly ascertained that they are not so. Those portions of the sandstones which are in immediate contact with the lava-beds are, however, more or less altered.

† *Op. cit.* p. 51.

thickness of at least a thousand feet, and probably somewhat more. Interstratified with these shales are numerous beds of volcanic ash, grit, and lava, which have a general parallelism, and a direction from north-west to south-east. The harder lava-beds often form oval or rounded bosses which stand out rather conspicuously from the level plain. The following section, taken across the northern extremity of Coal Hill, will serve to show the mode in which the volcanic beds and shales are interstratified.

These volcanic rocks differ considerably in their appearance and mineral structure. The ash has generally a light-greyish and greenish-grey colour, which becomes yellowish brown near the surface, from peroxidation of the iron it contains, and is made up for the most part of minute felspathic grains, with occasionally a few scattered imperfectly formed crystals of hornblende. Some of the harder and more compact varieties are of a bluish-grey colour, effervesce with acid, and contain sometimes as much as 11 per cent. of carbonate of lime*. The grits are more granular, and often cellular, of a brown or olive-brown colour, and without inspection might pass for sandstones; they contain, however, no siliceous particles †. The lavas are more variable in their appearance; some of them, as the one near Fowlet's Farm, are of a reddish-brown colour, amorphous, and compact, extremely tough, and resemble those which occur in the Hollybush Sandstones. For the most part, however, they are richer in augite, and of a dull greenish colour, with disseminated portions of greenish-black hornblende. In the boss at Rowick, and at Coal Hill, the rock has a more trap-like appearance, and the felspar and augite are more distinctly separated, but nevertheless can scarcely be called crystallized. Like trap also, and some modern lavas, the rock breaks into rectangular blocks, which, in weathering, cast off concentric layers, and leave rounded balls. At Rowick this lava has associated with it some highly calcareous blue shale; and similar shale occurs also on the east of Coal Hill.

The greater portion of the lava and ash-beds belonging to the Black Shales occurs between the north-west slope of the Keys End Hill and the turnpike-road leading from Tewkesbury to Eastnor; but a little further to the north, below the escarpment of the May Hill Sandstone, at the Obelisk near Bransill Castle, there are four other bosses of similar volcanic rock. It is mostly of a dark greenish-grey colour, with scattered portions of hornblende, and some cavities filled with carbonate of lime. Other portions are of a blue colour, and very compact, containing some carbonate of lime, but less than might have been expected from its appearance; and when this is removed by an acid, the residue has the same composition as the other portions. In the largest of these bosses, having a little plantation on the top of it, shale is interstratified with the lava-beds ‡.

* The Rev. J. H. Timins's MS.

† They fuse readily before the blowpipe.

‡ The rocks from several of these bosses, as, for instance, those near Bransill Castle, Fowlet's Farm, and Rowick, have been examined chemically by the Rev. J. H. Timins, and the results of his analyses are published in the *Edin. New Phil. Journ. New Series*, vol. xv. 1862, pp. 1 *et seq.*

The following sections taken at right angles to the strike of the beds, the one from Howler's Heath, across the end of Coal Hill, to the southern extremity of the Ragged-stone Hill, the other half a mile to the north of the former, will serve to illustrate the general structure of the country.

Fig. 4.—Section from Howler's Heath to the south-west spur of Ragged-stone Hill.

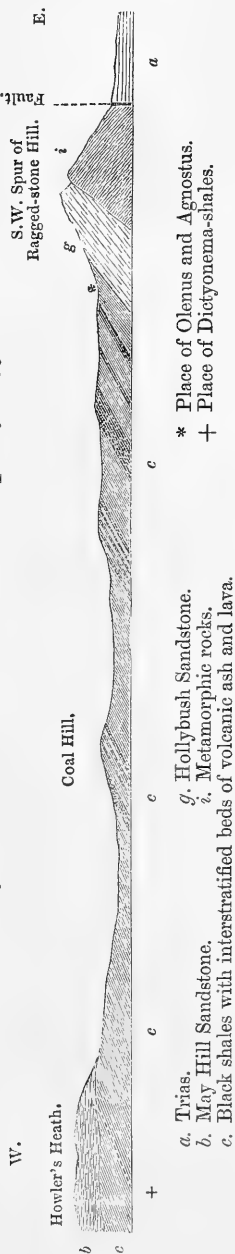
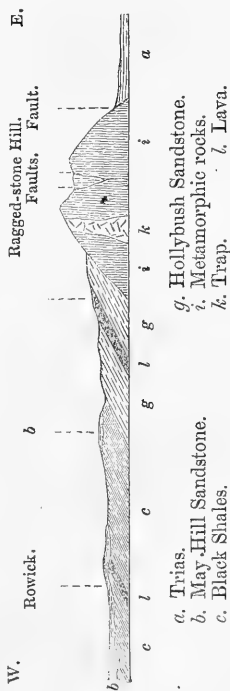


Fig. 5.—Section across Rowick and the summit of Ragged-stone Hill.



The fossils of the Black Shale, as far as they are at present known, are:—

- Olenus bisulcatus*, *Phill.*
- *humilis*, *Phill.*
- *scarabæoides*, *Salt. (O. spinulosus)*, *Phill.*
- Sphærophthalmus pecten*, *Salt., MS.*
- Agnostus pisiformis*, *Brongn.*
- Fragments of a larger species of *Trilobite*.
- Lingula pygmæa*, *spec. nov.*
- Obolella Salteri*, *spec. nov.*
- Spondylobolus* ?
- Minute bivalve shell.
- Cytheropsis*, *spec. nov.*

This area is about a mile in length, extending from the ravine nearly opposite Little Malvern to the middle of Castle Morton Common, and has an extreme width, opposite the southern extremity of the British camp, of three-eighths of a mile. It is invaded extensively by trap-dykes, to which the altered condition of the rocks is due. The central portion of the area, on the slopes of the hills forming the eastern buttresses of the Beacon, is occupied chiefly by highly siliceous rocks of a greyish and pale reddish-grey colour, which pass, where most distant from any trap-dyke, into semi-vitrified sandstone, mostly of light colours, and which becomes conglomeratic in the south-easternmost hill overlooking Castle Morton Common. For the most part, however, it is a hard, compact, often flinty rock, which in the vicinity of the trap-dykes frequently takes on an imperfectly porphyritic structure, small crystals of glassy felspar and a few scattered points of quartz appearing in the mass; and occasionally it becomes more or less spotted with diffused reddish spots, which appear to be feldspathic. These rocks are bordered on the north-west, west, and south-west by others that are softer and less siliceous, and which are probably derived from the shales. They vary greatly in appearance from black, greyish, and greenish-grey porcellanite to dark-green, dark-purple, and red or reddish-brown rocks which show no trace of bedding, and are usually much jointed. Near the trap they often become imperfectly granulo-crystalline, or have some minerals, such as nests of radiating crystals of epidote or small spherical masses of calcite, &c., scattered through them. In the offstanding hill near Little Malvern the rock is porphyritic, being composed of small, light-coloured crystals of felspar set in an amorphous greenish base; in the south-east slope of the hill overlooking Castle Morton Common it is a bright-red rock, spotted with green spots; and in other parts of the area, a variety of semicrystalline rocks occur, which have no very definite character. Many of these variable rocks are probably derived from the ash- and lava-beds that were interstratified with the shales and sandstones, and which have participated in their metamorphism*. Such also is the probable origin of a bluish-grey rock immediately under the southern extremity of the British camp, which appears to resemble very much some of the calcareous lava near Bransill Castle and Coal Hill; and at the extreme southern point of the area, near a cottage on Castle Morton Common, there are some less altered beds which also appear to be of volcanic character.

On the northern slope of the offstanding hill south-west of Little Malvern, previously mentioned, there is an unaltered sandstone containing grains of felspar similar to that of the Hollybush series on the western declivities of the Ragged-stone Hill; and in the middle of the long narrow ridge which jets out south of the keeper's lodge there is, among rocks less baked than elsewhere, some black and greenish shale which has undergone but little change;

* The chemical composition of some of these rocks appears to justify this inference.

and the identity of these altered rocks with the Upper Cambrian beds on the west of the southern extremity of the range is, I think, more than probable.

Of the trap-rocks which have been intruded into this area, four form irregular masses of some size, one of which is situated immediately to the north of the cave, and another to the south and south-west of it. A third occurs a quarter of a mile to the north-east of the cave, and a fourth about the same distance to the south-east of it, on the brow of the hills overlooking a farmhouse. The remaining outbursts form linear dykes, of which there are ten or more traversing the area in different directions. These trap-rocks differ in their physical appearance from the other trap-rocks of earlier date in their more confusedly crystalline structure, and, the majority of them, in their larger proportion of augite. In a few the felspar predominates. The felspar is of a brown or dull-greenish colour, and sometimes exhibits iridescent reflexions. In chemical constitution these traps resemble those previously described, and consist, according to Mr. Timins, of aluminous augite and labradorite, or an allied felspar. Their probable age will be alluded to hereafter.

IV. UPPER SILURIAN ROCKS: MAY HILL OR UPPER LLANDOVERY ROCKS.

All the remaining members of the Lower Silurian series are absent from the district, and the May Hill rocks which succeed have been laid down unconformably on the denuded surfaces of the Black Shales and Hollybush Sandstones. These Llandovery beds, emerging from beneath the Permian conglomerate of Bromesberrow Park at Hayes Copse, form a semicircular escarpment which, passing west of Rowick and Bransill Castle, closes in upon the hills near the northern extremity of Midsummer Hill. Some of the flaggy light-brown basement-beds, however, cap the higher ground on either side of the Ledbury and Tewkesbury turnpike-road, as seen above the lava-bed at Rowick, and to the north and east of it. More massive brown, greenish, and purple beds overlie these, and are seen at Howler's Heath and below the Obelisk at Eastnor; but the beds which flank either side of Swinyards Hill are still higher in the series, and at the "Silurian Pass," at its northern extremity, the upper part of the Llandovery, with its alternating bands of arenaceous limestone, rests directly on the crystalline rocks of the hills.

On the west of the Herefordshire Beacon the May Hill Sandstone is cut out altogether by a fault, but some of the lower purple beds occur high up on the hills in the rear of Mr. Johnson's house at the Wind's Point, being faulted into that position, and having a north-easterly dip. Round the point, on the western slope of the hill, towards Brand Lodge, and thence on towards the Wych, higher beds only rest on the metamorphic rocks, although seen at a lower level. None of the lower purple and conglomeratic beds of the May Hill rocks again occur until we arrive nearly at West Malvern, where they reappear between the flaggy beds and shales which form the upper half of the series and the crystalline rocks of the hills, and,

widening out as we proceed northward, are fully exposed at the northern extremity of the range, and in the anticlinal axis of Old Storage*.

All the overlying members of the Upper Silurian Series, and Lower Old Red Sandstone, follow each other in regular succession; and I have nothing to add, in respect to them, to the full description already given in the elaborate memoir of Prof. Phillips †.

V. FAULTS.

Allusion has been already made to the lines of brecciated rock which occur in many parts of the hills, and to the comminuted appearance some of the trap-rocks present, indicative of movements having taken place subsequent to their injection. But, independently of these, the several passes which divide the chain of the hills at intervals are probably, some of them at least, determined by lines of fault, as the direction of the strike of the rocks on opposite sides of these passes is in some cases abruptly altered.

These lines of fracture are probably such only as resulted from the many upheavals and subsidences to which the range was subjected. The fissures which have given rise to the quartzo-felspathic and granitic veins antedate those which gave vent to the eruptions of trap, and the lines of brecciated rock are, many of them at any rate, posterior to the traps, inasmuch as they contain fragments derived from them in greater or less abundance.

But, besides these ancient fractures, there are two systems of faults of later date, the one soon after the close of the Lower Old Red Sandstone, the other posterior to the age of the Lias.

Of the first of these systems, one occurs nearly opposite the ravine which separates the Worcestershire Beacon from Summer Hill. This fault has carried the Woolhope Limestone, on its southern side, 30 yards further to the west. The road from West Malvern to Mathon Lodge passes obliquely over both ends of the Woolhope Limestone, so as to make it appear that there are two beds of limestone at this spot.

Further to the south, a little beyond the Wych, there is a somewhat complicated system of faults, which has given rise to considerable lateral displacement of the beds. The principal fault is situated further to the south, and crosses the railway shortly after it emerges from the tunnel. The interval between the railway and the hills on the south side of the fault contains all the beds between the top of the Old Red Marls and the May Hill Sandstone inclusive, dipping at a high angle; while on its northern side, all these beds are carried to the northward,—the Wenlock Limestone as far as the turnpike-road, and the Aymestry Limestone to Brock Hill. There is, therefore, an interval between the Wenlock Limestone on the north

* Both at West Malvern and at Old Storage, these lower conglomerates contain pebbles and fragments derived from the metamorphic rocks of the hills. See further, Phillips, *op. cit.* pp. 59, 62, and 63.

† Memoirs of the Geological Survey, vol. ii. part 1.

side of the fault, and the Downton Sandstone on the south side, in which the Wenlock Shale is in contact with the Old Red Marl, and through the interval the railway emerges from the tunnel. Immediately north of this fault there are three smaller faults, which meet the former at an acute angle, and carry the May Hill Sandstone, Woolhope Limestone, and Wenlock Shale forward in the same direction; and still further to the north, from near the middle ventilating-shaft of the tunnel, there is a fourth, which crosses the turnpike-road beneath a cottage, and then runs down the little valley in the direction of Brock Hill. By these faults the Wenlock Limestone is carried entirely to the west of the tunnel to beneath the turnpike-road which runs along its south-eastern margin.

These faults, as well as the one previously noticed nearer West Malvern, appear to owe their origin to the upthrust of the metamorphic rocks of the hills pressing the Silurian beds off laterally, in order to make room for their increased breadth and mass at these particular parts; and to the same cause must be attributed the reversal of the dip observable in many places between Swinyards Hill and West Malvern.

At the constricted portion of the range immediately north of the Wind's Point, the hills are crossed by a line of brecciated rock, indicating a fault, which is probably continued down the ravine in a north-westerly direction, as a sudden reversal of the dip in the Wenlock Limestone on the road to Evendine Street, besides the configuration of the surface, renders the occurrence of this fault highly probable.

A nearly parallel fault passes down the ravine which separates the Wind's Point from the Herefordshire Beacon. The existence of this fault is not determined merely from the change in the strike of the beds previously mentioned, but also from the position of the lower purple beds of the May Hill Sandstone, in the rear of Mr. Johnson's house, at a higher elevation than the top of the series on the western side of the hill.

The only remaining fault which it will be necessary to mention occurs on the western foot of the Herefordshire Beacon. Its northern extremity is in connexion with the fault last mentioned, and its southern termination is somewhere below Walm's Well. This fault is caused by the upthrust of the metamorphic rocks of the Beacon carrying the Upper Silurian rocks before them, and bringing up the altered Hollybush Sandstone and Black Shale, from which the whole of the Upper Silurian beds have been subsequently denuded. The May Hill Sandstone and Woolhope Limestone are thereby entirely cut out on the western side of the Beacon, and the crystalline rocks are brought into contact with the Wenlock Shale.

The other system of faults occurs along the eastern base of the range, extending from the Severn between Newnham and Purton Passage, on the south, to Abberly and beyond it on the north. These faults have brought down the Keuper marls and sandstones, and with them the Lias, which both at Berrow Hill, distant less than two miles, and at Corse Wood Hill, about four miles off, is entirely

conformable to the former in position, and must have gone down with them. South of Newnham, the same series of faults has brought the Lias against the Old Red Sandstone. Along the eastern foot of the Malverns this fault is indicated by a line of brecciated rock made up of fragments from the adjacent hills, which, within the entrance of the tunnel, was ascertained by the Rev. Mr. Symonds to be about 9 yards in width.

VI. CONCLUSION.

The first question which presents itself in a review of the geological structure of the area thus briefly sketched has reference to the probable age of the metamorphic rocks. It has been shown that the lowest beds of the Hollybush Sandstone contain pebbles of quartz, felspar, &c., which, it can scarcely be doubted, were derived from the crystalline rocks against which they rest. From this I infer that the rocks of the hills were above the sea-level at the time these sandstones were being deposited. In confirmation of this inference, we find that the pebble- and grit-beds form the lowest part of the series, and are seen only at the base of the Ragged-stone Hill, in the Hollybush Pass, and that the beds which are in contact with the crystalline rocks higher up the hill are the overlying greenish and olive-coloured sandstones. Moreover these sandstones narrow towards the south, and on the western slopes of the Keys End Hill are overlapped by the Black Shales, which there rest on the metamorphic rocks without the intervention of the sandstone. Hence we may infer not only that the metamorphic rocks were above the sea-level at the period of the deposition of the sandstones and shales, but also that they were subsiding at the time, causing the upper beds to overlap the lower ones, and rise higher and higher up the slopes of the hills.

These metamorphic rocks are for the most part highly inclined, and are often in a nearly vertical position. Their disturbance and metamorphism, their being traversed by granitic veins, and still later their invasion by trap-dykes, and their subsequent elevation above the sea-level, were all events which must have occupied no inconsiderable period even of geological time; and the era of their deposition necessarily preceded this. When therefore we consider the vast thickness of these rocks (for there are few or no clear evidences of repetitions of the same beds), the probability even of their Cambrian age becomes questionable.

An examination of the direction of the strike of the beds of these metamorphic rocks will show that their area, uncovered by newer rocks, is only part of a much larger one, and small peaks of these rocks pierce the Upper Silurian beds nearly as far north as Martley, marking an entire length from north to south of 16 miles; and although neither in these outlying points on the north, nor at the southern extremity of the range at the Keys End Hill, are the rocks so highly crystalline as they are in the vicinity of the Worcestershire Beacon and North Hill, nevertheless neither is there in either direction any indication that the metamorphism is approaching its limits.

I presume it will not in the present day be maintained that the metamorphism of rocks over areas of any but very moderate extent is due to the intrusion of veins and erupted masses. The insufficiency of such agency becomes the more obvious when we consider the slight effects produced by even tolerably extensive outbursts, such as the granite of Dartmoor, &c., and in the case of the Malverns there is an absence of any local cause whatever. The more probable explanation in the case of these larger areas is, that they were faulted down, or otherwise depressed, to within the influence of the earth's internal heat, and this is the more likely as they belong to an epoch when the crust is believed to have been thinner.

Such general and extensive metamorphism, coupled with the events which it has been shown must have subsequently occurred before the laying down of the Hollybush Sandstone, carries the age of these rocks back to a very early period. The physical character of the rocks, and the total absence of conglomeratic beds and quartzites, throughout a thickness of many thousand feet, is not without significance when we consider the frequent occurrence of conglomerates and grits in the Cambrian system; and in the large proportion of diorite and other hornblendic rocks, and of gneissoid granite which they contain, and in the abundant intermixture of erupted traps, they bear a far closer resemblance to the rocks of Laurentian or Azoic age*.

The absence of the Lower Cambrian rocks from beneath the Hollybush Sandstone does not materially affect the question; for the Primordial zone is in direct contact with Laurentian rocks in other parts of the world, *e.g.* Labrador, Lower Canada, the eastern part of Upper Canada, Scandinavia, Bohemia†, &c.; and, as already pointed out by Prof. Dana‡, there is evidence that, even as early as Azoic times, the surface of the earth was mapped out into an Eastern and a Western continent; for the Laurentian rocks of North America have never been entirely submerged, and Lower Silurian strata are seen resting horizontally on their upturned edges§, showing that little subsequent disturbance has taken place. So in Northern and Central Europe, rocks of similar age form the general basis of all the other rocks, whether exposed by denudation or upthrust, or from not having been ever entirely covered up, although there are indica-

* Wherever rocks of known Cambrian age have been seen metamorphosed, they have been altered into micaceous gneiss, or into mica, talc, or chlorite-schists, quartzite, &c. These Malvern rocks, on the other hand, are rich in hornblende, a mineral widely distributed throughout the Pre-Cambrian rocks; and although free quartz is not absent, they contain a large proportion of basic minerals, such as felspar, with a low proportion of silica, hornblende, ferro-aluminous mica, epidote, &c., a peculiarity pointed out by Dr. Sterry Hunt as characterizing the Laurentian rocks of Canada. This last-named protosilicate is met with both forming veins and as an element of rock-masses, and is noticed by Horner (*op. cit.* pp. 292 & 293) as also occurring in the metamorphic rocks of Cumberland, the Hebrides, and the Channel Islands, all of which belong to the same Pre-Cambrian age as those of the Malverns.

† Barrande, *Bull. Soc. Géol. de France*, 2^{me} série, vol. x. p. 405.

‡ *Manual of Geology*, p. 732.

§ Logan, as quoted by Dana, *op. cit.* p. 142.

tions of more frequent oscillations of level in Europe than there are in North America; and whether the rocks which immediately overlie them in any particular district should be Cambrian, or Silurian, or even of more recent age, depended solely upon the relative distribution of land and water at the period of their deposition. The results of later investigations into the physics of the ocean show that the detritus obtained from the wear and tear of dry land, after being carried for a distance out to sea, is washed back again to the continent from whence it came, and that the débris of an oriental continent contributes nothing to the sedimentary deposits of an occidental, and *vice versâ**. Hence there is no reason for expecting to find the Lower Cambrian a more generally or widely spread system than any of those that succeeded to it.

Although, therefore, there is no direct evidence to enable us to say that these Malvern crystalline rocks are the *exact* equivalents in time of the similar rocks on the northern side of the River St. Lawrence, neither can we correlate those of Scandinavia or the Hebrides with them with greater certainty; but there is, I think, evidence that will enable us to say that they all of them form a part of the great Pre-Cambrian system, which is a "universal formation" †, and of which the Laurentian rocks of Canada are western representatives.

The grounds for concluding that the Malvern range was sinking during the period of the deposition of the Hollybush Sandstone and Black Shales have been already explained, and it is quite consistent with this view that the period should have been one of active volcanic action; for it is probable that slow, and perhaps intermittent, subsidence may be one cause of volcanic activity ‡, although the first outburst is said to have been more commonly attended by elevation §. This activity appears to have been less in the period of the sandstones than it was in that of the shales ||, but, owing to the overlap, we have no means of knowing what thickness of these sandstones lies deeply below the lowest beds exposed at the present base of the hills.

Even supposing a more extended acquaintance with the fossils of these sandstones and shales should not finally establish their Primordial age, but group them with the Llandeilo series, this would not, it appears to me, in any way affect the probable age of the metamorphic rocks below. No doubt the occurrence of the entire Cambrian and Cambro-Silurian series would establish their Azoic age; but the absence of some of these Palæozoic beds does not prove them to be the less ancient. These Malvern Hills may have stood up as an island in the Primordial sea, while, as it subsided, Cambrian and Cambro-Silurian strata were accumulated around it.

What higher beds were superimposed upon the Dictyonema-shales we have no means of ascertaining. That the subsidence was arrested

* Dana, *op. cit.* p. 659.

‡ *Idem*, p. 695.

† Dana, *op. cit.* p. 135.

§ Jukes, *Manual of Geology*, p. 344.

|| Since this paper was written, Mr. Salter has called attention to the occurrence of volcanic ash-beds in the Upper Lingula Flags of St. David's Head. *Quart. Journ. Geol. Soc.* vol. xx. p. 241.

for a time, and some amount of elevation succeeded, we learn from the denudation which affected them, and from the unconformable position of the overlying May Hill Sandstone without the intervention of the Llandeilo, Caradoc, or lower Llandovery rocks. This interval was the epoch of the outbursts of trap-rock which have altered the Primordial strata on the eastern side of the Herefordshire Beacon; for there are no remains of the May Hill Sandstone, which there probably would have been had it been involved in the outbursts.

Whatever may have been the oscillations in level which occurred during the latter part of the Lower Silurian period, we have evidence that the metamorphic rocks were again above the sea-level at the period of the deposition of the May Hill series, in the shallow-water conditions of its lower beds, and in the pebbles and fragments of the crystalline rocks which they contain*. There is, in fact, up to this epoch nothing to show that they had ever been entirely submerged. That the period of the May Hill rocks was, however, like that of the Hollybush Sandstone and Black Shale, one of subsidence, is seen in the overlapping of the beds which occurs in both series.

The subsidence of the range, which recommenced in the May Hill Sandstone period, appears to have been continued until after the laying down of the Lower Old Red Sandstone, as all the succeeding members of the Upper Silurian series follow each other in conformable succession. Some purplish and greenish-coloured shales at the top of the May Hill series may possibly be the representatives of the Tarannon Shales; and between these and the Woolhope Limestone, which in the Malvern district consists chiefly of greenish shales with a few impure calcareous bands, there is apparently a very gradual passage; and although a temporary oscillation may have occurred here and there, the general tendency was to a *regular* depression throughout.

It is probable that the whole range became completely submerged during this long epoch, judging from the relative height of the hills to the thickness and present position of the Upper Silurian beds. At the close of the Lower Old Red Sandstone period, however, elevation again took place, for not only is the middle division of the Devonian system probably absent in this part of the kingdom †, but the Upper Devonian beds, the Carboniferous Limestone, and the Millstone Grit are all attenuated in the direction of the Malverns, and the Coal-measures of Newent on the south, and of Martley, Bewdley, and South Staffordshire on the north, are laid down unconformably on the denuded surfaces of the Lower Old Red Sandstone and Upper Silurian rocks.

It does not follow that this rise was continuous. On the contrary, there were doubtless some oscillations, but from the period of the Lower Old Red Sandstone the general tendency was upwards; and

* The late Miss Phillips first observed this. (See also Phillips, *op. cit.* p. 125.) In the Gullet Wood Pass the conglomerate contains fragments of the altered rocks which form the eastern buttresses of the Herefordshire Beacon.

† At least, there is no evidence of its presence.

it is to this epoch of elevatory movement (*i. e.* after the close of the Lower Old Red period) that we must refer much of that tilting of the Upper Silurian rocks which has brought them into their present position, although something of this is probably also due to the subsequent changes of level. The faulting on the western side of the range must have belonged to a subsequent epoch, as some of the displacements are lateral, caused by the unequal pressure of the upheaved metamorphic rocks on already tilted beds.

To this epoch of elevation and denudation there succeeded one of gradual subsidence during the age of the Coal-measures. Between the Coal-measures and the Permian (Roth-todt-liegende?) there is again unconformability; and again between the latter and the Trias, as at Great Whitney, the Permian breccia is succeeded by the Keuper marls.

That the downthrow on the eastern side of the range, extending from Abberly, on the north, to Newent, and thence to near Purton Passage on the Severn, was posterior in date to the Lias, is shown by the relative position of the latter, in the Berrow and Corse Wood Hills, to the underlying Keuper marls and sandstones, and by its juxtaposition, north of Purton Passage, with the Old Red Sandstone.

Figs. 7-10.—Fossils from the Upper Cambrian Rocks of the Malvern Hills.

Fig. 7.

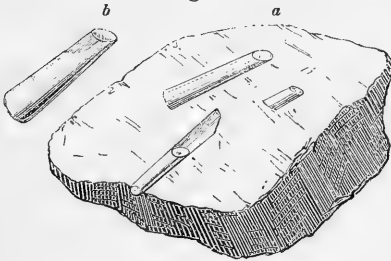


Fig. 8.



Fig. 9.

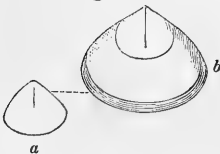
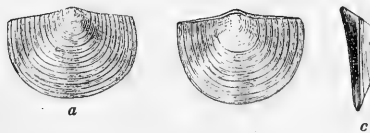


Fig. 10.



- Fig. 7. *Serputites fistula*, Holl: *a*, natural size; *b*, enlarged.
 8. *Lingula pygmæa*, Salter: *a*, natural size; *b*, magnified.
 9. *Obolella Salteri*, Holl: *a*, natural size; *b*, magnified.
 10. *Obolella Phillipsi*, Holl; magnified 8 diameters: *a*, ventral valve; *b*, dorsal valve; *c*, profile.

VII. APPENDIX.—*Description of the new Fossils of the Hollybush Sandstone and Black Shale.*

1. SERPULITES FISTULA, spec. nov. Fig. 7.

Cylindrical, straight, tapering very gradually to a point; shell thin, smooth. Length 1 inch to $1\frac{1}{2}$ inch; diameter about 1 line.

Position.—In the greenish-coloured upper beds of the Hollybush Sandstone.

2. LINGULA PYGMÆA, Salt., spec. nov. Figs. 8 a, 8 b.

Minute, subcylindrical, gibbous; beak somewhat obtuse; anterior margin truncate; shell thin; surface finely striated transversely. Length $\frac{1}{15}$, width $\frac{1}{20}$ inch.

Position.—In the Black Shales.

3. LINGULA SQUAMOSA, spec. nov.

Triangular, broad anteriorly, compressed; beak acute; anterior margin truncate; shell thick, strongly grooved from side to side by imbricating lines of growth. Length $\frac{1}{4}$ inch.

Position.—In the light-brown felspathic sandstone of the Hollybush series.

4. OBOLELLA PHILLIPSI, spec. nov. Figs. 10 a, 10 b, 10 c.

Semicircular, slightly broader than long; hinge-line straight, nearly equal to the greatest width of the shell. Ventral valve prominent at the beak, depressed near the margin; beak small, round, pointed, and situated close to the posterior margin. Dorsal valve evenly convex, slightly depressed at the angles; umbo obtuse. A slight mesial depression towards the anterior border in both valves. Surface marked with numerous moderately fine, sharply defined, rather unequal, concentric striæ, at about their own width apart. Length of a large specimen $\frac{1}{4}$ inch, width $\frac{1}{3}$ inch.

The shell-structure, where the outer layer has become exfoliated, is strongly punctate.

Position.—In the felspathic sandstones of the Hollybush series.

5. OBOLELLA SALTERI, spec. nov. Figs. 9 a, 9 b.

Compressed, subtriangular to nearly round, rather broader than long; shell thin; surface grooved concentrically by a few inequidistant, strongly marked lines of growth, and by numerous finer lines which are distinct only on the sides of the shell. Length usually about $\frac{1}{3}$ inch, width slightly more.

Position.—In the Black Shales.

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PROCEEDINGS
OF
THE GEOLOGICAL SOCIETY.

DECEMBER 7, 1864.

William Guybon Atherstone, M.D., M.R.C.S., Graham's Town, Cape of Good Hope; James Brogden, Esq., Tondy Iron Works, Glamorganshire; Lieut. Alexander Burton Brown, Royal Artillery, Gibraltar; F. H. Dickinson, Esq., Kingweston, Somerset; George Dowker, Esq., Stourmouth House, near Wingham, Kent; George Baker Forster, Esq., Backworth Hall, near Newcastle-on-Tyne; Charles Graham, Esq., B.Sc. Lond., University College, London; Thomas B. Lloyd, Esq., Spring Hill, Birmingham; William Craigton Maclean, Esq., Great Yarmouth; William Molyneux, Esq., Branston Cottage, Burton-on-Trent; William Prosser, Esq., M.R.C.P., Wilmslow, near Manchester; James E. Randall, Esq., Rudloe Lodge, Corsham, Wilts; James William Hamilton Richardson, Esq., 27 East Parade, Leeds; R. N. Rubidge, M.B. (Lond.), M.R.C.S., of Port Elizabeth, Cape of Good Hope, 83 Gower Street, Bedford Square, W.C.; The Rev. Richard Norris Russell, M.A., Beachampton Rectory, Stoney Stratford; William Walter Stoddart, Esq., 9 North Street, Bristol; The Rev. Robert Boog Watson, B.A., F.R.S.E., 4 Bruntsfield Place, Edinburgh; and J. Harris Wills, Esq., Houndiscombe Place, Plymouth, were elected Fellows.

The following communications were read:—

1. *On the GEOLOGY of OTAGO, NEW ZEALAND.*

By J. HECTOR, M.D., F.G.S., of the Geological Survey of Otago.

[In a letter to Sir R. I. Murchison, K.C.B., F.G.S.]

THE south-western part of the Province is composed of crystalline rocks, forming lofty and rugged mountains, intersected by deeply cut valleys, which are occupied on the west by arms of the sea, but on the east by the great lakes. The base-rock of this system is a foliated and contorted gneiss, corresponding to Humboldt's Gneiss-granite of South America. Associated with it are granites, syenites, and diorites. Wrapping round this batch of crystalline strata, and sometimes resting at great altitudes (say 5000 feet) on its surface, are a series of hornblende-slates, soft micaceous and amphibolic gneiss, clay-slates, and quartzites, associated with felstone-dykes, serpentine, and granular limestone. I believe these to be metamorphic rocks of not very ancient date.

To the eastward of these two formations the country is traversed by a depression that widens towards the south, and enters the mountain-chain by a pass only 2000 feet in altitude above the sea; this is the "Greenstone Pass" that I discovered last year. Along the line of this depression, and resting on the last-mentioned slates, &c. (unconformably?), are well-bedded sandstones, shales, and porphyritic conglomerates, together with soft greenstone-slates and diabase-rock in patches. This further reminds me of Darwin's great porphyritic formation in South America, and is probably also all that we have to represent the Lower Mesozoic rocks (No. VI.). In the N.E. and S.E. part of the Province, what I take to be the same formation, or an upper series of it, passes into sandstones and shales, thrown into bold plications and interbedded with diorites. They resemble exactly the formation that is included unconformably in the folds of the Carboniferous Limestones of the Rocky Mountains.

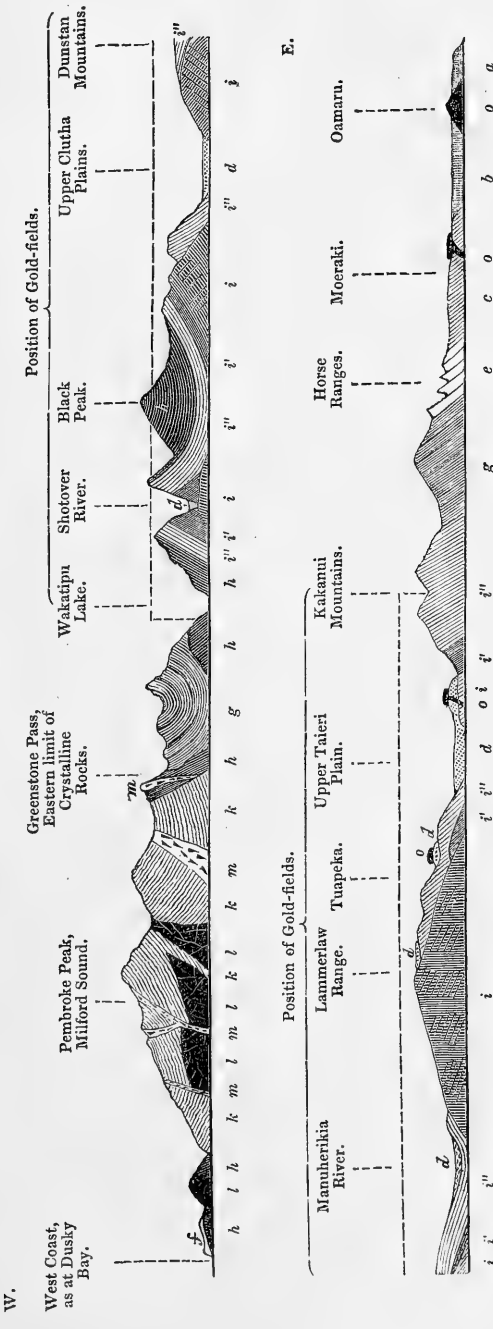
To the eastward of the depression (see section) we have a great development of the auriferous schistose formations, shaped as a flattened boss, rising to 4000 feet, and throwing off *h* and *g* to the westward, and only *g* to the eastward. In the section I have divided the schists into three parts.

1. *Upper (i)*.—A grey arenaceous, almost slaty rock, containing but little quartz, in the form of veins and laminae.

2. *Middle (i')*.—Soft blue slates, often highly micaceous, and intersected with quartz-veins of small size, the quartz often rotten and decomposed. The thickness of this formation is not more than from 100 to 200 feet, and it is probably the same from which most of the gold in the Western or Lake gold-fields has been derived, by the direct erosion of glaciers and mountain-torrents. This blue slate-formation has been removed by denudation from the greater part of the central boss, only remaining in a few localities that are difficult of detection, on account of its soft and perishable nature.

3. *Lower (i'')*.—Contorted schist. This is a clay-schist, foliated, not with mica nor with felspar, but with quartz. It is often chloritic, and in the upper part the quartz is nearly wanting. The

Section across the Province of Otago.



W.

West Coast, as at Dusky Bay.

Greenstone Pass, Eastern limit of Crystalline Rocks.

Pembroke Peak, Milford Sound.

Wakatipu Lake.

Shotover River.

Black Peak.

Upper Clutha Plains.

Dunstan Mountains.

Position of Gold-fields.

E.

- f. Carbonaceous formation of the West Coast.
- g. Sandstone, Porphyry, and Diabase.
- h. Quartzite, Slates, and Felstones, with Serpentine and Marble.
- i. Grey Schist.
- i'. Blue Schist.
- i''. Contorted foliated Schist.

- a. Alluvial Drifts.
- b. Oamaru or White Crag, with Fossils.
- c. Moeraki Clays, with Septaria.
- d. Ancient Lake-deposits; Brown Coal; Great Gold-drift.
- e. Carbonaceous sandstones; Brown Coal.

- k. Gneiss-Granite.
- l. Granite, Porphyry, and Syenite.
- m. Diorite, Hypersthene, &c.
- o. Basalt and Tuffaceous rocks: *Upper Tertiary*.

F 2

schists apparently lie very flat, and cover a great extent of country. The foliated quartz does not commence at a distinct horizon, but beds thus altered occur in the regular sequence of the strata separated by quartzless rock. In the lower part of the series, however, as exposed in the deep valley of the Clutha River, that cuts right through the central district of the province, the whole mass of the schist is intersected by concretionary laminae of quartz (generally of a bluish tinge and horny appearance), that conform to the planes of foliation, as in mica-schist. Gold occurs segregated in the interspaces of this contorted schist, but it is rarely found *in situ*. Quartz-reefs are confined to the upper schists, but there are very few instances of true "fissure-reefs" having been discovered, that is, reefs that cut the strata nearly vertically, and have a true "back" or wall independent of the foliation-planes. Only one reef is being worked in the same manner as in Victoria as yet, and the yield is about 1 oz. to a ton. I have nowhere seen in this Province the exact mineralogical equivalents of the auriferous slates of Victoria or California, as they resemble much more those of British Columbia. I believe the difference is due to the absence of true cleavage, and its having been replaced by foliation and joints; so the same internal changes by chemical action, due to infiltration, have not taken place,—that is, supposing, as I do, that both these, namely, cleavage-planes on the one hand, and the foliation and jointing on the other, have been due to mechanical impulse, followed in the first case by the segregation of the siliceous matter in distinct veins, and in the other in the form of laminae. In the one case the mechanical force has plicated the strata; and the cleavage-planes have the nature of fissures, and may be compared to the joints of the foliated strata. In these the shales have moved on their planes of stratification, commencing afresh at each line of joint. In either case, a system of drainage is established in the schistose rock, which facilitates the segregation of its mineral elements.

External to all the above formations we have a series of Tertiary rocks; the lowest of these, however, may possibly be of Upper Mesozoic age. The series consists of coarse conglomerates, sandstones, and shales, containing estuarine shells, and associated with thick deposits of brown coal (*e*), of excellent quality. The shales with the coal contain Ferns and Dicotyledonous leaves. This carbonaceous formation is generally tilted at considerable angles, and is unconformably overlain by the Newer Tertiary rocks. These consist of two series, the one *freshwater* (*d*), occupying basins or depressions in the schistose rocks of the interior, the other marine, confined to the coast-line and low altitudes. The relation of these one to another cannot be distinctly made out, but I think that some at least are contemporaneous. The lower marine beds are argillaceous (*c*), and contain septaria, sometimes of an immense size, as in the case of the Moeraki boulders*, which are quite spherical, and often reach 12 feet in diameter; they are washed out of this forma-

* See Mr. W. Mantell's description and figures, Quart. Journ. Geol. Soc. vol. vii. p. 324.

tion where it is breached by the sea. Over these clays come calcareous sandstone (*b*), containing abundance of fossils.

Where Dunedin is situated volcanic energy was displayed at a very early Tertiary date; but nearly all our basaltic rocks overlie the above-mentioned fossiliferous limestones, and were deposited to what is now a height of (say) 1800 feet as submarine lavas and tufaceous beds. The period of this volcanic energy was one of upheaval; and since it closed I see no evidence of there having been any great and general submergence of the island. On the other hand, there must have been an excessive elevation, far exceeding, at least in the mountain-region, that which it has at present. This is proved by the great depth of the valleys, which were excavated by glacier-action after the close of the above-mentioned formations. On the western coast the valleys have been scooped out to a depth which is now at least 1800 feet, in some cases, beneath the present sea-level, while on the east side, where the depression has not been so great, these valleys are occupied by lakes, the surfaces of which have a mean altitude of 1000 feet, but the bottoms of which are considerably below the sea-level. The evidence of the former extension of the glaciers, arising from the greater altitude and consequent enlargement of the area within the mean snow-line, is most distinctly marked. On the other hand, except in one part of the plains of Southland, I have seen no evidence of erratic deposits which have at all the character of the northern glacial drifts. Distinct evidence of the Post-tertiary oscillation of the coast-line, resulting in emergence, is only to be found in the eastern, southern, and north-western parts of the province. On the west coast, where the mountains rise directly from the sea, and are penetrated by the *fiords*, the evidence derived from the disposition of the detritus brought down by the mountain-torrents, and thrown into deep water, indicates rather a gradual submergence. Gabriel's Gully owed its richness to the gold having been freed from an ancient Tertiary drift-deposit, that occupied a valley cut through obliquely by the present watercourse.

The strike of our auriferous schists is on the whole N.N.W., but, so far as I have seen, they do not reach the west coast of this province. However, gold has been recently found on the sea-shore of the west coast of Canterbury, and within the last month a very promising gold-field has been found in the northern extremity of this island in the province of Marlborough. As the western part of the province of Nelson, according to Dr. Haast, is partly composed of crystalline rocks, it is very probable that the strike sweeps round to the N.E. The western districts of the island being very inaccessible, this will explain why the gold-diggings have been so long confined to Otago, and to a small extent to Nelson, and would lead us to expect that they may yet extend in a continuous belt right through the length of the island, but passing to the west of Mount Cook. Nevertheless, I am strongly of opinion that the richness of a gold-field is more dependent on the extent of the auriferous drifts, and the relation of the lowest level of the basins in which they have been collected to

the water-run of the country, than to the mere presence of the rock which forms the original matrix, at least in those cases where the segregation of the quartz, &c. has assumed the foliated form, and where the gold, therefore, has not been concentrated in well-defined reefs or lodes.

Synopsis of the Geological Formations in Otago Province.

(The *italic* letters refer to the section on p. 125.)

- I. Recent (*a*?).
 1. *Alluvial*. River-silts, shingles, and deltas.
 2. *Lacustrine*. Exposed by the gradual drainage of lakes.
 3. *Estuarine or Littoral*. Exposed by emergence of coast-line.
- II. Pleistocene. (Newer gold-drifts.)
 1. *Lacustrine*. In basins in the interior.
 2. *Glacial*. Moraine-deposits and loess.
- III. Pliocene? (*d*). (Great gold-drift.)
 1. Sand, &c. in basins in the interior (with lignite).
 2. Coastward deposits.
 - a*. Volcanic and tufaceous deposits.
 - β*. Sands and clays.
- IV. Miocene?
 1. Oamaru or calcareo-arenaceous series* (*b*).
 2. Moeraki or argillaceous series (with brown-coal) (*c*).
 3. Waitaki. Arenaceous.
- V. Carbonaceous series (*e* & *f*). Estuarine strata, with conglomerates, sandstones, shales, and brown-coal of fine quality.
- VI. Te Anau series (*g*). Porphyritic conglomerate, wacke, clay-stones, glossy slates and diabase, and porcellanite.
- VII. Kahiku series (*h*?). Quartz, clay-shales, sandstone, diorite-slate, black cross-cleaved slate, siliceous and true clay-slate.
- VIII. Foliated schists.
 1. Grey argillaceous. Kakanui series (*i*).
 2. Blue clay-slate. Micaceous or chloritic (*i'*).
 3. Contorted felspathic schist (*i''*).

All these are more or less impregnated with infiltrated quartz, and are auriferous.
- IX. Gneiss-granite (*k*). Quartzose with garnets, or Felspathic.

* Apparently the same as the "White Crag," or "Ototara Limestone" of Mantell. See Quart. Journ. Geol. Soc. vol. vi. p. 328.—EDIT.

2. *Note on communicating the NOTES and MAP of DR. JULIUS HAAST upon the GLACIERS and ROCK-BASINS of NEW ZEALAND.* By Sir R. I. MURCHISON, K.C.B., F.R.S., F.G.S.

[Abstract.]

IN a letter to Sir R. I. Murchison, Dr. Haast informed him that for five years he had attentively followed the discussions on glacier-theories, and that, independently of other authors, he came, in March 1862, to the same conclusions in New Zealand as Professor Ramsay had come to in Europe, namely, "that the numerous lakes met with on both sides of the high Alpine chain of New Zealand were formed by the action of glaciers." He further stated, that this view was communicated to various friends in Europe, and printed in his Colonial Reports, as Geologist of the Province of Canterbury.

Until recently, the constant field- and other occupations of Dr. Haast have prevented his carrying out his intention of writing a paper on the subject for the Geological Society. This paper he hopes to transmit soon; and in the meantime he has forwarded to Sir Roderick Murchison the following notes, as a *résumé* of his views, and has illustrated them by a skilfully executed MS. map, the general features only of which are given on p. 134. He has also transmitted to the Royal Geographical Society a series of very beautifully coloured sketches of all the chief glaciers of New Zealand, and their moraines.

Sir Roderick Murchison then quotes Dr. Haast as follows:—

"I fully agree with you that all valleys have not been excavated by glaciers; the more so as there is every proof that glaciers, like watercourses, choose any natural depressions, be it line of junction of two formations, fault, synclinal trough, or, as in the southern Alps, very often anticlinal breaks, to bring down the enormous masses of *nevés*, which, through the rising of the country or meteorological causes, have accumulated on the (at first) plateau-like ranges.

"But, at the same time, it is natural that such a mass of ice, of such an enormous weight and tremendous *vis à tergo*, will be able to scoop out sooner much larger and deeper valleys and gorges than the waters of a river, however considerable, the more so as the transporting power of the glacier is not only so much greater, but also adds to its weight. A glacier transporting an enormous load of *débris* on its surface will thus be able to scoop its valley much deeper, and will bring away much more easily the detached *débris* from the ranges, which would only obstruct the course of a river."

With reference to Dr. Falconer's remarks published in the 'Proceedings of the Royal Geographical Society,' Dr. Haast writes as follows:—

"I cannot agree with him concerning the filling up by glacier-ice of deep preexisting rocky basins, over which afterwards the glacier advances. What becomes of the ice in the deep hollow in contact with the rocky bottom at a higher temperature, and of the water

collecting under it? My theory, I think, will explain all possible occurrences; and I am certain, if applied to Switzerland or any other (Alpine) country, it will be found that, generally, all similar phenomena can be understood more easily by adopting it. You will observe, on looking at the map, how very close the line in which our Alpine lakes lie agrees with the general direction of the central chain throughout the islands.

“These lakes are indiscriminately in very hard rocks, as well as in loose, schistose strata, and are either lying in accordance with the strike or across it. In fact, every proof is offered that the geological structure of the country has nothing whatever to do with them. Only, the harder the rock, the shallower and shorter will they be found to be. Also, rocks disintegrating into shingle will sooner obliterate them than schistose rocks, which are more easily destroyed by the erosion in the rivers, and the mud carried away to the sea. Of course I have not the least intention to say that all rocky basins are formed by glaciers, but only allude to our New Zealand ones.”

Sir Roderick Murchison then remarks that the views of Dr. Haast differ in most essential respects from those which he has advocated, and that, whilst he has opposed, and still opposes, the theory of the excavation of hard rocks so as to have formed deep basins in them, the phenomena in New Zealand seem to be peculiar and well worthy of due consideration, the more so as Dr. Haast, in his letter, well describes those former geological changes of the surface which prepared the lines of depression in which the glaciers descended, but which he tells us they did not produce.

3. *Notes on the CAUSES which have led to the EXCAVATION of deep LAKE-BASINS in HARD ROCKS in the SOUTHERN ALPS of NEW ZEALAND.* By JULIUS HAAST, Ph.D., F.L.S., F.G.S.

[Communicated by Sir Roderick Murchison, K.C.B., F.R.S., F.G.S.]

(Abridged.)

THE author first states his views respecting the changes which had taken place in the physical features of New Zealand during the later geological periods. He considers that, after the deposition of the Pliocene strata of those islands, the country emerged, its chief physical feature being a high mountain-range, but with depressions which existed before the previous subsidence, though now partly obliterated, and which in most cases ran either on the junction-line of two formations or along faults, or else on the break of bold anticlinals.

It is then observed that several causes had combined to produce a great accumulation of *nevés* as soon as the higher portions of the country had risen above the snow-line, especially the equatorial north-west and polar south-east winds coming, charged with moisture, in directions at right angles to the principal mountain-range of the islands, which runs from north-east to south-west.

The sequence of changes effected by the glaciers is then traced, and attention is called to the fact that they soon formed for themselves channels in the plateau-like mountains, and that, running in these channels, they gradually became narrower and deeper; the specific gravity of the ice became greater, and consequently its scooping and triturating power much more considerable; thus, a constantly increasing quantity of detritus would be furnished for the formation of moraines. The loose Tertiary strata lying in the course of the advancing glaciers would soon be removed, unless protected by favourable circumstances. The existing depressions were widened and made straighter by the glaciers, and their reentering angles were either entirely removed or worn into *roches moutonnées*.

Dr. Haast next gives a sketch of the formation of the terminal moraines, and states that the water issuing from the glacier, being charged with finely triturated matter, would deposit it amongst the coarser material, so as to make the moraine impermeable, and that, the detrital matter being in excess of what could be transported to lower regions, the bed of the outlet would be raised. The result is stated as follows:—"From that moment the formation and scooping out of the rock-basin begins. Hitherto the ice of the glacier, having a sliding action, by gravitation, and pressure from the descending masses above, had only to overcome the impediment of the asperities of its bed, bottom, and sides. Now, the glacier in advancing would find an impediment in the form of a very compact mass before it, which, like rocks *in situ*, had to be ground down before it could make a new channel for the collected water. But this water could not accumulate below the ice, but would be forced up into the fissures of the glacier, until it reached the level of the lowest point in the moraine. The ice, being impelled downwards by the *vis à tergo*, would be pressed most heavily against the rocky bottom of its bed, where it had to ascend over the moraine, and would now find it a much easier task to plough out a deeper bed for the accommodation of the masses of ice pressed on it from behind. Moreover the finely triturated glacial mud would be forced into the body of the ice by the enormous pressure, and would assist in scooping out a hollow. Thus many causes would combine to give additional scooping-power to the glacier at the spot where the terminal moraines—now consolidated into one large mass—would impede the advancing of the ice, as well as the outflow of its former outlet."

All these operations were stated to be still going on in a minor degree; and the author illustrated his views by giving a description of the existing Tasman glacier, which was said to furnish a very close parallel to the requirements of his theory.

Pursuing the sequence of events during the glacial period, the author stated that, finally, the glaciers began their retreat, from various causes, especially the sinking of the country, the diminution of the plateau-like *nevés*-fields, through the ridge-making effects of the glaciers, and the wearing away of the heights by atmospheric influences. The rock-basin which had been excavated by the stationary glacier would now be exposed, and a lake would be formed

by the water issuing from the termination of the retreating glacier collecting in the depression. After this the form and extent of the lake became altered by the formation of a delta by the glacier-stream.

Dr. Haast concluded his paper as follows:—

“The old beds of glaciers are in all stages and conditions in the New Zealand Alps, from the deep narrow gorge-like character, with an outlet of clear, nearly colourless water (Lake Wanaka), to the shallow wide expanse, with an outlet the water of which is always coloured from glacial mud (Lake Pukaki and Lake Takago), or they are filled up or drained by the removal of part of the terminal moraine-masses, and the cutting of a channel through the rocks (Rangitata), or from extensive swamps through which the river meanders sluggishly (Valley of the Aturia).

“Often several of these drained lakes occur, one above the other, until they reach the present glacier-moraine, through which the river has forced a gorge-like passage, and behind them an expansion of the valley, with shingle-flats or swampy grounds.

“The rocky basins occur on both sides of the New Zealand Alps, as, for instance, Lake Brunner, Lake Ratorna, and Lake Rataiti, on the western side of the central mountain-chain of the Province of Nelson, whilst by far the greater part has been filled up as lying on the steep western side of the Alps, where in consequence greater destruction has taken place through denudation (Marnia plains, expansion of the Valley of the Grey, before it enters the plains, &c.).

“I have not made any allusion to the unequal ratio of elevation and subsidence, which will be necessary to explain many apparent anomalies; but I may state that, since the Pleistocene epoch, the greatest subsidence in this island has taken place towards the south-west, to which already the greater extent of the Alpine lakes in the Otago Province and the less altitude of the mountain-chains point, although they show enormous glaciation in former times; whilst the researches of Dr. Hector on the west coast of Otago have conclusively shown that its deep fiords are simply the channels of former glaciers, now depressed below the level of the sea, but still showing by their configuration that they are rock-basins.

“If this hypothesis, and the deduction drawn from it, be applied to other countries where the same phenomena are to be met with, I have not the least doubt that they will be able to explain there also the existence of rocky lake-basins, and why many others have been obliterated.

“In conclusion, I may state that all my observations have shown that the glaciation of New Zealand (like that of other countries generally) has been brought about by physical causes now in existence, and that I hope soon to be able to lay before the Society a more detailed paper, with illustrations, on the same important subject.”

4. *Notes to a SKETCH-MAP of the PROVINCE of CANTERBURY, NEW ZEALAND, showing the GLACIATION during the PLEISTOCENE and RECENT PERIODS as far as explored.* By JULIUS HAAST, Ph.D., F.L.S., F.G.S., of the Geological Survey of Canterbury, New Zealand.

(With Appendix.)

DURING the last four years I have occupied the autumn months in tracing some of the rivers of this Province to their glacial sources, hitherto entirely unknown. The accompanying map, which is a reduction of a larger one, shows the principal results which I have already described, in their geographical relations, in a paper read last March before the Royal Geographical Society of London.

Although the size of the principal glaciers is enormous, considering the narrowness of the central chain, the astonishment of the geological observer increases on meeting everywhere the signs of a still more considerable glaciation during the Pleistocene period.

It is not my intention to enter here into a detailed description of this most remarkable feature of our Alpine regions, for I hope to lay this at some future time before the Society, as this ancient glaciation will illustrate in a remarkable manner many subjects of the highest interest, being generally very distinct and undisturbed; but I may be allowed to point out some of the most striking phenomena.

The central range runs nearly from north-east to south-west through this island, and the lakes on both sides of it lie in the same line of direction. Most of the valleys are straight, and very little inferior in breadth to the lakes where the former Pleistocene glacier terminated. Most of these valleys run from north to south.

According to information received from Mr. Arthur Dobson, my former assistant, who is at present surveying the western slopes of the central chain of the Province, all the principal glaciers and valleys, from Mt. Hooker on the south to Mt. Tyndall on the north, strike in a north and south direction.

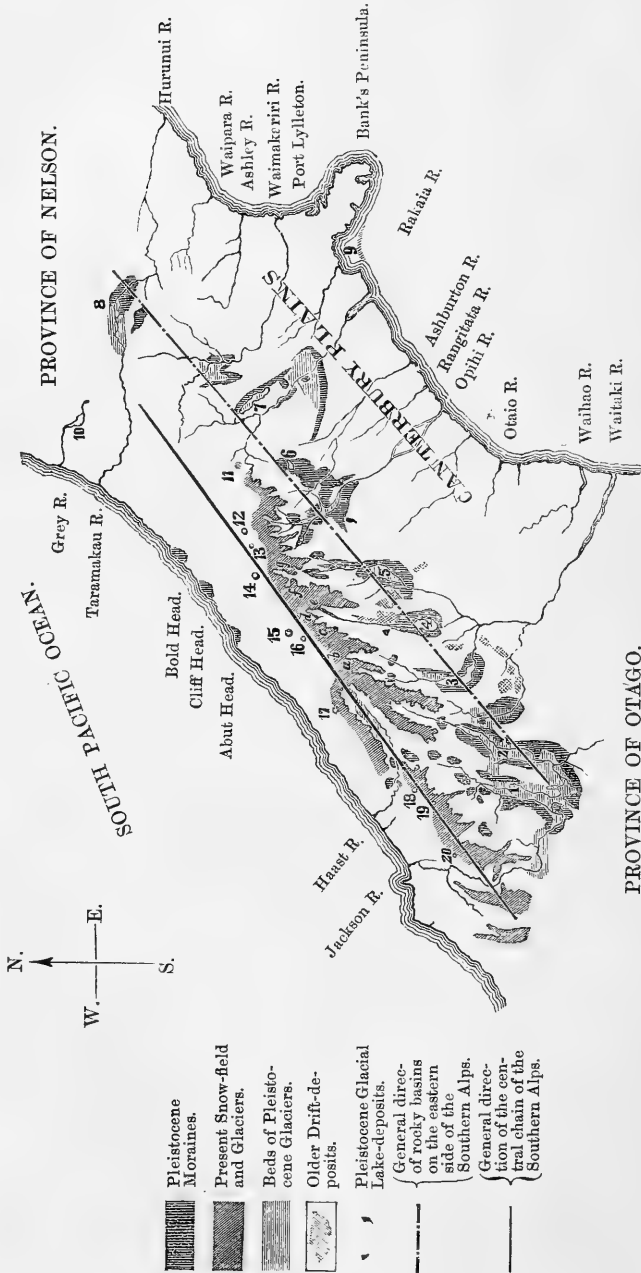
The west coast, at the same time, near the highest part of the central range, is formed by the remains of huge moraines; the promontories of Abut Head, Bald Head, &c., of frontal moraines.

In the map I have only shown those Newer Pleistocene glaciers which have left clear traces behind them, whilst it is evident that, in an epoch anterior to them, they extended much further and lower; this is proved by small remnants which exist in several localities.

The Canterbury Plains are the accumulations of the outlets of the Pleistocene glaciers, and the (Deltaic) subaërial deposits of torrents falling, in the average, fifty feet to the mile, from the foot of the ranges to the sea.

The following are the distances of the Pleistocene glaciers from the points in the central chain from which they took their rise:—

Sketch-map of the Province of Canterbury, New Zealand; showing the Glaciation during Pleistocene and Recent times, as far as explored.



- | | | | | | |
|-----------------|--------------------|---------------------|---------------------------|--------------------|----------------------|
| 1. Wanaka Lake. | 5. Lake Tekapo. | 9. Lake Ellesmere. | 13. Mt. Petermann. | 16. Mt. Delabèche. | 19. Mt. Albu. |
| 2. Hawea Lake. | 6. Lake Heron. | 10. Lake Brunner. | 14. Mt. Keith's ohnstone. | 17. Mt. Hooker. | 20. Castor & Pollux. |
| 3. Lake Ohau. | 7. Lake Coleridge. | 11. Mt. Arrowsmith. | 15. Mt. Beaumont. | 18. Mt. Dana. | a. Richardson Glac. |
| 4. Lake Pukaki. | 8. Lake Sumner. | 12. Mt. Tyndall. | | 19. Mt. Dana. | b. Selwyn Glacier. |
| | | | | | c. Great Tauman Gl. |
| | | | | | d. Hochstetter Glac. |
| | | | | | f. Glassen Glacier. |
| | | | | | g. Godley Glacier. |

Wanaka glacier	.....	48 miles.
Hawea	„	50 „
Akuriri	„	25 „
Ohau	„	40 „
Pukaki	„	50 „
Takago	„	48 „

The last four formed, before the Pleistocene epoch, a still larger glacier, which I shall call the Waitangi glacier, and traces of which are still visible far down the Waitangi.

Waitangi glacier	.....	78 miles.
Rangitata	„	40 „
Rangitata	„	} 35 „
	branch into Ash- burton Valley ..	
Rokaia	„	52 „
Rokaia	„	} 41 „
	branch into Ash- burton Valley ..	

The position of the summits of the central chain, where the glacier sources of the river Waimakariri lie, is not yet ascertained.

Thus these Pleistocene glaciers were not much longer than those still existing in Thibet, as shown by Captain Godwin-Austen, and they are inferior in size to those of a Pleistocene age in the same region, of which the same observer has traced the moraine-deposits for one hundred miles.

APPENDIX.

Note on the Climate of the Pleistocene epoch of New Zealand.

[Read January 25, 1865; but printed as an Appendix to the preceding paper by order of the Council.]

The investigations mentioned in the preceding papers have led me to the conclusion that the enormous glaciation of New Zealand in Pleistocene times was caused principally by the existence of extensive plateau-like mountain-ranges, lying above the line of perpetual snow; and that since, no sensible change in the climatal conditions had taken place, if we except a probable rise in the altitude of the perpetual snow-line from a different orographical configuration, caused by the ridge-making action of the glaciers.

In this view I have been confirmed by finding at several localities bones of *Dinornis* and *Palapteryx*, either among the Pleistocene terminal and lateral moraines themselves, or in the lacustrine deposits, formed immediately after these huge glaciers had retreated. The position of the bones convinced me at once that they occurred in the localities where they had originally been deposited, and not in reassorted (*remanié*) strata.

The two principal species, of which bones are frequently found, are *Dinornis robustus* and *Palapteryx ingens*, both of large size, and probably omnivorous, like the present Weka (*Ocydromus Australis*); although the enormous size and strength of their claws point more

towards a vegetable diet, if we suppose that they were provided for the purpose of digging for roots. As the bones of both species occur at present in our Alps, wherever favourable localities exist for their preservation, often only partly covered by vegetable soil, or even quite free amongst the grass and shingle, as if these huge birds had only died a few years ago, it is not unreasonable to deduce from such an important fact that, from the Pleistocene epoch to the present day, the flora of our subalpine and alpine ranges has not undergone any material change; and that the plants, which in the recent era have doubtless offered ample food to these wingless giants, are the same as those on which they existed in former times. It is not my intention to enter here into an investigation of the causes which have led to the extinction of *Dinornis*, *Palapteryx*, &c., which I intend to do at some future period; but I may state my conviction that in New Zealand, with its present configuration and with its present climate, protected from the invasion of man and the animals brought with him, all the necessary conditions for the existence of those large birds would still be found.

When examining and collecting the remarkable flora of our alpine regions, I was often struck with the enormous quantity and variety of the plants, the seeds and roots of which are capable of sustaining animal life, and which are now without any apparent use. The few large alpine parrots seem, however, to live on the seeds of these plants, and the Weka subsists on the heterogeneous animal and vegetable matter which comes within reach of its claws and beak—seeds, roots, insects, lizards, and smaller birds; and even the rat is a welcome dish for this fearless, pugnacious, and greedy bird. It is found everywhere, as high as 6000 feet, on the mountains and among the lateral and terminal moraines of our glaciers, where its bones will become some day enveloped and preserved, as those of its larger predecessors have been in Pleistocene times.

Among those plants which would offer great nourishing power, the different species of the remarkable genus *Aciphylla*, belonging to the *Umbelliferae*, are the most abundant; their seeds, as well as their roots, are juicy, the latter very much resembling a parsnip, with a strong taste of turpentine; they are well liked by the wild pigs, which, since Captain Cook's time, have multiplied so wonderfully that they are to be found in several localities feeding like large flocks of sheep. The extermination of these pigs, often very little inferior in size or in savage nature to the true wild boars of the continent of Europe, began in many parts of the country ten years ago with energy and skill, but has in many localities been exceedingly slow, and offers almost insurmountable difficulties.

Besides these Spur-grasses (*Aciphylla*), of which *A. grandis*, Hooker fil., is the most magnificent, and other alpine genera of umbelliferous plants with large roots and great quantities of seeds, there are several coniferous trees and shrubs; for instance, *Evocarpus Bidwillii*, *Phyllocladus alpinus*, *Podocarpus nivalis*, as well as shrubs and plants belonging to the large genus *Coprosma* (*Rubiaceae*), mostly bearing seeds, all of which are now, as it seems, without any apparent use.

That the character of our alpine climate (of a continental nature on the eastern side of the central chain) disappears as soon as changes in the orographical configuration are met with, is instructively seen in the valleys of the River Makarora (Lake Wanaka) and the River Hunter (Lake Hawea), both of the same breadth, altitude, and direction, and for at least fifteen miles above the lakes, with an equal gradient. Whilst in the former, over the low pass across the Central Alps which bears my name, the moist winds from the west coast can advance nearly to Lake Wanaka before all their moisture is extracted or condensed, the latter valley has a high mountain-range at its head covered with perpetual snow, and is therefore not exposed to the same amount of warm moisture. Consequently the valley of the Hunter has all the characteristic vegetation of a true alpine valley, abounding in *Aciphyllæ*, *Celmisiæ*, and coniferous subalpine and alpine shrubs and trees, whilst in the Makarora Valley they are missing, exhibiting a flora more similar to that of the west coast, or the lower regions of the east coast.

I have made this observation in order to show that the least change in the orographical conditions of this island gives at once to the flora an entirely different character, which, taking the preceding remarks into account, may offer a still stronger argument in aid of the hypothesis started in this note.

Thus the existence of the Moa bones found amongst the Pleistocene terminal and lateral moraines induces us, more than any other reason, to adopt the conclusion that nearly the same meteorological conditions existed then as now; offering at the same time a further reason for accepting the theory of large plateau-like ranges rising above the line of perpetual snow, as a principal cause for the greater glaciation of New Zealand during the Pleistocene epoch.

DECEMBER 21, 1864.

Henry Bowman Brady, Esq., F.L.S., Newcastle-on-Tyne; Richard Brown, Esq.; Major William Howley Goodenough, R.A.; John Jones, Esq., The Trindle, Dudley; and John Reginald Yorke, Esq., M.P., Tewkesbury, were elected Fellows.

M. Jules Desnoyers, of the Jardin des Plantes, Paris, was elected a Foreign Member.

The following communications were read:—

1. *On the COAL-MEASURES of NEW SOUTH WALES, with SPIRIFER, GLOSSOPTERIS, and LEPIDODENDRON.* By WILLIAM KEENE, Esq., Examiner of Coal-fields and Keeper of Mining Records, New South Wales.

(In a letter to the Assistant-Secretary.)

THE main feature in the geology of New South Wales is the "Sydney Sandstone," and in no case has any younger rock come under

my observation. From reports which can be depended upon, there is, however, no lack of more recent deposits in South-western Australia, and I possess specimens, given to me by an explorer, from the River Belliards (Queensland), very near the place of my own examinations in the North-east, containing fine Belemnites and Shells of the Cretaceous period.

In the southern part of New South Wales, near the head-waters of the Lachlan River, I found some remarkable blocks, containing large leaves in high relief, which would, at first sight, be pronounced Tertiary; but, from their position, I cannot separate them from the siliceous beds intercalated with the auriferous shales, far older than the Coal-measures. These leaves are accompanied by very distinct impressions of Ferns; and I beg to direct the special attention of phytologists to the specimens from these beds which will be found in the collection sent by me to the International Exhibition of 1862, and presented by the New South Wales Exhibition Commissioners to the Bath Philosophical Society.

The upper beds of the "Sydney Sandstone" contain shales which I have called "the false coal-measures" (the "Wymanatta shales" of the Rev. W. B. Clarke). These shales are invariably mistaken by even intelligent miners for the Coal-measures, and I have been frequently called upon to examine them for coal; but their position is 800 feet above the upper coal-seam; and the name I have given them is justified by the fact that, although in places they present a thickness of 150 feet, only a few thin coal-pipes have been found in them.

On approaching the coal-seams (from the false coal-measures), the *Vertebraria australis* makes its appearance; and this, with the *Glossopteris*, accompanies the entire series of the Coal-measures from the topmost to the lowest seam.

Reckoning the workable seams to be eleven in number (and I know from observation in many natural sections that this is not far wrong), we find, on approaching the two lower seams, abundance of fossils—*Pachydomus* and *Bellerophon*. *Spirifer* is rare, until we approach the lowest seam; and here, as well as below, the *Spirifer* abounds in great variety, as also *Fenestella* and *Orthoceras*; but I must repeat that the *Glossopteris* and the *Vertebraria* never cease, but are constant through the whole series.

Marine remains other than those indicated above are rare; but a fish with heterocercal tail, in a very distinct impression, was found in the Australian Agricultural Company's B. Pit at Newcastle, in the shales above the "Yard Seam."

Conglomerates indicative of strong drift-currents are found between nearly every seam of coal; and immediately below the Coal-measures coarse siliceous grits and porphyritic clays envelope a considerable amount of the Carboniferous flora. Very well-defined specimens of the *Lepidodendron* are occasionally to be met with in these siliceous deposits.

The lower fossiliferous limestone, the chlorite-schists, and the auriferous quartzites were, in many places, upheaved to a high angle

before the deposition of the Coal-measures, as I have shown in the section; and, as there indicated, I have found the quartz and limestone beds in unmistakable succession and juxtaposition, and have taken from their site a specimen of gold rooted, as it were, in the limestone passing into the quartz. The limestone itself is frequently so penetrated by siliceous matter as to be wholly unaffected by acids. It is sometimes found deposited on a floor of granite, and I believe it to be the most ancient of our fossiliferous rocks.

The Peak Downs range appears to me to be an upthrow, long posterior in date to the deposition of the Coal-measures, and from which those rocks have been denuded, except in a few isolated ranges, in which coal may still be found. The débris of the lower seams are to be met with over many miles of country, containing always the same plants (*Glossopteris* and *Vertebraria*). Near to the Peak Downs, amongst the silicified wood which strews the plains, I found a few fossil fruits of large size. One is depressed, or flattened, at both head and stalk, as though the juice had been squeezed out, and left an opening right through it; so that the seed-cases are very plainly to be seen from either side.

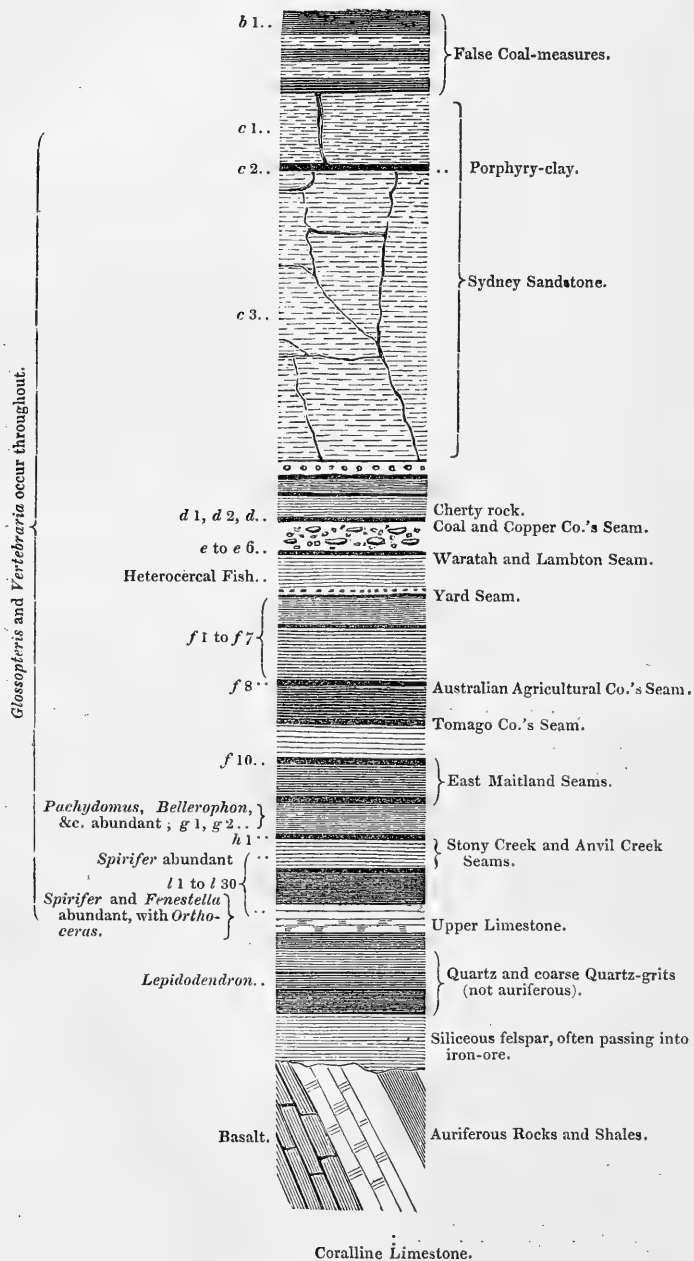
The fine black and fertile soil of the Downs is connected with the Peak ranges, which were discovered and attentively examined by Leichardt, who compared them to the igneous rocks of the Puy-de-Dôme. In my opinion, also, they are like those which have burst out in the same country along the northern side of the Pyrenees, described by Charpentier as consisting of ophite, weathering in large dome-like masses. These, too, are comparatively recent, and, as is well known to geologists, have upheaved the Nummulitic and later Tertiary rocks along nearly the whole line of the Pyrenæan range.

That the outburst of the Peak range is posterior to the deposition of the Coal-measures I had ample evidence at the crossing of the Mackenzie, where the igneous matter covers the coal-shales containing plant-remains; and, on close examination, I found in the lava a very perfect cast of a large mussel-shell, the same which now abounds in the river.

The long range of serpentine extending from Rockhampton nearly to the Peak Downs appears also to be a comparatively modern upheaval, and to have been erupted with such sudden force as to have cut through the lower fossiliferous and auriferous rocks. For this reason but little gold has been found along the serpentine range of Canoona.

I also divide the quartz as belonging to different epochs. That is to say, there is a quartz at the base of the Coal-measures, in many cases of great purity, in which I have in vain sought for any sign of gold; whilst the auriferous quartz is in upheaved beds, with which the Coal-measures are unconformable, and contains the old fossiliferous limestone; and drift-gold is to be found where this limestone and the accompanying quartzites and shales have presented their edges to destructive influences.

Vertical Section of the Coal-measures of New South Wales.



The numbered letters refer to the specimens accompanying the paper, and now in the Society's Museum.

Beyond (that is, when the fertile soil of the Peak Downs has been passed over), the edges of the quartzites and shales show themselves over a very extensive country, and here beds of iron- and copper-ore crop out, and are invested on either side by gold-bearing rocks.

These deposits are at this moment exciting the attention of diggers from all parts of Australia, and drawing them to their exploration; and wealthy merchants are investing largely in costly works and apparatus for bringing the copper-ore into a marketable state.

I have no doubt that this part of Eastern Australia will bear comparison with, and even rival, our richest metalliferous districts; whilst New South Wales, by her wealth in coal, facilitates communication from port to port, and contributes thus, unostentatiously, but not the less certainly, to the general prosperity.

At the same time that I recommend reference to my collection now in the Bath Philosophical Institute, I send herewith specimens which I am of opinion will prove satisfactorily that the coal-seams of New South Wales belong to as old a geological series as those of Europe; and I can affirm, from examination over a very extensive area, that they are equally inexhaustible.

2. *On the DRIFT of the EAST of ENGLAND and its DIVISIONS.*
By S. V. WOOD, jun., Esq., F.G.S.

[This paper was withdrawn by permission of the Council.]

(Abstract.)

In this paper the author divides the Drift of the country extending from Flamborough Head to the Thames, and from the Sea on the east to Bedford and Watford on the west, as follows:—*a*, the Upper Drift, having a thickness of at least 160 feet still remaining in places. *b* and *c*, the Lower Drift, consisting of an Upper series (*b*), having a thickness of from 40 to 70 feet, and a Lower series (*c*), with a thickness, on the coast near Cromer, of from 200 to 250 feet, but rapidly attenuating inland. *c* comprises the Boulder-till and the overlying contorted Drift of the Cromer coast, which along that line crop out from below *b* a few miles inland. In an attenuated form, *c* also ranges inland as far south as Thetford, and probably to the centre of Suffolk, cropping out from below *b* by Dalling, Walsingham, and Weasenham, and appearing at the bottom of the valleys of central Norfolk. *b* consists of sands, which on the east coast overlie the Fluvio-marine and Red Crag, but change west and south into gravels, which pass under *a* and crop out again on the north, south, and centre of Norfolk, and west of Suffolk and Essex, extending (but capped in many places by *a*) over most of Herts. The Upper Drift (*a*) consists of the widespread Boulder-clay, which over-

laps *b* for a small space on the south-east, in Essex, and again at Horseheath, near Saffron Walden, but overlaps it altogether on the north-west, resting on the secondary rocks in Huntingdonshire and Lincolnshire. The distribution of *b* indicates it as the deposit of an irregular bay, afterwards submerged by the sea of *a*, which overspread a very wide area. *a* now remains only in detached tracts, having been extensively denuded on its emergence at the beginning of the post-glacial age, so that wide intervals of denudation (separating the tracts) indicate the post-glacial straits and seas which washed islands formed of *a*. The author considers the so-called Norwich Crag of the Cromer coast as *not* of the age of the Fluvio-marine Crag of Norwich, but as an arctic bed forming the base of *c*, into which it passes up uninterruptedly. The author regards the beds *b* as identical with the Fluvio-marine gravels of Kelsea, near Hull, and thinks that the Kelsea bed is not above *a*, as hitherto supposed, but below it, having been forced up through *a* into its present position. He also regards the Upper Drift (*a*) as the equivalent of the Belgian Loess, and the beds *b* as the equivalent of the Belgian Sables de Campine.

DONATIONS

TO THE

LIBRARY OF THE GEOLOGICAL SOCIETY.

From October 1st to December 31st, 1864.

I. TRANSACTIONS AND JOURNALS.

*Presented by the respective Societies and Editors.*Abbevillois, L'. 25^{me} Année. No. 2888. August 6, 1864.American Journal of Science and Arts. Second Series. Vol. xxxviii.
No. 114. November 1864.

J. L. Smith.—New Meteoric Iron from Wayne County, Ohio, 385.

——. Meteorite from Atacama, Chili, 385.

O. C. Marsh.—New fossil Annelid (*Helminthodes antiquus*) from the
Lithographic Slates of Solenhofen, 415.

H. Haidinger.—Meteoric Iron, 424.

Hautefeuille.—Artificial Anatase, Brookite, and Rutile, 424.

F. von Kobell's 'Geschichte der Mineralogie von 1650–1860,' noticed,
426.

J. D. Dana.—Volcanic Peaks of Cotopaxi and Arequipa, 427.

Dinotherium an Elephantine Marsupial, 427.

Desor.—Discovery of Lake-habitations in Bavaria, 437.

Oldham.—Discovery of Fossil Stone Implements in India, 443.

Athenæum Journal. Nos. 1927–1940. 1864.

Notices of Meetings of Scientific Societies, &c.

Meeting of the British Association at Bath, 433, 465, 499, 530, 568.

J. Kelly's 'Notes upon the Errors of Geology, illustrated by Refer-
ence to Facts observed in Ireland,' noticed, 889.Berlin. Zeitschrift der deutschen geologischen Gesellschaft. Vol. xvi.
Heft 2. February to April 1864.

H. R. Göppert.—Beiträge zur Bernsteinflora, 189 (plate).

H. Credner.—Die Pteroceras-Schichten (Aporrhais-Schichten) der
Umgebung von Hannover, 196 (3 plates).

Berlin. Zeitschrift der deutschen geologischen Gesellschaft. Vol. xvi. Heft 2 (*continued*).

- G. von Rath.—Beiträge zur Kenntniss der eruptiven Gesteine der Alpen, 249 (plate).
 C. Rammelsberg.—Ueber die im Mineralreich vorkommenden Schwefelverbindungen des Eisens, 267.
 E. Weiss.—Leitfische des Rothliegenden in den Lebacher und äquivalenten Schichten des Saarbrückisch-pfalzischen Kohlengebirges, 272.
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 F. von Hochstetter.—Dunit, körniger Olivinfels vom Dun Mountain bei Nelson, Neu Seeland, 341.
 E. von Martens.—Fossile Süsswasser-Conchylien aus Sibirien, 345.

British Association for the Advancement of Science, Report of the Thirty-third Meeting, held at Newcastle-upon-Tyne in August and September 1863. 1864.

- R. H. Scott, R. Griffith, and S. Haughton.—Mineralogical Constitution of the Granites of Donegal, and of the Rocks associated with them, 48.
 A. Gages.—Synthetical Researches on the Formation of Minerals, 203.
 J. Darglish and G. B. Forster.—Magnesian Limestone of Durham, 726.
 R. C. Clapham and J. Darglish.—Minerals and Salts found in Coal-pits, 37.
 D. T. Ansted.—Metamorphic Origin of the Porphyritic Rocks of Charnwood Forest, 64.
 ——. Deposit of Sulphur in Corfu, 64.
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 ——. Fossils of the Skiddaw Slates, 69.
 ——. Hornblendic Greenstones and their relations to the Metamorphic and Silurian Rocks of the county of Tyrone, 70.
 J. Hogg.—Fossil Teeth of a Horse found in the Red Clay at Stockton, 70.
 H. B. Holl.—Metamorphic Rocks of the Malvern Hills, 70.
 Hulburt.—Facts relating to the Hydrography of the St. Lawrence and the Great Lakes, 73.
 J. G. Jeffreys.—Upper Tertiary Fossils at Uddevalla, in Sweden, 73.
 T. R. Jones and J. W. Kirkby.—Synopsis of the Bivalved Entomostraca of the Carboniferous Strata of Great Britain and Ireland, 80.
 — and W. K. Parker.—Fossil Foraminifera collected in Jamaica by the late Lucas Barrett, F.G.S., 80.

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PROCEEDINGS

OF
THE GEOLOGICAL SOCIETY.

January 11, 1865.

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

The following communications were read:—

1. *On the LIAS OUTLIERS at KNOWLE and WOOTTON WARWEN in SOUTH WARWICKSHIRE, and on the Presence of the LIAS or RHÆTIC BONE-BED at COPT HEATH, its furthest NORTHERN EXTENSION hitherto recognized in that County.* By the Rev. P. B. BRODIE, M.A., F.G.S.

THE Liassic outlier at Copt Heath, near Knowle, eleven miles south-east of Birmingham, has been referred to in the 'Geological Transactions' by my lamented friend, the late Hugh E. Strickland, and it was first noticed by my friend Dr. Lloyd; but it does not appear that any particular account has been given either of the one near Knowle or of the others in the neighbourhood of Wootton Warwen, which are, however, of sufficient interest to deserve a more

detailed report. The outlier at Knowle is of limited extent, being about a mile and a half in length and half a mile broad. It occurs in the midst of the Red Marl, by which it is surrounded on all sides. A few bands of limestone are seen cropping out on the side of the canal; but the main mass is quarried by a shaft, so that the order of succession is not very easy to be traced; and as the works did not pay, they have been again closed, though a quantity of stone was raised in 1857. Judging from the blocks of stone and shale still remaining, they seem to represent the Saurian beds; and the presence of beautifully preserved specimens of *Ammonites planorbis* confirms this. Some of the masses of limestone are of large size, and contain remains of Saurians, scales of Fish, *Ostrea*, *Modiola*, *Cardium*, and a few other shells; the black laminated shales yield, besides the *A. planorbis*, a small *Pecten* and plates of a *Cidaris*. It is impossible to say whether the Insect-limestone occurs beneath; if it does, it is probably confined to a single stratum, because the Lias here is both of limited extent and thickness. A few yards distant from the shaft some dark shales may be observed resting upon Red Marl; and amongst these, on the top of a small bank, I obtained fragments of a yellow micaceous sandstone, with *Pullastra arenicola*, a shell which always prevails low down in the series, in close connexion with the "bone-bed," and seems to have a very limited range. The section, unfortunately, is so covered up and obscure that I could not detect any "bone-bed" *in situ*; but at all events a band of sandstone connected with it may be traced at this spot, the furthest point northwards hitherto recorded in Warwickshire. This fact gives an additional interest to this small patch of Lias in this district. Mr. Hugh Strickland had noticed the same sandstone and associated black shales at a spot in the neighbourhood of Bidford, about fifteen miles south-east of this. Mr. Howell, of the Geological Survey, informs me that he has found this sandstone in an outlier of Lias not far from Uttoxeter, in North Staffordshire, which is the most northern extension of the Rhaetic beds hitherto known. Another outlier, but of larger extent, occurs at Wootton Park, near Henley-in-Arden; and at this point some of the lowest beds may be traced, from the *Pecten Valoniensis* bed up to the Lima-beds. Many specimens of *Cardinia ovalis*, so abundant in these latter, may be picked up in the fields; and the old workings of former quarries afford fragments of the *Pecten*- and *Cypris*- or *Estheria*-beds, and the little freshwater plant, *Naiadita lanceolata*. At Shellfield, on the western escarpment of the outlier, a small quarry is worked, exposing light-coloured shale with *Modiola minima*, and three layers of hard blue limestone containing *Ostrea liassica*. Similar strata are seen at Brown's Wood; and in both places the "Insect-beds," with the ordinary insect-remains, but unusually "abundant and well preserved," may be traced in their normal position, underlain by the *Estheria*- and *Pecten*-beds. The entire section resembles that at Wainlode Cliff, in Gloucestershire, excepting that the basement-beds overlying the Red Marl are much reduced in thickness in Warwickshire: but that they are to some

extent represented is clear, from the presence here of *Pecten Valoniensis* and the small bivalve Crustacean *Estheria minuta*, and of *Pulastra arenicola* at Copt Heath.

As most of the available stone in this outlier has been worked out, it is very difficult to get a section exposed, or to trace out the succession of the strata with any accuracy. Northwards, towards Moreton Bagot, the *Estheria*-bed is seen, and a limestone which belongs either to the Firestone or the White Lias, containing a species of small Coral not uncommon in this latter stratum.

The outlier at Brown's Wood is traversed by a line of fault running from north-west to south-east. This is entirely separated from the larger mass of Lias at Stooper's Wood, south of Warren Manor. The Lias in each case forms a long ridge or terrace, at a considerable height above the New Red Sandstone.

These two remnants of the Lias are the extreme limit of that formation in Warwickshire in a northerly direction; and no trace of it appears again nearer than the outlier in North Staffordshire before mentioned, and the other remarkable outlier on the borders of Cheshire and Shropshire, long since described by Sir R. I. Murchison*.

When the limit of the Lias has been fully determined, the strata below the Saurian beds, referred to in this paper, will probably come within the Rhætic series of the Trias.

2. *On the HISTORY of the LAST GEOLOGICAL CHANGES in SCOTLAND.*
By THOMAS F. JAMIESON, Esq., F.G.S., Fordyce Lecturer in the University of Aberdeen.

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* Geol. Proc. vol. ii. no. 38, p. 115.

§ 1. INTRODUCTION.

At the end of a paper forwarded to the Society in December 1859, and printed in the 16th volume of the Quarterly Journal, I gave a concise outline of what seemed to me to have been the geological history of Scotland since the commencement of the glacial period. The following pages are devoted to a further illustration of this subject. The facts on which I rest my conclusions are derived from the midland region of Scotland, chiefly from the part lying between the Moray Firth and the Firth of Forth. This district seems to me to contain remarkably good evidence of the changes that have taken place, and these changes, I believe, have been general over the greater part of Britain.

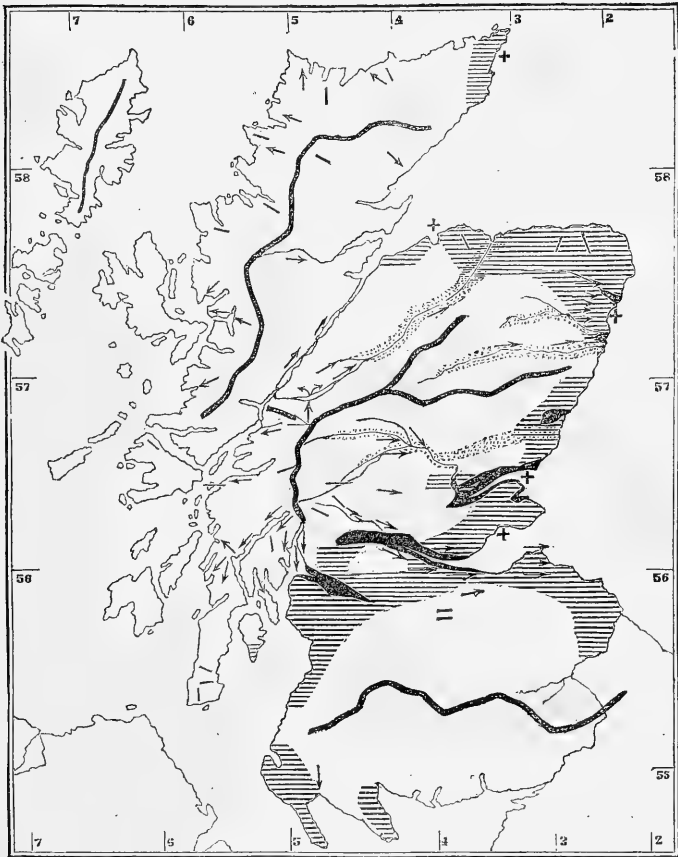
§ 2. PREGLACIAL TRACES.

The absence of the later Tertiary strata in Scotland leaves us in the dark as to the state of things that ushered in the glacial period in that country. There are, however, on the eastern coast of Aberdeenshire, in the parishes of Slains and Cruden, some thick masses of sand and gravel which appear to be of Tertiary age, and are probably equivalent to the Red Crag of England. These beds, in some places, contain remains of shells evidently belonging to a considerable number of species, but so broken and worn that in the great majority of cases it is impossible to arrive at a satisfactory determination of their specific character. Nevertheless I have got enough now collected to enable me to see that they form a group very distinct from those met with in our glacial beds, and more resembling what are found in the Crag strata of England. Some of them are of species that seem to be extinct. There are fragments of *Voluta Lamberti*, *Cyprina rustica*, *Nucula Cobboldia*, *Fusus contrarius*, *Purpura incrassata*, *Nassa elegans*, *Nassa reticosa*, *Turritella incrassata*, and probably *Trophon costiferum*,—forms unknown either in our glacial beds or in our present sea. Besides these there are the broken remains of many others, of the genera *Cardium*, *Pecten*, *Venus*, and *Astarte*, which differ from those found in any of our glacial beds; and one of the most common shells is the *Pectunculus glyçimeris*, which attained a large size.

The position of the sand and gravel containing these shells also leads me to think them preglacial. So far as I have seen, no Boulder-clay occurs below them, neither does the rock on which they rest exhibit any appearance of glaciation, nor do the pebbles show any glacial scratches. This Crag-gravel ranges up to about 200 feet above the present sea-level, and is covered in many places by red clay of the glacial period, containing large boulders and ice-scratched stones. Along its landward margin the gravel is frequently thrown into abrupt and irregular mounds, more especially at its south-western border, near the Loch of Slains*; and this I am disposed to attribute to the pressure of the land-ice during the

* See Quart. Journ. Geol. Soc. vol. xiv. p. 522.

Fig. 1.—*Sketch-map illustrating the Glacial Phenomena of Scotland.*



Explanation.—The arrows show the directions of the glacial markings; the thick black lines the chief ice-sheds, or lines whence the land-ice flowed during the period of the Boulder-earth. The ruled parallel lines show the districts where the Brick-clays and fossiliferous glacial-marine beds seem chiefly to occur. The dotted lines illustrate the distribution of the valley-gravel; the black patches mark the beds of old estuarine mud, or Carse-lands; and the sites of submerged forests are indicated by a cross (+).

glacial period. In other places, however, it lies in undisturbed strata, as in the base of the sea-cliff at Collieston Preventive Station (where it consists of a great thickness of fine soft sand), and along the coast from that to the old castle of Slains*.

There are also some other spots in this low north-eastern part of Aberdeenshire that seem to have escaped the erosive action of the ice, to which I ascribe the denudation of the older superficial deposits of North Britain. The extensive bed of chalk-flints covering the top of a low moory ridge for six or seven miles near Peterhead†, with its associated patch of Greensand at Moreseat, is the most notable of these. The remarkable bank of quartz-shingle, on the top of the Windyhills‡, near Fyvie, is perhaps another; large flints abound in it, in some of which I have detected chalk-fossils. On the top of a ridge near Delgaty Castle, and about two miles north-east of the town of Turriff, there is a bed of similar pebbles, all finely water-worn, and resting on the slaty rocks of the district. Here again are flints; but I also observed another circumstance which seemed to me of importance. This bed of shingle containing the flints is covered in some places by a mass of glacier-mud full of ice-scratched stones; and as this is on the top of a hill about 400 feet above the sea, with no height in the neighbourhood whence there could have been a slip, it seemed to me to establish a very old date for the formation of the shingle. The flint-pebbles at Windyhills and near Peterhead also lie on the top of a set of low hills of similar elevation.

In addition to the above there are indications of the Mammoth, or large fossil Elephant, having inhabited Scotland before the glacial period. These consist of a few instances of its tusks having been found imbedded in the Boulder-clay. Now the condition of Scotland during the glacial period, as I shall presently endeavour to show, seems to have been such as would be incompatible with the existence of the Elephant in that country; I therefore consider that the animals whose remains we find imbedded in our old Boulder-clay must have lived at an earlier time, when the climate and state of the surface were more favourable.

§ 3. PERIOD OF LAND-ICE.

a. *Glaciation of the Rocky Surface.*—The next condition of which we have any clear evidence is that indicated by the mark of the ice upon the rocky framework of the country. This we find here and there over the length and breadth of the land, from Aberdeen to the Hebrides, from the south of Scotland even to Orkney, Shetland, and the Faroe Islands, and from the tops of high hills in the centre of the country to the sea-shore down to low-water mark and further, as far as the eye can penetrate. The frequency, however, of these

* See Quart. Journ. Geol. Soc. vol. xiv. p. 515, where a sketch of the section is given, showing a deep mass of Crag-sand covered by glacial clay. In this sand I got *Nucula Cobboldia*.

† *Ibid.* p. 528.

‡ *Ibid.* p. 530.

markings, and the perfection in which they are to be seen, depend greatly upon the quality of the rock, and the circumstance of its having been well covered with clay so as to preserve the traces from obliteration. In the north and west Highlands the markings are more frequent and striking than elsewhere. Along the rocky shores of the west coast they may be studied with great advantage—as at the Gareloch, Loch Fyne, Ballachulish, and many other places. On the other hand, there are wide districts, as in Fife and the low north-east part of Aberdeenshire, where it is rare to find them; and it is only by keeping a look-out where quarries are opened, or railway-cuttings and such like works are in progress, and a fresh surface is thus exposed to view, that they are to be seen.

In the open country, and on the tops of ridges, the direction of the furrows is generally very uniform over wide districts; but in the deep mountain-valleys it conforms, as a rule, to the direction of the glen. Taking the country as a whole, we find, on coming to map the markings, that they radiate from the chief mountain-masses of the interior, and that the rubbed faces of the rocks look towards the great watersheds.

The group of hills stretching from Ben Lomond towards Ben Nevis, and from that mountain eastward to the sources of the River Dee, forms one line from which the erosive agent seems to have descended. Another lies along the watershed that extends from the head of Loch Arkaig northward to Loch Shin, and from that eastward to the Ord of Caithness, as shown in the little map accompanying this paper.

In a former contribution to the *Journal of the Society* (vol. xviii. p. 164), I have given my reasons for thinking that this remarkable action upon the surface of the country has, in the great majority of instances, been caused by land-ice moving downward and outward from the chief mountain-masses of the interior. Along these lines, when the ice was at its greatest development, there seems to have been an immense accumulation, not merely in the hollows and valleys, but even along the whole crest and centre of each ridge; and from each of these lines the ice seems to have flowed off, not in a multitude of separate glaciers, but in one wide and connected stream. At the same time I do not mean to deny that there has been some scratching by means of floating ice.

All the facts are in harmony with the notion that the ice was of enormous thickness. Thus the detached mountain of Schihallion in Perthshire, 3500 feet high, is marked near the top as well as on its flanks—and this not by ice flowing down the sides of the hill itself, but by ice pressing over it from the north. On the top of another isolated hill, called Morven, about 3000 feet high, and situated a few miles to the north of the village of Ballater, in the county of Aberdeen, I found granite-boulders unlike the rock of the hill, and apparently derived from the mountains to the west. Again, on the highest watersheds of the Ochils (a range of trap-hills stretching from Stirling towards Perth), at altitudes of about 2000 feet, I found this summer (1864) pieces of mica-schist full of

garnets, which seem to have come from the Grampian Hills to the north-west showing that the transporting agent had overflowed even the highest parts of the Ochil ridge. And on the West Lomonds in Fifeshire, at the Clattering-well Quarry, 1450 feet high, I found ice-worn pebbles of red sandstone and porphyry in the débris covering the Carboniferous Limestone of the top of the Bishop Hill. Facts like these meet us everywhere: thus on the Perthshire Hills, between Blair Athol and Dunkeld, I found ice-worn surfaces of rock on the tops of hills at elevations of 2200 feet, as if caused by ice pressing over them from the north-west, and transported boulders at even greater heights.

It was therefore not in the form of narrow glaciers like those of the Alps that the ice existed at this time, but as a thick cake, like that of North Greenland, enveloping both hill and dale, and flowing off, not so much on account of the inclination of the bed on which it rested, as owing to the internal pressure exerted by the immense accumulation of snow over the whole interior of the island, somewhat in the way that a heap of grain flows off when poured down on the floor of a granary. The floor is flat, and therefore does not conduct the grain in any direction; the outward motion is due to the pressure of the particles of grain on one another; and given a floor of infinite extension, and a pile of grain of sufficient amount, the mass would move outward to any distance; and with a very slight pitch or slope it would slide forward along the incline.

The want of much inclination in the surface of a country, and the absence of great Alpine heights, are therefore objections of no moment to the movement of land-ice, *provided we have snow enough.*

Now let us look the matter fairly in the face. It will be found that if instead of land-ice we are to use floating ice, or diluvial action of any kind, for the explanation of the facts, we must do so on a very large scale. These two cases of Schihallion and Morven neatly set before us the extent of the phenomenon, whichever way we are to take it. If we are to adopt the theory of floating ice, we require a submergence of 3000 or 3500 feet to suit these facts; in short, we require to have the whole of Scotland down below water to the top of all but the highest hills, and so with a diluvial action. We cannot take refuge in small local depressions to account for these cases; we cannot confine the submergence merely to the district of Schihallion or to that of Morven; for we find on the high ground over all the island (not to speak of Scandinavia) facts that necessitate the application of like conditions.

Again, if we are to use land-ice as the agency, these two cases are excellently adapted for showing us to what a prodigious extent the snow and ice must have accumulated.

b. *The Boulder-earth or Glacier-mud.*—Resting on the surface of the ice-worn rocks we find a widespread accumulation of boulder-earth, an unstratified mass of coarse gritty mud, in which are imbedded pebbles, boulders, and stony particles, often of many different kinds, and of all shapes and sizes, from a grain of sand to blocks of considerable weight. These are scattered promiscuously

through it, without any regular arrangement. The surfaces of the stones are often scratched and worn like the subjacent rock; and this is the case alike with the large boulders and smaller pebbles, pieces of the size of the finger-nail being frequently well marked if of a fine-grained quality; and it is on stones of this kind, such as clay-slate, serpentine, and limestone, that these appearances are best displayed. When the stone is of an elliptical form, the scratches run lengthways along it; they are not confined to one side, but often cover the whole surface; and it is worthy of notice that the scores on the boulders, as they lie imbedded in the clay, often coincide in their direction with the furrows on the solid rock beneath*. The stones themselves are of such kinds as occur in the direction towards which the ice-worn faces of the rock look; the scores on the subjacent rock point towards the mineral masses whence the boulders have come. Now all this shows that the boulder-earth, with its imbedded fragments, was pushed along by the same agent that scored the rocky bed on which it lies. Thus on the top of the sandstone-hills that form the south end of the island of Bute, we find the ice-worn débris of the mountains of Argyleshire; in the boulders of Inverness we find samples of the rocks that occur along the line of the Caledonian Canal; and at Aberdeen we get specimens of all those that are to be met with in the Valley of the Dee. The materials of this boulder-earth have therefore set out from the same regions as the striæ on the rocks, namely, from the lines laid down on the map (fig. 1), and as they moved along they have mingled with the débris of each successive formation they passed over.

Underneath the present glaciers of Switzerland there is found a bed of mud mixed with stones, which Agassiz describes as *la couche de boue*, or *la boue glaciaire* (see 'Système Glaciaire,' p. 574), being the stuff that arises from the triturating action of the ice on its rocky bed; and Dr. Hooker, in his *Himalayan Journals*, remarks that "the action of broad glaciers on gentle slopes is to raise their own beds by the accumulation of gravel, which their lower surface carries and pushes forward." The boulder-mud of Scotland (or *Till* as Sir Charles Lyell calls it), I therefore take to be the stuff resulting from the triturating action of the great fields of ice which overspread the country during the Glacial period. It lay beneath the ice-crust, and was compressed and pushed along by it, and accordingly its features correspond with this notion. It is generally hard and compact, as if it had been subjected to great compression. It is an azoic mass, destitute of all trace of contemporary animal or vegetable life. The beds that contain remains of sea-shells and other marine organisms belong, so far as my own observation goes,

* That is to say, supposing the scores on the subjacent rock point north-west, then the longer axes of the pebbles in the clay generally point in the same direction. In the bed of the Lothric burn, near the village of Leslie in Fife, immediately above Ballingall Mill, I observed a fine example of parallelism of the scratches on a number of large boulders—the direction being about W. 10° N.

to a later period, and are superimposed upon the irregular undulating surface of this old boulder-earth.

It is evident, however, that preexisting organisms, whose remains lay on the surface before the advance of the glacier, might be mixed up with the other superficial *débris* and carried along by it, and thus broken shells of the Crag-period, and remains of the Mammoth, may have come to be imbedded in the Boulder-clay. In the Boulder-clay of Norfolk broken bits of Crag shells are common, and in that of Yorkshire and of Scotland the tusks of the Elephant have occasionally been got.

If the whole country was buried under a thick covering of snow, it is clear that no proper moraines would be formed. Moraines are deposited along the outer edge of the ice, and consist for the most part of the *débris* hurled down upon its surface from the rocky slopes and precipices overhanging the glacier. This mass of stony rubbish lying on the top is not scratched and worn like that which lies beneath the ice; for it floats, as it were, on the surface, and is deposited quietly at the end (and sometimes along the sides) of the glacier. It is the stuff caught between the ice and its rocky bed that is rubbed and worn; the *débris* on the surface is not scratched. Now if the ice covered the whole land, so that no rocky cliffs protruded through it to send down their *débris* upon its surface, it is clear that there would be an absence of all this superficial stony rubbish which goes to form the moraine of a Swiss glacier of the present day.

In Aberdeenshire this old boulder-mud is of a dull greyish tint, such as might be derived from the trituration of the metamorphic schists and crystalline rocks. It may be traced from the shore at the Bay of Nigg all up the valley of the Dee for sixty miles inland, and from the sea to the height of 1500 feet, everywhere of very much the same general hue and character; the stones in it are often well rounded, some of the granite ones being nearly as round as cannon-balls. From Stonehaven to the banks of the Leven in Fife the Boulder-clay is reddish, owing to the broad zone of red sandstone which the ice had to pass over. In the basin of the Forth it is dull grey in the upper part of the valley (near the Loch of Monteith, for example), where the *débris* consists of stuff from the old crystalline rocks; near Stirling it is reddish brown, from the influence of the red sandstone; at Falkirk it is a deep brown, becoming blackish towards Edinburgh, owing to the gradually increasing effect of the *débris* from the coal-strata.

The ice that overspread Perthshire, as it moved south-east, carried along the boulders of Grampian mica-schist, and mixed them up with the red sandstone of the Lowlands, next with the trap of the Ochil Hills, and finally with the fragments of the coal-beds, until on the shores of the Firth of Forth it has left a medley of all the different kinds.

The granite-boulders from the Ben Muick Dhui mountains have been thrown in profusion north-westward into the valley of the Spey—even crossing that valley, and lying in thick beds high up on the slopes of the hills to the north of Aviemore; they have also

gone eastward down the valley of the Dee, but not southward, being repelled apparently by the ice descending from the high ridge of quartz-mountains that forms the boundary between the counties of Aberdeen and Perth.

As regards the midland region of Scotland, the Boulder-clay lies thickest on the eastern slope of the island; in the West Highlands there is comparatively little of it, the rocks being very much bared. This is what might be expected from the more gradual and longer slope of the east side. Over much of the low ground of the Scottish coal-field also there seem to be heavy masses of it. It is frequently disposed in banks of very irregular thickness, often thinning out abruptly, and having occasionally an irregularly undulating or hummocky surface.

The physical quality of this boulder-earth shows it to be due to some peculiar action. It may be said to consist of rough stony débris intimately mixed with a very fine mud, which seems to have been derived from the tear and wear of the stones. This implies powerful friction, combined with the presence of water, and yet an absence of any current to carry off the fine sediment. Earthy stuff dropped in the sea from melting ice I should think would form a different deposit; for the water would hold the fine muddy particles in suspension for a time, while the sand and stones would fall at once to the bottom. I consider that its true nature and origin was first indicated by Agassiz, in his communication to the Geological Society of London, on the 4th Nov. 1840, and more clearly developed by him in a subsequent paper in the Edinburgh New Philosophical Journal for 1842*.

§ 4. PERIOD OF DEPRESSION.

a. *Glacial-marine beds*.—Reposing on the irregular surface of the boulder-earth, we find, in some of the lower grounds adjoining the coast, beds of finely laminated clay and sand containing sea-shells, remains of starfishes and *Echini*, bones of seals, stones encrusted with *Balani*, *Foraminifera*, and other relics of marine life, showing that the sea had occupied a considerable part of what is now dry land.

Thick beds of this laminated marine clay frequently occupy basin-shaped hollows of very limited extent in the Boulder-clay, thinning out abruptly where the ground rises, as, for example, at Portobello near Edinburgh; this mode of distribution seems to occur chiefly where there is hilly ground in the neighbourhood. In the low north-eastern part of Aberdeenshire the marine clay is often spread in wide sheets, ranging up to a height of 300 feet above the sea: at this altitude there is a bed of it 13 feet thick on the brow of an eminence near the town of Turriff, eight miles inland, where it is dug for making bricks and tiles. It is rare, however, to find it of pure quality at this height. In most districts this fine laminated clay

* My confidence in the opinions I have formed regarding the glacial phenomena of Scotland is greatly strengthened by finding the same views ably advocated by Mr. Geikie in his admirable memoir on this subject, "On the Phenomena of the Glacial Drift of Scotland," Trans. Geol. Soc. Glasgow, vol. i. part 2.

is met with only at very low altitudes near the coast. It frequently alternates with beds of fine sand, and sometimes with gravel, and generally becomes more stony and of coarser quality on the higher ground. This may be seen along the line of the Forth and Clyde Junction Railway between Drymen and Bucklyvie, where I have found remains of marine shells. The greatest height at which I have met with these fossils is, in Aberdeenshire, 300 feet, in this instance in a deep mass of stratified gravel forming the crest of a low hill about five miles from the sea. The top of this gravel-bed reaches about 360 feet higher. At Gamrie, in Banffshire, the beds of sand and clay containing Arctic shells (first noticed by Mr. Prestwich) reach to very nearly the same height, but the position of the shells there is only about 150 feet. These are the highest positions known to me of marine fossils in the glacial beds of the north of Scotland. In the Clyde district, near Airdrie, they have been found up to 350, and in one case 512 feet, which is the greatest elevation yet reported from any part of Scotland. These facts indicate a considerable depression of the land, which seems to have extended over all North Britain, even to the furthest extremity of the island; and these fossiliferous beds of clay, sand, and gravel are proved to be of later date than the scratching of many of the rocks, and the deposition of much boulder-earth, from the fact of their being in many instances seen to rest upon the irregular and hummocky surface of the latter. This I have myself seen in the vicinity of Edinburgh, in Fifeshire, Aberdeenshire, and also on the west coast. Dr. Fleming has likewise given some good illustrations of the same in his 'Lithology of Edinburgh.'

This submergence seems to have followed very close upon the great glaciation of the country, if, indeed, it was not to some extent contemporaneous with it. It may have been that after the land-ice had reached its greatest development, a depression of the coast took

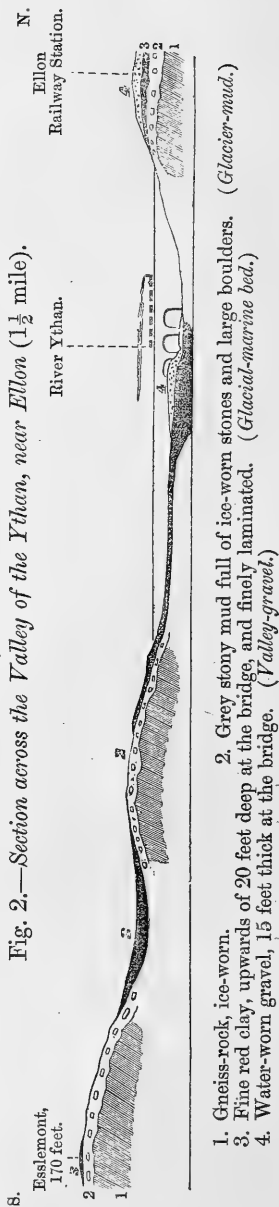
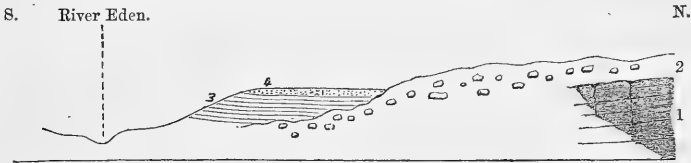


Fig. 2.—Section across the Valley of the Ythan, near Ellon (1½ mile).

place while the ice still kept possession of the unsubmerged land*. This, however, is one of the points regarding which more evidence is greatly wanted. If such was the case, it is probable that where the ice was thin it melted completely away; but in other parts, where it was in greater force, it protruded into the sea, its outer edge being floated by the water. In some cases it may have been so thick that the depth of water was not sufficient to float it off the bottom, and consequently in such places no marine beds would be formed †.

Fig. 3.—Section at Springfield Brickwork, in Fife.



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|---|---|
| 1. Sandstone-rock. | 2. Coarse stony earth with ice-worn boulders. |
| 3. Fine laminated clay or Glacial-marine bed; has yielded skeletons of Seal (Page). | 4. Sand and gravel. |

It is a remarkable fact, that although these marine fossiliferous beds may be traced in many places to a height of 200 or 300 feet above the sea, they are nevertheless totally absent, to all appearance, along many of the valleys in the interior of the country at much lower levels. Thus no marine fossils have been met with along the valley of the Caledonian Canal between Fort William and Inverness, although the summit-level of that valley is only about 90 feet above the sea; neither have any been found, so far as I can learn, along the whole line of the Highland Railway from Dunkeld to Inverness. In the valley of the Dee we have some patches of this marine clay and sand, of great thickness in the neighbourhood of the town of Aberdeen, close to the mouth of the river; but they vanish before we get a couple of miles up the valley, nothing being found beyond that except gravel and boulder-earth. And along all the mountainous seaboard of the West Highlands marine fossils are unknown, except in spots close to the shore and only a few feet above the reach of the tide. On the other hand, in the comparatively low outlying districts of Caithness, North-east Aberdeenshire, and Fife these marine clays

* This was the theory proposed by Dr. C. Martins, in a clever notice of the glacial phenomena of Scotland. See Edin. New Phil. Journ. for April 1851.

† The streams of water that escape from beneath glaciers are always loaded with fine muddy sediment, arising from the friction of the earthy matter produced by the pressure of the moving ice. M. Collomb long ago pointed out that the Loess-beds of certain valleys are accounted for by the deposition of this sediment. But we may suppose that where glaciers terminate in or near the sea the stuff will then go to form submarine mudbanks, like our laminated beds of brick-clay; and such has probably been the origin of many of these deposits. The formation of loess-beds on land, and brick-clays in the sea, during the Glacial period, therefore harmonizes well with the notion of an ice-covered country.

form wide sheets, and range up to 200 and even 300 feet above the sea.

Now these clay-beds have either never been deposited in the places I refer to, or something has removed them since their deposition. Two or three ways of accounting for this may be suggested: we may suppose that after the marine beds had been laid down in these places they were carried off by the sea itself when the land was emerging from the water, aided perhaps by the action of the rivers; or we may suppose that, after the land had emerged, the glaciers again took possession of the ground and swept these marine beds out of all the Highland valleys and mountainous tracts; or, thirdly, it may have been, as I have already hinted, that the sea obtained only a partial possession of the land, owing to the glacier-ice lying in too heavy masses to be floated off the bottom, and thus preventing the deposition of any marine sediment.

As a contribution towards the solution of this problem, I shall describe a case I observed last summer in that part of Perthshire which lies to the south-east of Ben Lomond.

From the south extremity of Loch Lomond there is a tract of low undulating ground stretching north-eastward along the line of the Forth and Clyde Junction Railway into the valley of the Forth near Bucklyvie, and forming a sort of low watershed between that river and the basin of the Clyde. The summit-level of this watershed is only about 220 feet above the sea. Now this tract of land is over-spread with marine clay and sand of the Glacial period. We find in some places (near Balfroon, for example) thick beds of red clay, very pure and finely laminated, and used for making bricks and tiles; in other places this clay alternates with, and passes gradually into, masses of fine soft sand, with occasional beds of gravel. In one of these gravelly seams, at a cutting near Gartness Railway-station, I found remains of sea-shells, generally much broken and water-worn, but some of the smaller ones entire. Of these I collected fourteen species (see Appendix, No. 4) of the same kinds and of the same northern character as those met with in the Clyde beds at Paisley and elsewhere. The position of this shelly gravel, as I learn from the levels of the railway, is about 120 feet above the sea. Stones and boulders are not uncommon in some of these marine beds, and much of the clay is of rather coarse quality.

Now when we descend into the valley of the Forth and go to the Loch of Monteith, which is only a few miles from Bucklyvie, and at a considerably lower level than the shelly gravel at Gartness, this red clay and sand is no longer to be seen, and we find ourselves among large abrupt mounds of gravel and rough stony *débris*, full of heavy boulders, and piled together in a confused manner without any regular stratification—in short, having all the appearance of glacier-moraines. This picturesque little lake, in fact, seems to be formed by a great heap of moraine-*débris*, which stretches across the valley of the Forth as if it had been formed by a glacier coming down from the flanks of Ben Lomond and Ben Venue; a transverse barrier has thus been produced which obstructs the drainage. The

surface of the Loch of Monteith, as I learn from the Ordnance Survey, is only 55 feet above the present mean level of the sea. A submergence, therefore, that would account for the marine strata of Gartness, would, in the present configuration of the country, cover the site of this little lake, as well as the greater part of these mounds.

Does it not, therefore, look as if the glacier had occupied the valley of the Forth, at least as far down as this little lake, after the marine beds were deposited on the higher grounds?

Part of the lake is said to be very deep; the bottom, therefore, is probably in some places lower than the present sea-level, seeing that the surface is only 55 feet above it.

The eastern base of the mounds meets the upper extremity of the "Carse" of Stirling, which is a flat expanse of fine alluvial soil, covered here and there with peat. The surface of this *Carse* is only 30 feet or so above the sea; it encircles these moraine-like heaps, and seems to overlap their base, as if it had been gently deposited around them long after their formation.

b. *Character of the Fossils.*—The Mollusca, whose remains are found in the glacial beds of Scotland, are of a much more northern character than the group which inhabits the seas of Britain at the present day. This result was clearly brought out by Mr. Smith of Jordan Hill many years ago; and all subsequent investigation has tended to confirm the accuracy of his induction. In the clays and sands of the east of Scotland the shells are much rarer, and in worse preservation, than they are in the Clyde beds.

Some of the shelly clays of the Clyde district and of the west coast seem to belong to the close of the submergence, when the land had risen well out of the sea, almost to its present height. This is well exemplified at the Kilchattan brickwork in the island of Bute, where we have at the bottom a thick mass of laminated clay destitute of shells, and lying upon an irregular surface of the boulder-earth, which, again, is found at the distance of 70 yards to repose upon the Devonian rocks, or Old Red Sandstone (see section, fig. 4). The surface of this fine laminated brick-clay is undulated; and resting upon the top of it, so as to fill up the undulations and bring the surface to a nearly horizontal plane, we find a looser, sandier clay full of shells. Of these I collected sixteen species (see Appendix, No. 3). The most common is the *Tellina calcarea* (*T. proxima* of Brown). It is very abundant, and of all sizes, from 1 inch in length down to very young individuals; and they are often quite entire, as if there had been a bed of them *in situ*. This loose sandy stratum varies in thickness from a few inches, or almost nothing on the top of the undulating rolls of the lower clay, to 3 feet or more in the hollows. Where there is much depth of it, the shells are chiefly in the lower part. Above this shelly stratum we find a heavy mass of stratified gravel and shingle from 4 to 10 feet thick, looking as if it had been formed on a beach. Here, then, we have, subsequent to the Boulder-clay, three changes of conditions in the marine beds: first and lowest, we have the

laminated clay, which probably has been a deep-water deposit, and seems to have been heaved up and its surface water-worn before the deposition of the next bed, or that containing the shells; and thirdly, above all, we have the beach-like gravel. The top of the section is not more than 25 feet above the present reach of the tide.

Fig. 4.—Section at Kilchattan Brick-work, in Bute.



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| 1. Sandstone-rock. | 4. Shell-bed. |
| 2. Boulder-earth. | 5. Stratified gravel and shingle. |
| 3. Fine laminated clay. | |

In 1860 I examined several of these clays of the west coast; they occur in a great number of places along the shores of Argyle-shire, and, coming from the comparatively barren district of the east coast, I was delighted with the abundance and fine preservation of the fossils; for in Aberdeenshire and on the east coast generally the shells are usually much broken, or, if found entire, they are so decayed as to be with difficulty obtained in a state fit for examination.

Many of the localities on the west coast have been explored and described by Mr. Smith of Jordan Hill, Hugh Miller, Mr. Geikie of the Geological Survey, the Rev. Mr. M'Bride, Mr. Crosskey of Glasgow, and probably others. The localities, however, where shells occur are so numerous that doubtless much remains to be done*. One of the most remarkable circumstances connected with them is that they are, as I have already mentioned, for the most part confined to very low levels, and to the immediate vicinity of the coast. I have observed them on the shores of Upper Loch Fyne, and in my paper "On the Parallel Roads of Glen Roy"† have described an instance near Fort William, which was also explored about the same time by Mr. Gwyn Jeffreys, who gave an excellent account of the fossil contents in the British Association Reports for 1862. This shell-bed near Fort William I believe to represent one of the last stages of the submergence. In the south of Arran, however, the Rev. R. B. Watson has discovered these shell-beds at much higher levels.

It will be seen from the list given in the Appendix, No. 1, that of fifty-four species enumerated from the east side of Scotland, all, according to Mr. Jeffreys, are now found living in the Arctic seas, none are extinct, thirty-two are still living on the coasts of Britain,

* The Rev. Mr. Crosskey, who has made large collections of the fossils, and has an intimate knowledge of the glacial beds, will, I hope, soon favour us with a paper on the subject.

† Quart. Journ. Geol. Soc. vol. xix. p. 235.

while only twenty are known to occur to the south of this country. This shows very clearly how northern is the character of the group. Another circumstance of interest is the large proportion of them, namely forty-nine, that occur on the east coast of North America, considerably more than what now live on our own shores*.

The proportions in 100 would be as follows:—

Living in the seas of Britain.....	59
Living to the south of Britain	37
Living within the Arctic Circle.....	100
Living on the east coast of North America	91

This might lead us to speculate on some connexion between the coasts of northern Europe and America during the glacial period. A column is added, headed North Pacific, to show the proportion occurring on the west coast of North America. I am afraid, however, that our knowledge of the Mollusca of that region is as yet too imperfect to warrant us in placing much confidence in the figures. It would seem, from the elaborate report drawn up by Mr. P. P. Carpenter, that several forms occur there which may be said to be representative of those found in the North Atlantic, being extremely like, although not altogether identical. If these had been included, the proportion would have been much larger.

c. *Boulders of the Brick-clay—Floating ice.*—Many of the beds of finely laminated marine clay of this period contain few or no boulders; but this is not always the case. Thus in the clay at Errol in Perthshire, which contains remains of Arctic shells, I observed that small stones are by no means uncommon, and many of them are glacially scratched. Occasionally one may be found with barnacles (*Balani*) on it.

S.

Fig. 5.—Section at Errol.

N.



1. Sandstone-rock.

2. Boulder-earth.

3. Fine clay with Arctic shells.

4. Carse, or old estuarine mud of the Tay.

In the Paisley brick-clay, which abounds in shells (see Appendix, No. 2), boulders of from 1 to 3 feet in length are not uncommon, and in the bottom of one pit I saw a block 6 feet in length. They are chiefly fragments of the older crystalline rocks, and many of them show the glacial striæ. These boulders occur imbedded here and

* This group probably belongs to an earlier stage of the submergence than those got from most of the clay-beds of the west of Scotland, and is of a more decidedly Arctic character. This is indicated by the prevalence of *Leda Arctica* and *Astarte borealis*, the rather larger average size of the *Tellina calcarea*, and the presence of some very Arctic forms, not yet reported from the western beds, such as *Cardium Grœnlandicum*, *Pecten Grœnlandicus*, *Leda lucida*, *Leda limatula*, *Thracia myopsis*, *Mesalia erosa*, *M. reticulata*, *Modiolaria lævigata*, *Axinus Sarsii*, and *Crenella faba*.

there at various depths in the fine clay—sometimes singly, but frequently one or two together. Now it is quite common in some of the pits to find a crust of *Balani* attached to one of these boulders, and I think it has generally been supposed that the *Balani* are confined to the upper surface and sides of the stone, as if they had grown upon it after it had been dropped into its present position. I satisfied myself, however, that this is not always the case; for I found that *Balani* do occasionally occur all over the lowermost side. For example, I observed one heavy stone, measuring 32 inches in length ($32 \times 14 \times 18$ inches), imbedded in the clay about 15 feet from the surface. This boulder had not been moved out of its original position, and there were remains of *Balani* on various parts of the surface. With the assistance of the foreman of the work, I dug round it, and heaved it out of its bed, and found that the whole under side of it was covered with a close thick crust of entire *Balani*, the points of which were sticking downwards into the soft clay beneath, showing clearly that they must have grown upon the stone before it was dropped into its muddy bed. Other instances of the same kind were observed by me in this brickwork. I conclude, therefore, with regard to some of these boulders at least, that *Balani* grew on them before they came to be lodged in the clay (probably when they lay on some shore), and that afterwards they had got encrusted with ice, and being floated off had dropped to the bottom when the ice about them melted*.

I noticed that these boulders, with the *Balani* on them, sometimes exhibit glacial scratches. Here, then, we have evidence of three distinct events: first, the boulder was scratched; secondly, barnacles grew on it; thirdly, it was carried off and dropped to the bottom of the sea. If this transportation was due to floating ice (and I do not see to what else we can ascribe it), it would therefore appear that the floating ice had nothing to do with the scratching of the stone.

I by no means deny that barnacles likewise grew on the stones after they had fallen to the bottom; I have no doubt they did. They also occur on some of the larger shells, such as the *Buccinum undatum*, and I picked up a specimen of the *Trophon scalariformis* with three attached to it.

In this Paisley clay I sometimes found, on heaving up a boulder, a number of young crushed mussel-shells beneath it, as if they had been squashed by the fall of the stone. The clay around also occa-

* I believe the species of *Balanus* on the under side of the boulder above mentioned was *B. balanoides* of Darwin's monograph, for I feel pretty sure it had no calcareous base; but not having brought away specimens, I am unable to be quite certain of this. Those I have, adhering to shells, are not this species, but *B. porcatus* or *B. crenatus*. Now *B. balanoides*, according to Darwin, is a species that lives only between tide-marks; if this is correct, then it could scarcely have grown on stones lying in water so deep as is indicated by the shells in this clay; and its presence could be explained only by some such theory as I have suggested. It would be an interesting fact should the *Balani* on the upper surface prove to be of a deep-water species, and those on the lower of a tidal one.

sionally exhibits black stains, as if from the decay of sea-weed that had been attached to the stone. I likewise noticed the *Littorina litorea* close beside a large boulder, as if it had been sticking to the stone like the *Balani*, and had gone down with it.

These heavy boulders in the middle of this deep mass of fine marine clay, far from any high ground whence they could have rolled down, afford the best evidence I have seen of the action of floating ice during the glacial period; for by what other means can we suppose that stones of such weight could have been lodged here and there in the midst of a bed of the finest sediment, having all the appearance of a tranquil deposit. The large shells of the *Cyprina Islandica* are very numerous and perfectly entire, and lie gaping half open and filled with fine mud. Even the most delicate bivalves, such as the *Nucula tenuis* and *Leda pygmaea*, occur entire, with the epidermis quite unruffled; and it is just alongside of such as these that we see now and then a boulder of some 2 or 3 feet in diameter. It was under the friendly guidance of Mr. Smith, of Jordan Hill, that in 1860 I made my first acquaintance with these Paisley beds, and he particularly drew my attention to the evidence of tranquillity, and of the long-continued presence of the sea, afforded by the growth of *Balani* on the upper surface of the stones.

d. *Stratified Beds at high levels.*—Beds of stratified clay and earthy matter may sometimes be observed at high levels. I have myself described a remarkable instance of such near Pitlochrie in Perthshire, where a thick bed of stratified débris stretches up to a height of 1200 feet above the sea. Although some of these may be marine, yet in the total absence of fossils I think it unsafe to rely upon any of those hitherto adduced as evidences of submergence, owing to the fact that similar stratified beds are frequently found in alpine districts that have been occupied by glaciers, as we know from the accounts of the Upper Himalayan valleys by Dr. Thomson and Dr. Hooker. Charpentier also mentions their occurrence in Switzerland, and describes how they may have been formed. Moraine-matter is occasionally deposited in singular situations in this way when it falls into a lake or pool confined by the ice.

Although, therefore, we have evidence from marine shells of submergence in Scotland up to 500 feet above the present sea-level, we are still in the dark as to the exact upper limit of this submergence. The marine beds are so very barren of fossils, at least on the eastern side of Scotland, that their occurrence is the rare exception, and their absence the rule; we are therefore not entitled to say that the submergence reached no higher than 500 feet, merely because marine fossils have not been discovered at greater heights. There are many places, even in the lower grounds, where the character of the superficial débris is such that it is doubtful whether it should be referred to submarine or supra-marine action, the true marine clay of this period being occasionally so charged with stones as to resemble some of the softer varieties of glacier-mud; and at high levels this is more generally the case. If it be also the fact, as I have already hinted, that the marine beds have been deranged, and sometimes

remanié by glacier-action, the confusion becomes still more confounded. Such obscure portions must be deciphered by the aid of the clear evidence afforded by more favourable localities. It seems indeed to be the character of glacial deposits in general, whether formed on land or in water, to have a confused arrangement, so that the character of a section changes at almost every step; and this may help to distinguish them from ordinary marine beds, whose sections have regular features over wide areas.

e. Cause of the submergence.—It is worthy of remark that in Scandinavia and North America, as well as in Scotland, we have evidence of a depression of the land following close upon the presence of the great ice-covering; and, singular to say, the height to which marine fossils have been found in all these countries is very nearly the same. It has occurred to me that the enormous weight of ice thrown upon the land may have had something to do with this depression. Agassiz considers the ice to have been a mile thick in some parts of America; and everything points to a great thickness in Scandinavia and North Britain. We don't know what is the state of the matter on which the solid crust of the earth reposes. If it is in a state of fusion, a depression might take place from a cause of this kind, and then the melting of the ice would account for the rising of the land, which seems to have followed upon the decrease of the glaciers.

§ 5. EMERGENCE OF LAND AND FINAL RETREAT OF THE GLACIERS.

a. Valley-Gravel.—Along the course of all our larger river-valleys, as in those of the Spey, the Dee and Don, the Tay, and others, we find extensive beds and terraces of rolled gravel, which seem to be of later date than the laminated clay with Arctic shells, seeing that in the lower parts of the valleys the gravel overlies this clay. The more recent origin of the gravel is further proved by its sometimes containing rolled lumps or nodules of the laminated clay, showing that the latter must have suffered some denudation.

In the absence of all fossils it is often impossible to distinguish freshwater gravel from that which is marine; for water arranges sand and pebbles in the same way whether it be salt or fresh. False bedding, as Mr. Sorby has pointed out, will sometimes help us to trace the effect of tidal action; although it is well to bear in mind that back eddies often occur along the sides of a river, so that oblique laminæ pointing in reverse directions may occur even in freshwater beds. I am therefore of opinion that it is only when this feature is well developed that we can rely upon it as a test.

Beds of gravel are by no means uncommon in the marine glacial deposits, and in some of the lower districts I have occasionally observed this "oscillating current structure," as Mr. Sorby terms it, very well developed. At Ladybank railway-station in Fife, I have noticed some good examples of it in a large side-cutting, also in some sand-pits at Old Aberdeen. In the great shoals of gravel, however, which overspread the bottom of the valleys in the more hilly districts, I have never observed any decided instance of this

structure; and along some of our Highland rivers, the Dee for example, we may trace this gravel for more than fifty miles inland, namely, from the sea-coast to their very source in the midst of the Grampians. In some places it is spread out in wide sheets; in others it lies in large irregular mounds. The sections displaying its internal structure vary greatly in their character. Beds of fine laminated sand occur oddly intermixed with heaps of large pebbles, and often exhibiting very curious undulations. All the materials are usually much water-worn and well washed, so as to be free from muddy sediment. No fossils occur, neither do the stones exhibit the glacial striæ. In following up the course of a valley we sometimes find a great aggregation of this rolled gravel at certain points, with intermediate spaces along which comparatively little of it occurs.

There can be no doubt that much of this *valley-gravel*, as we may call it, has been the result of the long-continued action of the rivers since they came into play after the glaciers commenced their final retreat. Its distribution and mode of arrangement show that it has been deposited by water flowing down the valleys, and as we know that glaciers previously occupied these valleys, there is good reason for supposing that, as they gradually melted and withdrew to the mountains, they would give rise to much watery action. Those who have studied glaciers with most attention tell us that they produce, by friction on their rocky bed, much sand and gravel, which is strewed in front of them by the water issuing from beneath the ice. If, therefore, we conceive a sheet of such gravel to lie in front of a glacier, and a succession of snowy seasons to cause a temporary advance of the ice, the result would probably be that the end of the glacier would push into the gravel and raise it into a steep curving mound all along its border, and thus form an elongated narrow ridge, such as we see in certain parts of Scotland, where they are sometimes called *kaims*. I do not mean to say that all the *kaims* have been formed in this way, but many of them probably were. The descriptions of the Himalayan valleys by Dr. Thomson, Dr. Hooker, and Captain Godwin-Austen show that these great glens (which were formerly occupied by glaciers) now exhibit mounds and terraces of gravel which, on a great scale, seem to be an exact counterpart of those in the valleys of our Scottish Highlands; and it is impossible to read their descriptions without being struck with the close resemblance of the superficial features, not only as regards the gravel-terraces, but also the moraine-heaps, the large transported boulders, and the occasional traces of what seem to have been glacier-lakes.

In the valley of the Spey there seems to have been a large lake extending from Kinrara towards Laggan. The bottom of the valley near Kingussie is filled with deep masses of pure sand, which was well exposed in the cuttings for the Highland railway. In one of these I saw a thickness of 30 feet of the finest sand, without a pebble, passing at the bottom into a sort of silt, but no fossils could be perceived here or anywhere else along the valley. I think this

lake has been caused by the glaciers of the Cairngorm mountains barricading the valley near Aviemore; for I found the fine sandy beds terminate towards Rothiemurcus, while great quantities of granite-boulders and well-marked moraines occur on the flanks of the hills on the west side of the Spey to the north of Aviemore. The mineral quality of the *débris* composing these moraines is such as to lead one to believe that they are due to glaciers that proceeded from the high mountains on the opposite side of the valley, while their position further accords with this notion. We may easily suppose that many lakes and large pools would arise from causes of this nature, and from the irregular masses of *débris* left by the glaciers acting as dams here and there, so as to obstruct the drainage of the valleys.

In Arctic countries the periodical thawing of the ice occasions great floods in the rivers, which at such times rise to great heights, and overflow their banks to an extent that we in this country can scarcely believe; and there seems every reason to think that towards the close of the Glacial period a similar state of things prevailed here. I am therefore disposed to credit the rivers with a large share in the formation of our valley-gravels, as I did in a former paper some years ago*. Nevertheless I still maintain, as I did then, that there are some of these gravel-beds which mere river-action will not explain. Thus at the northern extremity of the valley of the Caledonian Canal, near Inverness, there are masses of coarse water-worn gravel, rudely piled together in heaps, 200 feet thick, and which I traced up the flank of the hill near the Lunatic Asylum to a height of 400 feet. Some of the pebbles are so large that one might with more propriety call them boulders, instances being seen of a diameter of from 2 to 4 feet. The stones, however, are all water-rolled, and show no glacial *striæ*. The stratification of this gravel is often very far from horizontal, great undulations appearing without any good development of false bedding. There is no very great difference in the nature of the stuff from top to bottom, so far as I saw; there is no clay, nor even silt; all is of washed gravel, with here and there some seams of fine sand, and there seems to be a complete absence of all fossils.

Now this valley of the Caledonian Canal forms a great gash across Scotland from sea to sea, and its summit-level at Loch Oich is only about 90 feet high. How, then, can any river-action account for this immense pile of gravel near Inverness, reaching, as it does, to so much greater a height? The materials composing it look as if they had been derived from the rocks along the valley to the south-west; and if they have come from that direction, how did they get past Loch Ness, which is of great depth, in some places 780 feet. I remarked that the pebbles are of various kinds of metamorphic and crystalline schists, red sandstone and conglomerate, granites and porphyries. This accumulation of gravel extends for a mile or two south-west of Inverness, beyond which it is not remarkable. Its greatest development is near Dun Ian, where there is a good exposure

* *Quart. Journ. Geol. Soc.* vol. xvi. p. 353.

of it in the flank of the little hill called Torvane, or Tor Bhain, which seems to be entirely composed of gravel.

Believing that glaciers occupied the valley of the Caledonian Canal both before and after the period represented by the marine beds with Arctic shells, I cannot help thinking they had something to do with the formation of this remarkable heap of gravel; and if we might believe that the débris brought down by the glaciers was acted upon by the sea beating upon the terminal moraines, it might help to explain the water-worn character of the stuff, as well as the terraced appearance which it frequently presents.

A somewhat similar accumulation of gravel and pebbles, although not so extensive, is seen at the entrance to Loch Treig, and there is also a prodigious quantity of it on the west side of the Spey, near Fochabers.

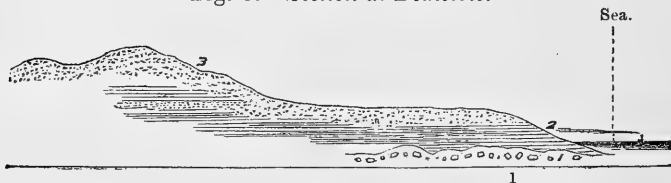
In the low grounds away from the mountains the superficial masses of rolled gravel are often of dubious origin, owing to the difficulty, where no fossils occur, of distinguishing that which is marine from what has been due to subsequent freshwater and glacial action. It seems likely that a good deal of gravel would be formed by the sea while the land was recovering from the depression that took place during the time that the marine clay was forming. If any sudden movements of elevation occurred, there must of necessity have arisen strong currents off the land, with several oscillations, which would effect a considerable denudation of the soft recently formed marine beds, and probably produce a large amount of rolled gravel. The tails of gravel on the seaward side of the rocky eminences near Edinburgh, long ago noticed by Sir James Hall, can hardly be referred to any river-action, and the marks of denudation around the Castle-rock and the base of Arthur's Seat show that some agency must have been in operation, subsequent to the deposition of the fine laminated clay near Lochend and Portobello, to carry off the small loose débris and sweep the surface bare.

At Aberdeen, and to the north of that city, there are mounds of loose gravel which are of later origin than the laminated clay containing Arctic shells; and Dr. Fleming tells us that Agassiz in 1840, on looking at some of these, pronounced them to be moraines. This would imply that the glaciers here extended to the present sea-coast after the deposition of the clay. At Belhelvie, four miles north of Aberdeen, there are remarkable piles of gravel, close to the sea, forming large irregular mounds. This gravel is certainly of more recent deposition than the clay close beside it, which contains Arctic shells (see Appendix). Its boundary to the north, at Millden, is sharply defined, and it seems to be a continuation of the gravel of the valley of the River Don, for I have traced it across the low intervening ground into that valley at a place called Dyce, four miles distant, where there is another large accumulation of it.

The River Don makes a sudden bend to the south at Dyce, and enters the sea two miles to the north of Aberdeen; but the valley-gravel does not follow it along that part of its course, but goes straight out to sea at Belhelvie, forming a series of mounds all the

way. Some of these mounds (especially those near the Corbie Loch) are certainly of a moraine-like character; but in general they consist of pebbly shingle and small gravel, like what mere watery action would produce; and this is the character of those large mounds near the coast, which I have already mentioned.

Fig. 6.—*Section at Belhelvie.*



1. Boulder-earth (inserted on the authority of Dr. Fleming).
2. Fine laminated clay and sand, containing remains of Arctic shells.
3. Gravel.

The moraine-character is much more strikingly displayed in the heaps of boulders and rough stony débris which cover the hills of Nigg—a set of low eminences running out to the coast immediately to the south of Aberdeen, and reaching an elevation of from 200 to 300 feet above the sea. These mounds of rough stony rubbish may be well seen beside a small lake called the Loch of Loirston, a little westward of the first railway-station to the south of Aberdeen, called the Cove. A good section of them is exposed at the mud-cliff facing the Bay of Nigg, where they are seen to rest directly upon the hard grey boulder-earth. The position and general character of these piles of stony rubbish at Nigg and Loirston would be explained by supposing them to be the moraine of a glacier filling the valley of the Dee; and I do not see how else they can be accounted for.

The foregoing observations will serve to show that these gravel-beds form a subject of much interest and difficulty, and one that will require a great deal of careful study before we can understand it thoroughly. Cases may have occurred of glacier-lakes bursting among the mountains, and sending a sudden deluge down the valleys, as sometimes occurs in the Alps and Himalaya at the present day. The letting off of the Glen Roy lakes, for example (if they were of this nature, as I believe them to have been), might have produced a considerable effect. The lowering of the water from the highest to the middle line, and from that to the lowest, would set free a large body of water into the valley of the Spey, while the final exit of the contents both of Loch Roy and Loch Gluoy would have been by the Caledonian Canal valley. Query, had this anything to do with the gravel-beds near Inverness, or with those in Strathspey?

In whatever way we are to account for the valley-gravel, it can be shown to be posterior to the laminated marine clay containing Arctic shells, both by the tests of superposition and of included fragments. It therefore represents a decided change of conditions fol-

lowing after those represented by the clay; and this is the point I am chiefly contending for in the present paper.

I am not aware that any evidence has as yet been got entitling us to say that the Mammoth or *Rhinoceros tichorinus* lived in Scotland after the Glacial period. No Mammalian remains have as yet been reported from our valley-gravel, which is singularly destitute of fossils of every kind.

b. *Moraines*.—Moraines occur in most, if not all, of the chief mountain-glens; and in tracing the valley-gravel up to the mountains, we frequently find it emerge into moraines.

In regard to the mounds in Glen Derry and other ravines of the Ben Muick Dhui mountains, I was formerly inclined to doubt their glacial origin, being at that time disposed to refer a larger amount of influence to marine agency in accounting for the superficial accumulations of our Highland glens. Our geological maps make the Ben Muick Dhui and Cairngorm mountains to be wholly of granite; and I remarked that these mounds in Glen Derry contained fragments of gneiss and laminated quartz, which was a circumstance opposed to the theory of their being glacier-moraines, if the maps were correct. I have, however, since satisfied myself that masses of metamorphic schist do occur in the midst of this mountain-group where our maps show nothing but granite, and therefore I no longer consider the above circumstance any difficulty. The absence of glacial striæ on the fragments, which I also mentioned, is likewise quite intelligible where the débris consists of stuff that lay on the surface of the glacier, for it is only that which lies between the ice and its rocky bed that is scratched.

There are some fine moraines in the glens that pierce the north flank of the Cairngorm mountains, as, for example, in Glen Innich and near Loch na Eilan and Loch Morlich. Those in Glen Spean, to the east of the entrance to Loch Treig, shown in my map of the Parallel Roads of Glen Roy, are also remarkably fine. To look at them is for ever to cease to doubt the former existence of glaciers in this country. The student of such phenomena will do well to betake himself to this region, or to the Cuchullin mountains of Skye, where Principal Forbes many years ago showed that there exists a fine exhibition of glacial action—or to the valleys of Caernarvonshire, which have been so well described by Buckland, Darwin, and Ramsay.

c. *Submarine Forest-beds*.—After the low grounds had emerged from the glacial sea, and the ice had retreated to the mountains, we have evidence that the land-area was more extensive in some districts than it is at present, owing to its higher elevation out of the sea. The evidence of this is, I think, sufficiently clear, and consists of the so-called submarine forests and beds of peat passing underneath the present sea-waters. In some of these cases the stumps of the trees may be traced, rooted manifestly in the spot where they grew, and surrounded by leaves, nuts, and seeds of land-plants. In regard to this point I shall content myself with referring to Dr. Fleming's account of the submarine forest in the Firth of Tay*,

* Trans. Royal Soc. of Edinburgh, vol. ix. p. 419 (1823).

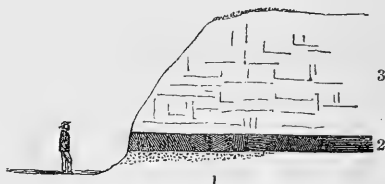
and to the same author's notice of the one in Largo Bay in the Firth of Forth*. Although Fleming's theory regarding these forest-beds was, I consider, erroneous, yet his facts are always valuable, and he entertained no doubt whatever as to the tree-roots in both of these cases being in the place where they grew, and he enumerates Birch, Hazel, and Alder as the prevailing species.

In the valley of the Tay this bed of peat is known to occur along a stretch of many miles, from the mouth of the Earn to Balmerino in Fife. It forms the bed of the present estuary in many places, and the tree-roots in it are frequently a source of annoyance to the salmon-fishers in hauling their nets. Now this bed of peat, full of remains of trees, passes right underneath the *Carse*, or old estuarine mud of the Tay. It does not intermingle with this clay, but lies clearly below it in a continuous stratum; and those engaged in sinking deep pits and wells near Abernethy are familiar with the fact that, after passing through some twenty feet of this fine silty clay, they get a bed of peat two or three feet thick, and beneath that no *Carse*-clay is found. Mr. George Buist deserves the credit of having clearly pointed out this in his memoir on the Geology of the south-east of Perthshire, in the 13th vol. of the Transactions of the Highland Society. I examined this peat-bed along the banks of some small streams that join the Earn, near Abernethy, and found it to be about 3 feet thick, in some places quite full of remains of trees, and lying clearly below the whole mass of *Carse*-clay. Dr. Dickie, who has examined for me some of the specimens I brought home, reports the trees to be Birch and Alder. Below the peat there is often a stratum of gravelly sand. The peat does not lie in disjointed masses as if it had been drifted, but, so far as I saw, forms a regular continuous bed of pretty uniform thickness and much compressed.

Near the farm of Invernethy I traced its outer edge, where it runs out apparently on the surface of some laminated clay, the boulder-earth emerging at a short distance. Dr. Fleming also states that at Largo Bay the tree-stumps are rooted in laminated brown clay.

A bed of peat, occupying the same geological position, is found in some places beneath the *Carse*-clay or old estuarine mud of the Forth, as we learn from Mr. Blackadder† and Mr. Home Drummond‡. This peat stratum was said to contain remains of Birch and Alder, together with seeds of a plant supposed to belong to the genus *Pedicularis*. In the *Carse*-clay immediately above it, part of

Fig. 7.—Section near Abernethy.



1. Sand and gravel.
2. Peat, full of remains of Birch and Alder.
3. *Carse*-clay, or old estuarine mud of the Tay.

* Quart. Journ. of Science, Lit., and Art. vol. xxix. p. 21 (1830).

† Memoirs of the Wernerian Society, vol. v. p. 424.

‡ *Ibid.* vol. v. p. 440.

the skeleton of a whale was got at Blair Drummond. I have also seen a stratum of peat, containing remains of trees below the raised estuarine mud of the Ythan in Aberdeenshire, the clay above it containing remains of *Scrobicularia piperata* and other estuarine shells. This was exposed in cutting a deep drain near the village of Newburgh; there was a thickness of 8 feet of clay and silt above the peat in some places (see fig. 10).

s. Fig. 8.—Section near Abernethy. N.

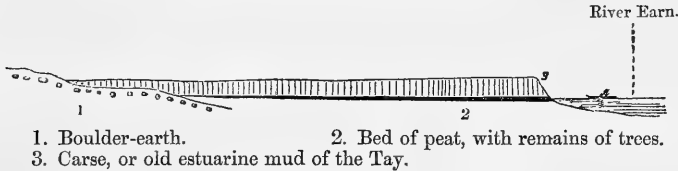
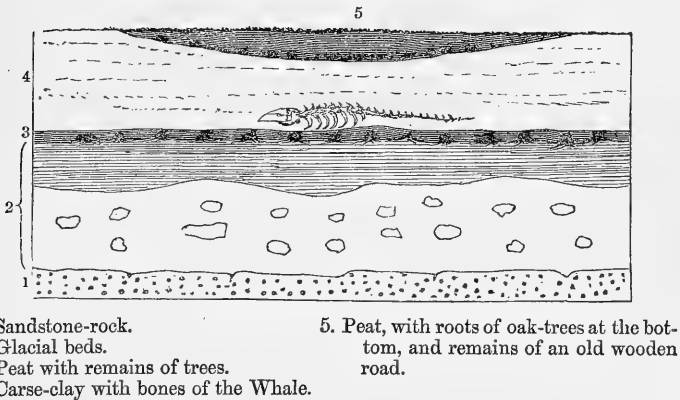


Fig. 9.—Diagram showing the relations of the superficial Deposits at Blair Drummond, in the Valley of the Forth.



I by no means deny the existence of *drift-peat*, for I am well aware that rivers flowing through mosses often float away great lumps of peat, as I have myself seen, but this need not blind us to the fact that there are also tracts of submerged peat, with remains of forest-trees, that have not been drifted, but lie where they grew. I believe, therefore, that this extensive bed beneath the Carse of Tay, together with the others I have mentioned, represents a land-surface of the period preceding the deposition of the old estuarine mud, and that it is not a mere local phenomenon, but will be found in the same geological position along many other parts of the coast. The submarine forest on the coast of Lincolnshire, explored by Sir Joseph Banks and Dr. Correa de Serra, appears to belong to the same period, for in some places there is said to be sixteen feet of

soil above it*. Hugh Miller tells us that in making a gas-tank at Rothesay, in the Isle of Bute, a bed of peat-moss, abounding in remains of trees and hazel-nuts, was found covered by seven feet of gravel. Miller classes this peat-bed with the submarine forests, and the overlying gravel he considers to be a raised beach (Sketch-book of Geology, p. 321). The peat here was 18 inches deep, and rested upon stratified sand and clay with marine Arctic shells.

De la Beche, in his Report on the Geology of Cornwall, Devon, and West Somerset, informs us that in the South of England these submarine forests are generally covered by estuarine deposits and gravel beaches containing shells of the species now living on our shores, and in the twenty-fourth chapter of his 'Geological Observer,' he gives a most instructive account of the subject in general. It seems to me that we entirely misapprehend the significance of these phenomena, if we suppose them to be due to mere local accidents that have affected a small bit of ground here and there along the coast. In truth they may be traced round the whole of Britain and Ireland, from Orkney to Cornwall, from Mayo to the shores of Fife, and even, it would seem, along a great part of the western sea-board of Europe, as if they bore witness to a period of widespread elevation, when Ireland and Britain with all its numerous islands formed one mass of dry land, united to the Continent, and stretching out into the Atlantic. Indeed, without something of this sort, how can we account for the immigration, of all the land animals and plants that have overspread these islands since the close of the Glacial period. They have all come from Europe, and how were they to get into Ireland, the Isle of Man, the Hebrides, and all the numerous islands of our west coast, without a land-route being open to them? Ice might have formed a bridge to some, but not to the greater part; and I maintain that the introduction of the present land flora and fauna of Scotland is almost wholly Postglacial, that is to say, posterior to the marine glacial beds, or the period of great submergence.

This bed of peat lying beneath the raised estuarine beds is the first appearance of that substance we meet with in Scotland; indeed the period during which peat was formed so extensively from the gradual accumulation of mosses, sedges, and various other plants, is perhaps even a stage later; for at the bottom of many of our peat-mosses we find remains of trees, and in some cases beds of shell-marl. These trees are all of existing species, now indigenous to Scotland. The Birch, Hazel, and Oak are amongst the most common, and hazel-nuts are frequently found. Now these trees testify, I think, to a condition more favourable to the growth of wood than what we have at present. They evidently preceded the commencement of the peat in a multitude of instances, for their roots are spread on the hard earthy subsoil beneath it, and it is since the death of these trees that many of our peat-mosses date. I am quite aware, however, that many extensive swampy mosses contain no remains of trees. The present or historical period is the true peat-period for Scotland; for this substance is growing rapidly just now,

* Trans. Roy. Soc. for 1799, p. 145.

and in the Western Isles Captain Thomas* has described how it has accumulated round the ancient stone circles in the Lewis, so as in some cases to envelope the stones completely, and even to cover the tops of a few of them; and he believes that these so-called Druidical monuments were erected before the peat began to grow there. It would seem that remains of trees are found at heights beyond where wood can now be got to grow. Thus in the Transactions of the Highland Society for March 1860, Mr. J. B. Webster, in a report on planting-operations at Balmoral, states that he had found the remains of old trees averaging from 6 to 12 inches in diameter at an elevation of 2500 feet above the sea, on the mountain called Lochnagar †; and Dr. Dickie, who has paid much attention to the zones of altitude of British plants, remarks, in his 'Botanist's Guide to the Counties of Aberdeen, Banff and Kincardine,' regarding the Scotch Fir (*Pinus sylvestris*), "The stems are to be seen in peat-mosses at high altitudes, where such trees cannot grow at the present day;" and in reference to the Birch (*Betula alba*) he says, "On the summit of the ridge north of Mount Keen, and at an elevation of 2200 feet, I have seen the dead remains of Birches far larger than any growing at lower altitudes on other mountains of the district." It may be said that the more generally wooded character of the surface before mankind began to multiply may have contributed to render the climate more favourable to forest vegetation. It is, however, clear that on the first disappearance of the ice, the trees must have had to make their way over a surface destitute of wood.

Although coniferous trees are not now indigenous to Orkney, yet a submarine forest, consisting of remains of small Fir trees rooted in their natural position, occurs in the Bay of Skail, on the west side of Mainland Island, and is sometimes to be seen during ebb tide in situations where the sea during flood rises at least 15 feet above it. (See Edinburgh Phil. Journ. vol. iii. p. 101, 1820).

It is to the time of this old land-surface with its forest vegetation that the remains of the Irish Elk and the Great Wild Bull (*Bos primigenius*) seem mostly to belong, although the latter survived to a later period; for it is in the marl-beds below the peat that the skeletons of the *Megaceros* are generally found. Although its remains are very rare in Scotland, yet they have been got. Thus in a marl-bed underlying peat in the parish of Maybole, in Ayrshire, the skull and horns of one were found, measuring 10 feet 4 inches between the tips of the antlers, while the breadth of the palm of the antler was 2 feet 7 inches. Horns of the stag, and remains of a large ox with concave forehead (apparently *Bos primigenius*), were got along with it. (See Statistical Account of Parish of Maybole.)

* Edinb. New Phil. Journ., new series, vol. xv. p. 235, 1862.

† H. C. Watson, in his 'Cybele Britannica,' vol. ii. p. 410, says that the present upper limit of the fir-woods on Lochnagar is at 1950 feet, and he cites Mr. Winch for the fact of trunks of large Pines occurring in peat in the north of England at an elevation of nearly 3000 feet. Mr. Watson further states that roots of fir occur in peat at an elevation of 2400 feet and upwards on the elevated tablelands of Forfar and Aberdeen.

§ 6. SECOND PERIOD OF DEPRESSION.

a. *Old Estuarine Beds and Beaches.*—After the period represented by the forest-bed just described we have evidence of a depression of the coast, which seems to have been very general along the shores of this country. In the Firths of Tay and Forth this depression caused the sea to reach about 25 or 30 feet above the present coast-line, so as to cover the rich flat country of the *Carses*, as they are locally termed. These Carse-lands are plains of fine silty clay, quite free from stones, and identical in character with the sediment now forming along the shallows of the present estuaries. It forms a smooth level sheet of rich mud occupying the whole width of each valley, and encircling the little rocky eminences and mounds of old glacial débris that project through it, much in the same way as the waters of a lake do the islands on its surface. In the district of the Tay it forms the Carse of Gowrie, the garden of Scotland, together with the flat lands at the mouth of the Earn. A narrow strip of it extends even a little above Perth, towards Scone, forming the rich ground of the Muirtown farms.

The Carse of the Forth, however, is the most extensive tract of this nature in Scotland. It stretches for many miles inland, overlapping the eastern base of the moraine-hillocks of the Loch of Monteith, and extending through a narrow opening up to Gartmore; while below Stirling it forms a broad margin on the south side of the valley down to Grangemouth, and on the north side to Alloa. Mr. Blackadder gave a good account of it many years ago in the fifth volume of the Wernerian Society's Memoirs, with a map showing its boundaries. A fine view of this beautiful plain is got from Stirling Castle. Marine shells of the kinds generally found in estuaries occur in some places abundantly.

For example, on the banks of the Forth, near Micklewood, some five miles to the west of Stirling, there are seams of shells imbedded in the old estuarine mud up to a height of 6 feet above the surface of the river; and as the tide is not now felt so far up the Forth, the elevation above the sea must be a little more. The species I found here were:—

Cardium edule. Abundant; generally of small size.

Mytilus edulis. Common.

Ostrea edulis. Frequent; many of the shells are very thick.

Tellina solidula. Occasional.

Scrobicularia piperata. Not very numerous.

Rissoa ulvæ. Frequent.

Littorina litorea. Rare.

Fusus antiquus. One broken specimen.

The most abundant of these by far was the Cockle (*Cardium*), the clay being in some places quite crowded with their remains. The size is small, as if they were young shells; many of them are quite entire, but the generality are decayed and broken. These shells occur in an undulating seam, which sometimes passes underneath the surface of the water, and at others rises a few feet above it. Occasionally there are two seams.

I also observed shells (*Scrobicularia piperata*) in the same clay at Stirling; and at Polgavie on the Tay a bed of similar shells occurs in the raised estuarine mud overlying the peat-bed with trees.

Three or four instances have occurred of remains of the Whale in this Carse-clay of the Forth, namely at Dunmore, Airthrey, Blair-Drummond, and Micklewood. Those at Airthrey and Dunmore* were entire skeletons about 70 feet long, and were imbedded in the clay at a height of fully 20 feet above the present reach of the tide†. The depth of this old estuarine mud is in some places very great, more especially below Stirling, where Mr. Blackadder says a depth of 70 feet has been reached; and Mr. Bald informs us that near Alloa there is 90 feet of it. A mass of such extent and thickness must have required a long time for its accumulation. This clay is generally stiffest and contains least sand near the surface, so much so as to be frequently employed for making bricks and tiles. There are works of this nature at Stirling, Micklewood, Inchtute, Perth, and elsewhere in the Carse; accordingly some people have confounded it with the older glacial clay, which is the stuff generally employed in Scotland for manufacturing bricks, tiles, and wares of that sort, although some of the beds of the Coal-measures are likewise used.

The fact of the Carse-clay extending up the Forth as far as Gartmore (see Mr. Blackadder's map), which is only ten miles from Ben Lomond and six from Ben Venne, and, fringing as with a smooth carpet the base of the moraine-hillocks of the Loch of Monteith, shows that it has been postglacial, and has never been disturbed by the ice. There is a remarkable absence of stones in it, even of the smallest pebbles.

The raised estuarine beds may be traced along the coast at various places, as at the Montrose basin, Aberdeen, and the mouth of the River Ythan, everywhere containing the same group of shells. The *Scrobicularia piperata* may be said to be characteristic of these beds; for it is not found in the glacial clays, and seems to have died out along the east coast of Scotland in many places where it was formerly abundant. In a fossil state it is plentiful in the raised estuarine mud of the Ythan, and also at Aberdeen, Montrose, and the Loch of Spynie, near Elgin, as well as in the Carse of the Forth. Mr. Gwyn Jeffreys tells me that it is not uncommon alive on the west coast of Scotland, and that it lives in the estuary of the Gotha, and other places on the coast of Sweden; its range, however, is essentially southward.

In tracing the distribution of these old estuarine deposits along the east coast of Scotland, I have remarked that their elevation becomes less as we proceed from the Firth of Forth to Aberdeenshire. In the basin of the Forth the Carse-clay lines the side of the valley to the height of 25 or 30 feet above the present sea-level. The old estuarine mud of the Tay reaches to about the same height. At the

* Edinb. Phil. Journ. vol. xi. p. 220 (1824).

† Edinb. Phil. Journ. vol. i. p. 393, where there is a good account of the finding of the Airthrey Whale by Mr. Bald (1819).

Montrose basin it seems to be less, or about 15 feet according to my observation, although I was unable to make a proper survey. But at the estuary of the Ythan in Aberdeenshire, where I have been able to make a leisurely examination and take measurements carefully, it does not exceed 8 feet above the limit of spring-tides; and at Aberdeen the elevation seems also to have been very little, only a few feet above high-water mark. In passing along the coast, therefore, from the Firth of Forth to Aberdeen the elevation is clearly less towards the latter point. A similar inference may be derived from an examination of the coast line generally. Near Edinburgh, as, for example, at the Craigentenny meadows, the raised beach may be distinctly seen, and has been well described by Charles Maclaren, Hugh Miller, and others, its height corresponding with the level of the Carse of the Forth. At St. Andrews in Fife, Mr. R. Walker* informs us that a mass of sandstone above high-water mark is riddled with *Pholas*-burrows. Between Dundee and Arbroath the old coast-line is very striking, at an elevation corresponding with the Carse of the Tay. Nowhere, however, from Stonehaven to Banff do we find evidence of a rise to the same extent, although at many points we can perceive that there has been an upheaval of a few feet. The amount of elevation has therefore been unequal, and consequently it is the land that has risen, and not the sea that has sunk.

b. *First traces of Man in Scotland.*—It is in these raised estuarine beds that the first traces of man have been found in Scotland. In his notice of the bones of a whale got in the Carse of the Forth at Blair Drummond, Mr. H. H. Drummond says, "It is a very singular circumstance that along with these bones there should have been found a fragment of a stag's horn, similar to that found along with the Airthrey whale, and having a similar round hole bored through it"†. This horn was sent, together with the bones, to the Museum of Edinburgh University. Several canoes of a primitive pattern, one of them containing a stone celt, have been found from time to time in the silt of the Clyde at Glasgow. Some of these were noticed by Mr. Robert Chambers, in his book on 'Ancient Sea-Margins,' in 1848, and more recently a very complete account of them has been drawn up by Mr. John Buchanan‡. The silt in which these canoes have occurred (more especially the one got in digging the foundations of St. Enoch's Church) is probably the equivalent of the Carse-clay of the Tay and Forth. Instances, indeed, are known of canoes having been found in the Carse of the Forth itself; but the circumstances of their occurrence have not been so well recorded.

The fact of some of the eminences that project through the Carse-clay bearing the Celtic appellation *Inch* or *Innis*, meaning an island, favours the opinion that these lands were under water during the time when that race had possession of the country, as Mr.

* Annals and Mag. Nat. Hist., 3rd ser. vol. xiv. p. 206, 1864.

† Memoirs of Wernerian Society, vol. v. p. 400 (1824).

‡ See Smith's 'Newer Pliocene Geology,' p. 160, and 'Glasgow, Past and Present,' also 'Report Brit. Assoc.' 1855, Trans. Sects. p. 80.

Chambers has remarked in his book just cited, although it would be unsafe to lay much stress on this circumstance, seeing that we find the same term occasionally applied to eminences similarly situated, which we cannot suppose to have been surrounded by water. Megginch, Inchmichael, and Inchtire are all eminences in the Carse of Gowrie, which would be insulated if the tide were to cover that fertile plain. The term seems to be of less frequent occurrence in the Carse of Forth, although there are many similar eminences in it.

The species of Mollusca, whose remains occur in these estuarine beds, are all living at present, both in the seas of Britain, and also to the south of this country, while some of them are not known to live in the Arctic regions. The group is therefore different from that found in the glacial beds, and seems to have more relations to the south than to the north, indicating a climate, if anything, milder than the present. (See Appendix, No. 5.)

§ 7. ELEVATION OF THE LAND TO ITS PRESENT POSITION.

a. *Beds of Peat and Blown Sand*.—After the deep masses of estuarine mud had been deposited at the mouth of the Tay, Forth, and other rivers, together with the corresponding gravel-beds and shingle-beaches along the coast, the land was elevated to its present level. Whether this took place suddenly, or by a gradual imperceptible movement, we do not know, and of the date of the event we are also ignorant. It has generally been supposed to have occurred before the Roman invasion; but this is doubtful; for Mr. Archibald Geikie, a most intelligent and accomplished geologist, after having made a special study of the question, has come to the opposite conclusion. I am unable to adduce anything new upon this point, and shall therefore content myself with referring to Mr. Geikie's interesting paper in the eighteenth volume of the Society's Journal, where the subject is ably discussed.

Although, therefore, we cannot tell exactly when the land attained its present level, the time is evidently remote when the extensive Carse district of the Forth was completely under water; for there seems to be no local tradition of such a state of things, and the depth of peat-moss which we find on the top of this raised estuarine mud at Blair-Drummond, and elsewhere, affords good evidence of a supramarine condition having prevailed for many centuries. Mr. Blackadder* tells us that this upper peat is from 8 to 14 feet deep in some places, and that remains of large oak-trees occur at the bottom of it, with their stumps rooted in the subjacent soil. These trees, we are informed, often bear distinct impressions of the axe, and a double row of the felled trunks have been laid to form a road across the swamp. This wooden causeway now lies at the bottom of the peat. The felling of the trees, and the construction of the road, have been ascribed to the Roman army under Severus, but I know not on what authority—probably on little else than mere conjecture. Some valuable tracts of Carse-soil have been reclaimed merely by clearing off the superincumbent peat; but large patches of it still remain.

* Wernerian Memoirs, vol. v. p. 424 (1824).

We see, then, that after the estuarine mud was raised above the reach of the tide, oak-trees grew upon it, and, since these have been cut down, a thick bed of peat has gradually accumulated over their roots. All this, of necessity, implies the lapse of much time. The extensive masses of blown sand that have accumulated on some parts of the coast since the land attained its present level afford additional evidence of the length of time that has elapsed since the event. The most remarkable of these in the district of which I am treating are the sands of Culbin in the Moray Firth, of Forvie and Foveran on the Aberdeenshire coast, and of Barry at the entrance to the Firth of Tay. These great heaps seem to have some connexion with the rivers entering the sea in their neighbourhood. Thus the masses at Culbin are probably derived in a great measure from the sand brought down by the Spey, the Findhorn, and the Nairn. Those on the coast of Aberdeenshire from what has been brought down by the Dee, Don, and Ythan, while the accumulations at Barry probably represent to some degree the sand of the Tay and the Earn.

b. Shell-mounds and Chipped Flints.—Another thing worthy of notice is the occurrence of old shell-mounds on the raised beach. Several of these occur at the mouth of the Ythan, in the desolate tract of drifted sand just mentioned, more especially on the north side of the river. There are hills of blown sand here 120 feet high. The shell-heaps are generally of an elliptical form, and from 30 to 90 yards in length. I have examined several of them, in company with my friend Mr. Robert Dawson of Cruden. We found them to consist usually of a thin stratum of decayed shells, reposing on a surface of drifted sand; but in one of them the mass of shells is 4 or 5 feet deep. These shells belong to the edible species of Mollusca now inhabiting the adjoining estuary, being chiefly mussels, cockles, and periwinkles. Mixed with them we frequently find some black carbonaceous matter like charred turf, together with pieces of burnt twigs. There are also a great number of stones, many of which appear to have been in a fire, and occasionally the sand underneath the spots where the charred turf and burnt stones occur is somewhat redder than usual, as if it had formed a hearth. Pieces of artificially chipped flint occur on the surface of some of the mounds, and are found abundantly in the immediate neighbourhood of one of them. A few of these flints lying on the mounds seem likewise to have been exposed to heat. Some teeth and split bones are also to be met with, but we found no pottery, nor anything made of metal in the Forvie mounds. The quantity of stones and pebbles on the surface of some of them is a curious feature. They seem to have a considerable resemblance, in many respects, to the Kjökkenmøddings of Denmark. Their antiquity, however, does not seem to be very great. The base of the largest of them is not 4 feet above the present reach of the tides in the estuary of the river, which shows that the land must have been as high as it is at present when they were formed. They are therefore later than the raised beaches and estuarine beds;

some of them perhaps a good deal later, seeing that there is much blown sand underneath them. I have also observed great quantities of artificially-chipped flints in certain places along the coast, both to the north and south of the Ythan, often in positions a very few feet above high-water-mark. These flints lie in many cases on a bed of smooth water-worn pebbles of the old beach, and the sharp broken edges of the flints show they have undergone none of the water-rolling that has rounded the pebbles, but have been brought there at a later time.

It is very probable that among the poorer and less civilized inhabitants the use of stone tools may have continued to a comparatively late period. No one who has seen the primitive implements still in use in some of the Western Isles of Scotland will think this unlikely. I therefore do not consider that the fact of such remains being found to be of later date than the raised beach forms an objection of any weight to Mr. Geikie's opinion as to this last elevation being posterior to the Roman invasion. A tribe of these "flint folks" seems to have inhabited this neighbourhood for a long period; for I have observed the débris of the stone manufacture, and traces of their encampments, in various places. The flints were doubtless got from the long ridge covered with these pebbles which runs inland from Peterhead.

§ 8. CONCLUSION AND RÉSUMÉ.

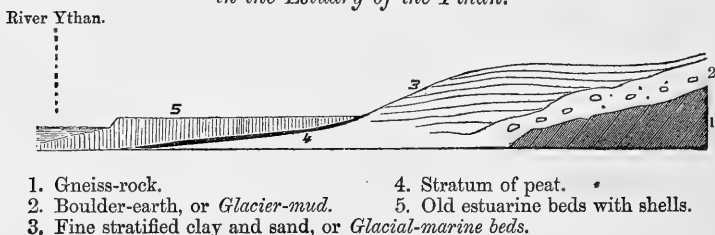
Such, then, are the series of changes which I believe have taken place since the commencement of the Glacial period. This succession has not been arrived at by picking out and putting together facts from distant places, and thereby erroneously inferring things to be successive which were perhaps contemporaneous; for we find the whole series represented in one locality. Thus, in the valley of the Forth above Stirling (fig. 9), we have (1st) at the surface the deep peat-mosses of Polder and Blair-Drummond, with their felled trees and ancient road at the bottom, all resting on (2nd) the old estuarine mud or Carse of Stirling, with its whale-skeletons and beds of estuarine shells; and below this we have (3rd) the lower peat-bed and trees of the submarine forest, or period of elevation; (4th) we have the later glacier-moraines of the Loch of Monteith emerging from beneath this postglacial series; (5th) we have the glacial-marine beds extending from Bucklyvie along the Forth and Clyde Junction Railway to Drymen, from their higher position evidently older than the moraines just mentioned, and shown to be a sea-deposit from the boreal shells they contain at Gartness; (6th) we have all along the valley, from Ben Lomond to Stirling and Edinburgh, and underlying the whole of the superficial deposits, the ice-worn floor of solid rock, covered here and there with the old glacier-mud and scratched boulders, and in this old boulder-earth, at Clifton Hall, there was found a tusk of the Mammoth.

In the valley of the Tay we have the raised estuarine mud of the Carse of Gowrie, with its bed of estuarine shells lying on the top of the peat-bed or submarine forest of the Tay at Polgavie and elsewhere. Emerging from beneath this postglacial series we have

the marine clay, at Errol brickwork, full of Arctic shells *in situ*, and reposing on the irregular surface of the azoic boulder-earth.

Even in the little valley of the Ythan we have a very complete exhibition of the series. Thus, in the section opened up by the railway, where it crosses the valley near Ellon (fig. 2), we have, commencing at the bottom (1st), the ice-worn gneiss covered by the grey glacier-mud with heavy scratched boulders all brought from the westward, and (2nd) reposing on this a mass of fine laminated red marine clay, found to be upwards of 20 feet deep at the foundation of the railway bridge; (3rd) resting on this clay at the bridge there is a mass of rough valley-gravel 15 feet thick; while, more recent than all these, we find at the estuary, fig. 10, (4th) the bed of peat with remains of trees resting on the gravel; (5th) the raised estuarine mud with shells on the top of this peat; and (6th) covering this raised estuarine silt we have heavy masses of blown sand, old shell-mounds and chipped flints, and in some places a little peat.

Fig. 10.—Section showing the relations of the superficial Deposits in the Estuary of the Ythan.



- | | |
|---|------------------------------------|
| 1. Gneiss-rock. | 4. Stratum of peat. |
| 2. Boulder-earth, or Glacier-mud. | 5. Old estuarine beds with shells. |
| 3. Fine stratified clay and sand, or Glacial-marine beds. | |

I therefore infer, from the evidence adduced in this and my former papers, that in Scotland there has been a succession of conditions during the Post-tertiary period somewhat as follows:—

1st. After the deposition of the Crag-gravel, and after the Mammoth had lived in Scotland, the country was covered with a great depth of snow and ice, which must have extinguished the pre-existing flora and fauna. This ice moved outwards in broad streams from the great watersheds of the country, carrying with it much stony débris and multitudes of boulders, which it left in irregular sheets, constituting the old boulder-clay or “till” of some authors; the ice also scratched and furrowed the rocks, destroyed the pre-existing alluvium, and exercised a considerable amount of abrasion on the surface of the country.

2nd. After this state of things had continued for a time, a depression of the land took place to the extent of some hundreds of feet, so that all the lower grounds were below the sea-level, but as to the full extent of the depression we are still ignorant. During this submergence the brick-clays containing Arctic shells were deposited, boulders were drifted here and there by floating ice, and it seems probable that the ice still covered much of the land, and even protruded into the sea along the main valleys in the form of large glacier-streams; so that the condition of the country would have been like the present state of Spitzbergen.

3rd. The country emerged from the water, but ice still lay on much of the land, and perhaps reoccupied some of the tracts over which the sea had spread, deranging by its intrusive action the marine beds of the preceding period.

4th. The glaciers at length began their final retreat, leaving behind them heaps of rough débris and mounds of gravel, more especially at those points where they halted for a time. Large quantities of rolled gravel were also strewed along the valleys by the water issuing from beneath the ice, and by the floods occasioned by rapid thaws, the absence of vegetation on much of the surface probably contributing to the effect.

5th. By this time the land attained a higher level than it has at present, so that the area of Britain was much larger than it is now, and, instead of presenting the appearance of a group of islands, formed a mass of connected land united to the Continent of Europe, the flora and fauna of which now spread into it. Woods of Birch, Hazel, Alder, and other trees covered the surface, and the Great Irish Elk, the Red Deer, the Great Wild Bull, the Wolf, the Bear, the Beaver, and probably the Reindeer, were amongst its inhabitants. In the valleys the rivers were gradually cutting their way through the masses of glacial débris to lower levels, and in doing so spread out much gravel and alluvial soil along their banks. This period is represented by the submarine forest and bed of peat underlying the Carse of the Tay and Forth.

6th. A depression now took place, cutting off the land-connexion with the Continent, isolating Ireland and the various islands, and thus stopping the land-migration from Europe. In the valley of the Tay and Forth this old coast-line was 25 or 30 feet above the present, but on the coast of Aberdeenshire not beyond 8 or 10. The old estuarine beds, or Carse, of the Forth, Tay, and other rivers were formed, together with corresponding shingle-beaches and caves along the coast. Man having by this time got into the country, evidence of his presence appears in the shape of canoes and primitive weapons of stone and horn buried in deposits of the period.

7th. A movement of elevation (whether gradual or sudden is uncertain) at length took place, so that the land attained its present position, thereby laying dry the Carse districts and old coast-line. Since this occurred much peat has been formed, and a great amount of blown sand has been heaped up on certain parts of the coast. In some districts the natives continued for a time to use tools and weapons of flint and stone, and left shell-mounds in the neighbourhood of the estuaries. Some of the wild animals were gradually extirpated, such as the Great Wild Bull, the Bear, the Beaver, the Wolf, and the Capercailzie,—the Great Elk and the Reindeer having probably disappeared at an earlier period. Since the dawn of Scottish history, and the occupation of the lowlands by the Saxon race, no noticeable change of level has been observed.

§ 9. APPENDIX, WITH LISTS OF SHELLS.

The following lists of shells owe their value almost entirely to the kind assistance I have received from Mr. J. Gwyn Jeffreys, F.R.S.,

&c., who has inspected my collection, and determined the species. The geographical distribution is also entirely on his authority.

I have inserted two species got at Elie by the Rev. Mr. Brown which are not in my own collection; for the others I am myself responsible. The names adopted are those proposed by Mr. Jeffreys. In regard to the British species I have appended as synonyms those of Forbes and Hanley where they happen to be different.

Explanatory Note regarding the Localities on the East of Scotland, referred to in the following List.

- Annochie.* On the Aberdeenshire coast, about five miles north of the town of Peterhead. The shells are entire, with the epidermis generally remaining; they are, however, much decayed, and are dispersed through a bed of fine clay, only a few feet above the sea-level, and passing underneath the beach. *Foraminifera* occur in this clay.
- Auchleuchries.* Twenty miles north of Aberdeen and seven miles inland. The shells occur in broken fragments, at an elevation of about 300 feet above the sea, in a thick mass of gravel forming the crest of a low hill. The fragments are very scarce, and occur deep in the gravel.
- Belhelvie.* A clay-pit close on the sea, five miles north of Aberdeen, and 30 or 40 feet above high-water-mark. The shells occur generally in fragments in a blackish stratum in the midst of a bed of laminated clay and sand. Dr. Fleming, who had visited it often when the section was better exposed than it is now, says this fine laminated clay "rests on the ordinary boulder-clay, and is covered by the usual sands and gravels."
- Ednie.* A bed of fine laminated clay on the north bank of the Ugie River, and four miles from Peterhead, and at no great height above the sea. The shells are scanty, and occur usually in broken fragments in a thin seam in the midst of the clay. The large *Saxicava*, however, has been got here entire.
- Elie.* On the coast of Fife, eleven miles south of St. Andrews. The shells are in a bad state of preservation, imbedded in clay which passes underneath the sea. Explored by the Rev. T. Brown, and the shells named by Dr. Otto Torell.
- Ellishill.* The shells here occurred in red clay in a railway cutting three miles west of Peterhead, at an elevation of about 120 feet above the sea, and were sent me by Mr. A. Stephen Wilson. *Saxicava* entire.
- Errol.* A clay-pit on the north side of the River Tay, eight miles east of Perth, and about 45 feet above the sea. The shells are entire, but much decayed. *Leda arctica* and the two *Modiolaria* very numerous. Entomostraca of the genus *Cythere* also occur.
- Gamrie.* On the sea-coast seven miles east of Banff. The shells were first noticed by Mr. Prestwich, and occur in a thin seam of sand at an elevation of about 150 feet; many of them are entire. The strata of fine sand and clay in which they occur are of great thickness, and extend to a height of 300 feet or more.

Invernettie. A brickwork on the Aberdeenshire coast one mile south of Peterhead; shells mostly broken. See Quart. Journ. Geol. Soc. vol. xiv. p. 517.

King Edward. About five miles S.S.E. of Banff. The shells occur in silt and gravel at an elevation of from 150 to 200 feet, many of them entire, and some of them *in situ*; but the nature of the section is not well exposed. I have been much assisted in collecting the fossils by Mr. J. Runciman, and by the Rev. T. Milne. *Foraminifera* occur here. The great similarity of the fossils to those of Gamrie leads me to think that both shell-seams belong to the same period.

Montrose. The shells are entire, but much decayed, and occur deep down in a mass of fine laminated reddish-brown clay of immense thickness (50 to 100 feet), and not many feet above the sea-level, in the brickworks of Dryleys, and Puggiston, about a mile west of the town of Montrose. The shells were first noticed by Dr. Howden, physician to the Montrose Lunatic Asylum, who has obtained a number of Starfishes from the Dryleys section. The skeleton of a seal was got some years ago at the Puggiston pit. Minute Entomostraca of the genus *Cythere* have been detected by the Rev. H. Mitchell of Craig, and occur both at Puggiston and at Dryleys.

Tyrie. On the coast of Fife, near Kinghorn. The shells were detected by that veteran naturalist Dr. Fleming. What he named *Pecten similis* was doubtless the same as *P. Groenlandicus*, which seems to be only a large northern variety of that shell. (See Jeffreys's 'British Conchology,' vol. ii. p. 72.)

1. List of Shells found in the glacial beds of the East of Scotland, between the Moray Firth and the Firth of Forth.

No.	Species and Localities.	Living on the Coasts of Britain.	Living to the South of Britain.	Living within the Arctic Circle.	Living on the East Coast of North America.	Living in the North Pacific.
1	<i>Anomia ephippium</i> , <i>Linné</i> . Gamrie	*	*	*	*	
2	<i>Aporrhais pes-pelecani</i> , <i>Linn</i> . King Edward	*	*	*		
3	<i>Astarte borealis</i> , <i>Chemnitz</i> . Gamrie, King Edward, Belhelvie, Invernettie, Auchleuchries, Errol = <i>A. arctica</i> , <i>Forbes & Hanley</i> .			*	*	
4	<i>Astarte compressa</i> , <i>Montagu</i> . Gamrie, Elie	*		*	*	
5	<i>Astarte sulcata</i> , <i>Da Costa</i> . var. <i>elliptica</i> , <i>Brown</i> . Belhelvie = <i>A. elliptica</i> , <i>F. & H</i> .	*		*	*	
6	<i>Axinus flexuosus</i> , <i>Montagu</i> . = <i>Lucina flexuosa</i> , <i>F. & H</i> . var. <i>Sarsii</i> , <i>Lovén</i> . Annochie			*	*	

List of Shells (continued).

No.	Species and Localities.	Living on the Coasts of Britain.	Living to the South of Britain.	Living within the Arctic Circle.	Living on the East Coast of North America.	Living in the North Pacific.
7	<i>Axinus ferruginosus</i> , <i>Forbes</i> . Annochie = <i>Lucina ferruginosa</i> , <i>F. & H.</i>	*	*	*	*	*
8	<i>Buccinum undatum</i> , <i>Linn.</i> Gamrie	*	*	*	*	*
9	<i>Cardium echinatum</i> , <i>Linn.</i> Gamrie, King Edward, Belhelvie	*	*	*	*	*
10	<i>Cardium Grœnlandicum</i> , <i>Chemnitz.</i> Gamrie, King Edward	*	*	*	*	*
11	<i>Cardium edule</i> , <i>Linn.</i> Ellishill	*	*	*	*	*
12	<i>Crenella decussata</i> , <i>Montagu.</i> Elie	*	*	*	*	*
13	<i>Crenella faba</i> , <i>Müller.</i> Errol	*	*	*	*	*
14	<i>Cylichna alba</i> , <i>Brown.</i> Annochie	?		*	*	*
15	<i>Cyprina Islandica</i> , <i>Linn.</i> Gamrie, King Edward, Auchleuchries, Belhelvie, Invernettie, Elie, Ellis- hill	*	*	*	*	*
16	<i>Dentalium entalis</i> , <i>Linn.</i> Gamrie, King Edward, Belhelvie	*	*	*	*	*
17	<i>Fusus propinquus</i> , <i>Alder.</i> Gamrie, King Edward .	*	*	*	*	*
18	<i>Lacuna divaricata</i> , <i>Fabricius.</i> Gamrie, King Edward = <i>L. vineta</i> , <i>F. & H.</i>	*	*	*	*	*
19	<i>Leda arctica</i> , <i>Gray.</i> Montrose, Errol, Elie, Tyrie . = <i>Nucula truncata</i> , <i>Brown.</i> = <i>Nucula Portlandica</i> , <i>Hitchcock.</i>			*	*	
20	<i>Leda limatula</i> , <i>Say.</i> King Edward			*	*	
21	<i>Leda lucida</i> , <i>Loven.</i> King Edward			*	*	
22	<i>Leda pygmæa</i> , <i>Münster.</i> Annochie, Montrose, Errol, Elie	*	?	*	*	
23	<i>Littorina squalida</i> , <i>Broderip & Sowerby.</i> Ellishill, Invernettie = <i>Turbo expansus</i> , <i>Brown.</i>			*	*	
24	<i>Mactra solida</i> , <i>Linn.</i> var. <i>elliptica</i> , <i>Brown.</i> Gamrie	*	*	*		
25	<i>Mangelia pyramidalis</i> , <i>Stromeyer.</i> Gamrie, King Edward = <i>Defrancia VahlII</i> , <i>Beck.</i>			*	*	
26	<i>Mangelia turricula</i> , <i>Montagu.</i> Gamrie, King Ed- ward	*	*	*	*	
27	<i>Margarita Grœnlandica</i> , <i>Chemnitz.</i> var. <i>undulata</i> . Errol = <i>M. undulata</i> , <i>Brod. & Sow.</i>	*		*	*	
28	<i>Mesalia erosa</i> , <i>Couthouy.</i> Elie = <i>Turritella polaris</i> , <i>Beck.</i>			*	*	
29	<i>Mesalia reticulata</i> , <i>Mighels & Adams.</i> King Ed- ward = <i>Turritella lactea</i> , <i>Möller.</i>			*	*	
30	<i>Modiolaria discors</i> , <i>Linn.</i> var. <i>lævigata</i> , <i>Gray.</i> Errol, Elie			*	*	*
31	<i>Modiolaria nigra</i> , <i>Gray.</i> Errol = <i>Crenella nigra</i> , <i>F. & H.</i>	*		*	*	*

List of Shells (continued).

No.	Species and Localities.	Living on the Coasts of Britain.	Living to the South of Britain.	Living within the Arctic Circle.	Living on the East Coast of North America.	Living in the North Pacific.
32	<i>Mya truncata</i> , Linn. King Edward, Elie.	*	*	*	*	*
33	<i>Mytilus edulis</i> , Linn. Gamrie, Ellishill	*	*	*	*	*
34	<i>Nassa incrassata</i> , Müller. King Edward	*	*	*	*	*
35	<i>Natica affinis</i> , Gmelin. Gamrie, King Edward . . . = <i>N. clausa</i> , Brod. & Sow.	*	*	*	*	*
36	<i>Natica Islandica</i> , Gmelin. Gamrie, King Edward . . = <i>N. helicoides</i> , Johnston, and F. & H.	*	*	*	*	*
37	<i>Natica Marochiensis</i> , Gmelin. King Edward . . . = <i>N. nitida</i> , Donovan, and F. & H.	*	*	*	*	*
38	<i>Natica pallida</i> , Brod. & Sow. Gamrie, King Edward, Elie, Errol = <i>N. Grœnlandica</i> , Beck. = <i>N. pusilla</i> , F. & H.	*	*	*	*	*
39	<i>Nucula tenuis</i> , Montagu. Annochie, Montrose . . .	*	*	*	*	*
40	<i>Pecten Grœnlandicus</i> , Sowerby. Montrose, Errol, Elie, Tyrie? = <i>P. vitreus</i> , Gray, but not Chemn.	*	*	*	*	*
41	<i>Pecten Islandicus</i> , Müller. Belhelvie, Ellishill . . .	*	*	*	*	*
42	<i>Pholas crispata</i> , Linn. Gamrie, King Edward . . .	*	*	*	*	*
43	<i>Purpura lapillus</i> , Linn. Auchleuchries	*	*	*	*	*
44	<i>Saxicava Norvegica</i> , Spengler. Belhelvie = <i>Panopœa Norvegica</i> , F. & H.	*	*	*	*	*
45	<i>Saxicava rugosa</i> , Linn. Annochie, Ednie, Ellishill, Belhelvie, Montrose, Errol, Elie, var. <i>arctica</i> , large form	*	*	*	*	*
46	<i>Scalaria Grœnlandica</i> , Chemnitz. King Edward . . .	*	*	*	*	*
47	<i>Tectura virginea</i> , Müller. Gamrie = <i>Acmœa virginea</i> , F. & H.	*	*	*	*	*
48	<i>Tellina Balthica</i> , Linn. Gamrie, King Edward, Belhelvie = <i>T. solidula</i> , F. & H.	*	*	*	*	*
49	<i>Tellina calcarea</i> , Chemn. Gamrie, King Edward, Belhelvie, Elie, Errol = <i>T. proxima</i> , Brown, and F. & H.	*	*	*	*	*
50	<i>Thracia myopsis</i> , Beck. Errol, Elie	*	*	*	*	*
51	<i>Trophon clathratus</i> , Linn. Gamrie, King Edward, Belhelvie = <i>Fusus scalariformis</i> , Gould. = <i>Fusus Peruvianus</i> , Sowerby = <i>Trophon scalariforme</i> , Searles V. Wood.	*	*	*	*	*
52	<i>Trophon clathratus</i> , Linn. var. <i>Gunneri</i> , Lovén. Gamrie, King Edward . . .	*	*	*	*	*
53	<i>Trophon truncatus</i> , Ström. Gamrie, King Edward . . = <i>Murex Bamfius</i> , Donovan. = <i>Trophon clathratus</i> , F. & H.	*	*	*	*	*
54	<i>Turritella unguilina</i> , Linn. King Edward, Auchleuchries = <i>T. communis</i> , Risso, and F. & H.	*	*	*	*	*

	Per cent.
British	59·3
Southern	37·0
Arctic	100·0
N. E. American	90·7
N. Pacific	18·5

My friend Mr. Robert Dawson of Cruden, who has explored the malacology of the Aberdeenshire coast with great success, tells me that when dredging he finds a great many semifossil Arctic shells belonging to species which he never meets with alive. These he supposes (and, I think, with great probability) to be derived from glacial beds passing underneath the sea, and extending for a considerable distance out from the coast. He has kindly furnished me with the following list of these shells, in reference to which he says, "All the fossils included in the list were dredged by me off the coasts of Cruden and Slains, at a distance of from three to eight miles from land, and at the depth of from 30 to 45 fathoms. As, however, some of them (*Trophon scalariformis* and *Gunneri*, *Pecten Islandicus*, &c.) have been brought up by the fishermens' lines at the distance of thirty miles from land, I believe that the fossil-deposit, whatever it may be, extends to a great distance seaward. The reason why they are not found nearer land appears evidently to be that the sea-bottom, for at least three miles from shore, consists of fine sand, covering probably the fossil-deposit beneath. None of these species have been found by me *alive*; and from the appearance of all the specimens, I believe that none of them are alive in this district."

No.	Species.	Living on the Coasts of Britain.	Living to the South of Britain.	Living within the Arctic Circle.	Living on the East Coast of North America.	Living in the North Pacific.
1	<i>Astarte borealis</i> , <i>Chemn.</i>			*	*	*
2	<i>Astarte sulcata</i> , var. <i>elliptica</i>	*		*	*	*
3	<i>Astyris</i> (<i>Columbella</i>) <i>Hölböllii</i> , <i>Beck</i> (= <i>Mangelia Hölböllii</i> , <i>Möller</i>)			*	*	*
4	<i>Cardium exiguum</i> , <i>Gmelin</i> (= <i>C. pygmæum</i> , <i>F. & H.</i>)	*	*	*	*	*
5	<i>Corbula gibba</i> , <i>Olivi</i> (= <i>C. nucleus</i> , <i>Lam. & F. & H.</i>)	*	*	*	*	*
6	<i>Cyclostrema costulatum</i> , <i>Mörch</i> (= <i>Skenea? costulata</i> , <i>F. & H.</i>)			*	*	*
7	<i>Lepeta cæca</i> , <i>Müller</i> (= <i>Patella cerea</i> , <i>Möller</i>)			*	*	*
8	<i>Margarita striata</i> , <i>Brod. & Sow.</i> (= <i>M. cinerea</i> , <i>Couthouy</i>)			*	*	*
9	<i>Mesalia? borealis</i> , <i>Beck</i> (= <i>Scalaria Eschrichti</i> , <i>Möller</i>)			*	*	*
10	<i>Mya truncata</i> , var. <i>Uddevallensis</i>			*	*	*
11	<i>Natica affinis</i> , <i>Gmelin</i> (= <i>N. clausa</i>)			*	*	*
12	<i>Natica Islandica</i> , <i>Gmelin</i> (= <i>N. helicoides</i> , <i>F. & H.</i>)	*		*	*	*

List of Shells (continued).

No.	Species.	Living on the Coasts of Britain.	Living to the South of Britain.	Living within the Arctic Circle.	Living on the East Coast of North America.	Living in the North Pacific.
13	<i>Pecten Islandicus</i> , Müller			*	*	
14	<i>Rhynchonella psittacea</i> (= <i>Terebratula psittacea</i> , Lam.)			*	*	*
15	<i>Saxicava rugosa</i> , var. <i>arctica</i> , large form			*	*	
16	<i>Tellina calcarea</i> , Chemn. (= <i>T. proxima</i>)			*	*	
17	<i>Trophon clathratus</i> , L. (= <i>Fusus scalariformis</i> , Gould)			*	*	
18	<i>Trophon clathratus</i> , var. <i>Gunneri</i> , Lovén			*	*	

2. List of Shells collected in the clay-pits at Paisley, near Glasgow; about 20 feet above the sea. (See page 176.)

1	<i>Astarte compressa</i> , Montagu. Common	*		*	*	
2	<i>Axinus flexuosus</i> , Mont., var. <i>Gouldii</i> . A few			*	*	*
3	<i>Buccinum undatum</i> , Linn. Of all sizes, not uncommon	*	*	*	*	
4	<i>Cardium edule</i> , Linn. One valve	*	*	*	*	
5	<i>Cyprina Islandica</i> , Linn. Very common, and of all sizes	*	*	*	*	
6	<i>Lacuna divaricata</i> , Fabricius. Two	*	*	*	*	*
7	<i>Leda pernula</i> , Müller. A few	?		*	*	*
8	<i>Leda pygmaea</i> , Münster. Not uncommon	*	?	*	*	*
9	<i>Littorina litorea</i> , Linn. Four, one of them of large size.	*	*	*	*	
10	<i>Littorina limata</i> , Lovén. Two			*	*	
11	<i>Littorina squalida</i> , Brod. & Sow. Two			*	*	
12	<i>Littorina rudis</i> , Donovan. A few	*	*	*	*	
13	<i>Mangelia pyramidalis</i> , Stromeyer. One			*	*	
14	<i>Mya truncata</i> , Linn. Several young shells	*	*	*	*	*
15	<i>Mytilus edulis</i> , Linn. Not uncommon	*	*	*	*	*
16	<i>Mytilus modiolus</i> , Linn. Not uncommon	*		*	*	*
17	<i>Natica pallida</i> , Brod. & Sow. Five; one of them $\frac{3}{4}$ of an inch	*		*	*	
18	<i>Nucula tenuis</i> , Mont., var. <i>inflata</i> , Hancock. Not uncommon	*		*	*	*
19	<i>Pecten Islandicus</i> , Müller. One valve			*	*	
20	<i>Rissoa parva</i> , Da Costa. A few	*	*	*	*	
21	<i>Rissoa striata</i> , Montagu. A few	*	*	*	*	
22	<i>Tellina calcarea</i> , Chemn. Common, of various sizes			*	*	
23	<i>Trophon clathratus</i> , Linn. Six; the largest $1\frac{1}{8}$ of an inch			*	*	
24	<i>Trophon clathratus</i> , var. <i>Gunneri</i> , Lovén. One, nearly an inch long			*	*	
25	<i>Trophon truncatus</i> , Stromeyer. Three	*		*	*	
26	<i>Velutina undata</i> , Brown. One = <i>V. zonata</i> , Gould.			*	*	

	Per cent.
British	61·5
Southern	38·4
Arctic	100·0
N. E. American	84·6
N. Pacific	23·0

3. *List of Shells from the brick-work at Kilchattan, in the island of Bute, about 20 feet above the sea. (See page 174.)*

No.	Species.	Living on the Coasts of Britain.	Living to the South of Britain.	Living within the Arctic Circle.	Living on the East Coast of North America.	Living in the North Pacific.
1	<i>Anomia ephippium</i> , <i>Linn.</i> , var. <i>aculeata</i> . One specimen	*	*	*	*	
2	<i>Axinus flexuosus</i> , <i>Mont.</i> , var. <i>Gouldii</i> . Eight or nine single valves			*	*	*
3	<i>Buccinum undatum</i> , <i>Linn.</i> . A few	*	*	*	*	
4	<i>Cyprina Islandica</i> , <i>Linn.</i> . A few	*	*	*	*	
5	<i>Lacuna divaricata</i> , <i>Fabricius</i> . Three	*	*	*	*	*
6	<i>Leda pernula</i> , <i>Müller</i> . Nine, mostly entire	?		*	*	*
7	<i>Leda pygmaea</i> , <i>Münster</i> . One valve		?	*	*	*
8	<i>Littorina litorea</i> , <i>Linn.</i> . Two	*	*	*	*	
9	<i>Montacuta ferruginosa</i> , <i>Mont.</i> . One entire valve, full size			*	*	
10	<i>Mya truncata</i> , <i>Linn.</i> . Several	*	*	*	*	*
11	<i>Mytilus modiolus</i> , <i>Linn.</i> . One small valve	*		*	*	*
12	<i>Mangelia pyramidalis</i> , <i>Strom.</i> . One			*	*	
13	<i>Natica pallida</i> , <i>Brod. & Sow.</i> . About a dozen	*		*	*	*
14	<i>Natica affinis</i> , <i>Gmelin</i> . One or two			*	*	*
15	<i>Scrobicularia prismatica</i> , <i>Montagu</i> . One entire specimen	*	*	*		
	= <i>Syndosmya prismatica</i> , <i>F. & H.</i>					
16	<i>Tellina calcarca</i> , <i>Chemn.</i> . In great abundance and entire, of all sizes up to one inch			*	*	

	Per cent.
British	68·7
Southern	50·0
Arctic	100·0
N. E. American	87·5
N. Pacific	31·2

4. *List of Shells found in a seam of gravel at a railway-cutting between Drymen and Gartness, Stirlingshire, at about 120 feet above the sea. (See page 172.)*

1	<i>Anomia ephippium</i> , <i>Linn.</i> . One	*	*	*	*
2	<i>Astarte compressa</i> , <i>Mont.</i> . Four entire valves and many fragments	*		*	*
3	<i>Astarte sulcata</i> , <i>Da Costa</i> . var. <i>elliptica</i> , <i>Brown</i> . Broken pieces very common	*		*	*

List of Shells (continued).

No.	Species.	Living on the Coasts of Britain.	Living to the South of Britain.	Living within the Arctic Circle.	Living on the East Coast of North America.	Living in the North Pacific.
4	<i>Buccinum undatum</i> , <i>Linn.</i> A few fragments . . .	*	*	*	*	
5	<i>Cardium echinatum</i> , <i>Linn.</i> One fragment . . .	*	*	*	*	
6	<i>Cyprina Islandica</i> , <i>Linn.</i> Broken pieces very common . . .	*	*	*	*	
7	<i>Littorina litorea</i> , <i>Linn.</i> Six, more or less broken . . .	*	*	*	*	
8	<i>Littorina squalida</i> , <i>Brod. & Sow.</i> One . . .	*	*	*	*	
9	<i>Mya truncata</i> , <i>Linn.</i> Two hinge-pieces . . .	*	*	*	*	*
10	<i>Natica affinis</i> , <i>Gmelin</i> , = <i>N. clausa</i> , <i>Brod. & Sow.</i> One small specimen . . .			*	*	*
11	<i>Pecten Islandicus</i> , <i>Müller.</i> Many fragments . . .			*	*	
12	<i>Tectura virginea</i> , <i>Müller.</i> One small imperfect specimen . . .	*	*	*		
13	<i>Trophon clathratus</i> , <i>Linn.</i> Two specimens, not very large . . .			*	*	
14	<i>Trophon truncatus</i> , <i>Strom.</i> One . . .	*		*	*	

	Per cent.
British	71·4
Southern	50·0
Arctic	100·0
N. E. American	92·8
N. Pacific	14·2

5. Shells of the old estuarine beds of the East of Scotland. Post-Glacial. (See page 188.)

1	<i>Cardium edule</i> , <i>Linn.</i> Ythan, Aberdeen, Montrose, Forth	*	*	*		
2	<i>Cylichna obtusa</i> , <i>Montagu.</i> Montrose (<i>Rev. H. Mitchell</i>)	*	*			
3	<i>Fusus antiquus</i> , <i>Linn.</i> Forth. One specimen	*	*	*		
4	<i>Hydrobia ulvæ</i> , <i>Pennant.</i> Ythan, Montrose, Forth = <i>Rissoa ulvæ</i> , <i>F. & H.</i>	*	*	*		
5	<i>Littorina litorea</i> , <i>Linn.</i> Ythan, Aberdeen, Montrose, Forth	*	*	*	*	
6	<i>Mytilus edulis</i> , <i>Linn.</i> Aberdeen, Forth	*	*	*	*	*
7	<i>Ostrea edulis</i> , <i>Linn.</i> Forth	*	*	?	*	
8	<i>Scrobicularia piperata</i> , <i>Gmelin.</i> Spynie, Ythan, Aberdeen, Montrose, Forth	*	*			
9	<i>Tellina Balthica</i> , <i>Linn.</i> Ythan, Aberdeen, Montrose, Forth	*	*	*	*	

	Per cent.
British	100·0
Southern	100·0
Arctic	66·6
N. E. American	44·4
N. Pacific	11·1

JANUARY 25, 1865.

William Grylls Adams, Esq., M.A., Fellow of St. John's College, Cambridge, Lecturer on Natural Philosophy in King's College, London; and Capt. Stewart Smyth Windham, 14 Connaught Place, W., were elected Fellows.

The following communications were read:—

1. *On the CLIMATE of the PLEISTOCENE EPOCH in NEW ZEALAND.* By JULIUS HAAST, Ph.D., F.G.S.

[This paper was printed in No. 82, p. 135, by order of the Council.]

2. *On the ORDER of SUCCESSION in the DRIFT-BEDS of the ISLAND of ARRAN.* By JAMES BRYCE, M.A., LL.D., F.G.S.

THE island of Arran has long been celebrated for the number of rock-formations, sedimentary and plutonic, which it contains, and for the varied relations in which they are displayed. A new interest has lately been imparted to it by the discovery of fossils in its superficial beds. Deep accumulations of clay, gravel, and sand had long been known to exist in its southern glens; but no one had examined them, either in the hope of finding fossils or with the view of working out an order of succession among the beds.

The fossils are shells chiefly of Arctic species; and the fortunate discoverer was the Rev. R. B. Watson, of Edinburgh. An account of the discovery was laid by him before the Royal Society of Edinburgh, on the 4th of January, 1864, and published in brief abstract in the 'Proceedings' of the Society in April of that year. The paper itself did not appear until five months later*. From this abstract, which came into my hands soon after its publication, it appeared that the entire mass of beds, often above 100 feet thick, was designated as Boulder-clay, and that the shells were not assigned to any particular place in the deposit. Now as this view was opposed to that which I held in common with most geologists of the west of Scotland, namely, that the entire mass of beds ought not to be embraced in one term "Boulder-clay," and that the Arctic shells have a peculiar position, I was anxious to examine the Arran beds for myself, in order to test the accuracy of the view, under the favourable circumstance of having a district wholly isolated from connexion with any other. It is but justice to Mr. Watson to say that when I mentioned to him my intention of visiting Arran in order to examine the beds, he at once, in the most frank and cordial manner, made known to me all the localities in which he had found the shells, and gave me other information which saved me much time and labour on my first visit in May last. I found in a few hours ten of the seventeen species discovered by Mr. Watson.

* "On the Great Drift-beds with Shells in the South of Arran," by the Rev. Robert Boog Watson, B.A., F.R.S.E., Trans. R.S.E. vol. xxiii. part 3.

I satisfied myself that the shells lay on a particular horizon, and that the drifts were capable of a clear division. A second visit was paid to these beds early in June, when additional shells were found, and the entire series again most carefully examined*.

In conducting this examination, the object of enlarging the list of fossils was held quite subordinate to that of working out the natural succession of the beds, and establishing definite relations among them. It has long been common, and the practice still prevails to some extent, to overlook the distinctions among the Drift-beds and to class the whole, under the term "Boulder-clay" or "Till," as one formation. There can be little doubt, however, that if the beds of each particular district were carefully examined, an order of succession marked by distinct characters would be found in most cases to exist. But the subject is difficult, and the appearances misleading; causes of error present themselves which are not met with in the case of rocky strata. These must now be briefly stated.

The upper layers under the surface-soil are of loose texture and pervaded by fissures, while the lower layers, consisting of dense clay, are retentive of water. Thus a great hydrostatic pressure comes to be exercised; and since the beds have not that coherence which enables one part to lend support to another, a slip takes place. The same effect is produced by the undermining of a stream, or the action of waves and tides. The order of the beds is thus completely masked; a bed high in a bank or cliff may by such a landslip be placed in front of the lowest bed, and so remain for a long time, until by successive slips and undermining the whole is washed away and the natural order of the beds is once more revealed. If taking place throughout the whole height of the bank, it will often happen that such a slip will show itself by inequalities along the grassy brows at the summit; but in many cases there is no such evidence of its occurrence, and the slip can only be detected by careful searching and an experienced eye. There is, beside all this, the action, in the exposed surface of such a vertical section, of the sun and air, the beating of rain, and trickling of runlets of water: these produce a general wash-over, which gives the same facing to all the beds, and completely obscures the natural order of succession. The wash renders it impossible to see the line of junction, and it is often necessary to search over a large surface. One finds a hammer almost useless among such beds; a pickaxe and spade are needed for opening up the beds, and clearing off debris; but these are weapons which the geologist can seldom carry to the field; yet without them he will find it impossible to clear off the planes of junction so as to expose the true succession.

The Arran shell-beds are most easily visited from the hotel at Lag, near the south end of the island. They are well exhibited in

* On the second visit, I had the pleasure of being accompanied by the Rev. H. W. Crosskey, of Glasgow, one of the most zealous and successful labourers among the newer Tertiaries of Clydesdale since Mr. Smith, of Jordanhill, ceased to work actively among them.

the banks of the Torlin and Slaodridh Burns and their two main tributaries; and the best sections are within an easy distance of the hotel. The Clenid Burn enters Torlin-water a little way above Lag; and on its eastern bank, about a quarter of a mile up, there is a good development of these beds. The base of the section here, over the sandstone rock, is an unstratified clay of a red or chocolate-brown colour, often with a bluish tinge, full of boulders of all sizes, both angular and rounded, usually striated and thrown together pell-mell. The clay is excessively hard and tough, workable only by the pickaxe. The stones are of all sizes, from small pebbles to very large boulders, and confusedly mixed without reference to weight. It is very striking to observe the striations upon the great majority of the stones, the rounding off upon the edges and the high polish acquired by all alike, of whatever size. The majority of the stones are local; but though sandstone is here the prevailing rock, and the deposit rests on it, comparatively few of the boulders are sandstone; porphyry, syenite, and greenstone, which form the higher grounds and hills northwards, abound; but there are also granite of the coarse-grained or Goat-fell variety, and slate, both from the northern mountains, between which and the present lodgment of the blocks there are many high ridges and deep glens.

The bed we have been describing is the true old Boulder-clay, or lower Till, and that alone which ought to be designated by this name. The mineral structure above assigned to it, its striated stones, and unworkable nature are sufficient to distinguish it from the other drifts. By the last character it is but too well known to contractors and workmen; it can neither be blasted nor digged into, and is only effectually assailed by a heavy pickaxe, so that the process of removing it in railway-cuttings and foundations is very tedious and costly, more so than the same mass of solid trap or granite would be*.

In the Clenid Burn section this Boulder-clay is from 15 to 20 ft. thick; the upper surface declines southward, or down the burn, so that the bed becomes thicker upwards. Over it and conforming to its upper surface there is a bed of a fine dark clay, hard and compact, with a good many small stones, not generally striated. This bed is very different from that below, being much less compact and more easily worked, and contrasting remarkably in the size and markings of the stones. It is the repository of the shells, and is 7 or 8 feet thick, in the upper part reddish and slightly sandy, in the lower assimilating to the Boulder-clay below, thus

* This character is familiar to Glasgow builders. The deposit swathes the sides of all the hills and lesser slopes within the city, and the foundations of all the higher streets are laid in it. Its rocky masses are most varied; in fact, a nearly complete collection of Scottish rocks may be made from its imbedded stones. Such a collection was, in fact, exhibited in Glasgow at the last meeting of the British Association there. From some of the sections of this deposit within the limits of the city we have obtained polished, grooved, and striated boulders, even more readily than in the terminal moraine of a Swiss glacier. The origin of many of these is to be sought only in the remote mountains of Dumbarton and Argyle.

showing that it was formed partly out of the Boulder-clay, and on the spot, over the bottom where the shells were living. The only shells found in this bed which are absolutely Arctic are *Pecten Islandicus* and *Astarte borealis*, but these are sufficient to show the Arctic character of the bed. The greater number of the shells are in a broken state or in single valves, yet the fragments are generally so large that the species can be determined. The following occur either fragmentary or in single perfect valves, in addition to the two species already given:—*Cyprina Islandica*, *Modiola modiolus*, *Astarte compressa*, *A. elliptica*. The shell-bed is seen over the Boulder-clay from the southern end of the section across its entire front, ascending northwards with the slope of the bed below: the same species are found in it throughout. The part of it most accessible for working is on a slip towards the southern part of the section. The shells are found in no other part of the series except when washed out and carried to lower levels.

Over the shell-bed there is a series of other beds presenting considerable diversity of character among themselves, but, when covered in front, with their facing looking very like the Boulder-clay. When, however, the false face is removed they are seen to be very different; they are more sandy and less compact, more loose and easily broken. The imbedded stones are usually angular; striation or polishing is rarely seen, or if polished there is a far less perfect finish than on the stones of the Boulder-clay, as if they had been exposed, after the polish was put on, to a continual wearing-action. They are, indeed, very like a river-deposit, and have much resemblance to the heaps of detritus left by floods on the banks of the stream below. The series may be designated the "Upper Drifts." The following section presents in descending order the whole series of beds at this place:—

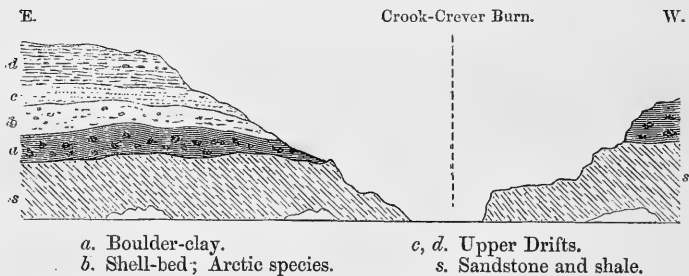
7. Surface soil.
6. Sand and stones, usually reddish; thickness variable.
5. Compact bed of stones, 5 or 6 feet thick, forming a marked line on the cliff; difficult to reach here.
4. Sand, clay, and stones; thickness variable.
3. Dark sandy bed, of open texture, 4 or 5 feet; apparently local.
2. Clay-bed with shells, 7 to 10 feet.
1. Boulder-clay, 12 to 20 feet thick.

On the principal stream, the Torlin-water, opposite to Kilmorie Church, and on the west side of a sweep in the bank, there is a remarkable section. The true Boulder-clay (that is, the lowest bed) is everywhere subject to great and sudden undulations; the upper surface seems as if thrown up in waves and depressed into deep hollows; in some places it becomes rudimentary or thins out wholly, in others, not far removed, it attains great thickness. At the place above indicated, the true Boulder-clay or lower Till is absent, and the shell-bed rests on the natural rock and thins out southward; in the opposite direction there are indications of the Boulder-clay coming on under the shell-bed as the ground rises

up the river. The shell-bed here is very similar to the one already described: it is a dark-coloured, compact clay, with small stones and the same species of shells. Over it is a sandy bed, 12 to 15 inches thick, and above this an Upper Drift of earth and stones. A small part only of the section is vertical; the largest part, up the river, is broken and tossed, and covered with wild shrubs. An observer who had not previously studied the Clenid Burn section would be very likely to confound the shell-bed here with the Boulder-clay.

On the east bank of the Crook-Crever Burn, a tributary of the Slaodridh, about one mile north-west of Lag, fine sections of these beds are seen. The one I shall first notice is at the upper end of a long and deep gorge which the river has cut out in soft sandstone and shale. Sandstone-rock is the base of the section; over this is a bed of Boulder-clay, 30 or 40 feet thick, the clay being hard, compact, and of a structure almost unworkable, with fine examples of striated stones, both blocks and of small size. Its upper part for the thickness of a foot is a hard, dark-coloured, gravelly sand or sandy gravel, extremely hard and obdurate under the pickaxe. Over this, and strongly contrasted with it, lies the shell-bed: it has a structure very similar to that already described. The clay is dark and compact, but very different from the Boulder-clay below in the comparative facility of working it; there are a few small stones, rarely striated. Besides the shells already named, a perfect *Leda* was here met with, and fragments of a *Balanus*. Above the shell-bed are Upper Drifts, like those already described, and strongly contrasting with the true Boulder-clay at the bottom of the section.

Fig. 1.—Section of the Drift-beds of Arran.



Another very good section is met with further down the stream, a little way below the sandstone-gorge above referred to. The bed and banks of the stream are here formed of soft shale, dipping S.W., and rising high on the east side. Over this the Lower Till and other beds are laid in the usual order, following the inclination of the shale, and apparently thinning out westwards. The wash or facing and the débris having been cleared away, the entire section was laid open, from the underlying shale to the Upper Drift-bed; and nothing could be more interesting or perfectly satisfactory than to notice the con-

tacts and the complete distinction between the contiguous beds. The lowest bed, or true Boulder-clay, has its usual character, and does not yield a single shelly fragment; directly the overlying clay is reached, the shells become abundant. The shell-bed has the same structure and contents as in the other sections; over it are the Upper Drifts, strongly contrasting with the Boulder-clay, but less completely shown here owing to the nature of the ground.

This section is highly illustrative of a case which is very apt to mislead an observer, especially when it occurs among basin-shaped or level deposits. It often happens that the beds thin out at the outcrop as rocky strata do, either from an inequality in the original deposition or from their successive erosion. The beds are thus brought so close together that the distinction passes unobserved, and shells from an upper bed get on to the surface of a lower, or perhaps a little way into its substance; on a gently sloping bank by the sea, or by a river-side, the shell-bed might be swept off and its fossils get into the Boulder-clay forming the floor, and thus appearances the most misleading be produced.

The following list contains the species found by the Rev. R. B. Watson in the Arctic shell-beds of Arran:—

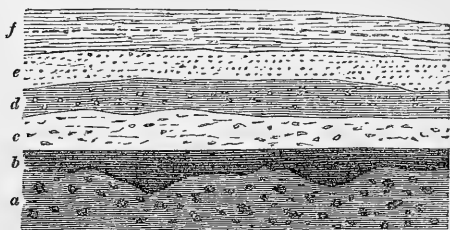
Balanus crenatus.	Cyprina Islandica.
Purpura Norvegica.	Leda pygmaea.
Astarte elliptica.	—— pernula.
—— arctica.	Pecten Islandicus.
—— compressa.	—— opercularis.
—— striata.	Litorina litorea.
Cryptodon Sarsii.	Turritella communis
Modiola modiolus.	Natica (?).
Tellina Baltica.	

Of Foraminifera and Entomostraca the following species, named by Mr. Rupert Jones, were found by Mr. Crosskey and myself; there are, however, several others which Mr. Jones has not yet had time to name:—*Rotalia Beccari*, *Polystomella striato-punctata*, *Cythere* (a new species closely allied to *C. Lamarckiana*, an Atlantic living form undescribed). Besides these, we found also *Cardium fuscium*, *Rissoa globulus*, *Serpula spirillum*, and fragments of *Echinus* (species not determinable).

Comparison with the Clyde Beds.—When the beds we have just been describing are compared with those which form the Clydesdale series, some remarkable differences appear. The most remarkable feature is the constant presence of a laminated clay in the basin of the Clyde, dividing the Boulder-clay from the Arctic shell-bed. It is a fine fissile clay, easily opening up into thin laminae like the leaves of a book; it is unfossiliferous and entirely without stones—even the trace of a pebble. It is thus in most striking contrast with the Boulder-clay on which it rests. It has been already shown that the shell-bed in Arran rests on the Boulder-clay directly, the laminated clay being absent. The state of the shells presents another contrast. Those of the Arctic bed in Clydesdale are generally entire, even delicate shells being well preserved; while in Arran the shells are generally fragmentary, at least there

is a very much greater proportion of broken shells. A third feature is the presence of shells of British species in the Upper Drifts in many places in Clydesdale, while they have not as yet been found in Arran. These shells are in a much less perfect state of preservation than those of the Arctic bed*.

Fig. 2.—Section of the Clydesdale Drifts.



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| <p><i>a.</i> Boulder-clay.
<i>b.</i> Laminated clay.
<i>c.</i> Shell-bed, containing Arctic species.</p> | <p><i>d.</i> Clay, sand, and gravel, with stones.
<i>e.</i> Shell-bed, containing British species.
<i>f.</i> Upper Drifts, covered by surface soil.</p> |
|--|---|

Theory of the Origin of the Beds.—The mineral structure and fossil contents of these beds, and the contrasts which have been stated, point to a formation under general conditions alike over wide areas, with variations in the mode of action in particular places. Mr. Smith's happy generalization connected the Arctic shells with the striated and transported stones, as both indicating the prevalence of a cold, probably a subarctic climate; and there is now an accumulating weight of evidence and opinion in favour of the original hypothesis of Agassiz, namely, a general covering of ice rather than the agency of icebergs. My own opinion has for several years inclined to the former view. A careful examination of the lake-district of England, and a comparison of the markings there and in Scotland with those in Switzerland, have led me to conclude that the regularity and persistency of the markings, and other evidences of ice-action, could only have been produced by an icy envelope in a constant state of advance. Now streams of granite-blocks have emanated from the granite nucleus in the north

* Mr. Smith, of Jordanhill, was the first, after many years of careful research, to establish a division of the superficial beds of Clydesdale. He placed shell-beds on two horizons, separated by beds without shells; the lower contained 10 to 16 per cent. of Arctic species, the upper only British species. Active observers, following the course so ably marked out by Mr. Smith, have been enabled to make a more complete classification of the beds. The most zealous and successful have been the Rev. A. McBride, of Ardmory, Bute, and the Rev. H. W. Crosskey, of Glasgow. They have intercalated the laminated clay above spoken of, as a constant member of the Clyde series, and have more carefully distinguished the Upper Drifts, while they have added very largely to the fauna of the period. The results of these researches and of many others relating to the surface-evidences of ice-action in Scotland, with many valuable observations of his own, have been brought together by Mr. Geikie in an able and comprehensive memoir, 'The Glacial Drift of Scotland': Glasgow, 1863.

of Arran adown all the glens to the outer margin of the island, on all the coasts. Some of these, even at remote points, are of enormous magnitude, such as water never could have borne; and they have passed down slopes, across glens, up steep inclines, again and again, to reach the points where they are now lodged. A few masses of slate and Old Red Sandstone have also travelled; but the majority of the travelled blocks are of granite of the two kinds which constitute the northern nucleus. They are in two streams: one, on the east side of the dividing ridge of the island, is wholly of the coarse-grained granite constituting the Goatfell group; while another, on the west, and emanating from Glen Iorsa, consists partly of the fine-grained variety which forms the bottom and sides of that glen, and partly of the coarse-grained which rises over it in high ridges. In many places striated and grooved rocks and "roches moutonnées" are found, indicating the action of ice as high as 1200 feet. There is a wide enough space near the centre of the mountain-group to maintain a considerable snow-field as a feeder of glaciers. Now, as supporting the view towards which these facts point, it is most worthy of note that, as regards these appearances, Arran is perfectly isolated: the transported blocks are, undoubtedly, all of its own granites and other rocks; nothing has been contributed by the adjoining mainland*. Terraces on the sides of the valleys, composed of alluvial matter, not of rocks, and great mounds at the mouths of the glens, such as those at Iorsa waterfoot, which are the admiration of all visitors, point in the same direction. We thus seem almost shut up to the conclusion that the whole island, raised as now, or perhaps to higher levels, may have been wrapped in sheets of ice, across which the granite blocks falling from the precipices where snow could not lie, or torn off from the sides of the glens, would be carried forward in all directions on the glaciers filling the valleys. The glens being filled up with ice to the level of the bounding ridge, this might thus be passed over, and a new descent begun, and thus the load of blocks might surmount successive obstacles, and so come to crowd the southern plateau, and strew the southern shores. In this state of the surface the true Boulder-clay or lower Till may have been formed by the joint action of ice and streams of water existing among the glaciers, after the manner of the beds now laid down on land by ice. The absence of fossils, the unstratified character, the pell-mell admixture of striated stones of all sizes, unite in proving for the Boulder-clay *an origin on land*, with which ice, acting with powerful force, was somehow connected. The angular form of many of the blocks, and the preservation of the striation and polishing on all alike, clearly show that there was neither an after readjustment by currents nor a lengthened transport; for such an action would have obliterated the markings, as in the case of the alpine streams. Now the distribution of the shell-bed marks the limit of a former

* This interesting and important fact was first published by Dr. Macculloch, in 1819, but has not been alluded to by later writers. He showed that the transported blocks all belonged to Arran; without forming any theory, he ascribed the fact in a general way to revolutions of the surface.

sea; and hence the land must have sunk until the Boulder-clay was wholly depressed below the waters, whose temperature, as well as that of the air, would, under these conditions of the land and the prevalence of a cold climate, favour the development of an Arctic fauna. This would flourish under and outside the rim of ice which then girt the island, and would be as peculiar and as Arctic as that group of Testacea which finds shelter under the ice-belt on the Greenland shores. That the deposit is in no sense a drift, but a genuine Arctic fauna abundant on the spot, is manifest from many facts—the distribution of the shells, their peculiar grouping, the profusion of certain Arctic species, and the perfect preservation of some that are tender*. All these facts render unassailable the argument for a cold climate derived from the shells. The duration of the period must have been considerable to allow of such a development; and the depression must have been great, if to the height of the present shell-bed we add *the depth due to the species*. Some of those found, as *Cyprina islandica*, require a depth of 30 fathoms; and fossils occur in Arran as high as from 70 to 180 feet, making in all a depression there to the amount of 360 feet. The depression may have been even 100 feet more, but of this I cannot speak with confidence†. Whatever may have been the precise amount of this depression, it cannot have been so great as to obliterate the dominant features of the land. These must have remained much the same as they are now—an inner estuary sheltered by Arran, and an outer Firth exposed to storms and swept by currents. This is clearly indicated by the presence of the fine laminated clay-bed over the Boulder-clay and under the shell-bed in Bute and in Clydesdale, and by the perfect preservation of the most tender shells; while in Arran the laminated clay is not found, and the shells are much broken. The inner waters would afford conditions favourable to the deposit of beds of fine sediment, which the stormy waters and tidal currents, sweeping the south coast of Arran, would not allow to settle down over the surface of the Boulder-clay when the land was sinking. On the immigration of the fauna into these new fields after the deposit of the fine, stoneless, unfossiliferous clay, the same geographical features would favour a prolific development of life and the preservation of the shells. The laminated clay may be due to the deposit of fine sediment from the glacier-streams before the sea-bottom became fit for the support of life—an origin suggested by Mr. Crosskey in a short notice of the Chappel Hall beds, laid before the Society with

* In the case of the Clyde beds the force of this argument is much enhanced; for there multitudes of delicate bivalves are found perfect, with the epidermis preserved; northern boring species are in their natural upright positions; and *Mya truncata* has the siphon preserved. The fragmentary condition of many of the Arran shells indicates a disturbed state of the waters on the coast where they lived, and is not necessarily due to transport. But even on a stormy coast with stony shores there are many sheltered nooks and quiet creeks, inside points, behind banks and rocky ledges, where beds of unbroken shells might be expected to be deposited; and such may yet be found among the Arran beds.

† Col. Bayly, R.E., has kindly furnished me with the heights of the banks where the shell-beds occur, from the Ordnance Survey of Arran, now in progress.

the present paper (see p. 219). Beds very similar to it occur in the valley of the Aar, above the great gorge, and on the low south-west shores of the Lake of Brienz. In regard to the origin of the Upper Drifts there are many formidable difficulties. They are most probably due to disturbances attendant on the re-elevation of the land, and may have been partly formed out of the waste of the Boulder-clay by the action of glaciers which had become local as the ice was disappearing, and partly by the action of rivers, necessarily, under the supposed conditions, larger than now. The resemblance, indeed, to a river deposit is in many places remarkable. As shell-beds are not found among these Drifts in Arran, we need not here speculate in regard to a second subsidence. Shells of recent British species are indeed found in the caves of the cliff which marks the old sea-line, and on the terrace at its base, as Professor Ramsay long ago showed; but these are much below the level of the Upper Drifts. This terrace, which around the Arran shores has an elevation of 25 feet, *is carved out upon Drift-beds and rocks alike*; it was once a sea-bottom, most probably after the close of the Glacial period; its elevation marks the last change which affected the island, and gave to Arran its present maritime border and the inland cliff which forms a singularly picturesque feature in its coast-scenery.

3. *On the OCCURRENCE of BEDS in the WEST of SCOTLAND beneath the BOULDER-CLAY.* By JAMES BRYCE, M.A., LL.D., F.G.S.

AN examination of the Drift-beds in the island of Arran, undertaken last summer with the view of determining their true sequence, led me to the conclusion that the lowest bed there—the lower Till or true Boulder-clay—did not contain any fossils. Having noticed, while conducting the inquiry, how many difficulties and causes of error are met with, which an observer does not encounter in the case of rocky strata, I began to doubt the accuracy of the statements so often put forward that fossils occur in this bed, and to consider that the supposed cases which are on record might be explained in various ways. Other drifts with boulders, though superior in position, may readily be mistaken for the Boulder-clay. The upper surface of this last-named bed undulates violently; and shells in part of the overlying Arctic-shell bed, occupying a hollow in the undulation, might seem to be in the older deposit, especially if, as in Arran, the laminated clay, which usually in Clydesdale divides the Boulder-clay from the shell-bed, happened to be absent,—the observer being, of course, supposed to overlook the undulation. And, further, the wash or facing, formed over the whole surface of a drift-section by atmospheric causes and runlets of water, might contain shelly fragments from the bed above, which, adhering to the surface merely, would yet appear to be in the Boulder-clay. There was yet another explanation. It was possible that fossils said to be deep in the Boulder-clay might really be in beds beneath it, of different mineral structure,

whose position and character were unnoticed by an observer. And since in two of the most celebrated Scottish cases which are on record the remains found were those of Elephants, and since in England such remains are abundant in beds lower than the Boulder-clay, though occurring also in beds above it, the idea naturally occurred that the remains in question might really be older than the Boulder-clay. On these grounds I determined to investigate one of the most celebrated cases for myself, in order to come to some definite conclusion—to replace hypothesis by fact, and so help towards the completion of an important classification. I was not proceeding upon the grounds of a preconceived theory that it is impossible there can be fossils in the Boulder-clay; for although I regard it as certainly a land-formation, yet as it once formed a sea-bottom, marine fossils may have been swept over it, and imbedded in its upper surface, while a rare combination of circumstances might place land-Mammalia in an ice-deposit formed on land.

The case above referred to as celebrated was the discovery of Elephant-remains and marine shells at Woodhill quarry, situated at equal distances from Kilmarnock and Kilmaurs in the county of Ayr. The first discovery was made in the last week of December 1816; but remains were again found in 1825 and 1831*. Dr. Scouler, an authority in every way competent, has determined that the Elephant-remains are those of the Mammoth (*Elephas primigenius*). An account of the discovery was laid before the Wernerian Society by Mr. Robert Bald, the celebrated engineer†; but his account wants precision, as he never visited the spot. Inferentially, for reasons which do not appear, he places the tusks in the “new Alluvial cover”—what we should now call the “Upper Drifts,”—his “old Alluvial cover” being our “true old Boulder-clay.” All the writers, however, who have referred to the case, have simply adopted the view first made public, on the authority of Dr. Scouler, by Mr. Smith, of Jordanhill‡. He informs us that Dr. Scouler and Dr. W. Couper, Professor of Mineralogy, Glasgow University, visited the place together, and assured him that the bed in which the remains were found was the true Boulder-clay—that is, the lower Till. Mr. Geikie states that Dr. Scouler informed him that “previous to his visit the remains of four Elephants and a half, in the shape of nine tusks, had been obtained;” and that “he had picked up from the clay-heaps a small fragment of a molar”§. Dr. Scouler tells me that this visit was paid in 1840, and that the molar found by him was in the “cast stuff” in front of the quarry—a much more precise statement than “clay-heaps,” and very important, as in this “cast stuff” all the matters above the sandstone rock, and also sandstone fragments,

* Edinb. Phil. Journ. vol. xiii. p. 181.

† Wern. Mem. iv. p. 58, 1817. In vol. ii. p. 662, and iii. p. 525, under the head of “History of the Society,” there are notices that communications regarding the bones, by Mr. M’Kenzie, of Irvine, and Mr. Hood, Surgeon, Kilmarnock, were read by the Secretary.

‡ Trans. Wern. Soc. Apr. 21, 1838, vol. viii. p. 53. (See also Smith’s ‘Newer Pliocene Geology,’ p. 10. Glasgow, 1862.)

§ Glacial Drift of Scotland, p. 69. Glasgow, 1863.

would be commingled. Mr. Geikie also states* that Dr. Scouler has lately examined some antlers in the Hunterian Museum, brought by Dr. Couper from Kilmaurs, and determined them to be unquestionably horns of Reindeer.

Such, so far as I have been able to make out, was the state of knowledge on the subject when I resolved to examine the case. I visited the spot in November last, in the hope of seeing a section of the beds, but found that about twenty years ago the quarry had been abandoned, the front levelled down, and the old workings with the adjoining brows on both sides planted with trees, now of tall growth. Woodhill was the name of the old quarry; the present quarry, a few hundred yards to the south, is called Greenhill; both are close to the eastern bank of the Carmel Water. This quarry is now rented by Mr. Andrew Roxburgh, a most intelligent and well-informed man, who, when a youth, had worked in the Woodhill quarry, and felt great interest in the discovery; he perfectly remembered the exact place where the remains had been found. He undertook, if permission from the proprietor were obtained, to direct workmen where an opening ought to be made in order to expose the beds, and to superintend the operations. Meanwhile, until this permission should be obtained, I proceeded to collect the evidence of several persons who had been eye-witnesses of the discoveries, and to institute a search for the shells which had been found. I carefully noted the statements of the deponents, in order to compare them with one another and with the section when it should be opened. One of the men, Alexander Lamberton, aged 82, a most intelligent person, in full possession of his faculties, also furnished me, through the Rev. Mr. Maxwell, Kilmaurs, with a descriptive section of the beds from the surface-soil to the rock below, with their respective thicknesses, indicating upon it the bed in which the remains were found. I did not understand the section at the time, but afterwards viewed it with no little astonishment. On the judicious suggestion of Mr. A. Mackay, author of the 'History of Kilmarnock,' I applied to D. Murray Lyon, Esq., proprietor of the 'Ayr Advertiser,' for copies of any notices of the discovery which might have appeared at the time. Mr. Lyon, with ready kindness, complied with my request, and forwarded in a few days copies of two paragraphs which appeared in successive weeks immediately after the discovery, the second of which (January 23rd, 1817) is justly styled by the editor at the time as "more distinct and scientific" than the other. The comparison of this latter with Lamberton's section interested me very much.

I now brought the nature and importance of the inquiry under the attention of F. J. Turner, Esq., of Dean Castle, resident factor to the Duke of Portland, and requested permission to open up the front of the old quarry, a vertical height of fully 40 feet. Mr. Turner not only kindly complied with this request, but employed four men for a week in digging a wide and deep trench, which exposed in the most complete and satisfactory way the whole series of beds, from the

* *Op. cit.* p. 71.

sandstone at the base to the surface-soil at the top of the old quarry. The operations were directed with great judgment by Mr. Roxburgh. Mr. Turner kindly visited the place while the work was going on; and many important suggestions were made from day to day by my friend the Rev. David Landsborough, of Kilmarnock. When the opening was completed, I found the section to consist of the following beds in ascending order:—

1. Carboniferous Sandstone, terminating upwards in beds of sandy clay resembling a fire-clay.

2. Hard gravel with a little clay, and small bits of round, smooth stones, most of them quartz and trap, but all free from striation. There are also many white and grey spots, and small decomposing lumps of sandstone and limestone, often with an unctuous feel, as if containing steatite. The mass has something of the look of an artificial cement—a resemblance noted by all the men, who spoke of it as if “run together.” Thickness, 2 feet.

3. A fine dark-blue clay, with occasionally small bits of quartz and other pebbles, extremely distinct in character. Thickness, 9 inches.

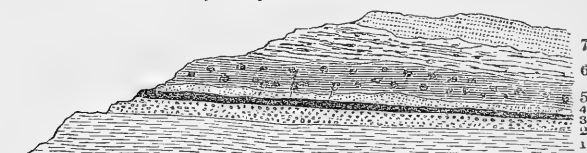
4. Sand, irregular in structure; very fine in places, and again coarse, approaching gravel, very like river-sand. 6 to 18 inches.

5. Boulder-clay, of reddish-brown colour, very tough and unworkable, full of large boulders and smaller stones, mostly smooth, polished, and striated; bits of coal-shale covered with striations, not crushed. 16 feet.

6. Upper Drifts, with stones, but much more open in texture, no striations. 20 feet.

7. Subsoil and surface-soil.

Section of Drift-beds at Kilmaurs.



1. Sandstone of the Coal-formation, rising in a low cliff from the banks of Carmel Water.

2. Gravel.

3. Clay.

4. Sand.

5. Boulder-clay.

6. Upper Drifts.

7. Subsoil and surface-soil.

None of these beds was found to contain any fossils; it was not to be expected that a section of such limited horizontal extent should bring them to light. No such object, indeed, was in view in opening the section. It was felt from the first that the case must rest on other evidence—the consistency, namely, of the account given by eye-witnesses in regard to the fossil-bearing beds, with the order actually exposed among these beds in the cutting. Intelligent observing men, employed all their lives among such strata, come to

discriminate the several layers with great exactness, and to designate them in many cases by appropriate descriptive terms. Any Scotch geologist would at once recognize the true old Boulder-clay by Lambertson's running description on the section furnished me—"Very hard and stiff, causing great labour to the workmen, with divisions in it as smooth as if they had been made so by a trowel." These smooth markings in the Boulder-clay are most characteristic of it; they are, in fact, of the nature of "Slickensides," and doubtless due to the displacement of the mass by horizontal or slightly inclined thrusts. Now all the men, who had been connected with the quarry at any of the times when fossils were found, agreed in placing them below the "hard and tough Till," which was never known by them to contain anything but large and small stones, and in referring them to the two beds below it, the sand and clay over the gravel—that is, the beds Nos. 3 and 4. Of these the sand-bed No. 4 was stated to be most irregular in its development, occurring rather in "nests" than as a continuous bed under the Till throughout the whole extent of the workings. This bed, indeed, even through the limited extent to which I traced it in searching for shells, varied much: it seemed thinning out southwards, while northwards it increased in thickness from 6 to 18 inches. This bed was the chief repository of the shells, the clay below it that of the Elephant-remains; between them, and partly imbedded in the clay, the horn of the Reindeer, with a portion of the skull attached, was found, further forward in the cutting, and later than the Elephants' bones, but the geological horizon was exactly the same*. The account of the discovery in the 'Ayr Advertiser,' already alluded to, refers the Elephant-remains to the same bed, and thus confirms the statements of the men and Lambertson's section.

The account is as follows:—

"The tusk was found between a stratum of extremely dingy, dark-coloured clay, that lay incumbent above it, and a stratum of gravel with rolled stones immediately below it, on which it lay; and some sea-shells of that kind called clam-shells were also found in the same place, but which fell at once into powder on being exposed to the air"†.

The expression "same place" here probably does not refer to the same stratum, but to the immediate neighbourhood; the clay-bed is but 9 inches thick, and shells now taken out of our clays stand exposure to the air perfectly. It is, therefore, most probably the sand-bed that is indicated. Lambertson places the shells in the sand-bed, and affirms that the more sand there was the more numerous were the shells. That several shells were taken out of the beds, and stood

* The letters *a*, *b*, on the section mark the positions of the Elephant-remains and shells exhumed as the workings advanced, 1816–1825; *c*, that of the Reindeer-horns and skull, 1831.

† The rest of the account is much the same as that given by Mr. Bald; it describes the size of the tusks, and notices the highly offensive smell of the earth as indicating that one or more carcasses had been deposited in the spot. The 'Ayr Advertiser' appeared weekly, and was at this time the only journal published in the county. It is still a respectable and ably conducted paper.

the exposure perfectly, appears from the original published account, as well as from statements made to Mr. Landsborough and myself by persons who had some of the shells in their possession, or had seen them with their friends.

Such is the evidence on which I propose to remove the fossils from the Boulder-clay and place them in the beds beneath. There is the concurrent testimony of five witnesses, examined independently and without the manifestation of any bias or preconceived view, which, while to some extent dishonest in me, would have been to them unintelligible. There is the agreement of this testimony with the account in a weekly newspaper, published a fortnight after, and the consistency of both with the sections of the beds laid open by the excavation. On these grounds I do not hesitate to place all the fossils below the Boulder-clay. But the precise age of the deposit cannot be fixed in the absence of shells of known species*. The abundance of Mammoth-remains suggests a correspondence with the Cromer forest-bed of the Norfolk coast, the chief repository of the remains of this species, though they occur also rarely in beds above the Boulder-clay. It is not meant, however, that our deposit is not a member of the Glacial series, for the Boulder-clay merely marks the climax reached by refrigerating causes which had long operated. It is only intended in the meantime to indicate an analogy: the facts do not warrant an attempt at classification. Another analogy with the English series is presented by the estuarine character of the Kilmarnock deposit. The beds of sand, sandy gravel, and clay underneath the Till have all the characters of such a deposit, or one formed near a river-mouth on the sea-shore. This opinion, formed on the first inspection of the section, was afterwards confirmed by chemical examination of the sand, in which a small quantity of common salt was detected. The Woodhill quarry is 90 feet above the level of the sea, and five miles distant from it in a direct line.

* Shells of several genera were undoubtedly found with the Elephant-remains on both occasions; but no certain knowledge is now to be obtained regarding the species. The Earl of Eglinton very kindly informs me that those which were placed in the collection at Eglinton Castle are not now to be found. A Kilmarnock lady, now resident in Glasgow, who had an early fondness for Conchology, assures me that several shells obtained from the proprietor of the Woodhill quarry were at one time in her possession; they were given away, however, on her leaving the neighbourhood many years ago, and afterwards lost. Having a knowledge of shells, the lady was able to describe them in such a way that I have no doubt there were several bivalves, a large *Pecten* or *Cyprina*, a *Mactra* or *Mya*, and a few univalves, probably *Natica*, *Litorina*, and *Turritella*. The Rev. D. Landsborough, of Kilmarnock, has taken much trouble in instituting a most persevering search among the scattered members of the various families whom he knew to be in any way connected with the discovery, but, I regret to say, without success.

4. *On the TELLINA CALCAREA BED at CHAPPEL HALL, near AIRDRIE.*
By the Rev. HENRY W. CROSSKEY.

[Communicated by Dr. J. Bryce, M.A., F.G.S., &c.]

ONE of the most perplexing cases in Scotland, upon any theory of the formation of Boulder-clay, has been the alleged occurrence at Chappel Hall, near Airdrie, of a bed of clay containing *Tellina calcarea*, intercalated between two masses of true Boulder-clay.

The facts relating to the discovery of these shells have been recorded by Mr. Smith in a paper read before the Geological Society, April 24th, 1850. The present paper will simply examine the question whether the superincumbent matter was, without doubt, the true Till.

By the true Till is meant that formation covering so large a part of Scotland, possessed of the following characteristics, and to which it is proposed that the term "Boulder-clay" should be entirely restricted:—

(1) The clay contains a large proportion of striated stones, even pieces of soft shale having been so firmly and yet gently held that they have been polished and striated without being broken.

(2) The stones on the whole are not far travelled, a small proportion being traceable to the more distant mountains, and the greater part to the flanks of the nearer ridges.

(3) There is no stratification, although there are occasional patches of sand.

(4) The colour as well as the general character of the enclosed stones is determined by the mineral character of the district.

(5) It is closely compact, and hard to be worked, even with the axe.

The true Boulder-clay thus appears to represent a force extending from a distance, and yet acting with local intensity, having a grasp upon the more remote heights but exercising in each immediate place of deposition its greater strength, with a heavy pressure compacting the mass of rude material, but acting with slowness and persistency rather than with spasmodic and sudden efforts.

Upon this Boulder-clay rests, through the Clyde district, a bed of finely laminated clay, probably formed from the fine mud always borne along by rivers issuing from ice-regions, at the period when the land was sinking and the Boulder-clay had not become a sea-bottom.

The well-known shell-bed of the Glacial epoch rests upon this laminated clay, in every normal section on the west coast. The Glacial shells in the west are never found within the Boulder-clay proper; they are invariably above it, and separated from it, not merely by an epoch of time, but by a difference of condition.

The occurrence, however, of a *Tellina calcarea* bed in strata interposed between two thick beds of Boulder-clay has been described at Chappel Hall, and the ascertainment of its exact character becomes a question of considerable importance in its bearings on the whole geology of the district.

Mr. Russell (the original discoverer of the shells) reports that the shell-clay occupied a kind of basin in the Lower Till, the section being the following:—

	ft.	in.
I. Clay (supposed to be true Boulder-clay)	14	0
II. Clay, finer, containing smaller stones, with <i>Tellina calcarea</i> , <i>Cyprina Islandica</i> , and a large <i>Balanus</i> in the deepest part, but rapidly thinning out	2	1
III. Boulder-clay, resting on Carboniferous beds		

With great kindness, Mr. Russell sank a fresh well, seven yards from the old one, and the following section was exposed:—

I. Surface soil	1	0
II. Upper clay	5	3
III. Boulder-clay, not pierced through	9	6

The following observations were made:—

1. There were decided distinctions between the upper and the lower clays. The stones were most finely polished in the lower bed; but in the upper, only a few stones had slight indications of striation, and these were nearly obliterated. The upper clay itself was looser and more easily worked than the lower. The line of division was so marked as easily to be traced by the workmen engaged in the operation, who found a great difference in the labour required.

2. The Lower Boulder-clay of the well is exactly similar to that observed in an old brick-field about a mile and a half distant, forming the base on which a fine brick-clay rests, from which shells have been taken by Mr. Russell.

3. The junction between the two clays was recognized by Mr. Russell as the exact position at which he had found the original shell-bed.

4. The beds in the well dipped to the N.E., towards the shell-bed, in such a way as to form exactly the basin within which it rested.

Taking these observations into consideration, and remembering that the new well is within seven yards of the old, with a rapid dip of the strata towards it, it will appear at least doubtful whether the shell-bed was intercalated between two Boulder-clays (in the true sense), and very probable that it rested upon the old Boulder-clay, in the normal position of the corresponding beds through the Clyde district, and was covered by that Upper Drift which is perfectly familiar to local students.

As regards this upper clay, indeed, the whole aspect of the country shows how easily it might have been the wash from a ridge of true Boulder-clay, which rises above it, and against the slope of which it rests.

There are within sight numerous isolated hills of Boulder-clay, rising like towers to heights of twenty and thirty feet, and long ridges of the same material sweep round and form large basins. In the immediate neighbourhood also is a large fault, forty-four fathoms to the N.E., another, of seventy-five fathoms, to the S.W.,

with a cross fault to the N.W., which has manifestly helped to protect certain patches of Boulder-clay, and expose others, giving an unequal activity and various directions to the denudation which during the rise of the land took place to so large an extent over the whole district. The undulations in the Boulder-clay are often exceedingly rapid and deep, within very limited areas.

At the same time there is evidence that the land was uplifted by a force acting upon different points with different degrees of intensity. A series of shell-beds may be traced from the half-tide mark opposite Dumbarton, by Dalmuir, Jordan Hill, to Airdrie, occupying levels which gradually rise until at Chappel Hall they reach the height of 526 feet.

Recollecting, therefore, that the shell-bed in question is on the slope of a ridge of Boulder-clay, and that the denuding and elevating forces were both unequal, it is evident in what way the old Boulder-clay may have been carried over the shell-bed, its stones in the process losing their striations and much of their smooth polish, at a period long subsequent to its own original deposition.

As regards the whole case, it is submitted that while there is no evidence whatever that the Chappel Hall fossils were *in* the Boulder-clay, in any sense which would make that clay a marine formation, it is also not proved that they occupy any position different from that held by the common shell-beds of the Glacial epoch in the west of Scotland.

FEBRUARY 8, 1865.

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

The following communications were read:—

1. *On the SOURCES of the MAMMALIAN FOSSILS of the RED CRAG, and on the DISCOVERY of a NEW MAMMAL in that Deposit, allied to the WALBUS.* By E. RAY LANKESTER, Esq.

[Communicated by Prof. T. H. Huxley, F.R.S., F.G.S.]

(PLATES X. and XI.)

I. THE SOURCES OF THE MAMMALIAN FOSSILS OF THE RED CRAG.

THE very remarkable deposit extending over a small area on the east coast of England, and known as the Red Crag of Suffolk, from time to time furnishes fresh remains of a very various Mammalian fauna. Indeed, so diverse are the forms which occur in this small deposit (whose total number of Mammalian fossils does not exceed

at present 20 species), that, apart from lithological or stratigraphical considerations, the conclusion is forced upon us that we have, in the Red Crag, fossils derived from several preceding deposits—in fact, we have not one fauna, but a mixture of selections from several. As an example of this, in the list of Mammalia alone, we may take the occurrence of such forms as—1st, the Ziphioid Cetaceans; 2nd, the *Mastodon*, *Rhinoceros*, *Tapirus*, *Felis*, *Hycena*, and *Sus*; and 3rd, the *Hyracotherium* and *Coryphodon*, which forms are elsewhere eminently characteristic of very distinct Pliocene, Miocene, and Eocene strata.

In speaking of the terrestrial Mammalia as probably identical with Miocene forms, it must not be supposed that I in any way overlook the excellent researches of the late Dr. Falconer; and indeed I am quite disposed to consider the *Mastodon* identical with the Subapennine form *M. Arvernensis*, and distinct from the *M. angustidens*. But since, in his otherwise exhaustive and satisfactory treatise, Dr. Falconer does not finally decide the affinities of the Crag *Rhinoceros*, *Tapirus*, *Sus*, and *Felis*, one must still regard it as a doubtful question whether they are Miocene or Pliocene forms.

An examination of the Molluscan fauna of the Red Crag demonstrates its late Pliocene age, and the researches of Sir Charles Lyell, published in the Journal of the Geological Society for 1852, which I have lately been able to confirm upon more ample data, indicate that the Red Crag was a littoral deposit of the same sea as that which formed the Upper or Yellow Crag of Antwerp. This fact has never been directly called in question; and since it is allowed to be true, there arises the necessity of explaining the occurrence, in this Upper Pliocene deposit of Suffolk, of fossils which properly belong to Middle or Lower Pliocene, perhaps Miocene and Eocene formations.

The teeth, otolites, facial and other bones of Cetaceans abound in an unworn and unrolled condition in the Middle Crag of Antwerp, where I have collected them; the teeth and bones of forms of *Mastodon*, of *Rhinoceros*, of *Tapir*, and of *Sus*, similar to those of the Red Crag, occur in the Miocene of Darmstadt on the one hand and in the Pliocene Subapennine formations on the other; but in neither case are they associated with Ziphioid Cetaceans, and they are always well preserved and little fractured. The teeth of *Coryphodon* and *Hyracotherium* are well known as characteristic Eocene fossils, unassociated with any of the forementioned Mammalia. All these forms, however, are met with, indiscriminately associated, in this littoral deposit of the Upper Pliocene, namely the Red Crag, and more or less at the base of the *Coralline Crag*. It might be hazarded as an explanation of this phenomenon, that all or some of these types existed together under peculiar conditions, and that their remains were simultaneously imbedded in a common sepulchre. The correctness of this view, however, must appear at once to be very improbable, since nowhere else are these remains associated: and seeing that an examination of the other fossils of the deposit does not bear it out in any way, this improbability is rendered almost a

negative certainty when the character and preservation of the Mammalian fossils is observed, and the conditions of their occurrence noted.

The Crag is, as is well known, a very loose sandy deposit, containing a very unusual amount of oxide of iron, which stains it of a deep-red or orange colour; all the shells of Mollusca which it contains, and which are not *known* to be derived from previous deposits, are excessively fragile, disintegrated, and merely superficially stained by iron, the action of which has tended to render them fragile and pulverulent, rather than to mineralize or strengthen them, whilst the shells and other fossils which are acknowledged to be washed from preceding beds have considerable tenacity, are very heavy, and deeply impregnated with mineral matter. As examples of these two classes of fossils the *Tellinæ*, *Mactræ*, and *Fusi* may be quoted on the one hand, and the derived specimens of *Terebratula spondyloides*, *Voluta Lamberti*, and numerous Crustacean and Piscine remains on the other. The action, then, of the Red Crag on its *proper* fossils appears to be a fragilizing and destructive one; its action on derived fossils an indurating and preservative one. This action may doubtless be satisfactorily explained by the laws of chemical affinity. The oxide of iron, which so deeply colours the Red Crag, existed in the sea as carbonate of the protoxide. It is well known that with recent organic matters, which are necessarily decomposing, this salt of iron forms a sulphide of the metal, whilst water and carbonic anhydride are liberated. The unfossilized shells, bones, &c., therefore, in the Red Crag sea were not subjected to the action of the protoxide of iron at all, the sulphide of iron being formed, which rapidly decomposes and destroys the structure it invests.

Phosphatic nodules, however, and bones and shells thoroughly deprived of their organic matter by previous fossilization, do not act similarly on the carbonate of the protoxide of iron. It infiltrates them, and thoroughly mineralizes them, eventually becoming deposited within their structure as peroxide, silicate, or phosphate, as the case may be, part of their constituents being dissolved and removed by the carbonic acid.

The question here involved, although a chemical one, is of very great importance to the palæontologist; and the investigation of the processes of fossilization cannot but afford the inquirer important results. Much and very valuable assistance has already been furnished to this branch of inquiry by Dr. Bischof in his work on Chemical Geology. It appears that no fossils in any loose sandy deposit attain that degree of mineralization and firmness observed in most bones and teeth from the Red Crag, until they have been subjected for the second time to the action of water containing mineral matter, either by the submergence of the whole deposit or by the separate action on individual specimens.

The fossils of the Middle Crag of Antwerp, of the Darmstadt Miocene, and of those beds of our own Tertiaries which are sandy and *not argillaceous* are all very friable, light, and slightly mineralized.

It is only in such deposits as the older sandstones, which have been in a great measure altered, or in clays where water can accumulate, that heavy and thoroughly mineralized specimens are formed.

If, bearing these facts in mind, the fossil Mammalian remains of the Red Crag are examined, a very important light may be thrown on the origin of their association. With the exception of a few very rare, fragile, and indeterminable pieces of bone, all the Mammalian fossils of the Red Crag are very heavy, compact, thoroughly mineralized, and indurated. This induration could not have taken place in the Crag Sea whilst these remains were fresh, nor in the Crag afterwards; hence it is inferred that the specimens were washed from previous strata, and that those not destroyed by rolling and water-action were thoroughly imbued with salts of iron. No specimen of bone from the Crag is free from evidence of much rolling and washing as though on a sea-beach, and all are disconnected and fragmentary: the so-called Coprolites, now acknowledged to be concretionary nodules, often when *in situ* show fractures across their former centres of concretion, with worn edges; so that semi-circular and rectangular pieces often occur. These facts again point but to one conclusion with regard to the association of the Mammalian fossils, Sharks' teeth, and phosphatic nodules with the Molluscan fauna of the Crag; and it is that the sea in which the Molluscan fauna lived broke up various previous Pliocene, Miocene, and Eocene beds, and appropriated some of their organic contents.

It is allowed by most geologists that this is the case as far as concerns the teeth of *Coryphodon*, *Otodus*, *Lamna*, &c., and the phosphatic masses, which all occur in abundance in the Lower Eocene clays of Sheppey; and the same reasoning should apply in the case of the Ziphioid Cetaceans and Miocene Mammalia which occur so abundantly in the earlier strata of Antwerp and Darmstadt in an *unrolled* condition.

There is, however, further evidence of the derivative nature of these two latter groups of remains. Fractured specimens occur of Cetacean bones and teeth which must have been broken subsequently to their partial fossilization, on the broken surfaces of which "*Balani*" of Crag species are attached. A dark indurated matrix, totally differing from the Red Crag, and resembling the Middle Antwerp deposit, frequently surrounds the Cetacean teeth; it could only have been attached to the teeth by their having previously been imbedded in such a deposit as that of Antwerp. The teeth of the Mastodon and the Rhinoceros, again, frequently contain in their interstices and cavities a light-coloured fine matrix, which must have been obtained by their deposition in an earlier bed totally differing from the Red Crag.

On the following grounds, then, it seems fair to conclude that the Mammalian fossils of the Red Crag are mostly derived from earlier beds—the Ziphioid Cetaceans (with *Carcharodon*, &c.) from an equivalent of the Middle Antwerp Crag, the Mastodon, Rhinoceros, Tapir, *Sus*, *Felis*, &c. perhaps from a late Miocene, or more probably from an early Pliocene bed:—

1st. The occurrence of the Mammalian remains in question elsewhere, separately, and in widely different formations.

2nd. The improbability of the coexistence of several Mammals of Miocene and early Pliocene "facies" with a Molluscan fauna shown elsewhere to be of late Pliocene origin.

3rd. The rounded, washed, and worn nature of the specimens, as well as their rarity and fragmentary character.

4th. The complete mineralization of these fossils, their hardness and great weight, which tend to prove their derivative nature,

(1st) Because the proper fossils of the Crag are light, unmineralized, disintegrated, and pulverulent.

(2nd) Because specimens known to be derived are heavy and hard, as these are.

(3rd) Because a loose sand, such as the Crag, cannot produce the complete induration of specimens.

5th. The very frequent presence of attached marine organisms of the Crag age on the broken surfaces of these specimens.

6th. The occurrence of a matrix surrounding the teeth differing entirely from the Red Crag.

In addition to the considerations thus stated, there is, with regard to the terrestrial Mammalia, the very important fact that the teeth of *Mastodon* and *Rhinoceros* of the same species as the Red Crag forms have been found at the base of the Coralline Crag, associated with phosphatic nodules and other débris, which leaves very little room for doubt that, whatever species they may be identical with, the *Mastodon*, *Rhinoceros*, and other molars are derived from beds of a period previous to the Red Crag era. For these reasons I would urge the probability of a previous extension of the Middle Crag of Antwerp*, and also possibly of the earlier Pliocene or late Miocene deposits of North Europe, along their natural horizon to the line of the present coast of Suffolk—an extension which does not *primâ facie* appear at all unlikely or impossible. From the Middle Crag beds, then, the Ziphioid and other Cetacean remains were derived; from the Miocene or early Pliocene, the terrestrial Pachyderms; from our own Tertiaries, the *Coryphodon*, *Hyracotherium*, &c. The appended Table may be of assistance in explaining the relations of the various strata. The percentages of Mollusca are compiled from the various publications of Mr. Wood and Mr. Nyst; and perhaps in some cases either or both of these gentlemen have been too prone to establish new species distinct from recent forms, which makes the percentage of living Mollusca appear unusually small.

The remarks made in the foregoing pages must be considered merely as an extension or modification of views which have been formerly advanced, chiefly by Mr. Searles Wood, sen., who, in 1859, published a valuable paper on the extraneous fossils of the Red Crag, in which, however, less conclusive evidence was adduced †.

* On these beds, see my paper in the *Geological Magazine*, vol. ii. pp. 103 & 149, 1865.

† Since this paper was read, Professor Owen has forwarded me an abstract

Red Crag Coralline Crag . .	}	Molluscan fauna, northern, tropical, and extinct species, 53 per cent. recent. Derived Ziphioid Cetaceans, <i>Mastodon</i> , <i>Rhinoceros</i> , <i>Tapirus</i> , <i>Sus</i> , <i>Hipparion</i> , &c., <i>Carcharodon</i> , <i>Otodus</i> , Phosphatic nodules.
Upper Antwerp Crag		Molluscan fauna, northern, tropical, extinct, 53 per cent. recent. Few bones, derived teeth of <i>Oxyrhina</i> .
Middle Antwerp Crag	}	Molluscan fauna, 41 per cent. recent. Ziphioid Ceta- ceans, <i>Carcharodon</i> , <i>Oxyrhina</i> proper.
Black Crag (Ant- werp)		Molluscan fauna, 35 per cent. recent. Few Sharks, Cetaceans?
Miocene (Darm- stadt)	}	<i>Mastodon</i> , <i>Dinotherium</i> , <i>Sus</i> , <i>Hipparion</i> , <i>Rhinoceros</i> , &c.
Lower Eocene (Sheppey)		Phosphatic nodules. Fish-remains: <i>Otodus</i> . Mam- malia: <i>Coryphodon</i> , <i>Hyacotherium</i> .

II. TRICHECODON HUXLEYI, A NEW MAMMALIAN FOSSIL FROM THE RED CRAG OF SUFFOLK.

Specimens and localities.—Amongst a variety of specimens of Mammalian teeth which I had collected from the Red Crag, certain pieces of a large tusk were observed, the form and structure of which seemed to indicate the presence of a new form of Mammal of very considerable size.

Examples of these tusks have been in the collections of Mr. Whincop, of Woodbridge, the late Mr. Acton, and others, for some time, and have been supposed to be either the ponderous lower incisors of a species of *Dinotherium*, or else belonging to the *Mastodon angustidens*, whose molar teeth are so frequently met with in the Red Crag. There is nothing, however, in their structure to warrant this supposition, although in their size and outline they somewhat resemble the tusks of *Dinotherium*. The matter is one which has never as yet been handled by any competent persons, excepting on one occasion, when a fine specimen of one of these tusks, brought to the British Museum by a dealer, was declared *not* to be *Dinotherium* or *Mastodon*; but what it was, was not hinted at. The various specimens of this fossil which have come under my notice are as follows:—1. Three large specimens, more or less perfect, from the Red Crag of Sutton and Felixstow, in the collection of Mr. Whincop. 2. Four smaller specimens of the terminal points of young tusks, from Felixstow, Bawdsey, and Sutton, also in the collection of Mr. Whincop. 3. Three fine specimens of portions of the tusk, as well as smaller ones, in the collection of Mr. Calvert,

of a paper by him on some Mammalian fossils from the Red Crag of Suffolk, read Feb. 20th, 1856. In this paper he expresses his opinion that the "Red Crag is the *débris* of former Tertiary strata, and in a great proportion of the Miocene period."

from various Crag pits. 4. Large fragments from Felixstow, in the author's cabinet. To this list I may now add two fine fragments, which I lately observed in the collection of my friend Mr. Packard, of Westerfield.

When travelling in Belgium last summer, I was much gratified by finding a large portion of one of these tusks in the collection of Professor Van Beneden, of Louvain. This specimen, which is unique, was not obtained from the "Crag supérieur" or "Crag jaune," which is the exact equivalent of our Red Crag, but was met with in the "Crag moyen" or "Crag gris," an older and well-defined deposit, abounding in unrolled remains of Cetaceans and Sharks, as well as Molluscan fossils. Professor Van Beneden had been unable at this time to decide the affinities of the animal to which this tooth belonged; but since then he has communicated his opinion to me in a letter, that it was closely allied to the Walrus—a conclusion at which I had previously arrived. The grounds upon which this conclusion is founded will now be given.

General Form and Outline.—The majority of the specimens of the tusk which have been obtained are its pointed terminations; but other specimens, of the base and intermediate portions, have come to light. Throughout its length, which in some examples must have been fully three feet, the tusk is slightly curved; but in those which appear to be fully grown the curve is considerably greater towards the terminal point, the direction of the curve probably giving the tusk, if its Pinnigrade affinities be established, a retroflected position, as in the *Dinotherium*. The Crag tusk is very much compressed laterally, so that its transverse section has an elliptical outline, whilst that of the *Dinotherium*-tusk is nearly circular. The amount of lateral compression is, however, extremely variable, as it is also in the living Walruses; the amount also of the lateral as well as the antero-posterior flexion of the tusk appears to vary, as in the recent *Trichecus*, the variability of which in the size and form of its tusks is well known. A single large furrow on the outer surface, two on the inner, and one on the inner curved margin, extend along the whole length of the tusk in many specimens, exactly similar to those noticed on some tusks of Walrus; but in both the recent and fossil specimens they are subject to much variation, in their major or minor development. No appearance of any wearing of the point of the tusks by use during life is observable; and indeed the greater backward curvature of that part seems to result from its freedom from usage, since in the Walrus the point of the tusk is rapidly worn away, which of course checks any tendency to curvature which might become apparent if the tusk were not used against such hard substances as rocks and blocks of ice (Pl. X. figs. 1-3).

From an examination of the general contour and form of the tusks, without regard to their substance or structure, one would unquestionably be led to regard them as belonging to an animal similar to the existing Walrus, inasmuch as it is in this animal alone that this form of tusk, with its longitudinal furrows, great length, and gentle curvature, is found.

The tusks of Proboscideans are cylindrical, uncompressed, without furrows, and generally much curved. Those of the *Sirenia* are a great deal smaller, proportionately to the body, than these probably were; they are also unfurrowed, nearly cylindrical, and almost straight; whilst the canines and incisors of the *Hippopotami* have an entirely different form.

Structure of the Tusks.—Probably one of the most satisfactory methods of demonstrating the arrangement of the mineral matter in teeth is by means of fossil specimens, since the complete destruction of their organic constituents, and the infiltration and absorption of various chemical substances, in most cases disintegrates them, and develops or renders apparent a structure which would otherwise escape observation. Thus the fossil tusks of the Mammoth easily split up into a series of superimposed hollow cylinders; the Cetacean teeth from the Red Crag often, owing to the varying absorption of iron in the different tissues of the tooth, may be broken into long laminæ, such that the “crusta petrosa” or “cement” is removed, and a very remarkable gyrate and striated arrangement of the subjacent dentine is exposed. So with the fossil tusks under description; the exterior is, when properly preserved, smooth, but marked by a number of fine longitudinal cracks, which are most apparent in the small or young specimens. The lamina of the tooth in which these cracks exist very frequently splits off, and the subjacent surface is thereby exposed. A microscopical examination of this external lamina shows it to be the “cement” investing the whole tusk, no enamel occurring in these teeth. When much of the cement layer has been removed, as very frequently happens, the solid matter of the “dentine” which underlies it is seen to have a very curious arrangement. Its surface, which becomes very glossy and bright in these Crag fossils, is sculptured by a series of small longitudinal grooves or furrows, producing a fluted ornamentation, whilst minute ridges or striations cross these at right angles, the two series of markings together giving an appearance very similar to that observable on the surface of the canine of the *Hippopotamus* (Pl. X. fig. 1).

This structure in the fossils under notice has led to their being regarded as belonging to a form of *Hippopotamus*; but inasmuch as in that animal the grooves and striations are entirely superficial, whilst in the Crag tusks, as also in Cetacean teeth of the same deposit, these markings are only displayed by the removal of the external lamina of cement, no weight can be attached to an assimilation of the two forms of tusk based upon these grounds.

The “dentine” of the fossil tusks has a tendency to split up into long concentrically annular laminæ, displaying, when removed by the action of the sea or otherwise, a similar series of longitudinal groovings; so that this arrangement of the mineral matter of the dentine may be regarded as persistent throughout its thickness. In a transverse section of one of the tusks, an arrangement of the constituent tissues of the tooth is displayed which leaves very little room for doubt with regard to the affinities of its possessor (Pl. X.

fig. 5). The area of the pulp-cavity, which is very large, is throughout the whole length filled up, a very small and flat space, which is the only true pulp-cavity, existing at the base. The substance which occupies its place, and which is known in other teeth as "osseo-dentine," appears to be composed of a number of small globular bodies, closely agglomerated and compacted, and presenting that peculiar appearance and structure which is characteristic of the tusk of the Walrus, and was compared by Cuvier, when writing of that animal, to "pudding-stone." Thus:—"L'ivoire des défenses du Morse est compacte, susceptible d'un poli presque aussi beau que celui de l'Hippopotame, mais sans stries; la partie moyenne de la dent est formée de petits grains ronds placés pêle-mêle, comme le cailloux dans la pierre appelée *poudingue*; c'est ce qui le caractérise. Les dents molaires de cet animal ont leur axe composé des mêmes petits grains que celui des défenses. Elles n'ont aucune cavité dans leur intérieur" *.

This structure, which is in reality formed by numerous distinct calcifications around various vascular canals, from which radiate tubules similar to those of the dentine, occupies a large part of the fossil, as it does of the Walrus-tusk, diminishing as the point is approached. The microscopical appearance of this part of the tusk, and of the dentine and cement exterior to it, is shown in the accompanying drawings of sections, obtained with some difficulty, from the fossils and from the tusk of the living Morse (Pl. X. figs. 4 & 6).

The dentine which surrounds the peculiar "osseo-dentine," and forms the bulk of the tooth, is very hard and compact, and has a radiated fibrous appearance, owing to the direction taken by the dental tubules, which, although excessively minute, are thus far rendered apparent by the selective infiltration of mineral matters. The tubules do not appear to exert the least influence on the direction of the fracture of the tooth, which is, as before stated, in longitudinal annular laminæ. Deorganized tusks of the Walrus present this same form of disintegration.

In its microscopical structure, the dentine of the fossil tusks presents a complete resemblance to that of the tusk of the Walrus, which will perhaps be best understood by reference to Plate X. figs. 4 & 6. The dental tubes are very nearly of the same size, and equally closely packed, and are connected with stellate lacunæ in some numbers near the periphery of the tooth. This structure, which is not peculiar to the Walrus, is nevertheless a test of affinity, inasmuch as the form of the lacunæ varies in different animals. They are not met with in the tusks of the Proboscidea or the Hippopotamus, but occur in the curious incisors of the Dugong. The "dental cells" of the Crag tusks also resemble those of the Walrus.

The "cement," as seen in a transverse section of one of the fossil tusks, which was cut at a distance of nine inches from its terminal point, and the diameter of which was there $2 \times 3\frac{1}{4}$ inches, appeared not to be more than the sixth of an inch in thickness, whilst the thickness of the "dentine," compared to that of the

* Cuvier, *Leçons d'Anat. Comparée*, tom. iii. (1805), p. 106.

“osseo-dentine,” was about as 3 : 1. In structure the cement exactly resembles that of the Walrus, displaying vascular canals, bone-lacunæ, and canaliculi, of the same form and disposition; but the proportion which it bears to the thickness of the other tooth-tissues appears to be larger in the Walrus than in the fossil.

From the foregoing remarks it will be apparent that we have in these fossil tusks characters which ally them most closely to the large canines of the genus *Trichecus*. It will perhaps be well to enumerate the points of form and structure which distinguish them from the tusks of other animals, and those which assimilate them to the canines of the Walrus.

1. They are distinguished from the Proboscidean tusks generally by their lateral compression, slight curvature, and deep superficial groovings, and by the absence of that cylindrical form, smooth surface, and great curvature, which is present in Proboscidean tusks. Structurally by the presence in the fossil tusk of a large core of peculiar globular “osseo-dentine,” by the presence of stellate lacunæ in the dentine, by the size and form of its tubes, and by the amount and structure of the cement; and by the absence of peculiar “engine-turning,” or “guillochis,” which marks the ivory of the Proboscidea.

2. They are distinguished from the tusks of the *Dinotherium* in particular, by all the above-mentioned characters but the last; to which may be added the absence of a deep conical basal pulp-cavity, observed in the tusks of *Dinotherium* and of the Elephants and Mastodons also.

3. They are distinguished from the tusks of *Sirenia*, which resemble somewhat those of the Walrus, by their definite form, grooving, and curvature; by their much larger core of osseo-dentine, and by their short and wide, instead of elongate and angular, pulp-cavity.

4. From the tusks of *Hippopotami* they are distinguished by every character of form and structure, the fluting of the dentine (recalling the markings on the surface of the canine of *Hippopotamus*) being the only similarity between the two.

Lastly, they resemble the large canine tusks of the living *Trichecus* in their curvature, varying lateral compression, large surface-furrows, short and wide pulp-cavity, globular “osseo-dentine,” and every detail of minute structure. They differ from them in their greater curvature at the point of the tusk, their greater lateral compression, and minor development of cement.

I accordingly propose to establish the genus *Trichecodon* to receive the animal thus indicated. The justification of a generic separation must be sought in the fact of the great antiquity of the Red Crag, and the consequent probability of the association of other and more distinctive attributes with those of the tusks. The name *Trichecodon* was proposed to the author by M. Van Beneden, as one aptly describing all that we at present do, and probably ever shall, know of this animal. In searching for a specific title, I have thought that I cannot do better than dedicate this somewhat interesting form to

my much-valued friend Professor Huxley, whose name has already been associated with the history of the Crag Mammalia by his recent researches on Ziphioid Cetaceans.

It appears that the *Tricheodon Huxleyi*, like the Cetacean remains of the Crag and large Sharks' teeth alluded to in the first part of this paper, is a derived fossil in the Red Crag, belonging properly to the Middle Crag, which is not now observable in this country, but is well developed at and near Antwerp.

III. THE PROBABLE IDENTITY OF THE TEETH OF THE SO-CALLED *BALÆNODON PHYSALOIDES* WITH THOSE OF SPECIES OF THE GENERA *BELEMNOZIPHUS* AND *SQUALODON*.

The Cetacean teeth which occur in great numbers in the Red Crag, of large size and more or less conical shape, are at present in this country referred to the *Balenodon physaloides* of Professor Owen (Pl. XI. figs. 3 & 5). From a comparison of many hundreds of specimens in various collections, I have ascertained that there are two forms of these teeth—those which simply taper more or less towards the crown and have large bases, and those which have a more elongated base and a nipple-shaped crown coated with enamel (Pl. XI. figs. 6 & 7). To the first form belongs the original specimen figured as *Balenodon physaloides* in the 'British Fossil Mammalia,' whilst the second form, which is most obviously and clearly distinguished from the first in specimens which are only slightly rolled, is entirely distinct. The excavations which have now for some years been going on at Antwerp, have furnished most abundant and beautiful remains of a fossil Cetacean fauna from the Middle Crag. The teeth of the lower jaws of the Ziphioids have been identified, and the remains of the remarkable Cetacean *Squalodon* have been obtained in very fine preservation. M. Van Beneden, who has had the charge of all the Mammalian remains obtained, and whose researches on the subject are well known, assures me, from a comparison with the Antwerp fossils of specimens which I sent to Louvain, that the *Balenodon* teeth of the first form (that originally described) are without doubt the teeth of the bident lower jaws of those Ziphioids whose remains occur with them in the Red Crag; whilst the more elongated teeth with an emarginated nipple-like crown of enamel, more or less worn, are the teeth of a species of *Squalodon*, probably the *Squalodon Antwerpiense*, the restoration and description of which by MM. Van Beneden and Gervais are well known.

If this be the case—and the amount of material afforded to M. Van Beneden by the workings at Antwerp is of so perfect and satisfactory a nature that there can be little doubt on the matter—the *Balenodon physaloides* will have to be removed from the list of our British fossil Mammals, and species of *Ziphius* and *Squalodon* adopted in its place.

EXPLANATION OF PLATES X. & XI.

PLATE X.

- Fig. 1. Fragment of the tusk of *Trichecodon Huxleyi*; terminal portion, showing the fluting of the dentine. From the Red Crag of Suffolk. One-third the natural size.
2. A flatter specimen of the same, with point complete, and the surface of cement preserved. One-third the natural size.
 3. Basal portion of the same, with the cement preserved. One-third the natural size.
[These three specimens are in the cabinet of W. Whincop, Esq., of Woodbridge.]
 4. Section of a portion of the tusk of *Trichecus rosmarus*, showing the microscopic structure of the three layers. Drawn from specimens prepared for the author.
 5. Section of a portion of the tusk of *Trichecodon Huxleyi*. Drawn from specimens prepared for the author.
 6. Transverse section of the specimen drawn in fig. 1, showing the "core" of granular "osseo-dentine." Natural size.

PLATE XI.

- Fig. 1. Restoration of the tusk of *Trichecodon Huxleyi*.
2. Tusk of *Trichecus rosmarus*.
 3. Tooth of a large Ziphioid Cetacean, probably one of the *Belemnoziphii* (*Balenodon physaloides* of Owen), from the Red Crag, Felixstow: in the author's cabinet. Three-fourths the natural size.
 4. Tooth of *Squalodon*, Van Beneden & Gervais; from the Red Crag, Suffolk. In the Woodwardian Museum, Cambridge.
 5. *Balenodon physaloides*; from Owen's 'British Fossil Mammalia,' p. 536.
 - 6 & 7. Teeth of *Squalodon*, more or less worn, sometimes attributed to the *Balenodon* of Owen.

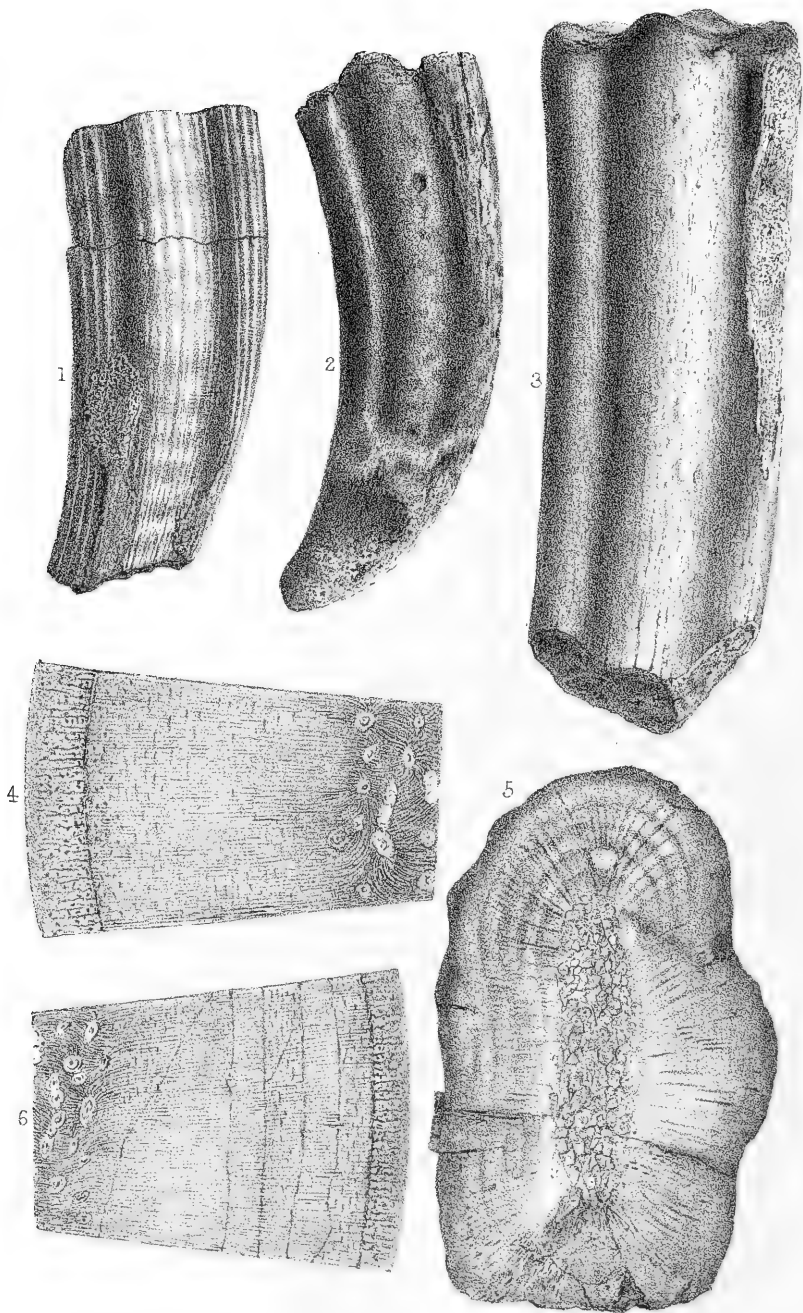
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2. *Note on the GEOLOGY of HARROGATE.* By JOHN PHILLIPS, M.A. Oxon., LL.D. Dublin, F.R.S., F.G.S., Professor of Geology in the University of Oxford.

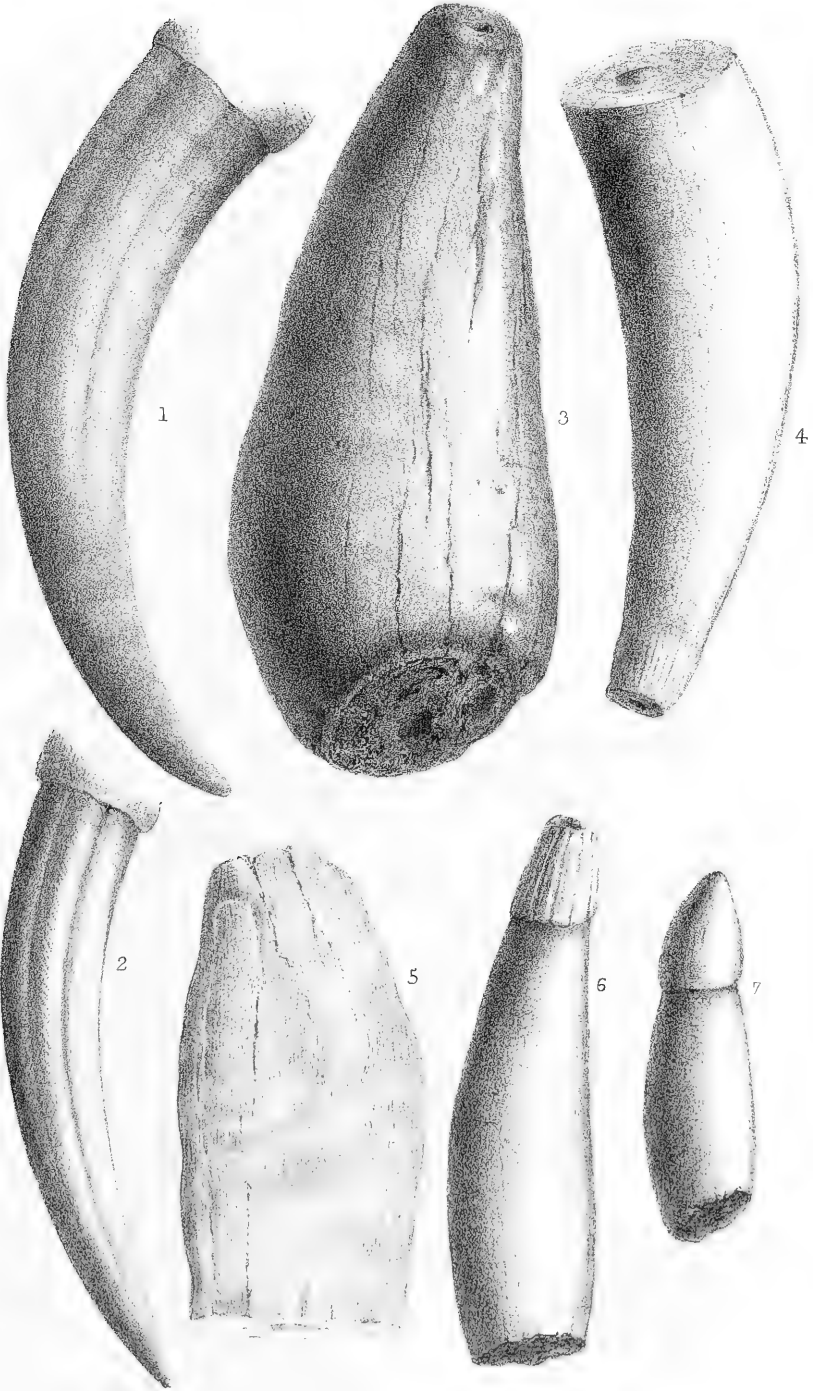
DURING more than forty years the uncommon arrangement of the strata about Harrogate has attracted my attention, and I have made frequent examinations of the surrounding country to learn the peculiarities of structure of the Upper Palæozoic rocks which are there exposed. Of late years the information furnished by many quarries has been increased by the cuttings on the North-Eastern Railway, and thus not only the ranges of Millstone-grit, calcareous roadstone, and Yoredale shales have been settled, but some light has been thrown on the relation of the Permian grits to those of the older series, which was formerly doubtful. The mineral springs are also much more surely referable to a deep source along an axis of movement than was possible when, now almost thirty years since, I published my map of the north-western tract of Yorkshire*.

Founded on a mass of particular notices, I propose now to offer to the Society a few results relating to this district, such as it may be well to consider before the closer scrutiny of the Geological Survey

* Illustrations of the Geology of Yorkshire, vol. ii. 1836.







De Witte, lith ad nat.

Crag MAMMALIA

Hannart, imp.

shall have completely mapped out and measured the whole of the large region of elevated Mountain-limestone, Millstone-grit, and Coal-measures of the North and West Ridings.

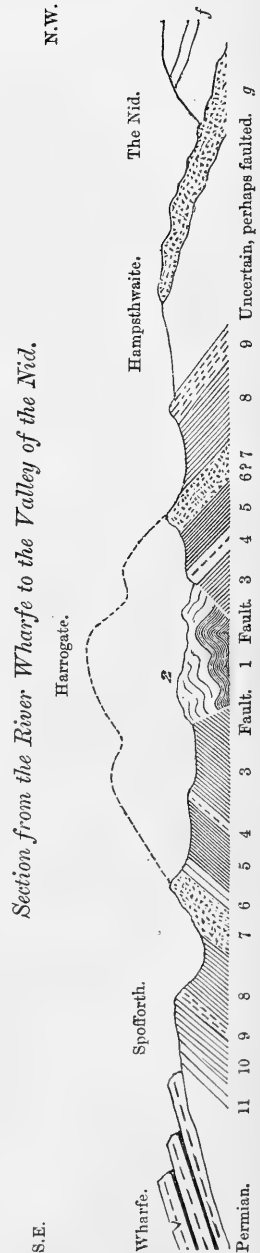
On the map of this part of Yorkshire, and further to the west, the whole country south of the Craven fault, for a length (E. to W.) of fifty miles and a breadth of twenty, is marked by many nearly parallel anticlinals, by which the Great Scar limestone and the black limestones of the Yoredale series are frequently brought up in narrow elliptical patches, whose direction is about E.N.E. or N.E. Thus at Greenhow Hill, Nursa Knot, Skipton Castle, Coningby, Thornton, Gisburn, and many other places these ridges occur, until we reach the remarkable examples at Clitheroe, Whitwell, and Trough of Bolland.

To this list Harrogate must be added; its anticlinal is in the same direction, and I am now satisfied, and have been for some years, that the strata exposed at Low Harrogate are part of the Yoredale series of limestones, shales, and grits. Formerly (1836) I classed them with the Millstone-grit.

In a line of section between the Wharfe and Harrogate the strata appear as in the Section, all in a general sense dipping away to the S.E. from the broad and somewhat complicated and faulted anticlinal of Harrogate. Placed in succession downwards, this appears to be the order of the beds below the unconformable Permian rocks:—

Rocks.	Estimated thicknesses.
11. Spofforth Hags roadstone and fossils.	10 ft.
10. Dark coal-shales and <i>Stigmara</i> ..	unknown.
9. Follifoot coal-grit, with <i>Stigmara</i> ..	30
8. Shales	500
7. Almes Cliff Millstone-grit	50
6. Pannel roadstone	30
5. Shale	unknown.
4. Harrogate Tunnel sandstone	20
3. Shale	unknown.
2. Harrogate roadstone	50
1. Shale	unknown.

Similarly in the continuation of the section to the Nid, the strata follow in the same order, but are not to be observed with the same clearness and certainty. No. 6 is not recognized there. There is probably a fault-line both on the north-west and on the south-east of the Harrogate roadstone-beds. The Almes Cliff grit, No. 7, is remarkably well seen



S.E.

on the north on the road to Blubber Houses, covered by Nos. 8 and 9 at Acton Houses, and equally well on the S.E. at Pannal. By these outcrops the other parts of the section may be adjusted.

I regard this Millstone-grit as probably the lowest of three bands (namely, the grit of Ingleborough, Penyghent, and Pendle Hill), having poor Coal-measures above it, with Stigmarian grits and shales. I have not determined whether it is the same grit (*g*), raised by faults, which sinks down to the Nid through the picturesque grounds of Hampsthwaite, or that the shelly subcalcareous stone (*f*) which was cut through in the railway under the village of Clint, appearing again at Padside, west of Dacre, and at Hartwith, on the road from Ripley to Pateley Bridge, belongs to the Follifoot beds. I suppose not*.

The beds here called roadstone are calcareous according as they contain Crinoids or Shells. Crinoidal fragments abound in the lowest Harrogate roadstone. Crinoids, *Producti*, *Strophomenæ*, *Goniatites*, and *Euomphali* occur in the upper or Follifoot bands. In these latter bands, about the year 1800, W. Smith found a remarkable discoid shell (which formed part of his collection, now in the British Museum), with a row of nodules on each side. The Pannal band is cherty and slightly crinoidal. I am rather of opinion that the Harrogate band corresponds to the main or 12-fathom limestone at the top of the Yoredale series: all these limestones lose themselves in cherty or sandy representatives as we go to the east and south. On the line of the Harrogate anticlinal we have several mineral springs, in each of which the essential bases seem to be chloride of sodium, with sulphates of lime, soda, &c. Several of them issue through peaty deposits, and there probably undergo the usual change when sulphates come into contact with decomposing vegetable matter and release the sulphuretted hydrogen, for which particular springs are remarkable at Harrogate. One general subterranean source, determined by the axis of dislocation, and subdivided toward the surface into several branches, which follow the fissures of the rocks, and there meet with various local conditions, seems enough to explain the diversity of the waters of Harrogate, Starbeck, and Bilton.

Another point deserves attention. Few rocks are more variable in composition, while regular in sequence, than the Lower Permian sandstones and shales. Where the sequence is immediate from the upper Coal-measures to the Permian beds, as in Durham, North Staffordshire, and part of Yorkshire and Derbyshire, the analogy of the two sets of strata is considerable, even if they do not exchange beds. But in this part of Yorkshire the Permian beds are in no sense or manner conformed to the Coal-system or to any part of it. They are strictly transgressive, and very much so, resting on extremely different members of the great Carboniferous system, and of very different age. In this particular district the Millstone-grit probably underwent enormous waste after the anticlinal was formed, and before the Permian beds were deposited. These Permian beds of coarse and fine purple sandstone are full of the detritus of Millstone-grit. The felspar is

* See Geology of Yorkshire, vol. ii. p. 58, &c.

rolled, but quite recognizable; and the mica appears in ferruginous patches. The rock is often quite undistinguishable from Millstone-grit in hand-specimens; even the purple colour (due to decomposed ferruginous mica) fails sometimes, and, as at Plumpton, great and lofty cliffs of solid rock appear, such as may have yielded the Devil's Arrows, those massive monoliths of the British settlement which preceded ancient Isurium. As we proceed to the south, and reach the Leeds coal-basin, the Permian beds lose their similitude to Millstone-grit; and as we pass to the north and encounter the Mountain-limestone, so also the resemblance to Millstone-grit is lost; nor is it recovered in Durham or Northumberland, nor does it occur in any other part of the kingdom, though quartzose pebbles and coarse sand accompany it in many parts. From this we may draw a confirmation of the opinion, very probable on other grounds, that the Lower Permian beds were of littoral aggregation, by currents operating on the waste of the neighbouring coasts.

On Harrogate Common, the railway-cutting exposed northern Drift, the usual Boulder-clay, with much variety of rock-fragments, all, as far as I saw, from the limestones and gritstones lying to the north.

FEBRUARY 22, 1865.

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

The following communications were read:—

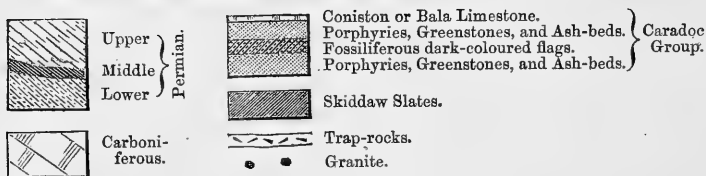
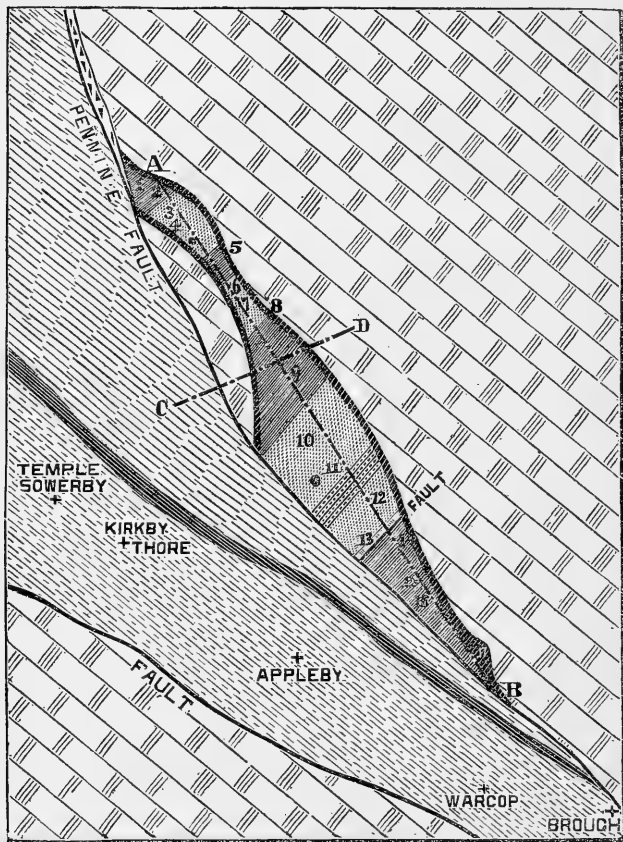
1. *On the LOWER SILURIAN ROCKS of the SOUTH-EAST of CUMBERLAND and the NORTH-EAST of WESTMORELAND.* By PROFESSOR R. HARKNESS, F.R.S. L. & E., F.G.S.

CONTENTS.

1. Introduction.
2. The Lower Silurian Rocks of the South-east of Cumberland.
3. The Lower Silurian Rocks of the North-east of Westmoreland.
4. Fault through the Lower Silurian Rocks of the South-east of Cumberland and the North-east of Westmoreland.

1. *Introduction.*—The district to which this memoir has reference consists of a narrow band of country on the western side of the Pennine Chain, possessing external features which indicate a difference in mineral nature from the rocks which form those Pennine escarpments, and also from those which, in Cumberland and Westmoreland, usually lie on their western side. The area occupied by this narrow band of Lower Silurian rocks extends in length about fourteen miles in a N.N.W. and S.S.E. direction; and it has a varying breadth from a very narrow strip to about a mile and a

Fig. 1.—*Geological Sketch-map of the South-east of Cumberland and North-east of Westmoreland.*



 Upper Old Red Sandstone.

1. Melmerby Scar.
2. Aw Fell.
3. Cuns Fell.
4. Ashlock Syke.
5. Ardale Beck.
6. Wythwaite Top.

7. Grumpley.
8. Crowdundle Beck.
9. Burney Hill.
10. Knock Pike.
11. Dufton Pike.
12. Gregory.

13. Keisley.
14. Highcup Gill.
15. Murton Pike.
16. Murton Beck.
17. Roman Fell.

AB, CD, lines of section, figs. 2 and 3.

half, the average width being about a mile. Its northern limit is in the township of Melmerby, in Cumberland, and its most southern point is in that of Hilton, in Westmoreland, this narrow band of Lower Silurian Rocks running from Melmerby through Ousby and Kirkland in Cumberland, and through Milburn, Knock, Dufton, Murton, and Hilton in Westmoreland.

The northern boundaries of this Lower Silurian area are the rocks which usually form the base of the Pennine escarpment, namely, the Upper Old Red Sandstone and the Melmerby Scar Limestone—the base of the Carboniferous formation in the north of England. The boundary on the W.S.W. side is more varied: the more southern portion, being the Great Pennine Fault, which brings the Lower Silurian Rocks and the Upper Permian Sandstones in contact, is very regular; but the more northern portion has a very irregular outline, and consists of Upper Old Red Sandstone and Lower Carboniferous Rocks, these having been broken from the Pennine range and thrown down to the west by a fault. These newer Palæozoic strata come in contact with the Great Pennine Fault on the west, where they have a regular margin; but on their eastern side, where they join the older Palæozoic Rocks, their outline is very irregular.

The country occupied by the Lower Silurian Rocks in this portion of the north of England presents a very strong contrast to the areas which bound them both on their E.N.E. and W.S.W. sides. To the E.N.E. the bold wall-like limestone-escarpments, the comparatively unbroken summits, and the easy eastern slopes of the Carboniferous rocks, exhibit features widely removed from those of the Lower Silurian masses; and the gently undulating surface of the Permian formation to the W.S.W. presents a still more distinct contour of country. The Lower Silurians of this area are boldly conical in their outline, probably more so than in any other portion of the British isles; and to such an extent does this conical form prevail that a volcanic origin has been assigned to the rocks—a conclusion which has been partially borne out by the abundance of porphyries in some of the conical hills.

The peculiar outline of the Lower Silurian rocks can be well seen from the neighbourhood of Appleby, where Knock, Dufton, and Murton pikes, to the east, rise boldly from the gently undulating Permian country at their western bases. It is also distinctly seen from the north and south, in the case of the two former pikes, a deep narrow valley separating them from the Pennine Chain.

This conical outline was probably the result of rolls in the rocks, and of a fault which runs between the Pennine chain and the Pikes of Knock and Dufton. Subsequent denudation has also greatly modified the original form of this Silurian area. With reference to the latter, the present drainage of the country, which is the only source by which the rocks are exposed in some localities, has cut valleys running nearly east and west, or almost at right angles to the direction of the fault just referred to; and through these the streams flowing from the steep Pennine escarpment rush westwards with great

eroding power through the Silurian area in their course to the river Eden.

The Lower Silurian rocks and the strata which bound them have been referred to in a memoir by Dr. Buckland*. This, however, was at a time long antecedent to Sir Roderick Murchison's labours among the older rocks; and consequently the relations described by Dr. Buckland are such as are inapplicable to the present state of our knowledge of the older Palæozoic series. Professor Phillips, in his 'Geology of Yorkshire,' has also alluded to the rocks of this district as forming the base upon which the Old Red Sandstones and the Carboniferous strata of the north of England repose.

2. *The Lower Silurian Rocks of the South-east of Cumberland.*—It has been already stated that the extreme northern limit of the Lower Silurian rocks in the south-east of Cumberland is in the township of Melmerby. In this locality these rocks are exhibited, flanked on their western side by the Upper Permian sandstones, which have been brought into contact with the older Palæozoic rocks by the Great Pennine Fault. On the north and north-east the Upper Old Red sandstones are seen bordering the Lower Silurian rocks, reposing unconformably upon them, and dipping towards the north-east at a low angle. Immediately contiguous to the Lower Silurian strata, on their western side, as seen in Rake Beck, about a mile east of Melmerby village, is a mass of trap which sends veins into them. This trap soon disappears from the old rocks southward from Rake Beck; it can, however, be seen north of the extreme northern limits of the Silurian strata, forming low hummocky hillocks along the base of the Pennine escarpment; and it is *probably* a portion of that line of igneous rock which intersects the Permian strata in the centre of Cumberland, cutting across them from Renwick, in a W.N.W. direction, through Barrock Fell to Petterell Crooks, near Wreay Station, on the Lancaster and Carlisle Railway.

The Lower Silurian rocks are exposed in the upper portion of Rake Beck, in the parish of Melmerby, and in the streams which join this rivulet. They compose a hill called Mickle Aw Fell, on the north side of Rake Beck; and in its neighbourhood the strata have been extensively worked for diking purposes.

The rocks, as seen here, are hard flaggy slates, usually of a dark-grey colour, but having occasional green bands among them. At Mickle Aw Fell they dip S.S.E. about 50°, and possess all the characters of the flaggy beds of the Skiddaw slates. The evidence of the occurrence of fossils in them is imperfect, consisting only of impressions and elevations having a *Gorгона*-like aspect, and possessing a distinct central axis, which sends off from each side a reticulated structure with interspaces. Impressions and elevations of a like nature are also seen among the Skiddaw slates of the Lake-country. In the course of Rake Beck, below the junctions of the streams flowing from Mickle Aw Fell, the Skiddaw slates are also seen; but they have a different mineral character from the flaggy slates of Mickle Aw Fell.

They are black in colour and soft in nature, in which features

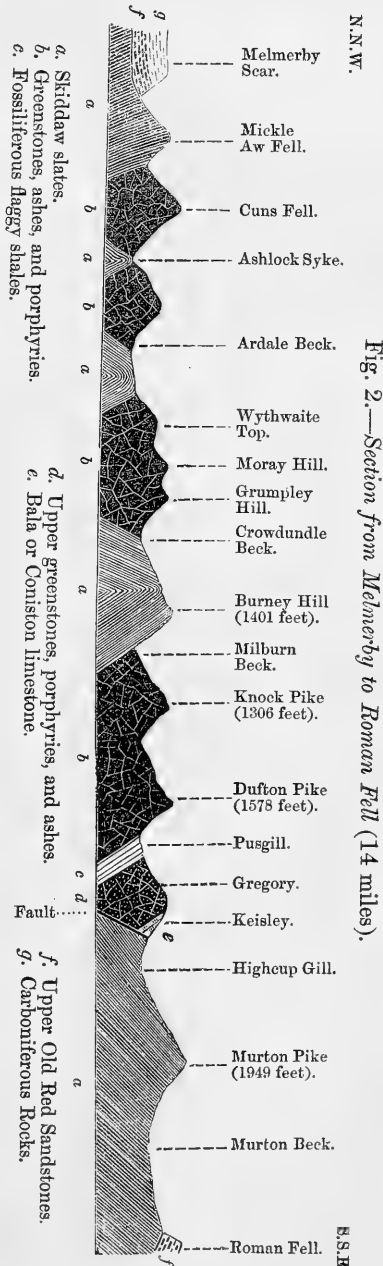
* Geol. Trans. 1st series, vol. iv. p. 105 *et seq.*

they agree with the higher beds of the Skiddaw slate series as these are seen near the junction with the succeeding green slates and porphyries of the Lake-district proper.

South-east from Mickle Aw Fell, another hill of greater elevation is seen. This, named Cuns Fell, has a very different mineral nature from the elevations which are composed of Skiddaw slates. Cuns Fell has also a different outline from Mickle Aw Fell. Its summit is craggy; and the upper portion of its eastern side presents prominent bosses of rocks, which have strewn this side and the south-eastern slope with an enormous quantity of débris.

The rock forming Cuns Fell is a greenish crystalline porphyry, in which crystals of felspar are abundant; it has considerable affinity to the green rocks of the lower portion of the green slates and porphyry series of the Lake-district, especially as these are seen in Barton Fell, overlying the Skiddaw slates, but in the latter locality the green rocks are somewhat less crystalline than in Cuns Fell.

These green porphyries form also the great mass of the rounded hill called Catterpelt, lying immediately south-west of Cuns Fell, to the north-east of which, like the Skiddaw slates, they pass under the Old Red Sandstone. On the south side of Cuns Fell there is a rather large and somewhat semicircular valley known as Ousby



Dale, from the eastern side of which (the Pennine escarpment) several small rivulets flow, and by their junction form the stream called Ousby Dale Beck. In one of these small rivulets Skiddaw slates make their appearance, dipping N.N.W. 70° , or under the green rocks of Cuns Fell. This local exposure of Skiddaw slates is very small, being succeeded immediately on the west and on the south by rocks appertaining to the greenstone and porphyry series. There is, near this spot, but a little to the south of it, a small area of syenite, which is now being worked.

The ridges on the south side of Ousby Dale (namely, Windy Gap, Hawse Crag, Sharp Shears, and Kit's How) are all composed of yellowish-grey porphyry resembling some of the porphyries which make their appearance in the lower portions of the green rocks overlying the Skiddaw slate in some parts of the Lake-district. To the south of these ridges the country, for a short distance, is comparatively flat; and at Ashlock Syke the same yellowish-grey porphyries are seen lying upon the upper soft shales of the Skiddaw slates, which are highly cleaved here, but the strata seem to be nearly vertical. Ashlock Syke is the position of an anticlinal axis. Between Ashlock Syke and Ardale Beck, which lies about half a mile south from Ashlock Syke, the area is made up of low hills composed of porphyry; and at Ardale Beck, which flows by the village of Ousby, the porphyry is again found having the same relations to the underlying Skiddaw slates as at Ashlock Syke. The Skiddaw slates at Ardale Beck afford Graptolites belonging to the genus *Tetragrapsus*. From Ardale Beck, for a short distance S.S.E., the area occupied by the Lower Silurian rocks becomes greatly narrowed, in consequence of the Upper Old Red Sandstone and the overlying Carboniferous rocks of Cocklock Scar on the E.N.E. coming nearly into contact with the same rocks on the W.S.W., which form Bank Rig. In the intervening narrow area the Skiddaw slates cannot be distinctly made out; but a short distance southwards, on the south-east side of Kirkland Beck (a stream which probably marks the S.S.E. boundary of this Skiddaw slate area), hard green rocks make their appearance and form the hill called Wythwaite Top. These green rocks resemble those of Cuns Fell, but they are somewhat more compact in their nature, and they cannot be distinguished from the green rocks of Barton Fell, near Ullswater, at which place they come into contact with the Skiddaw slates*. Rocks appertaining to the same green series occur to the S.S.E. of Wythwaite Top. They form Moray Hill and Grumpley Hill, but, as seen in these latter elevations, they are more porphyritic than in Wythwaite Top. These three hills form the west and south-west base of Cross Fell, under which the green and porphyritic rocks extend. Their S.S.E. boundary here is the Crowdundle, a stream which separates in this area the counties of Cumberland and Westmoreland.

3. *The Lower Silurian Rocks of the North-east of Westmoreland.*—On crossing the Crowdundle Beck into Westmoreland, the outline of the country presents a strong contrast to that of the area on the

* *Vide* Quart. Journ. Geol. Soc. vol. xix. p. 127.

Cumberland side of this stream. On the south-east side of Crowdundle, the country, for about three-quarters of a mile, is comparatively flat; but the surface is curiously intersected by small, shallow, sinuous valleys, many of which are dry. There is, however, a fine section laid open in this flat area by a stream called Middle Tongue Beck, which flows from the south-east into the Crowdundle.

This section exposes a fine series of Upper Skiddaw slates, contorted, but on the whole dipping N.N.W. under the porphyries of Grumpley Hill. These soft shaly Upper Skiddaw slates have in them the masses with the "*cone-in-cone*" so common to this portion of the series in the Lake-country. They have also cleavage highly developed; and Graptolites characteristic of the Skiddaw slates occur in them. The flat area which they occupy is known as Milburn Pasture; but on the south-east of it the Skiddaw slates attain an elevation of 1400 feet above the level of the sea, forming here Burney Hill.

A stream known as Milburn Beck, or as Knock-one-Gill Beck, flows from the Pennine escarpment and along the south-east side of Burney Hill.

In one spot, about a mile north-east of Milburn Grange, this stream cuts a fine section in the rocks on the south side of Burney Hill. Here also we have the upper shales of the Skiddaw slates, with "*cone-in-cone*" masses exposed; and here the dip is opposite to that seen in Middle Tongue Beck, or S.S.E. A short distance below this, in the course of Milburn Beck at Swineside, a mass of yellowish porphyry comes on, and, continuing down the stream, forms its bed to near Milburn Grange. This porphyry also has a great affinity to some of those which occur near the base of the green rocks of the Lake-country.

South-east from Milburn Beck the country exhibits a very broken surface, the hills having the prominent conical outline before alluded to. Of these, Knock Pike (1306 feet) presents itself on the south side of Milburn Beck. The northern, western, and southern slopes of this hill are clothed with fine grass, but the eastern side is somewhat craggy and abounds in débris. The rocks and débris on this side afford a clear insight into the composition of this hill. Porphyry, similar to that at Swineside, is the constituent rock of Knock Pike; it crosses the valley on the north-east side of the Pike, and forms a hill called Flagdaw (1355 feet), which has a contour similar to Knock Pike. From Flagdaw this rock extends north-eastwards, passing under the Upper Palæozoic rocks of the Pennine escarpment.

To the south-east of Knock Pike is a stream called Swindale Beck, which, after leaving the Pennine escarpment, flows over porphyry similar to that of Knock Pike. As it approaches the village of Knock the character of its bed becomes altered, the rocks consisting of purple and green slaty masses, dipping S.S.E., reposing on the porphyry of Knock Pike, but passing under the rocks which compose Dufton Pike. These purple and green slates of Swindale Beck

have their analogues among the green slates which are associated with the porphyries and ash-beds of the Lake-district.

Duften Pike (1578 feet), which is on the south side of Swindale Beck, has, on its northern side, porphyries resembling those which make up Knock Pike; and these are not confined to the northern slope of Duften Pike, for they form the principal portion of this hill. These porphyries are penetrated by a mass of fine-grained granite, as seen in a field called Barky Close. This granite extends westwards, and is also seen in the narrow road immediately below the farm of Halsteads. It possesses many of the features of felstone, and has crystals of mica disseminated through it. Its occurrence here, and its nature, have been noticed by Dr. Buckland*.

The porphyries which form the bulk of Duften Pike also make up the mass of Brownbar (1695 feet), a hill lying about half a mile north-east of Duften Pike. The north-eastern side of Brownbar comes abruptly against the newer Palæozoic rocks. Brownbar is separated from Duften Pike by a deep narrow valley, a continuation S.S.E. of the valley which separates Knock Pike from Flagdaw.

Although the great mass of Duften Pike consists of hard porphyries, these are not the exclusive components of this hill. Its south-east side exhibits rocks which are distinctly laminated, which have a well-marked cleavage, and which are composed of felspathic ashes. These ashy rocks have been partially quarried on the south-east side of Duften Pike. They mark a considerable change in the nature of the rocks in this area; and they are succeeded by other rocks still further removed from the porphyritic series.

Immediately south-east of the base of Duften Pike is an area having a very different outline from the conical-hill country just alluded to. This area possesses gently undulating features, and is drained by small streams which alone afford exposures of rock. One of these, named Pusgill, flows along the south-east base of Duften Pike, and the rocks intersected by this stream consist of dark flaggy shales impressed with a distinct cleavage; and these shales, wherever they occur in the bed of the stream, are highly fossiliferous along the laminæ of deposition †. Rocks of the same nature are also seen in the course of the small stream (Duften Syke) which supplies the village of Duften with water; and the strata here are even more fossiliferous than in Pusgill. The dark flaggy fossiliferous shales also occur in Billy's Beck, where this stream intersects Bale Moor; and we have them still further to the south-east, in the bed of Harthwaite Syke.

These dark-coloured fossiliferous flaggy rocks, which have a S.S.E. dip, occupy a zone, measured on their dip, of more than three-quarters of a mile wide; and, like the porphyries, they too pass under the Newer Palæozoic rocks on the north-east, and on the south-west they are brought into contact with the Upper Permian

* Trans. Geol. Soc. 1st series, vol. iv. p. 109.

† My attention was first directed to the fossiliferous nature of the Pusgill shales by Mr. Wallace, of Duften, the author of 'The Mineral Deposits of Alston Moor.'

Sandstones by the Great Pennine Fault. The fossils which occur in these dark shales, although not very numerous in species, are very characteristic forms, and are as follows:—*Stenopora fibrosa* (branching variety), *Crinoid stems*, *Lingula ovata*, *Leptæna sericea*, *Orthis testudinaria*, *O. calligramma*, *O. alternata*, *Modiolopsis orbicularis*, *Bellerophon bilobatus*, *Orthoceras Brongniartii*, *Tentaculites annulatus*, *Beyrichia strangulata*, *Trinucleus concentricus*, *Calymene Blumenbachii*, *Homalonotus bisulcatus*, *Lichas laxatus*, and *Ampyx mammillatus**.

To the south-east of Harthwaite Syke the outline of the country differs widely from the gently undulating area lying between this small stream and the south-east base of Dufton Pike. The country becomes hilly, and the low hills again assume a conical form.

One of these hills, called Gregory, lying a short distance from Harthwaite Dyke, has a porphyritic nature, and its west side has been worked extensively for dyking-purposes. The porphyry here has a greenish-grey aspect. It extends a short distance south-west through Harthwaite Pasture, but towards the south-east it is soon succeeded by felspathic ashes, which are well exposed about four hundred yards north of Keisley, and which continue south-east a short distance beyond this exposure. These ashes are also seen at Studgill Tarn, a small lake a short distance east of Keisley; and, although much contorted, they have a prevailing S.S.E. dip.

The felspathic ash-beds just referred to are succeeded immediately south-east of Keisley and Studgill Tarn by a series of rocks which have no representatives in the country which has been previously described. This series consists of limestones of a dark-grey colour, with purple blotches, well bedded, and dipping S.S.E. at 35°. Some of the beds of this limestone have a somewhat concretionary aspect, and have interbedded irregular shaly bands associated with them. Near Keisley, this limestone has been worked for many years; and although fossils are not plentiful in the quarries, the walls built of this limestone afford abundance of animal remains from the weathering of the rock. The following are the fossils which the Keisley limestone affords:—namely, *Stenopora fibrosa*, *Halysites catenulatus*, *Petraia subduplicata*, *Nebulipora lens*, *Crinoid stems*, *Lingula brevis*, *Siphonotreta*, sp., *Orthis calligramma*, *O. elegantula*, *Strophomena tenuistriata*, *S. corrugata*, *S. expansa*, *Leptæna monilifera*, *Fenestella assimilis* (Portl.), *Ptilodictyum dichotomum*, *Modiolopsis Nerei*, *Orthoceras vagans*, *O. politum?*, *Theca triangularis*, *Theca*, sp., *Conularia elongata*, *Holopea concinna*, *Cheirurus clavifrons*, *C. bimucronatus*, *Ampyx tumidus?*, *Ilænus Davisii*, *Lichas*, sp., *Harpes*, sp., *Cythere phaseolus*, an Entomostracan which occurs in great abundance in the limestone of the Chair of Kildare, and a pygidium, probably of *Cheirurus octolobatus*. This group of fossils from the Keisley lime-

* Many of the above fossils were first obtained by my friend Mr. Henry Nicholson, of Penrith. In one locality in the higher part of Pusgill he detected a spot in which the shales were full of *Beyrichia strangulata*, *Orthoceras Brongniartii*, and *Stenopora fibrosa*. I am also indebted to him for many fossils from Keisley, a locality subsequently alluded to.

stone has a great affinity to the contents of the Bala limestone, but it is even more nearly related to the Coniston limestone, the northern equivalent of the Bala calcareous rocks: when the *strike* of the Keisley limestone is looked at, and this *strike* connected with the range of the Coniston limestone in the north-west of England, the relation of the Keisley area with the limestone of the Lake-country is seen to be still more intimate. We can trace the Coniston limestone (as shown by Professor Sedgwick) extending from Broughton in Furness, by Monk Coniston, Low Wood, at the north-east end of Windermere, Applethwaite, Kentmere, and Longsleddle, to Shap Wells, where it is overlain by the Upper Old Red Sandstone and the Carboniferous Rocks of the centre of Westmoreland. Thence extending E.N.E., it passes under the Permian Rock of the Vale of the Eden, and reappears at Keisley on the same line of *strike* as at Shap Wells, where it passes underneath the newer Palæozoic Rocks.

With reference to the fossiliferous flaggy shales which underlie the ash-beds of Keisley and the porphyritic rocks of Gregory, but which succeed the thick porphyritic masses of Dufton and Knoek Pikes, these as yet have no recognized analogues in the Lake-country. They have, however, their equivalents in North Wales. The black slates which are superposed on the igneous rocks of the Arens and Arenigs are their representatives in this country, since they afford similar fossils.

The fossiliferous rocks of the Snowdon series, occurring between felspathic traps and ash-beds, also exhibit the same fossil contents, and occur likewise under nearly the same conditions as the flaggy shales occupying the gently undulating area south-east of Dufton Pike.

If we take collectively the group of rocks from the N.N.W. limit of the Lower Silurian area of the south-east of Cumberland, and of the north-east of Westmoreland, we have the following sequence:—namely, first and lowest, Skiddaw slates, or Lower Llandeilo, with characteristic fossils. Second, a thick mass of porphyries, including green and purple slates, and having ash-beds in their higher portions. As yet these have afforded no fossils, and they represent the Upper Llandeilo. Upon these Upper Llandeilo fossiliferous thick black shales, felspar-porphyries, ashes, and limestones occur, which, both in mineral nature and fossil contents, represent the Caradoc or Bala group*.

A short distance to the south-east of the Keisley lime-quarries a mass of rocks presents itself having a nature altogether different from the calcareous strata, and with a dip directly opposite to that of the Keisley limestones. It is well seen in a hill called Whinskill,

* In the determination of the fossils, I have been assisted by Professor T. Rupert Jones, who examined the Entomostraca for me, and Mr. W. H. Bailey, palæontologist to the Irish Geological Survey, who has gone over a portion of the remains from the Keisley limestone with me, and who recognized the affinity of this limestone with that of the Chair of Kildare both in fossils and mineral character.

nearly in contact with the Keisley limestones which form the northern slope of this hill. On the south-east side of Whinskill there are several quarries which have been wrought for dyking-purposes, and in these we have good exposures of the rocks which occur to the south-east of the Keisley limestone.

Here the strata consist of hard, dark-coloured, flaggy slates with a highly inclined N.N.W. dip. They have also a vertical cleavage, and in every respect they resemble the coarse Skiddaw slates which underlie the softer shaly beds of the higher portion of this series.

The altogether discordant dip, and the mode in which the Skiddaw slates of Whinskill come in contact with the Coniston limestone of Keisley, indicate the existence here of a great fault, which brings the Lower Skiddaw, or a lower portion of the Lower Llandeilo, into contact with the Coniston or Bala limestone. The amount of the throw-down to the N.N.W., produced by this fault, cannot be exactly determined, since there is as yet no means of knowing the exact position of the portion of the Skiddaw slate in contact with the Coniston limestone, or the total thickness of the porphyries, green slates, ashes, and fossiliferous flaggy shales which intervene between the top of the Skiddaw slates and the base of the Coniston limestone. There are, however, good grounds for assuming that the amount of throw exceeds 10,000 feet, which is probably the thickness of the interposed rocks separating the Skiddaw slates from the Coniston limestone. This fault is of an ancient date, as it in no way affects the Upper Old Red Sandstone and the Carboniferous strata which overlie the Older Palæozoic rocks.

Whinskill forms the north-west boundary of a deep hollow called Highcup Gill, which, after traversing the Lower Silurian rocks, penetrates the Old Red Sandstone and Carboniferous group. This hollow is drained by a stream called Highcupgill Beck*. On the south-east side of this hollow, at Harbour Flat, the flaggy Skiddaw slates are also seen, having been worked at a quarry here. They dip N.N.W. at 60°, and they are intersected by the coarse vertical cleavage before alluded to. The same rocks form the west slope of the hill called Middle Tongue, where they are capped by an escarpment of the newer Palæozoic rocks. The hard flaggy Skiddaw slates occur on the north side of Murton Pike (1949 feet), and are here much intersected by quartz-veins. They are still better seen on the western side of this hill; and at the base of the southern slope they are well exposed in a cliff called Thornarbour Scar. These Skiddaw-slate rocks form the whole of Murton Pike, except the eastern side, where they are overlain by the newer Palæozoic strata. Wherever the flaggy slates are seen in Murton Pike they have a N.N.W. dip and vertical cleavage; and they retain throughout the same type of mineral character.

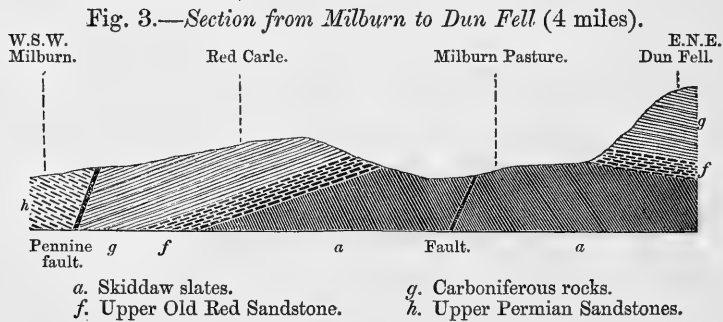
Immediately south-east of Murton Pike, the same rocks are seen in Murton Beck. They occupy the slope between Murton Beck

* In this glen one of the finest sections of the Carboniferous Rocks (including the Whinskill) of the Pennine escarpment occurs.

and Hilton Beck, and are succeeded on the east by the Old Red Sandstone and Carboniferous Limestone of Delfkirk Scar. We have them also occurring with a N.N.W. inclination in Hilton Beck, at the Smelt Mill, very near the line of the Great Pennine Fault. From Hilton Beck south-eastward the same Skiddaw slates are seen. They form the northern and western slopes of Roman Fell, and they are seen in the course of a small stream which intersects the western side of this hill. At Roman Fell the Skiddaw slates are capped by a thick mass of Old Red conglomerates and sandstones; and to the south-east of Roman Fell this capping hides the Lower Silurians.

We have no further trace of them beyond Roman Fell in the east of Westmoreland, the Carboniferous rocks coming into immediate contact with the Upper Permian Sandstones along this portion of the line of the Great Pennine Fault.

4. *Fault through the Lower Silurian Rocks of the South-east of Cumberland and North-east of Westmoreland.*—Allusion has already been made to an ancient fault which brings the Skiddaw slates against the Coniston Limestone. This fault has a direction which nearly accords with the strike of the Lower Silurian Rocks. Another fault cuts through the Lower Silurians of the south-east of Cumberland and the north-east of Westmoreland.



The direction of this fault is nearly at right angles to that which brings the Skiddaw slates and the Coniston Limestone into contact; and its course is nearly parallel to that of the Great Pennine Fault. Indications of this fault can be seen among the Carboniferous rocks on the road from Melmerby to Alston, about a mile N.N.E. from the former village. It can be still better observed among the Old Red Sandstones and Carboniferous rocks on the south side of Melmerby Scar, the western portion of this, called the Nib, being broken off from the bulk of the Scar and thrown down to the westward.

The Lower Silurian rocks afford very little indication of this fault; but the newer Palæozoic series, the Upper Old Red Sandstone, and the Carboniferous formation indicate the extension of the fault, in a N.N.W. and S.S.E. direction, through and beyond the older Palæozoic rocks.

There is in the townships of Ousby and Kirkland in Cumberland, and in the township of Milburn in Westmoreland, an area lying W.S.W. of the Lower Silurian Rocks and E.N.E. of the Great Pennine Fault, occupied by strata appertaining to the Carboniferous formation and the Upper Old Red Sandstone. These rocks can be seen in Ashlock Syke, a short distance from the church at Ousby. They are still more apparent in Ardale Beck, from Ousby Town Head for about half a mile E.N.E., where they are succeeded by the upper shales of the Skiddaw slates. The limestones of the Carboniferous formation have been worked here, and the pebbly beds of the Old Red Sandstone occur beneath them, but the whole are greatly broken up. The occurrence here of these rocks has been noticed by Dr. Buckland*.

The outcrop of the Old Red Sandstone occurring in this detached area can be traced from Ardale Beck along the north-east, east, and south-east escarpment of the Common called Bank Rig. This escarpment, in its eastern part, is in almost close contiguity with the Old Red Sandstone of Cocklock Scar, the former passing under the limestone of Bank Rig, and the latter under the Melmerby Scar limestone of Skirwith Fell, the slight interval separating these Old Red Sandstones and limestones being occupied by the Skiddaw slate, as before mentioned. The limestone overlying the Upper Old Red Sandstone of Bank Rig is worked on the Common, and has a S.S.E. dip at 15°. From the occurrence of the pebbly Old Red Sandstone below it, this limestone is doubtless the lowest of the Carboniferous strata, the Melmerby Scar limestone. A short distance to the south of Bank Rig, Kirkland Beck intersects the Old Red Sandstone, which has here a south-west dip, being directly opposite to the inclination of its equivalent, as this underlies the Carboniferous rocks of the Pennine escarpments.

Passing into Westmoreland, we find this detached and south-western Carboniferous area separated from the Pennine chain by the Skiddaw slates of Milburn Pasture. Limestone has been extensively worked in this portion of the area, at Thrushgill and other spots on Red Carle. We find it again about a third of a mile south-east of Howgill Castle, beyond which, southward, we lose all traces of this newer Palæozoic area, the Skiddaw slates, porphyries, ash-beds, fossiliferous flags, or Coniston Limestone coming into contact with the Upper Permian sandstones on the line of the Great Pennine Fault.

This detached area of Old Red Sandstone and Carboniferous rocks commonly occupies a much lower elevation than the corresponding rocks of the Pennine escarpment, from which it has been broken off and thrown down to the south-west. It is probably the relic of a much larger area which at one time covered up the Lower Silurian Rocks, their exposure being the result of denudation.

The extension of this fault through the older Palæozoic rocks, beyond the south-eastern termination of the detached Old Red Sandstone and Carboniferous area, is difficult to determine.

There is, however, as before alluded to, a deep valley separating

* *Loc. cit. supra*, p. 113.

Knock Pike from Flagdaw, and Dufton Pike from Brownbar; and probably the direction of this valley is the course of the fault. It seems also to extend S.S.E. along the western and south-western flank of Murton Pike, and continues this course through the Skiddaw slates. Beyond these, to the S.S.E., it can be again recognized among the Carboniferous rocks of Warcop Fell, a portion of which is thrown down to the west. Here, however, denudation has not been sufficient to uncover the underlying Lower Silurian rocks. The conditions under which we meet with this N.N.W. and S.S.E. fault show its recent origin as contrasted with the W.S.W. and E.N.E. fault which brings together the Skiddaw slates and the Coniston limestone. Its true age, however, is difficult to make out. It may be older than the Great Pennine Fault, or it may have been formed at the same time. If so, an immense amount of subsequent denudation must have taken place to remove not only a thick mass of Carboniferous rocks, but also the great development of Permian strata which reposed upon them. The parallelism of this fault with the Great Pennine dislocation would tend to support the inference of similarity of age; and this inference is still further supported by the occurrence of other parallel small faults in the Permian Rocks of the Vale of the Eden. In the latter area, one of those N.N.W. and S.S.E. faults occurs near Croftends, about a mile north of Appleby, by means of which Carboniferous grits, shales, and clay-ironstone on the east are brought against the Lower Permian Sandstones on the west. A similar fault is seen on the east side of the Eden, in the Vale of St. Nicholas, about a quarter of a mile north-west from Appleby, where Carboniferous grits and shales on the east, which are overlain by the Lower Permian breccia, have, on their western margin, rocks appertaining to the base of the Permian formation.

LISTS of FOSSILS from the LOWER SILURIANS of the SOUTH-EAST of CUMBERLAND and NORTH-EAST of WESTMORELAND.

I. *Skiddaw Slates of Rake Beck.*

1. Gorgonia-like markings.

II. *Black flaggy Shales of Dufton.*

1. Homalonotus bisulcatus.
2. Trinucleus concentricus.
3. Calymene Blumenbachii.
4. Ampyx mammillatus.
5. Lichas laxatus.
6. Beyrichia strangulata.
7. Tentaculites annulatus.
8. Leptaena sericea.
9. Orthis testudinaria.
10. — calligramma.
11. — alternata.
12. Lingula ovata.
13. Bellerophon bilobatus.
14. Orthoceras Brongniartii?

15. Modiolopsis orbicularis?

16. Crinoid stems.

17. Stenopora fibrosa.

III. *Keisley Limestone.*

1. Stenopora fibrosa.
2. Halysites catenulatus.
3. Petraia subduplicata.
4. Nebulipora lens.
5. Crinoid stems.
6. Lingula brevis?, *Portlock.*
7. Siphonotreta, sp.
8. Orthis calligramma.
9. — elegantula.
10. Strophomena tenuistriata.
11. — expansa.
12. — corrugata, *Port. (S. undulata, M'Coy).*

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| 13. <i>Leptæna monilifera</i> , <i>M' Coy.</i> | 23. <i>Cheirurus clavifrons.</i> |
| 14. <i>Fenestella assimilis.</i> | 24. — <i>bimucronatus.</i> |
| 15. <i>Ptilodictyum dichotomum.</i> | 25. <i>Illænus Davisii.</i> |
| 16. <i>Theca triangularis.</i> | 26. <i>Ampyx tumidus.</i> |
| 17. <i>Theca</i> , sp. | 27. <i>Lichas</i> , sp. |
| 18. <i>Conularia elongata.</i> | 28. <i>Harpes</i> , sp. |
| 19. <i>Holopea concinna</i> , <i>M' Coy.</i> | 29. <i>Pygidium</i> , probably of <i>Cheirurus octolobatus.</i> |
| 20. <i>Modiolopsis Nerei.</i> | 30. <i>Cythere phaseolus.</i> |
| 21. <i>Orthoceras vagans.</i> | |
| 22. <i>O. politum</i> ?, <i>M' Coy.</i> | |

2. *Note on the VOLCANIC TUFFA of LATACUNGA, at the foot of COTOPAXI; and on the CANGÁUA, or VOLCANIC MUD of the QUITENIAN ANDES.* By RICHARD SPRUCE, Esq.

[Communicated by Sir R. I. Murchison, K.C.B., F.R.S., F.G.S.]

(Abstract.)

IN this paper it was stated that the town of Latacunga (in lat. 1° S., and 9000 feet above the sea) is entirely built of a volcanic tuffa, immense deposits of which occur there, that this tuffa is due to ancient eruptions of Cotopaxi, and that the smiths of Latacunga and Ambato use it instead of charcoal whenever their stock of that combustible is exhausted. Mr. Spruce then described the tuffa as whitish, light, porous, and more or less fibrous. It fuses after having been heated to redness for a considerable time, and on cooling becomes a vitreous mass with a glossy white or greenish surface. It has then only half its original volume, but nearly the same weight.

The deposits of volcanic mud called "Cangáua" were also described. This substance is met with throughout the Quitenian Andes, and the modern towns of Ambato and Riobamba are built of it, though it is said not to constitute a good building-material; it is compact, slightly argillaceous, more or less saline, and yields very slowly to atmospheric agencies or even to running water. The most extensive beds of it, the date of which is known, occur in valleys east of Carguairazo. This mountain was formerly as high as Chimborazo; but on the night of June 29th, 1699, its hollow cone fell in, with a shock that destroyed the neighbouring towns, including Ambato, Riobamba, and Alausi, the latter nearly a degree of latitude to the southward. Very few of the inhabitants of Ambato escaped; and scarcely had they gathered together on the ruins of the town when they were driven away by floods of fetid mud, which united just below its site. The river Patate (a tributary of the Pastasa) and the Ambato, which runs into it, were for some weeks blocked up, and their waters spread over the country, forming large lakes; but they finally re-excavated their original channels*. One valley, however, between Ambato and the village of Tisaleo

* These particulars were obtained by the author from an account of the catastrophe in the archives of Ambato, written by one of the few survivors.

was completely filled up, and so remains to this day, the stream which traversed it having found another outlet. Here the Cangáua spreads out into broad sheets nearly a quarter of a mile across.

3. *On the DISCOVERY of FLINT IMPLEMENTS in the DRIFT at MILFORD HILL, SALISBURY.* By H. P. BLACKMORE, M.D.

[Communicated by John Evans, Esq., F.R.S., F.G.S.]

(Abridged.)

SINCE the discovery of flint implements in the higher-level gravel at Fisherton, on the west of this city, an interesting account of which was given by my friend John Evans, Esq., in a valuable paper published in the August Number of the Society's Journal, a second discovery of a large number of very excellent weapons has been made in the drift-gravel of Milford Hill, a deposit of the same age as the Fisherton Beds, but situated on the opposite side of the Avon, immediately to the east of Salisbury. In the Ordnance Map the name of Milford Hill has been erroneously applied to what is known on the spot as Cricket Down, Milford Hill proper being a continuation of Mizmaze Hill.

The gravel in which these implements are found is composed of the ordinary subangular chalk-flints, a few well-rolled Tertiary pebbles, some small blocks of saccharoid sandstone, also of Tertiary origin, and a much larger percentage of fragments of Greensand chert than occurs in the gravel at Fisherton. All these materials are blended with a variable proportion of sand and stiff clay, and are stained pretty uniformly of a dark-ferruginous colour. Many of the chalk-flints are of large size, with sharp, well-defined angles, and present scarcely any marks of violent rolling or water-wearing.

When we look at any of the sections of chalk in this neighbourhood, and remark the comparatively few and widely scattered bands of nodules, we feel that one can barely form an adequate notion of the immense bulk of chalk which must have been denuded and disintegrated to produce these large accumulations of flint-gravel, or form any approximative idea of the vast period which such a gradual process must have involved.

The drift at Milford completely invests the summit of the hill. It is thickest at the top, where it attains a thickness of from 10 to 12 feet, thins out gradually on the sides, and ceases altogether rather more than halfway down. It is quite free from anything approaching stratification, rests unconformably upon the Chalk, running down in many places into shallow pot-holes, and attains a height of about 100 feet above the present level of the river Avon. The position of the gravel is interesting and of considerable importance.

Milford Hill is a low chalk spur, placed immediately above the point where a small stream called the Bourne joins the river Avon,

thus forming a kind of buttress which separates the two valleys. It is, however, separated from the main tract of high land which intervenes between the two valleys by a transverse valley about 30 feet in depth, so that it forms, in fact, an isolated hill entirely disconnected, by valleys of greater or less depth, from any higher ground. From the conformation of the valley, it must be evident to any one, that when the gravel was deposited on Milford Hill the ancient river must, during the continual variations of its course, have extended from Laverstock Hill on the east to Harnham Hill on the west, a distance of about three miles.

Some few years since, a good section of this drift was exposed on the south-eastern side of the hill, in the cutting made for the London and South-Western Railway; and here, near the base of the gravel, a narrow seam of loose light-coloured sand and shells was discovered. The shells in this single spot existed in the greatest profusion, and, although extremely friable, were mostly entire and unbroken. They consisted principally of *Helix hispida* in all stages of its growth. There were a few specimens of *H. arbustorum*, mostly broken, two or three of *Pupa muscorum*, and a single individual of *Zua lubrica*. It is rather remarkable that all these shells are terrestrial, and in every way agree with examples of the same species still living in the adjacent fields.

With the single exception of a fragment of an upper molar tooth of a species of *Equus*, no bones or Mammalian remains have as yet been discovered; and at no other point in the gravel has any seam of sand with shells been found, although diligent search has been made at every opening.

There is in many places at the base of the compact gravel, resting upon the Chalk, an irregular deposit of pale fawn-coloured chalk-rubble, containing a small admixture of flint-gravel, but no organic remains.

With regard to the implements themselves, they are, with two or three exceptions, all of the long pointed type, thus confirming the opinion of Mr. Evans that this particular form is mainly characteristic of the higher-level gravels. They are found scattered unevenly throughout the deposit; the majority, however, occur low down, in many cases imbedded in the chalk-rubble above mentioned.

The implements on the side of the hill are relatively only half as numerous as on the top.

The condition of the surface of the weapons varies considerably. The majority are water-worn, and show evident traces of having travelled some distance in very rough company, and bear marks of many a hard knock and jostle by the way; others, however, have the angles of the chippings as sharp and well preserved as if they were made but yesterday. Some are stained of a deep yellow colour, others only partially so, and some not at all. It is rather remarkable that this staining does not appear to be due to their present position in the gravel, as some of the darkest-coloured ones have been dug out of the pale chalk-rubble side by side with fragments of flint retaining its original hue; and, on the other hand,

perfectly unstained examples have been obtained from the dark ochreous gravel. From the great attention paid to the excavations by Mr. Brown and others, a very considerable number of implements have been seen absolutely *in situ*; so that there is no possibility of any erroneous observations on this point. Nearly all present a greater or less amount of dendritic markings, and very many have a slight incrustation of carbonate of lime on the lower or under surface. With a single exception, the implements are made from flint derived directly from the Chalk. The exception alluded to is a small specimen of coarse Greensand chert, and is stained of a deep yellow colour. This kind of chert is much less easily worked than flint, but is more tough, and hence probably compensated by this quality for the additional trouble required to chip it into shape.

The implements are simply chipped into form, and show no subsequent rubbing down, as seen in those of the later Stone-period. The result of this mode of manufacture is evidenced by the presence in the gravel of a large number of rough outside and "waste flakes," namely, those flakes of so awkward a form as to be useless for the purpose of implements; but, rough as these pieces are, all are characterized by a well-marked "bulb of concussion," indicating the spot at which the blow was given to detach the flake from the parent mass.

The workmanship of some of the tools is rude in the extreme, and has frequently brought from the labourers the remark, "This one must have been made by a 'prentice hand." Indeed, taken as a whole, the implements found in this locality are ruder and less skilfully made than most of the specimens from the valley of the Somme.

Since the publication of Mr. Evans's valuable paper on the implements found at Fisherton, I have to record the finding of a very carefully worked specimen from the brick-earth, associated with the remains of the extinct Mammalia a list of which he has already given. This is the first example hitherto found in the Fisherton brick-earth; the other specimens were from the higher-level gravel, at a considerable elevation above this deposit.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPER.

On the SPECIES of MASTODON and ELEPHANT occurring in the FOSSIL STATE in GREAT BRITAIN. PART II. ELEPHANT (imperfect). By the late HUGH FALCONER, M.D., F.R.S., F.L.S., For. Sec. G.S.

[Read June 3, 1857*.]

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I. INTRODUCTION.

IN the remarks introductory to the preceding part of this essay, I adverted to the importance, for sound reasoning in geology, that

* For the abstract of this communication already published, see Quart. Journ. Geol. Soc., vol. xiv. p. 81. Part I was published in full, with illustrative plates, in vol. xiii. p. 307. This part (unfortunately imperfect, as it is wanting, at least, in the description of *Elephas antiquus*, and in a portion of that of *E. primigenius*, neither of which desiderata appear to have ever been written) is now published posthumously without illustrations; but should the figures or specimens designed to illustrate it be satisfactorily determined, the illustrations will be published in a future number of the Journal. The Assistant-Secretary has received much invaluable assistance, in editing this paper, from G. Busk, Esq., F.R.S., F.G.S., especially in the determination of specimens and figures referred to, but the numbers of which were not filled in by the author.

every Mammal found in the fossil state should be determined specifically with precision, and I endeavoured to illustrate the point by the entanglement and confusion of the Faunas of the Miocene and Pliocene periods, which had arisen from so many distinct forms of different ages having been ranged by Cuvier and later palæontologists under the common name of *Mastodon angustidens*.

The observation applies with still greater force to the case of *Elephas primigenius*, to which a scope in space and time, taken together, has been assigned, without a parallel, I believe, within the whole range of the Mammalia, fossil or recent. D'Archiac, in his excellent 'Histoire des Progrès,' so late as 1848, gives a brief summary of the localities in which the remains of the "Mammoth (*E. primigenius*) have been said to occur, namely, from the British Isles across the whole of the temperate zone of Europe and of Asia, and along all the coasts and islands of the Icy Sea, as far as the frozen cliffs of the east coast of Behring's Strait; in Escholtz Bay; in Russian America as high as 66° of N. lat.; over most of the United States of North America; in the great valley of the Mississippi; and along the coasts of the Gulf of Mexico"*.

Struck with the extent of this vast area, including all the emerged lands between the parallels of 40° and 75° N. lat., he puts a query whether the Elephantine remains met with by Humboldt on the plateau of Quito and at Cumanacoa in Columbia, did not also belong to the same species†. De Blainville, going a step beyond most other palæontologists, doubtfully referred the fossil remains of Elephants found so abundantly in tropical India to the same species‡, thus assigning at least half of the habitable globe for the pasture-ground of the Mammoth.

The duration allotted to the same species is equally remarkable. Discovered fresh, either in the frozen cliffs or in ice-blocks at the mouth of the Lena, it has been traced, through its osseous remains, in the superficial gravel-beds over nearly the whole of northern and the greater part of central Europe. Here it has consistently been found in company with the Siberian Rhinoceros (*R. antiquitatis*, Blum.), the Musk-ox, and the Reindeer. The same specific form has been carried down into the so-called "Pleistocene" clay, loam, and mud deposits which are so massively developed on the Norfolk and Suffolk coast, in company with *R. leptorhinus*, *Hippopotamus major*, and other extinct forms; thence through the submerged forest and lignite-bed of Happisburgh and Mundesley into the Crag in company with *Mastodon (Tetralophodon) Arvernensis*; and abroad into the "Older Pliocene" beds of the Subapennines, and of

* Bronn enumerates the following localities:—Spain, Apulia, and Sicily; the Islet of Gozo near Malta, Athens, and Odessa; the whole of Europe except Scandinavia; from the Caucasus, through the whole of Siberia, north to the Polar Sea, and Kamtschatka; on the north-west coast of America as far as Escholtz Bay; on the east side of North America, in Ohio, Kentucky, and South Carolina, including the parallels between 40° and 75° N. lat. (*Lethæa Geognostica*, Band iii. p. 819.)

† *Op. cit.* tom. ii. p. 378.

‡ 'Ostéographie': "Des Eléphants," p. 222.

Monte Mario, Monte Verbo, and other localities in the south of Italy. The measure of time involved in the thus-implied duration of the species is best appreciated by considering some of the changes that appear to have taken place in Europe during the interval. The Alps, the Pyrenees, and the Apennines have all undergone a considerable amount of elevation. When the earliest Elephants were roaming over the emerged land of Italy, a wide and open sea-communication would seem to have existed between the Mediterranean and the Atlantic Ocean, admitting of a common province for the Mollusca of the shores of the Crag-sea and of Italy, and a common resort for the Whales and Dolphins which abounded at that period in European waters. Portions of the Pliocene sea-bottom of the Subapennines, consisting of stratified beds full of marine shells, and containing nearly entire skeletons of Elephants and Rhinoceros, have been thrown up into hills, which, after a long series of ages of degradation, still maintain an elevation of 1700 feet above the level of the adjoining sea. Yet, if we are to accept the confidently expressed opinion of Cuvier, long after his early inferences had been questioned, the same form of Mammoth lived through all these mighty changes, and it is only yesterday as it were, in relation to the Human epoch, that its last remnant was exterminated and frozen up in the perennial ice cliffs of the Arctic Circle.

It will hardly be denied by any one who attempts to reconcile the English and Continental classifications, that the arrangement of the newer Tertiary and Glacial deposits in successive chronological order is at present in a very unsatisfactory state, probably more so than that of any part of the older Tertiary series: and it appears to me that nothing has contributed more to retard the progress of this section of geology in Britain than the generally accepted belief in the specific unity of the Mammoth, wherever fossil remains of Elephants were discovered in European strata. The percentage of extinct Mollusca, so valuable a guide in the identification of the middle Tertiaries, becomes in the newer Tertiaries an evanescent quantity—at every step more elusive as we ascend upwards; and if the geologist tried to extract some help from the associated Mammalian remains, he was at once perplexed by the ubiquitous presence of the Mammoth. The very name of *Elephas primigenius* was suggestive of “transported gravel,” “diluvial action,” “glacial drift,” or some other explanation suggested by the image of the Woolly Mammoth, frozen in, flesh and bone, at the mouth of the Lena; so that every stratum in which Elephant-bones were met with was regarded in some degree under the influence of a foregone conclusion. Numerous instances might be cited of the force of this bias upon the views of some of the ablest writers on the geology of the later Tertiary deposits.

The object of the present communication is to show that several European fossil species, belonging to two distinct subgenera, have been generally confounded under the name of *Elephas primigenius*, that these species are susceptible of being discriminated, not on mere trivial or uncertain, but upon broad and well-founded distinctions,

and that their range in time is consonant with what is known of other well-determined species of Mammalia, namely, that they have been restricted within definite eras. In order to give any weight to the specific distinctions among the fossil Elephants which I shall endeavour to point out, it will be necessary to explain the grounds upon which they are founded in greater detail than is set forth in the remarks introductory to the preceding part of this essay, when treating specially of the Mastodons; and, at the risk of being chargeable in some measure with repetition, I must solicit the indulgence of the Society on the subject.

The specific name of *Elephas primigenius*, adopted from the eminent German naturalist, Blumenbach, was applied by Cuvier to all the fossil Elephantine remains occurring in Europe, Northern Asia, and America, up to the date of his last edition of the 'Ossemens Fossiles.' De Blainville, swayed by his adherence to the dogma of a *single* and simultaneous creation of living beings, subject to incessant extinctions, but never repeated, in admitting *Elephas primigenius*, extended its area for the reception of the living Indian Elephant, as he held the opinion that there were not sufficient grounds for regarding them as specifically distinct*. Owen adopted Cuvier's limitation of the Mammoth; but, struck with the wide differences presented by molars from various British strata, he endeavoured to account for them on the hypothesis of a gradation between thick- and thin-plated varieties†. Gervais‡, while fully admitting the *à priori* improbability that the same species of Elephant ranged from the Pliocene up, through the Pleistocene, to the Postpliocene period, adheres to the specific unity of *Elephas primigenius*; and he endeavours to escape from the difficulty by assuming that the so-called Pliocene remains of Elephants have been wrongly determined, and ought to be referred to the genus *Mastodon*. To avoid cumbering the present communication by a tedious citation of other authorities, I may refer to the two latest compilations on palæontology, respectively by Bronn and Pictet, for the existing state of knowledge and opinion upon the subject. Bronn, after an exhaustive exposition of the literature on fossil Elephants, sums up by stating that the number of fossil species, exclusive of two or three Indian forms and of *E. priscus* (upon which he does not venture to decide), is limited to a single, or, at the utmost, two fossil species; and he ranges all the European forms, with the exception of *E.*

* "En sorte que le résultat définitif auquel on est conduit par une logique rigoureuse, c'est que dans l'état actuel de nos collections du moins au Muséum de Paris, il est encore à peu près impossible de démontrer que l'Éléphant fossile, dont on trouve tant de débris dans la terre, diffère spécifiquement de l'Éléphant de l'Inde encore vivant aujourd'hui."—De Blainville, 'Ostéographie: Des Éléphants,' p. 222.

† "If these varieties" (*i. e.* thick- and thin-plated) "actually belonged to distinct species of Mammoth, those species must have merged into one another, so far as the character of the grinding-teeth is concerned, to a degree to which the two existing species of Elephant, the Indian and African, when compared together, offer no analogy."

‡ Paléontologie Française (1848-52), p. 35.

priscus, under the synonymy of *E. primigenius**. Pictet doubts the veritable fossil nature of the specimens upon which *E. priscus* was founded; the other nominal species he considers as not established on sufficient grounds, and he would continue them all, inclusive of *E. meridionalis*, under the common designation of *E. primigenius*. He questions the occurrence of Elephant-remains in the Pliocene period, leaning to the opinion of Gervais, that the asserted instances should be referred to the genus *Mastodon* †.

The restriction of the European fossil Elephants to a single species was first called in question by Nesti, as far back as 1808, upon fossil remains discovered in the Val d'Arno, for which he proposed two new designations ‡. Nesti was in possession of the most ample materials for the establishment of one of these, *E. meridionalis*; but, unfortunately for science, he described the lower jaw of *Mastodon* (*Tetralophodon*) *Arvernensis* as that of an Elephant, and abandoned the characters furnished by the molar teeth as untrustworthy and uncertain; and his *Elephas meridionalis* and *E. minutus* succumbed to a criticism by Cuvier. The former was revived by Croizet and Jobert in 1828, for remains found in the Velay § under the name of *Éléphant de Malbattu*: it has been admitted by Christol || and Pomel ¶ for others from Auvergne and Montpellier; and by Morren, in his account of the Elephant-remains occurring in the fossil state in Belgium **. In 1847 it was applied, in the 'Fauna Antiqua Sivalensis,' to remains from the Norwich Crag and lignite-bed.

Goldfuss, in 1821, proposed the name of *Elephas priscus* for some supposed fossil molar teeth, bearing a strong resemblance to the molars of the existing African Elephant. Cuvier disputed their authenticity as real fossils; and it is not a little curious that Goldfuss would appear in this case to have founded a veritable species upon spurious materials. I detected in the British Museum molars of indubitable fossil origin from the brick-earth deposit of Gray's Thurrock, in the valley of the Thames, presenting characters closely resembling Goldfuss's species, and figures of them were published †† under the name of *E. priscus* in 1847. Pomel applies the name to some fossil molars described by Laizer in Auvergne.

Fischer de Waldheim, Eichwald, and Morren together have proposed eight nominal species as distinct from *E. primigenius*; but

* "Die Anzahl der fossilen Arten mag sich, ausser 2 bis 3 *östindischen* am Fusse des *Himalayah* gefunden, und abgesehen von *E. priscus*, über den wir nicht entscheiden wollen, auf eine bis höchstens zwei beschränken, womit auch die *americanische* dickplattige Form, *E. Americanus*, Leidy, übereinzustimmen scheint."—Bronn, *Lethæa geognost.* (1856) edit. 3, Band iii. p. 814.

† Pictet, *Paléontologie*, 1853, tom. i. p. 284.

‡ *Annali del Museo di Firenze*, tom. i., "Di alcune ossa fossili de' Mamiferi che s'incontrano nel Val d'Arno."

§ *Oss. Foss. du Puy-de-Dôme*, p. 123–132.

|| *Ann. des Sci. Nat.* 1835, 2^{me} sér. Zool. tom. iv. p. 197.

¶ *Catal. Méthod. et Descript.* 1854, p. 74.

** *Mémoire sur les Ossemens fossiles d'Éléphants trouvés en Belgique*, 1834, p. 13.

†† *Fauna Antiqua Sivalensis*, pl. 14. figs. 6 & 7.

these were based, for the most part, on such obviously trivial characters that discredit was reflected on the species which had a better foundation.

In 1847, I proposed the name of *E. antiquus* for molars which are met with in vast abundance in certain of the newer Tertiary beds in England, and in corresponding deposits on the Continent, more especially in Italy; but no descriptions having accompanied the published figures, the species has hardly been noticed, and nowhere admitted, by other palæontologists.

II. THE SUBGENERA OF ELEPHAS.

In the first part of this essay it was attempted to be shown that the species of *Mastodon*, with the single exception of *M. Sivalensis*, are susceptible of being arranged in two natural groups, *Trilophodon* and *Tetralophodon*, according to a definite and isomeric numerical expression of the crown-ridges of the three "intermediate molars" of both jaws, and that this formula implies the ridge-characters of the other molar teeth.

In the Elephants, the divisions of the crowns of any one of the "intermediate molars" are never less than six; and in the species, fossil and recent, that are furthest removed from *Mastodon* in affinity, they range as high as 16 or 18 in the penultimate true molar, or third of the "intermediate" series. They are not isomeric, as in the *Mastodons*, but deviate from the numerical symmetry either by an augmentation of one ridge to the crown of the last "intermediate molar," constituting the *hypisomeric* forms, or they are more numerous, and augment by progressive increments corresponding with the increase of age, including the *anisomeric* forms.

The Elephants with hypisomeric-ridged molars are divisible into the two natural groups, *Stegodon* and *Loxodon*; the *anisomeric* species form a third natural group, for which, as already explained, the term *Euelephas* is proposed.

III. CHARACTERS OF THE STEGODONS.

1. *General Remarks*—The *Stegodons* form the nearest approach, in natural affinity to the *Mastodons*, and more especially to that subdivision of the section *Tetralophodon* which comprises *M. (Tetraloph.) longirostris* and *M. (Tetraloph.) latidens*. This is evinced by the low elevation and transverse direction of the crown-ridges, by their nearly uniform height throughout the length of the crown, by their thick enamel, and by the mammillary form of the ridge-processes. A fragment of one of these teeth, denuded of its coat of cement, and seen by a naturalist for the first time, would at once be referred to *Mastodon* rather than to *Elephas*; and it was this broad resemblance which struck Clift so forcibly that he applied to them the designation, at the time very appropriate, of *Mastodon elephantoides*. But when the essential characters are analyzed, the species are seen to partake more of the nature of true Elephants,—

1st. In the greater number of the crown-ridges and of the mammillæ or points that enter into the composition of each. 2nd. In

the agreement of the "ridge-formula" of certain of the species with that of the existing African Elephant and other *Loxodons*. 3rd. In the convex outline of each ridge in the transverse direction when unworn, the central mammillæ being the most elevated; and in the absence of the longitudinal line of division along the middle of the crown which is so characteristic of the *Mastodons* on the one hand, and so generally absent in the *Elephants* on the other. 4th. From the enormous quantity of laminated cement that fills up the valleys in most of the species. 5th. In the pronounced arc of a circle described by the molars as we trace them forwards in the jaws, as in the *Elephants*, instead of the nearly horizontal line of protrusion observable in the most typical *Mastodons*, such as the species of North America and of Simorre. 6th. In the obverse relation of the planes of detrition of the opposed teeth during wear, the *inner* side of the upper teeth, and the *outer* side of the lower, continuing higher in the *Stegodons*, as in the typical *Elephants*, while the converse holds in the *Mastodons*. 7th. From the absence or extreme rarity of premolars in both jaws, and of mandibular tusks, neither of which, though occurring among certain *Mastodons*, have been as yet detected among the *Stegodons*. The aggregate weight of so many points of agreement turns the balance strongly on the side of the *Elephants*.

It is deserving of remark, that all the species of the *Stegodon*-group at present known belong to the series indicated in the preceding part of this paper, as being of the *Dinotherian* or *Eurycoronine** type, in that the crowns of the molars are broad, the ridges uniformly transverse, and the valleys open, without being in the least degree interrupted by outlying tubercles, as is seen in the *Hippopotamine* or "*Stenocoronine*" type. Sir Proby Cautley and myself have thought we could distinguish four species of *Stegodon*, namely *E. (Steg.) Cliftii*, *E. (Steg.) bombifrons*, *E. (Steg.) insignis*, and *E. (Steg.) Ganesa*? The first, besides other distinctive marks, is at once characterized by the broad distinction of the antepenultimate and penultimate true molars being six-ridged, or *hexalophodont* in number, the last true molar conformably presenting an additional ridge and "talon." The first of the "intermediate series," namely the last milk-molar, has not yet been observed entire *in situ* in the jaw, but I am prepared to expect that, when determined, it will present five or six ridges. This species, the remains of which were discovered by Mr. Crawford in Ava, constitutes the passage into the *Mastodons*; this is indicated both by the limited (*i. e.* senary) number of ridges, and by the circumstance that the crowns of the molars exhibit a very obsolete or indistinct trace of a longitudinal bipartient cleft, as in the *Mastodons*. Further, in the only well-preserved palate-specimen at present known, the outer side of the upper molars is higher, and the inner side lower and more worn, being another point of

* It has been suggested to me that the contrasted terms of *Dinotherian* and *Hippopotamine* types may mislead, through being supposed to imply a greater amount both of affinity and of difference than is intended. I propose therefore to substitute for the former "*Eurycoronine*" or broad-crowned type, and for the latter "*Stenocoronine*" or narrow-crowned type.

agreement with the Mastodontoid rather than with the Elephantoid type. Where nearly allied groups inosculate, the intermediate forms commonly partake more or less of the character of both. But the sum of the characters, and more especially the identical form of the divisions of the crowns and the ridge-formula, connect this species more with the other Stegodons than with any group of *Mastodon*. The next two species, namely, *E. (Steg.) bombifrons* and *E. (Steg.) insignis*, have from seven to eight, and occasionally even nine ridges in their different intermediate molars; and their teeth are exceedingly alike in character, although the species are distinguished by an excessive amount of difference in the form of the cranium, greater even than that between the African Elephant and the Mastodon of North America. Regarding the specific distinctness of *E. (Steg.) Ganesa* I am by no means so well assured; this species is chiefly founded on a huge cranium in the British Museum with long tusks, presented by Colonel Baker. I have not been able to reconcile the form of this cranium with either that of *E. (Steg.) insignis* or *E. (Steg.) bombifrons*; but at the same time I must confess that I have failed in tracing its dentition satisfactorily as a distinct form through different ages. Three species of this group appear to be distinct beyond question; and I cite them chiefly, on the present occasion, in reference to determinations in the sequel, to show that Elephantine forms may approach very closely in their dental characters, as occurs in other Mammalia, and still be distinct species.

The Stegodons, so far as is at present known, are exclusively confined to Tropical Asia. It is therefore unnecessary, on the present occasion, to describe in detail the peculiarities of their dental characters; and I shall confine myself to the leading points in their "ridge-formula," that place them in connexion with the Mastodons on the one hand, and with the Loxodons on the other.

2. *Elephas (Stegodon) Cliftii*.—Of this species the youngest milk-teeth are as yet unknown. The third upper milk-molar, or first of the intermediate molars, is seen *in situ* in the specimen represented in the 'Fauna Antiqua Sivalensis,' pl. 30. fig. 1 *b*, entire on one side, but worn down to the common base of ivory, so that the divisions of the crown have entirely disappeared, leaving no certain data for determining the ridge-formula of this tooth. Behind it, in the same palate, specimen from Ava (presented by Colonel Barnes to the British Museum) the three anterior ridges of the antepenultimate true molar are seen *in situ*, the posterior half being broken off. But the detached tooth on the upper jaw is seen entire, and beautifully preserved, in the specimen fig. 2 of the same plate, presenting six ridges and a small hind talon. The same tooth is represented by fig. 6 of pl. 39 of Mr. Clift's Memoir (Geol. Trans. vol. ii. 2nd series). It is there described as an upper molar tooth of "*Mastodon elephantoides*," under which title Mr. Clift included specimens that are referred in our arrangement to two distinct forms*. The Ele-

* Mr. Clift, in his excellent memoir, includes the Ava fossil Proboscideans under two species, *Mastodon latidens* and *Mastodon elephantoides*. In the 'Fauna Antiqua Sivalensis,' and in the synoptical table appended to the preced-

phantine affinities of this tooth are indicated by the absence of a longitudinal line of division along the crown, and by the great number of points (about eleven in each) that enter into the composition of the ridges. This tooth shows six principal ridges and a small "talon." The penultimate true molar (or third of the intermediate series) is presented *in situ* on both sides of the superb palate-specimen represented by Clift in pl. 36 of the memoir above referred to. It is proved to be the penultimate by its large dimensions, and by the circumstance that part of another tooth of still larger size, and inferred to be the last, is seen behind it in the jaw. The same specimen is more carefully represented by figs. 3 and 3 *a* of pl. 30 of the 'Fauna Antiqua Sivalensis.' The crown-ridges are all more or less worn, and partly damaged by fracture; but enough remains to show that the tooth was composed of six ridges and a hind talon. The last true molar of the lower jaw is represented by fig. 5 of pl. 30 of the 'Fauna Antiqua Sivalensis.' The crown consists of eight ridges and a talon. The anterior large fang had been absorbed, but the portion of the crown sustained by it remains. The six posterior ridges have their fang-elements confluent into a continuous plate or shell, thus maintaining the Elephantine affinity indicated by the crown-characters. Taking the data furnished by these teeth, the cipher 6 is seen to prevail in the two last of the intermediate molars, indicating a Hexalophodont type, or $6+6+8$ for the ridge-formula of the true molars.

3. *Elephas (Stegodon) insignis*.—The only other form among the Stegodons, which it is necessary to notice, is that for which the name of *E. (Steg.) insignis* has been proposed. In this species the crown-ridges are constructed very closely upon the model of *E. (Stegodon) Cliftii*, the principal difference consisting in the much greater mass of laminated cement that fills up the valleys. In some sections, as many as eleven distinct strata of this substance may be counted*. But the ciphers yielded by the "ridge-formula," place the species in close affinity with the Loxodons, and more particularly with the species named *E. (Lox.) planifrons*. Remains of *E. (Steg.) insignis* have been discovered in immense abundance in the Sewalik Hills, and specimens illustrative of the dentition of every age and in every stage of wear are contained in the great Indian collection of the British Museum. The rigid constancy in the number of ridges observable in the two subgenera of *Mastodon* is no longer maintained. As stated in the preceding

ing part of this paper, the former name is retained for the specimens of the *Tetralophodon* type, figured by Mr. Clift, pl. 37. figs. 1 & 4; pl. 38. fig. 1, & pl. 39. figs. 1, 2 & 3. Of the others, the palate-specimen, pl. 36 (*Mastodon latidens*, Clift), together with the detached molar, pl. 38. fig. 6 (*Mastodon Elephantoides*, Clift), are referred to *E. (Stegodon) Cliftii*; and the lower-jaw specimen, pl. 38. fig. 2 (also *M. Elephantoides*, Clift), is referred to *E. (Stegodon) insignis*. The specimens regarded by him as of his *M. Elephantoides* being here considered to belong more properly to the genus *Elephas*, it became necessary to resort to another specific designation. Hence the origin of *E. (Stegodon) insignis*.

* Fauna Antiqua Sivalensis, pl. 6. fig. 7.

part of this paper, the higher the numerical expression of the "ridge-formula," in the species, the more liable is the number of ridges to vary within certain limits dependent on the race, sex, and size of the individual, and the molars of the lower jaw often exhibit an excess. After examining a very large number of specimens of all ages, the prevailing numerical expression of the ridge-formula, exclusive of "talons," in *E. (Stegodon) insignis* has appeared to me to be thus:—

Milk-molars.	True molars.
2+5+7:	7+ 8 +10-11.
2+5+7:	7+(8-9)+11-13

I have already remarked that all the known species of *Stegodon* belong to that species of the Proboscideans in which the ridges are transverse, and the valleys open. It may be expected, without much temerity, that other species remain to be discovered in the fossil state, in which the mammillæ will be disposed more or less alternately, with outlying tubercles and interrupted valleys, as in the "Stenocoronine" type.

IV. PENTALOPHODON.

From the circumstance that so many Mastodons present the ciphers either 3 or 4 constantly in the ridges of the intermediate molars of two groups of species, and that in the next allied group, *Stegodon*, *Elephas (Stegodon) Cliftii* in like manner presents the cipher 6 in two of the same teeth, while the prevailing number augments in *E. (Stegodon) bombifrons* and *E. (Stegodon) insignis*, with faith in the harmony of nature it might have been with some confidence anticipated that another Proboscidean type remained to be discovered in the fossil state, intermediate between *Tetralophodon* and *Stegodon*, in which a quinary ridge-formula would be presented, constituting a third subdivision of the genus *Mastodon*, to which the name of *Pentalophodon* would be applicable.

It appears to me that the Indian fossil species *M. (Tetralophodon) Sivalensis*, figured in the 'Fauna Antiqua'*, presents the first indication in that direction. In the "intermediate molars" of this form, both upper and lower, besides the usual anterior "talon" and four large ridges, there is a fifth ridge, somewhat reduced in size, but exactly corresponding with the other in form, composed of several large mammillary tubercles, separated from the next ridge by a valley, and throwing off an outlying tubercle, which reduces the valley, as in *M. (Tetralophodon) Arvernensis*, to lateral gorges. This fifth ridge is not a mere offset from, or subordinate appendage to, the fourth ridge after the ordinary manner of a "talon." It is supported directly by the last fang, and is separated, both on the outer and inner sides, from the latter by the intervening valley. In most of the species of *Mastodon* having alternate mammillæ, the hind "talon" in the upper molars (and conversely in the lower) forms a crenulated "bourrelet," which is given off from the inner posterior mammilla, descending obliquely around the base of the

* *Op. cit.* pl. 36. figs. 1-6.

outer division, and generally more or less effaced by the pressure of the next posterior molar during its progress forwards. In a fine specimen of a penultimate upper molar of *Mastodon Sivalensis*, which is now before me, the fifth ridge, although well developed and attaining the height of the fourth, bears no trace of a "talon" appended to it; while an antepenultimate lower, which I have also before me, shows distinctly five ridges, the last differing in no respect of complexity or development from the others, except in being a little smaller, and it bears a distinct crenulated adpressed "talon" appendage, having the appearance of a terminal "bour-relet."

In the preceding part, when discussing the conditions of the "ridge-formula" in *Trilophodon* and *Tetralophodon*, it was stated that while the penultimate milk-molar always presents one ridge less than the "intermediate molars," the last true molar presents one ridge more. Conformably, the last true molar in *M. Sivalensis* presents six ridges, besides the hind "talon," thus maintaining throughout, so far as the dentition is known, the numerical characters to be inferred from the ridge-formula, as ascertained in *Trilophodon* and *Tetralophodon*. I consider it sufficient, on the present occasion, to call attention to this as a point of some interest and importance in the systematic and palæontological relations of the Proboscidean family, in reference to the indications they present of an order of successive serial development, without entering in detail upon the evidence in support of the view here taken. That the species is a distinct form is abundantly borne out by the marked characters of the skull*, independently of the strong dental distinctions. The ridge-formula for the true molars in *Mastodon Sivalensis*, is inferred to be $\frac{5+5+6}{5+5+6-7}$; and when the dentition is fully made out, it is anticipated that the complete ridge-formula will be nearly thus:—

Milk-molars.	True molars.
$2+4+5$	$5+5+6$
$\frac{2+4+5}{2+4+5}$	$\frac{5+5+6-7}{5+5+6-7}$

V. CHARACTERS OF THE LOXODONS.

1. *General Remarks*.—The existing type of this group is the African Elephant, which Fred. Cuvier, in 1835, proposed to erect into a distinct genus under the name of *Loxodonta*, having reference to the rhomb-shaped disks of wear of the molar teeth. He held the opinion that, in its general form, in the structure of its grinders, in the form of the head, and in that of some of the external parts of the organs of sense, the African differs as much from the Indian Elephant as the Dog from the Hyæna, the Paca from the Agouti, the Lagomys from the Hare, and the Hog from the Plicochœre†. Besides the African Elephant, the group *Loxodon* com-

* *Fide* 'Fauna Antiqua Sivalensis,' pl. 32.

† F. Cuvier, 'Histoire Naturelle des Mammif.' tom. iii., "Eléphant d'Afrique."

prises three fossil species, of which one is Indian, *E. (Loxod.) planifrons*, from the Sewalik Hills, and two European, namely, *E. (Loxod.) priscus* and *E. (Loxod.) meridionalis*. The essential characters by which the molar teeth of the Loxodons differ from those of the Stegodons is that the ridges or colliculi, while closely corresponding in regard of number, are considerably more elevated and compressed. This is best seen when they are sawn up longitudinally and vertically: the section in the Stegodons exhibits a series of chevron-shaped ridges, of which the height does not much exceed the base, with thick enamel, and assimilating closely in form to the true Mastodons*; while in the Loxodons† it presents a succession of elongated wedge-shaped processes, with thinner enamel, constituting an intermediate stage between the former and the nearly parallel thin-plated ridges of the next group, *Euelephas*. In the technical definition of the subgenera appended to the preceding part, this distinction is attempted to be expressed by the terms “*coronis complicata*” applied to the teeth of the Stegodons, and “*coronis lamellosa*” to those of *Loxodon* and *Euelephas*‡. It forms the basis of the arrangement of the species of the Proboscidea, by De Blainville, into two groups, *i. e.* “*Eléphants mastodontes*” and “*Eléphants lamellidontes*,” the whole comprised in a single genus, *Elephas*.

2. *African Elephant*.—De Blainville has attempted to describe and figure in detail the dental succession, from the first milk-molar of the young calf to the last true molar of the adult state, in *E. (Loxod.) Africanus*. Of some of the “intermediate molars,” he was not in possession of perfect specimens; in these cases, his determination of the ridge-formula can only be regarded as approximate. Another point, which materially affects the numerical estimate of the ridges assigned by him to the different teeth is, that in every case he counts the accessory ridgelets, or “talons,” as ridges. His results may be expressed thus for the number of ridges in the different teeth:—

Milk-molars.	True molars.
4+7+6	7+(9-10)+ 10
4+7+?	?+(8-9) +10-12.

This determination is open to the objections that the third milk molar has a smaller number of plates assigned to it than the penultimate, which is very much smaller in size, and that the penultimate upper true molar is described by De Blainville as possessing the same number of ridges as the last. This occurs in no species of

* ‘*Fauna Antiqua Sivalensis*,’ Illustrations, pl. 2. figs. 6 a & 6 b.

† *Ibid.* pl. 2. figs. 4 a & 4 b.

‡ These terms are adopted from the logical and accurate Illiger. The expressions “*Bildung*” or “*Entwicklung*,” “*Pyramidal*,” “*Prismatisch*,” applied by Von Meyer and Bronn to characterize the difference in structure between the teeth of Mastodon and Elephant appear to convey the same meaning respectively as the “*dens complicatus*” and “*dens lamellosus*” of Illiger (*vide* Illiger’s ‘*Prodrom.*’ p. 22, and Bronn’s *Lethæa Geognost.* Band ii. pp. 753 and 797).

Mastodon or Elephant. He has figured an instructive specimen, which proves that the theoretical first or preantepenultimate milk-molar is occasionally developed in the lower jaw of the African Elephant.

Professor Owen has briefly described the ridge-characters of the teeth of this species in the "Odontography," and assigns the following numbers to the ridges in the six successive molars, *i. e.* $4+7+7$: $7+(8-9)+(10-12)$, the last of the ciphers being attributed to the sixth (or last true) molar of the lower jaw. In this estimate, the "talon" is apparently reckoned in some of the cases as one of the principal ridges. I have examined the specimens upon which De Blainville's descriptions were founded, and various molars of all ages in different collections contained in museums in this country or abroad, and, excluding the two "talons," the ridge-formula in the African Elephant has appeared to me to be thus:—

Milk-molars.	True molars.
$\frac{3+6+7}{3+6+7}$	$\frac{7+8+10}{7+(8-9)+11}$

The amount of development in the posterior talon is subject to considerable variation. In some cases it forms merely an insignificant splent appended to the last ridge; in others it attains the proportions of a reduced ridge, and, according to the degree of its evolution, it may be differently regarded by different naturalists, either as a distinct ridge or as an appendage. The hypisomerous character of the ridge-formula, in the intermediate molars of the Loxodons, is exhibited by the succession of ciphers assigned above to the ridges in the last milk molar and the antepenultimate and penultimate true molars, *i. e.* $7+7+8$. I have seen specimens in which the penultimate true molar of both the upper and lower jaws presented nine ridges. Cuvier states that he had never observed a tooth of the African Elephant showing more than ten plates. A last molar of the upper jaw, left side, procured from Cape Coast by Mr. Samuel Turner, exhibits, in a length of 11 inches, thirteen plates, *i. e.* eleven principal ridges, besides front and back talons.

The well-known and very constant distinctive characters in the molars of the African Elephant consist of the rhomb-shaped pattern yielded by the disks of the ridges after advanced wear, together with the relative narrowness of the crowns as compared with those of the Indian Elephant. The systematic signification of these peculiarities appears to me to be, that this species among the Loxodons represents the groups of forms in *Trilophodon* and *Tetralophodon*, described in the preceding part, as having the ridges of their molars characterized by outlying flanking tubercles and blocked-up valleys, and as belonging to the "Stenocoronine" type. In the African Elephant, the digital processes are less divided and more speedily confluent than in the Mastodons: each ridge throws out, in front and behind, a mesial angular projection, which meets or overlaps the corresponding part of the next contiguous ridge; and the transverse continuity of the valleys, which are filled up with cement, is interrupted in consequence. The adjoining rhombs, in the process of

wear, are in contact by their opposed angles, and at length become confluent in a common disk. The angular expansions of the disks are the modified homologues of the flanking tubercles of the Mastodons; and as the character prevails in several forms among the latter, its presence in so pronounced a degree in the African Elephant might have led us *à priori* to expect in nature other allied species in which it would be more or less exhibited. Premolars have not as yet been observed among the teeth of this species.

3. *E. (Loxodon) planifrons*.—In order show the constancy of the hypsimerous character of the ridge-formula among the Loxodons, as furnishing a reliable aid in the distinction of certain of the European fossil Elephants, it is necessary to refer briefly to the dentition of another form in the subgenus, being the Indian extinct species from the Sewalik Hills, *E. (Lox.) planifrons*, the characters of which, yielded both by the skull and teeth, are so pronounced, and the accessible materials in European collections so abundant, as to place its specific distinctness wholly beyond question. In this form the ridge-formula of the deciduous and true molars is thus:—

Milk-molars.	True molars.
$3+6+7$	$7+8+10$
$\frac{3+6+7}{3+6+7}$	$\frac{7+8+10}{7+ \quad +}$

Vertical sections of an upper and lower true molar contrasted with corresponding teeth of the African Elephant are shown by figs. 5 *a* and 5 *b* of pl. 2 of the 'Fauna Antiqua Sivalensis.' The ridges are seen to be much more elongated vertically than those of *E. (Steg.) insignis*, figs. 6 *a* and 6 *b*, but to be considerably less so than in the African Elephant, figs. 4 *a* and 4 *b*. Other distinctive characters from the latter species consist in the enormous quantity of cement which fills up the valleys and envelopes the ridges, and in the much greater thickness of the folded plates of enamel. When the teeth are regarded from the crown aspect, the disks of wear assimilate more in general form to those of the existing Indian than of the African Elephant. They form transverse bands, which are broader, fewer in number, and wider apart than in the Indian Elephant, sometimes with the bounding edges of enamel nearly parallel, in other cases showing a slight angular expansion, or throwing out a salient loop (outlying tubercle) near the middle, as in figs. 8 and 9 of pl. 14, but never exhibiting the systematic lozenge-shaped expansion so characteristic of the African Elephant. The enamel edge or *machæris* is very thick, and generally free from plaiting. The tips of the digital processes are thick, and yield well-marked circular disks before they become confluent by wear. These characters are represented throughout by the figures of plates 11 and 12 of the 'Fauna Antiqua Sivalensis,' which include the principal varieties in the form of the molar crowns.

Of the different teeth in the upper jaw the antepenultimate upper milk-molar is represented by fig. 1 of pl. 12 of the 'Fauna Antiqua,' and in vertical section by fig. 1 *b*, showing three principal ridges, with a basal ridgelet in front, and a hind talon. The penultimate milk-

molar, of which a finely preserved unfigured specimen is now before me, presents six principal ridges, with a distinct front and back talon. It measures 2 inches in length by 1 in front, and 1 behind. The third milk-molar and the antepenultimate or first true molar are present *in situ* on both sides in another palate-specimen. The former exhibits the disks of six worn ridges, besides a seventh ridge behind, which is enveloped by cement. The first true molar is in a germ state, and presents seven intact principal ridges, together with a front and back talon. The penultimate true molar is seen *in situ* in the upper-jaw specimens, figs. 4 and 6 of pl. 12, presenting eight main ridges. The last true molar is seen in germ, and intact on one side and well worn on the other, in the cranium-specimen, figs. 1 to 4 of pl. 10, with eleven ridges and talons. In other cases, such as fig. 6 of pl. 12, the last upper molar presents only ten ridges.

Of the inferior molars, the antepenultimate and penultimate milk-teeth are seen *in situ* in the lower-jaw fragment, fig. 10 of pl. 14, drawn to the natural size*. The former presents three ridges with talons, and the latter six principal ridges besides talons. Another lower antepenultimate is yielded by the young mandibule, figs. 7 and 7 *a* of pl. 12, also presenting six principal ridges. The empty alveolus of the small antepenultimate tooth is exhibited in the same figure at *b*. The last milk-molar, or first of the intermediate series, is seen in fig. 8 of the same plate to possess seven principal ridges, with a front talon. The antepenultimate or first true molar is represented by fig. 10, showing also seven principal ridges. The two specimens last mentioned are further remarkable in showing each a premolar tooth *in situ*. The penultimate true molar varies in presenting eight or nine ridges. The specimen, fig. 8 of pl. 11 of the same work, exhibits a penultimate, with nine ridges and a small back talon. The last true molar is beautifully preserved on either side in the mandibular specimen, fig. 2 of pl. 11, showing about eleven principal ridges. Other specimens of the same tooth, presenting nearly the same number of ridges, are seen in the specimens figs. 12 and 13 of pl. 12 †. The last true molars, upper and lower, are subject to a certain amount of variation in the number of the ridges, which will be more fully considered in the remarks upon the next subgenus *Euelephas*. All the molars, both upper and lower, are, relatively to the length of the crown, much broader in this extinct species than in the existing African Elephant.

A very important part of the dentition of *E. (Loxodon) planifrons*, in relation to the systematic affinities and characters of the Elephants, remains to be considered, namely the premolars. The presence of these teeth in this species is adverted to in the preceding Part, p. 312, and in the observations which follow the technical definition of the genus *Elephas*, p. 318. The lower-jaw fragment,

* At the bottom of the plate in the 'Fauna Antiqua,' the specimen is referred to *E. Hysudricus*, but this is doubtless an error.—G. B.

† Fig. 13 *a* of the same plate has no connexion with fig. 13. It is misplaced there, and belongs to the series of illustrations of *E. (Euelephas) Hysudricus*, not to *E. (Loxod.) planifrons*.

fig. 8 of pl. 12, cited above, displays three teeth *in situ*, viz. in the posterior extremity the last milk molar, in front of it the penultimate milk molar (*b*) nearly worn out, and emerging from below the latter a small vertically succeeding premolar (*c*) is exhibited. The penultimate premolar is represented of natural size (*c*) in fig. 9 of the same plate. It is considerably smaller in all its dimensions than the antepenultimate milk-molar, fig. 1 *a*, drawn to the same scale. It is of a roundish form, and shows no distinct indications of ridge-divisions. It was therefore, in all probability, of but small importance functionally in the economy of the species. In like manner figs. 10 and 10 *a* of the same plate furnish an illustration of the last lower premolar *in situ*, in front of the first or antepenultimate true molar. That the latter is one of the true molars is clearly proved by its large dimensions and by the mature form of the jaw. Fig. 11 *b* represents the last premolar (natural size) vertically divided through the middle, the anterior portion being wanting. Although partly emerged, it is still imbedded in the alveolus, and intact, while the tooth behind it is well worn. It is of comparatively small size, but presents distinct indications of two transverse ridges, terminating in the thick digitations characteristic of the species.

Of the upper premolars only the penultimate has been discovered *in situ*. A beautiful example is seen in the cranial fragment represented by figs. 4, 5, and 6 of pl. 6 of the same work, on the left side of the palate, the tooth of the right side having dropped out. Behind the premolar are the last milk-molar, well worn, and the antepenultimate true molar in germ. The premolar, in plain view, is of a very broad or round oval form. The crown is composed of a number of tubercles irregularly huddled together, somewhat in a botryoidal manner, and presenting no distinct indication of transverse ridges. The surface of the crown has attained the level of the first disk of wear of the tooth immediately behind; it bears but slight marks of abrasion, which however appear to indicate that it was opposed to a corresponding tooth below. This penultimate premolar is represented of the natural size by fig. 6 of pl. 6 of the work above referred to.

Dr. Kaup has given a very instructive illustration* of the beautifully preserved young lower jaw of *M. (Trilophodon) angustidens*, which I detected in the collection of M. Ziegler Ernst at Winterthur†. The two premolars are seen *in situ* in this specimen, the penultimate emerged, the last imbedded in the jaw, below the last milk-molar. The specimens cited above place it beyond question that the Sewalik species, *E. (Loxodon) planifrons*, had the premolar series as complete numerically as either *Dinotherium giganteum* or *M. (Trilophodon) angustidens*. I have already explained that palæontologists have heretofore entertained an opinion adverse to this being found to occur in any species of Elephant.

The above remarks may appear to be beside the professed object of the essay, but they are essential to the proper estimate of the cha-

* Beitrage, Heft iii. 1857, p. 9, tab. i. figs. 1-3.

† Vide Part 1, p. 324.

acters to be adduced in the sequel, in proof of the specific distinctness of the British fossil *Loxodons*, which will now be considered.

4. *Elephas (Loxod.) priscus*.—Has the African Elephant ever been found in the fossil state in Europe? and if so, within what geographical limits? These are questions of the highest interest, and to which a new kind of importance attaches, from the investigations of some of the later French palæontologists. In 1821 Professor Goldfuss, of Bonn, published an account, with figures, of a reputed fossil molar, found in the collection of the Canon Mehring, of Cologne, the precise origin of which was not well ascertained. The crown presents seven disks of wear, with the well-marked rhombs, shaped exactly as in the existing African Elephant. The dimensions of the tooth are—length, 5·4 inches, by an extreme width of 2·3 inches, determining it to be a true molar. The specimen is described as being much decomposed; the crust of cement friable and of an ochre-yellow colour, the ivory greyish white, and the plates of ivory and enamel separated by fissures. In another memoir of a later date, the same author describes other teeth, presenting similar characters, and asserted to be derived from a diluvial deposit, on the banks of the Rühr in Westphalia; and he affirms that he had seen in other collections similar fossil teeth. He inferred that the valley of the Rhine was formerly inhabited by a species of Elephant which more nearly resembled the existing African species than *E. primigenius* does the existing Indian. But he did not hazard an opinion whether or no it was specifically different from the existing African, which could only be satisfactorily established by the discovery of a skull, and he named the species provisionally. Cuvier questioned the fossil authenticity of these specimens, and of other instances of the same nature, which he enumerates. In the autumn of 1847 I had an opportunity of examining the specimens above referred to, in company with Dr. Goldfuss, at Bonn. They were much sun-cracked, resembling in this respect grinders of the existing Asiatic Elephant as they are presented in India after long exposure to atmospheric agencies; but the fracture and texture of the ivory yielded the glistening sericeous appearance characteristic of recent teeth, and conveyed to my mind a corresponding impression that the molar was probably of modern origin.

The celebrated C. E. von Baer describes, with exemplary caution, two reputed fossil molars from the north of Germany, resembling exactly those of the African Elephant. One of those he unhesitatingly regards as being of modern origin, from the circumstance that some of the cellular membrane lining the alveolus was still preserved upon the tooth*. The other, discovered in the sandy foundations of the monastery of St. Adalbert, near Dantzic, is, from the description,

* "Quid amplius, tunicæ et telæ cellulosæ alveolum vestientis partem in dente siccata invenimus. Partes molles per tot sæcula in nostris regionibus servari posse credat Judæus Apella! Nos vero dentem non fossilem suspicamur." He also describes a tooth certainly fossil, but of uncertain origin, in the Museum of St. Petersburg, referring it to *E. priscus* (Mém. de l'Acad. de St. Pétersbourg, tom. i., Bulletins Scientif. p. 16).

"Sic status fossilis testimonia certa non cognoscimus et non habemus quo catalogi assertum confutemus."

manifestly of the African Elephant; and the tooth, from its partially worn condition, is evidently not one that had been naturally shed. Von Baer cites the opinion of Rathke, that it may have been derived from a casualty in some travelling menagerie, but he with reason doubts if an African elephant was ever brought to Dantzic, either during the Roman empire or subsequently. After carefully balancing the texture and consistence of the specimen and the circumstances under which it appears to have been found, he could arrive at no satisfactory opinion whether it was really fossil or not, and he leaves the point undetermined. It may be remarked on this head, that the freshness of preservation of teeth and tusks of Elephants discovered in Postpliocene deposits furnishes no argument against their being of really fossil antiquity; for ivory tusks of the Mammoth have been found in silt in Britain, in such perfect preservation as to have been fit for turning into chessmen*. I have examined a skull of the Mammoth, discovered in the Lehm of the valley of the Rhine, and now preserved in the Museum at Mannheim, which is quite as fresh, and appears to retain as much animal matter, as crania of existing Elephants that have long been exposed in public collections. It is in a better state of preservation than skulls of domestic animals that have been buried for a long time within the historical period and subsequently disinterred.

The most characteristic specimen of *Eleph. (Loxodon) priscus* that has yet been discovered in British deposits is a tooth which was purchased by the late Mr. König, then keeper of the Mineralogical and Palæontological Gallery, for the British Museum, of Mr. Ball, a well-known trading collector. It was stated to have been procured from the brick-earth excavations at Gray's Thurrock, in the valley of the Thames—a locality rich in Mammalian fossils, and first brought to notice by the able investigations of Mr. Morris. No precise particulars as to the history of the specimen were ascertained or put on record by Mr. König. But on paying a visit to Gray's Thurrock, in company with the late Professor Edward Forbes and Colonel James, in the summer of 1845, with the express object of examining the association of extinct Mammalia in this very interesting deposit, I was informed on the spot that the tooth in question belonged to the skeleton of an Elephant, the greater part of which was found spread out in one place by the workmen, when digging for brick-earth. Most of the bones were destroyed in the operation; but besides this molar, another, belonging to the same animal, was retained by Mr. Meeson, the proprietor of the brick-field.

The specimen (no. 39370† of the Brit. Mus. MS. Cat.) is a last molar, left side, of the lower jaw. The mineral characters, friability, test by the tongue, colour, dull fracture, and general appearance, leave no doubt as to its being a veritable fossil. Mr. König,

* The fossil tusks of the Mammoth form an article of commerce in Siberia, and are largely used in the manufacture of ornaments and statuettes, &c.—G. B.

† This specimen is one of those which the author intended to figure in illustration of this paper. It is referred to frequently on pp. 274 & 275 as "the Gray's Thurrock specimen," and it will probably be figured, with other specimens, in a future number of the Journal.—EDIT.

to place this important point beyond question, permitted it to be sawn up, and the condition of the interior was equally conclusive of its fossil nature. The longitudinal section is represented by fig. 7 *b* of pl. 14 of the 'Fauna Antiqua Sivalensis;' and if it is compared with fig. 5 *b* of pl. 2 of the same work, representing a vertical section of a penultimate lower molar of the existing African Elephant, it will be seen that there is the closest general resemblance between the two, in all that relates to the relative proportions of the alternate layers of ivory, enamel, and cement, and in the cuneiform character of the ridges. If the comparison is extended to the sections of the teeth of the Mammoth and of the existing Indian Elephant, figs. 1 and 2 *a*, pl. 1, of the same series, the difference from them is equally apparent. The specimen consists of the part of the tooth extending from the sinus between the first and second fangs to the last ridge. The anterior portion supported by the first fang, and which in the African Elephant consists of the front talon and the two foremost ridges, is wanting. The fragment exhibits the disks of eight worn ridges finely preserved. The three anterior disks are worn low; the next four are successively less and less abraded; the last ridge shows only the tips of two digitations, with a considerable interval between them. There is no distinct hind talon. The disks of wear present an unmistakable resemblance to those of the existing African Elephant, in breadth, lozenge-shaped outline, and mesial expansion; but when examined in detail, there are obvious points of distinction. In the living species the lozenges are more strictly rhomb-shaped; the salient edge of enamel is distinctly crimped; the lateral terminations of the rhombs are flattened; and the mesial angles of the contiguous disks are either more approximated or overlap each other laterally. In *E. (Loxodon) priscus*, the disks are rounded at their lateral terminations, and broader. Although the mesial expansion is quite as great as in the African Elephant, it is less sudden, and in the general outline there is a tendency to a reniform or obsolete crescentic shape, the anterior enamel boundary of each disk being somewhat concave, and the posterior convex. The horns of the crescents are bent abruptly forwards. This is best seen in the fourth, fifth, and sixth disks; the first three, being more worn, show this peculiarity less distinctively. Another obvious character is that the enamel plates are thicker, and present a less degree of crimping, than in the African Elephant.

When viewed laterally, the resemblance to the existing species is as marked as in the crown-aspect. The ridges are alike broad in both, and the fangs are similarly disposed, those which support the five posterior ridges being confluent into a common shell. (Compare figs. 7 *a* and 5 *a* of pl. 14, 'Faun. Antiq. Sival.')

The vertical height of the seventh ridge, although but slightly worn, does not exceed $2\frac{1}{2}$ inches, while the greatest width of the crown is 3 inches. The flexuous bend of the enamel plates vertically, at the posterior end as seen in the section, is not a distinctive peculiarity, since it is met with in inferior molars both of the Indian Elephant and of *E. (Eueleph.) antiquus*.

The principal dimensions of this specimen are—	inches.
Extreme length of crown surface	8
Width of crown surface at first ridge	2·35
" " at the fourth ridge ..	2·8
" " at the seventh ridge ..	1·8
Height of the seventh ridge	2·5
Width of second disk at mesial expansion	0·95

There are eight disks of wear to a length of 8 inches, being an average of one ridge to the inch, a proportion corresponding closely with that presented by the oldest teeth of the African Elephant. The front fang, in the last lower molar of the latter species, generally supports two principal ridges besides the anterior talon. It is inferred, therefore, that the corresponding fossil tooth of *E. (Loxodon) priscus*, when entire, was composed of ten or eleven ridges, and that it was about 11 inches long.

Another specimen (no. 18966 of the British Museum Collection), also reputed to have been procured from the brick-earth deposits of the valley of the Thames, is represented by fig. 6 of pl. 14 of the work above cited. It is a fragment mutilated at both ends, showing only the entire disks of five partially worn ridges. The outline of the disks corresponds very closely in form with those of the posterior ridges of the larger specimen from Gray's Thurrock, described above. There is the same mesial angular expansion, and a still greater tendency to the disks assuming a crescentic form. The mutilated condition of this specimen renders its identification somewhat doubtful; but it is inferred to belong to *E. (Loxod.) priscus*, and to be a penultimate molar of the lower jaw, left side. The dimensions are—

	inches.
Length	5
Width of the crown behind	3
Height of " "	2·8

Besides the five entire ridges, the fractures pass through the middle of a disk at either end; so that the specimen may be considered to possess six ridges in a length of 5 inches, being an average width of ·83 to each, near the summit, where but little worn.

The only other British specimen referable to this species, that has come under my observation, is a fragment of a lower jaw, with which I have lately become acquainted, in the rich and valuable collection of mammalian remains from the Norfolk coast, between Cromer and Lowestoft, formed by the Rev. John Gunn, of Irstead, who has liberally placed this specimen, with many others, at my disposal for description*. It is a rolled and mutilated fragment, comprising the symphysis and anterior part of both rami, the beak apophysis being entirely rubbed off. A single molar is present on the left side; none on the right, which is very mutilated.

The tooth, which is inferred to be the penultimate true molar, presents the crown nearly entire and well worn. Its length is determined by the anterior and posterior fangs, which are exposed,

* The author intended to figure this specimen also (*vide* p. 270, footnote).—EDIT.

The front talon, together with a portion of the first principal ridge, supported upon the anterior fang, are partially broken. The crown exhibits the disks of the seven posterior ridges and part of the first, indicating in all eight main ridges. There is no posterior talon, the last ridge descending continuously, for insertion upon the fang. The crown is very narrow in front, and expands gradually as far as the sixth ridge. The disks of wear are broad, with a mesial angular expansion as in the African Elephant; but at the same time they exhibit a very pronounced crescentic outline, the horns or lateral terminations being much more bent forwards than in the specimen from Gray's Thurrock. The general contour of the anterior enamel plate of each disk is markedly concave, and the posterior one convex. The mesial expansion of the third disk, measured between the outer surfaces of the enamel, is exactly $\frac{3}{4}$ ths of an inch. The disks are uniform in shape, from the first to the last, the difference between them depending solely upon the greater or less amount of wear. The projecting edge of enamel is irregularly crimped, and to a much more obvious degree than in the Gray's Thurrock specimen. In this respect it approaches more nearly the character of *E. (Eulephas) antiquus*, to be described in the sequel.

The principal dimensions of this fragment are—

	inches.
Vertical height of the ramus, measured from the lower margin to the summit of the first ridge of molar ..	9·1
Length of the molar crown (part wanting in front) ..	6·7
Width of crown at the second disk	1·9
" " fourth disk	2·4
" " sixth disk	2·6
Height of the seventh ridge	about 3·0
Mesial expansion of the second disk of wear	0·75
" " seventh "	0·7

In front of the molar there is a well-marked triangular cicatrix, indicating the remains of a nearly filled-up fang-cavity, at the anterior angle of which a small portion of an ivory stump is visible. The plane of the cicatrix slopes suddenly downwards upon the diasteme, and the line of the interior margin does not follow the direction of the alveolar margin of the molar *in situ*. The length, measured from the anterior angle of the fang-scar to the back of the tooth, is 8·1 inches. A question arises, whether this alveolar scar belongs to a distinct younger tooth that had been shed; or does it represent the remains of an anterior portion of the tooth now seen *in situ*, which was supported by a fang anterior to that described above as being the large front fang? In the latter case, at least three other ridges would have to be added to the crown, making eleven in all, and the tooth would then present the character of the last lower of the African Elephant instead of the penultimate. There is no positive character to decide the question either way; but I am led to consider that the tooth has its full proportions in what now remains, from the circumstance that the crown narrows so much at the first ridge, *i. e.* to less than two inches, while it is three inches

wide behind. The fang-scar in this view is regarded as indicating the position of a shed antepenultimate.

The jaw is so rolled and mutilated, that it affords but few distinctive characters for description. The most striking point is the very great proportional height of the ramus, which in a line with the anterior termination of the molar is upwards of 9 inches. This proves that the jaw is that of an adult animal, and that the molar is certainly not of a younger age than a penultimate. The inner side of the ramus is flat, and the jaw appears to have been very high and compressed in front. What remains of the symphysis indicates that the gutter was broad, and that the rami diverged considerably. Two mentary foramina are present on the left side, with an interval of about 3 inches between them, and close to the edge of the diasteme*.

This valuable specimen was found on the Palling beach, near Happisburgh, where fossil molars of Elephants are so abundant. There is no certain information from what bed it was derived, whether from the "Elephant-bed" of Mr. Gunn, below the "submerged forest-bed," or from the "laminated blue clay" above it. But he is satisfied that it was derived from a deposit below the "dark-mud Boulder-clay." The same uncertainty applies to the greater part of the Mammalian remains found along the beach from Happisburgh to Mundesley. They have rarely or ever been observed in the cliffs *in situ*; and in the present instance there is no matrix upon the specimen to aid in arriving at an opinion upon this point. It is entirely free from ferruginous impregnation. The ivory is white, and adheres freely to the tongue.

Authentic remains, referable to this obscure form, are so rare in European collections, that it is of importance to make known any specimen calculated to throw light upon it. By the liberal and obliging permission of Dr. Emilio Cornalia, I was enabled to examine minutely a very fine fossil molar, preserved in the Natural History Museum of Milan, which I refer to *E. (Loxodon) priscus*. This specimen is a last molar of the lower jaw, left side, nearly entire, the only deficiency being in the anterior talon and part of the first ridge borne by the large anterior fang. The crown exhibits twelve principal ridges and a posterior talon, the ten anterior of which are worn down into transverse disks, while the last three are but slightly abraded. All the disks of wear present a broad rhomboidal expansion in the middle, as in the African Elephant, but modified by a crescentic tendency as above described in the fossil molars from Gray's Thurrock. The first disk is fractured, vertically, and confluent at either side with the second, which is also nearly confluent, from advanced wear, with the third. The fourth disk is very broad (antero-posterior diameter), and exactly corresponds in form with the first disk of the Gray's Thurrock specimen, the mesial expansion being .75 of an inch. The outer termination of this disk is bent forwards somewhat like the fourth in that specimen, but more ab-

* In this respect the jaw in question would seem to differ from *E. Africanus*, in which species the mentary foramina are always placed a considerable distance from the edge.—G. B.

ruptly pronounced. The ivory surface is deeply excavated, so that the enamel edge projects in high relief above it. The fifth and sixth disks are of a similar form, but, being less worn, they are less expanded. Their *cornua* are bent forwards on the inner side, with the crescentic character seen in the fourth, fifth, and sixth disks of the Gray's Thurrock specimen. The anterior enamel plate of the sixth disk projects very much (to the extent of seven-tenths of an inch) above the contiguous stratum of cement, while the included ivory surface is but slightly depressed. The seventh, eighth, and ninth disks present a corresponding form, getting narrower successively in consequence of being less worn, but each showing more or less of a mesial angular expansion. The tenth ridge is but slightly worn, and the disk is barely continuous across. The eleventh and twelfth ridges show each two distinct disks. The posterior talon shows the tips of two denticles or digitations, like the last ridge of the Gray's Thurrock specimen. To the posterior surface of the last there is appended a single thick digitation, which projects backwards in a salient gibbosity, being the converse of what is seen in the re-entering sinus, on the posterior surface of that specimen.

The grinding-surface is very concave from back to front, a chord stretched from the front to the last ridge being fully 1·4 inch above the level of the sixth and seventh disks. It is also a good deal contorted, the anterior inner side sloping backwards and outwards, while the posterior outer angle slopes forwards and inwards, corresponding precisely in this respect with the specimen of the last lower molar of *E. (Euelephas) Hysudricus*, represented by fig. 13 *a*, pl. 12 of the 'Fauna Antiqua Sivalensis.'

The enamel plates are very thick; and their outer edges present an appearance of crimping, caused by the deep vertical grooving of the outer surface, namely that in contact with the stratum of cement; but they are not plaited.

The principal dimensions are as follows—

Length of crown	about 12	inches.
Width of crown at fourth ridge	3·1	
" " sixth " 	3·35	
" " eighth " 	3·4	
" " tenth " 	3·1	
" " twelfth " 	2·6	
Width of posterior talon	1·65	
Height of crown at fourth ridge (much worn) ..	1·6	
" " sixth " outer side	3·1	
" " ninth " " 	4·5	
" " twelfth " " 	5·2	
Mesial expansion of fourth disk	0·75	

The crown includes twelve ridges in a length of about 12 inches, being an average of one inch to each. The specimen was compared with an exact drawing, of the natural size, of the Gray's Thurrock molar; and the two agreed in the closest manner, making allowance for their different stages of wear. This very important specimen

bears a record of having been discovered by Count Gazzola, in a calcareous deposit upon Monte Serbaro, in the valley of Pantena, about eight miles from Verona, along with the remains of other herbivorous quadrupeds. In its mineral condition and appearance, it presents undoubted evidence of being a true fossil.

This completes what I have to adduce in proof of *E. (Loxodon) priscus* being a distinct species; and it must be freely admitted that, considering the area explored and the number of museums examined, both in Britain and abroad, the evidence, although strong in kind, is, in the form of authentic materials, quantitatively very limited. It may be asked, If this is a well-founded species, how does it happen that determinable remains of it are everywhere so rare? To which it is replied that the pliocene *Mastodon (Triloph.) Borsoni*, respecting which there is now no question among those mammalian palæontologists who have studied the remains attributable to it, is in the same predicament, and almost equally rare. A single molar of that species was discovered by Abbé Borson in 1820 in the Pliocene deposits of the Astesan, since which date, up to 1856, not a single additional specimen had been acquired for the collections of Florence, Pisa, Turin, Milan, or Pavia, although the ossiferous Pliocene strata of the Astesan had subsequently been largely laid open by railway-cuttings. The detailed proofs have been obtained from deposits in Auvergne and elsewhere in France. In 1845, I was unable to reconcile the characters yielded by the Gray's Thurrock specimen with those of any recognized species of fossil Elephant, except *E. priscus*; and after an interval of twelve years, with a large addition of experience in the investigation of the subject, and with more materials, my conviction of its being distinct is as strong as that in favour of any other species in the genus. In mammalian palæontology, when the evidence furnished by the teeth can be crucially tested by means of the varied characters of the cranium and of the bones of the extremities, a safe and satisfactory conclusion as to the distinctness or otherwise of the species can generally be attained. But when a few teeth only are available, the area of the evidence becomes very limited, and there is a constant unperceived tendency in the observer either to magnify the value of the differential remarks, or to under-rate them, as the case may be, according to his inclination, from some extraneous influence, to make the species distinct or merely a variety of some other form. In this case I have tried to guard myself against a bias either way, and the evidence has appeared to me to be conclusive of the distinctness of the species. Although so little is known of the details of the different teeth, the ridge-formula is inferred to be 7:7+8+11 in the last milk molars and three true molars, as in the African Elephant. The known limits to the dimensions of the molars in the Elephants, coupled with the average great antero-posterior extent of the ridges in this form, namely, one inch to each, necessarily involves a limited number of the latter. The distinction from the African species is founded upon the characters that the lozenges are regularly rhomboidal in the one, and somewhat crescentic, with the angular expansions more apart, in the other. Both

species belong to the "Stenocoronine" type of *Loxodon*. The distinction from the fossil form to be next described, *E. (Loxodon) meridionalis*, is borne out by well-marked characters, the crowns of the molars in the latter being constantly very broad, the digitations thick and distinct, and the disks of wear free from mesial rhomboidal expansion. If *E. (Loxod.) priscus* could be reconciled with any other fossil species, it would be with *E. (Euelephas) antiquus*, in which the disks of the worn ridges exhibit a certain amount of expansion. But in this species the ridges are very numerous, elevated, and attenuated, their number, as in the existing Indian Elephant, ranging as high in the last lower molar as from twenty-four to twenty-seven, while in *E. priscus* they do not exceed twelve or thirteen. These points will be brought out more in detail in the sequel, when treating of these species.

Elephas (Loxodon) priscus occurs in Italy in the Subapennine pliocene strata of the Romagnano; in England, in the fluviatile deposits of the valley of the Thames, and in undetermined strata on the coast of Norfolk, but believed to be below the "Boulder-clay." I have not observed it among the exposed specimens in the public collections in Paris, nor in any museum in France that I have visited. The name is enumerated by Pomel in his 'Catalogue of the Fossil Remains of the Loire and the Allière,' as having been found in the Plain of Saliève, Collection of Laizer. He describes it briefly as *Elephas priscus* (Goldf.): "Espèce ayant les lames de ses molaires disposées comme dans l'Éléphant d'Afrique." Whether this means the ancient race of the existing species attributed to the valley of the Rhine, or the distinct fossil form, with crescentic disks of wear, I am unable to determine.

5. *E. (Loxodon) meridionalis*, Nesti.—Of this species, the materials in European collections, more especially in Italy and England, are fortunately so abundant and perfect, as to place its specific distinctness beyond question. But this conclusion has been so long opposed by the highest palæontological authority, namely, by Cuvier, De Blainville, and Owen, and the geological inferences involved in it are of such importance that I consider no apology necessary for entering fully upon the evidence bearing on the subject.

The "Val d'Arno Superiore" has, from remote ages, been celebrated for the vast abundance of fossil remains found there. Huge bones and teeth of Elephants were especially numerous. A large collection of these was formed by Targioni Toretta, which ultimately found its way into the Grand Ducal Museum at Florence; and numerous additions were made by Nesti, who, in 1808, soon after the publication of Cuvier's 'Memoir of the Mammoth' (*Annales du Muséum*, tom. viii.), examined the Tuscan Elephantine remains, and was so satisfied of their difference from those of the Mammoth, that he proposed for them two specific designations, namely, *Elephas meridionalis* and *E. minutus*. Influenced by the fact that Cuvier had laid so much stress upon the peculiar form of the lower jaw, and beak of the symphysis, as distinctive marks of *E. primigenius*, Nesti (not a professed anatomist) was naturally led to direct his attention,

in the first instance, chiefly to the same parts in the Val d'Arno remains. Unluckily the specimen that presented the most pronounced beak had lost its molar teeth; Nesti assumed it to be of an Elephant. But this selected "pièce justificative" for his *Elephas meridionalis* was proved by Cuvier to be the lower jaw of *Mastodon Arvernensis*, and *E. minutus* to be merely a young Elephant.

After a long interval, during which Cuvier had visited the Tuscan collections, Nesti brought out another memoir upon the subject, in which, upon greatly extended observations on specimens of all ages, from the fetus upwards, including crania, lower jaws, molars, tusks, and bones of the extremities, he upheld the soundness of his first inference in regard to the distinctness of *E. meridionalis*, while he admits tacitly the force of Cuvier's criticism upon his second species, *E. minutus*. The memoir is accompanied by figures of the cranium, lower jaws, and molars, but so imperfectly executed, that they proved of little service either in establishing his case or in guiding other palæontologists to a satisfactory conclusion. Another circumstance, which materially damaged the authority of Nesti upon a question of such difficulty and importance, is that he states that, after examining a vast number of molars of all ages, he had found them to vary so much—some having thick plates, others thin, and the same tooth presenting such different patterns, according to its age and degree of wear—that he had abandoned the characters yielded by the molar teeth as worthless (!) for any reliable marks of specific distinction. In the teeth themselves he had discovered no sensible differences from the characters figured and described of those of *E. primigenius*. This singular conclusion is, in some measure, explained by the fact that hardly a specimen of a molar of the true Mammoth exists in the Florentine Museum for comparison. It is, perhaps, still more remarkable that the experienced eye of Cuvier should have glanced over the multifarious evidence supplied by the Tuscan collections, without being convinced that *E. meridionalis* was a well-founded species, considering the rapidity with which he seized, and the logical precision with which he characterized, the distinctive marks of the Mammoth from the existing Indian Elephant.

Failing the teeth, Nesti drew his specific distinctions from the form of the cranium and lower jaw. Ample evidence is afforded by them for establishing *E. meridionalis* as an independent form.

It would be both tedious, and beside the scope of this essay, to detail the various opinions that have been expressed by different palæontologists respecting *E. meridionalis*. They will be found embodied in systematic works upon the science; and, on the present occasion, I shall confine myself to such as have had most influence, either in throwing light upon the characters of the species or in discrediting it.

Cuvier rested the specific distinction of the molars of the Mammoth upon three characters, namely, the great width of the crown, the attenuation of the plates, and the absence or small amount of crimping in the edges of the enamel. He admits that he had ob-

served some notable exceptions as regards the two last. The first example that he cites is the "dent de Paurentrin" from the valley of the Rhine, above Strasburg, which is remarkable for a great amount of plaiting in the enamel plates. But, as will be shown in discussing *E. primigenius*, this specimen is not fossil, but of an existing Elephant. The only other exceptions cited are three Italian specimens from Romagnano, Monte Verde, and the Val d'Arno, in all of which the plates are very thick, and which in reality belong to *E. meridionalis*. No exceptional illustration is adduced from Siberia, or any other northern locality, where the true Mammoth prevails. It is implied that they constantly present attenuated and uncrimped plates. Cuvier therefore supposed the two last characters to be inconstant, and adhered to the great width of the crown, which, however, is common to the Mammoth and to *E. meridionalis*. It is obvious that the prepossession in his mind in favour of a single European fossil species of Elephant, which is manifest throughout the 'Ossemens Fossiles,' had unconsciously led the great anatomist to undervalue the very characters which he was the first to inculcate.

The Abbé Croizet, to whom palæontology is indebted for so much valuable research on the fossil fauna of Velay, was the first who had the courage to question the decision of Cuvier against *E. meridionalis*. In his work upon Puy-de-Dôme, he has figured and described a fragment of an upper (?) molar (lower left of Croizet and Jobert) discovered at Malbattu. It is a good deal mutilated, and the figure is not so exact as to be conclusive; but in the form of the disks of wear, in the thickness of the enamel plates, and in the slight degree of crimping along the edges, it differs alike from *E. (Euelephas) primigenius* and *E. (Euelephas) antiquus*, and corresponds with Italian specimens of *E. meridionalis*. In plate 10. fig. 1 of the same work, he gives a representation of a fossil molar discovered by Lecoq at Clermont, which exhibits similar characters. He refers to Nesti's researches, and sums up by inferring that, as there are two living Elephants, so there were two fossil species—the one with attenuated plates, being the Mammoth of Siberia, the other with thick plates, as seen in specimens from Paurentrin, Romagnano, Monte Verde, Laufen (in Germany), and the Val d'Arno. He considered the facts sufficient, but assigned no other name to the second species than that of "Éléphant de Malbattu," and awaited the results of further discovery for confirmation of the inference.

Professor Owen has entered very fully into the question of distinct species, in the part devoted to *Elephas* of his Report to the British Association for 1843, and subsequently reproduced in his separate work on the 'British Fossil Mammalia.' The result at which he arrived, after examining a vast number of specimens, was that there had been only one species of fossil Elephant in Britain, namely, *E. primigenius*; and while fully recognizing the marked differences presented by molars from different localities and different deposits, he had found so many intermediate grad-

tions, that he was unable to draw a well-defined line between the thick-plated and thin-plated varieties. The consideration of the grounds upon which this opinion was founded will fall more properly into the discussion on the fossil species of *Euelephas*. In regard to *E. meridionalis*, he alleges that the variety of molar (*i. e.* thick-plated) on which this proposed species is founded occurs not only in England, but in Siberia and as far north as Escholtz Bay; and, in proof, he appeals to the specimens described by Buckland in the appendix to the 'Voyage of the Blossom.' Professor Owen refers to this thick-plated variety of the Mammoth certain British molars, which will be noticed in the sequel, as belonging to *E. (Loxod.) meridionalis*. I may remark that the conclusions to which I have been led on all the points involved in the question of distinct species or varieties in the European fossil Elephants are widely different from those set forth in the 'Report to the British Association' and in the 'British Fossil Mammalia.'

Early in 1844, my attention was directed to the European fossil Elephants as subjects of comparison with the Indian fossil species from the Sewalik Hills. I had satisfied myself, upon the indisputable evidence of entire crania and well-pronounced dental distinctions, that, exclusive of the Stegodons, there were three Indian fossil species of *Elephas*, two from the miocene Sewalik deposits, namely, *E. (Euelephas) Hysudricus* and *E. (Loxodon) planifrons*, and one from the pliocene beds of the Nerbudda, *E. (Euelephas) Namadicus*, which were as distinct as the two existing species are from each other. On comparing them with British specimens, I found that there was one series among the latter which resembled the molars of *E. (Loxod.) planifrons*, and that they were chiefly derived from the "Norwich Crag" or its vicinity; while another series, found in vast abundance on the "Oyster-bed" and in other localities along the Norfolk coast and elsewhere in England, differed constantly from characteristic specimens of the Mammoth of the superficial glacial deposits, and were closely allied to *E. (Euelephas) Namadicus* from the Nerbudda. I was in this manner convinced that there were two British fossil species, besides *E. primigenius* and *E. (Loxodon) priscus*. The prevailing opinion, at that time, among the best geological authorities in England, was that the Crag deposits were either of a miocene or very old pliocene age. On referring to the description and figures given by Nesti, Croizet and Jobert, and by Cuvier, of molars attributed to *E. meridionalis*, I found that they were so indecisive, either from their reduced scale or their imperfect execution, that it was impossible to identify the British specimens satisfactorily by them; and in the metropolitan collections I could discover no good series of Val d'Arno specimens to assist me. In consequence, I came to the conclusion, but hastily as it proved, that the fossil species from the Norfolk coast and fluviatile beds of the Thames valley was the same as the extinct Elephant of the Val d'Arno; and the figures illustrative of it in the 'Fauna Antiqua Sivalensis' were published under the name of *E. meridionalis*, while those from the "Crag" and

superjacent "Elephant-beds" were designated *E. antiquus*, under the impression that it was the oldest of European Elephants then known. But, on paying a visit afterwards to the Oxford Museum, I found Val d'Arno specimens in Dr. Buckland's collection, which satisfied me that I had made a mistake, and that the "Crag" molars were identical with those of *E. meridionalis*. It was too late to correct the error in the published plates; and it appeared to me that less confusion would arise from my continuing, in the subsequent plates, the nomenclature which I had adopted in the earlier ones, than if altered names were partially introduced, as I intended to give a full correction of the whole in the letter-press. I regret to find that the delay in the publication of this correction has led to a good deal of misconception and to misgiving as to the validity of the species both at home and abroad. I beg leave to explain now, that all the plates bearing the name of *E. meridionalis* in the 'Fauna Antiqua Sivalensis,' including the outline-figures of crania in plate 42, belong to *E. antiquus*, while those that bear the latter name belong to *E. (Loxodon) meridionalis*. In the descriptions which follow, they will be cited as such.

Before entering upon the details of the British specimens of *E. meridionalis*, I think it best to communicate the results of my examination of the Tuscan collections, as the evidence furnished by all parts of the skeleton is more complete and abundant in them than anywhere else.

A. *Tuscan Specimens*.—The Grand Ducal Museum at Florence contains seven crania, or considerable portions of crania, of this species. One of these, a late acquisition, is attached to a mounted skeleton, the trunk part of which is complete, but the extremities wanting. Another specimen consists of a crushed cranium, with the lower jaw attached, containing the three milk-molars, more or less consolidated both above and below, *in situ*. The first milk-molar is free from wear, proving that the animal must have died, if not in the foetal state, at least very soon after its birth. Another specimen, also of a young calf, shows both maxillaries, with the palate and floor of the nasal cavity entire, the rest of the cranium being wanting. The two anterior milk-molars in this specimen, and in the corresponding lower jaw, are worn to a degree indicative of the animal having been about a year old. There are five adult crania, indicating by the form of the tusks both sexes. Three of those described by Nesti, of enormous size, are still extant. In another, of a very old animal, the tusks are beautifully perfect. Another specimen, limited to the incisive sheaths, also shows the tusks in their natural position quite perfect. There are numerous lower jaws and bones of the extremities of colossal dimensions, and an abundance of detached molars of all ages and in every stage of wear. These Elephantine molars (including probably both *E. meridionalis* and *E. (Euelephas) antiquus*) were so common in the Val d'Arno, near Figlinie, that the peasants were formerly in the habit of using them promiscuously with boulders in constructing the dry stone walls surrounding their fields. The osteological materials available for the determination of the Val

d'Arno Elephant, which exist in the Florentine Museum, are therefore as abundant, and nearly as complete, as those of the Mammoth at Moscow.

a. *Upper Milk-molars*.—The beautiful specimen comprising both maxillaries shows the two front or antepenultimate and penultimate milk-molars in place on both sides, the alveolar part of the third being wanting. The antepenultimate, on the right side, is perfectly entire in its contour, but well worn. The general form is a broad oval, narrowest in front and broadest in the middle. It presents three principal ridges, with a front and back talon. The disks of wear are very wide (antero-posteriorly), with thick enamel plates, exactly like fig. 4 of plate 9 of Cuvier's 'Ossemens Fossiles.' The dimensions of this tooth are .95 inch in length by .75 inch in width at the second ridge where broadest.

The penultimate upper milk-molar of the same specimen is fully formed and consolidated. It presents a broad oblong crown, narrow in front, but wide behind, composed of six principal ridges, with a front and back talon. The anterior talon and three first ridges are touched by wear, the other three being intact. The ridges are wide apart, and the disks of wear show thick enamel plates. The enamel surface, where denuded of cement, is very rugose from deep and intricate grooving, as is seen in specimens from the Crag. The tooth bears no mark of pressure behind from an impelling last milk-molar. The dimensions are—length of crown 2.5 in. by 1.1 of width at first ridge, and 1.6 at the fifth ridge where broadest. The height of the crown at the fifth ridge is also 1.6, the tooth thus presenting at a very early age one of the distinctive marks of the species, namely, a proportionally broad crown, with a low elevation to the ridges.

The original of fig. 4 of plate 9 of the 'Ossemens Fossiles' is also a penultimate upper milk-molar, of which a part is worn away. What remains presents five ridges and a hind talon well worn. The ridges are wide apart, with thick enamel plates.

The last (third) upper milk-molar is seen in a detached specimen in the Florentine Museum (marked no. 98), the cement of which is covered with dendritic crystallizations of manganese. It is well worn, but quite entire, showing the anterior talon and the disk of pressure against the preceding tooth. The crown presents eight ridges, besides a front and back talon. All of them are more or less touched by wear, but none confluent, except the first with its adjoining talon. The three anterior ones present continuous transverse disks, with thick unplaited enamel, the outer surface of which, where in contact with the cement, shows a crimped edge caused by the section intercepting the superficial grooves. The third disk exhibits a small mesial loop in front. The fourth and fifth ridges show each three distinct transversely oblong disks, with about three digitations to each. The sixth and seventh show five distinct oval or roundish disks. The apex of the eighth ridge is barely touched, the posterior talon being enveloped by cement. The general contour of the crown is a broad oblong. The ridges are separated by wide open intervals, and the enamel plates are thick. The dimensions of the specimens are—

	Inches.
Extreme length of crown	4·6
Width of ditto at first ridge	2·0
Ditto at seventh ridge	2·5
Height of seventh ridge, barely worn only	2·0

From these dimensions, it will be seen that the length of the crown is less than twice the width, and that the width exceeds the height of the seventh ridge; or, in other words, a broad crown with low ridges, wide disks, and thick enamel.

b. *Upper true Molars*.—The antepenultimate (or fourth of the entire series in the order of antero-posterior succession) is presented *in situ* in a mutilated cranium of a semi-adult and probably female Elephant, which comprises both maxillaries with two molars in each, and the incisive bone of the left side with the corresponding tusk. The anterior of the molars is the antepenultimate, the crown of which is so far advanced in wear that the anterior ridges are ground down into a common flat disk. There are six distinct disks of as many ridges behind, with a talon. The enamel is very thick, with deep grooving on the exterior surface, but scarcely any plaiting. The digital tips of the little-worn back ridges are thick, well separated, and they yield well-defined rings by abrasion. It is inferred that the crown possessed eight ridges besides the talons.

A detached left antepenultimate, entire as regards the crown, but without fangs, shows nine ridges with a front and back talon; the first two ridges are worn, the next intact. It agrees with the specimens above described in the leading characters of well-separated ridges, with thick unplaited enamel, and a low elevation to the plates, the dimensions being—

	Inches.
Length of crown	6·2
Width of ditto in front	2·4
Height of the third	3·8
Height of the eighth	3·1

Another detached antepenultimate shows only eight ridges besides front and back talon. It has the three first ridges barely touched by wear, showing annular disks. The enamel is very thick and rugous, the digitations are deeply divided and distinct, and the ridges wide apart. The length of the crown of this specimen is $6\frac{1}{2}$ inches. The other dimensions were not taken. The number of plates in the antepenultimate upper appear to vary from eight to nine.

Of the penultimate upper (fifth in the order of succession) molar there are numerous noble specimens in the Florentine Gallery. One of the left side, having the enamel tinged black, and grey cement, shows nine principal ridges and a front and back talon. The first four ridges only are worn; the digitations are thick, well separated, and distinct, the ridges wide apart, the crown broad, and the height low. The dimension of this specimen are—

	Inches.
Length of crown	about 9·0
Width of ditto at first ridge	3·2
Width of ditto at base of fifth	4·0
Extreme height of fifth	5·4

} ratio of
8 : 11.

In this specimen we have an illustration of the constancy of the distinctive characters—namely, a broad crown and the height of the enamel ridges, not much exceeding the width, being nearly in the ratio of 11 : 8.

Another detached penultimate upper molar, having the first five ridges worn, shows ten and a talon. The digitations in this case are so distinct that the disks of each of the first three ridges present three subordinate disks. The dimensions of this specimen are—

	Inches.
Length of crown	8·75
Width of crown at first ridge	3·5
Height of crown at sixth ridge, unworn	5·2

This tooth exhibits all the distinctive characters noted of the other teeth. The number of plates in the penultimate upper molar of *E. meridionalis* appears to range from nine to ten.

Of the third or last upper true molar (sixth in the order of succession) there are numerous specimens in the Florentine Museum, some of them *in situ* in entire crania, others detached. They are distinctly shown in good preservation in three huge male skulls, with enormous tusks, and in one female (?) head with smaller tusks; but in each of these cases the most anterior ridges are, from extreme age, worn out; and I prefer drawing an illustration from a perfect detached specimen for the exact determination of the ridge-formula. Among the most instructive of these are a pair belonging to opposite sides, and so much alike that they were probably of the same individual. The molar of the right side (no. 9261 of the old Catal. Florent. Mus.) shows thirteen ridges, besides talons. The disks of the first two ridges and talon are nearly confluent into one common wide surface; but the presence of the large anterior fang proves that no part of the crown is lost in front. The eight succeeding ridges are more or less abraded, the three last being intact. In consequence of the plane of advanced wear intercepting the ridges obliquely, the enamel plates appear to slope a great deal where they emerge from the cement, and the edges project much above it. The ninth ridge, which is but slightly abraded, exhibits eight or nine distinct thick digitations. The crown contracts a good deal towards the hind talon, which is enveloped by a thick mass of cement. The principal dimensions are—

	Inches.
Extreme length of crown	about 11·0
Width of crown at the fourth ridge	4·3
Width of ditto at base of ninth ridge	4·0
Height of enamel plate at tenth ridge	4·5

In this specimen, all the characters noticed as distinctive of the anterior true molars are strongly marked. There are thirteen

main ridges in a length of 11 inches, being an average of about 0.85 inch to each; and, taking the talons into account as distinct ridges, there would still be an average of about 0.75 inch to each ridge. The relatively low elevation of the ridges, and the very great width of the crown, are also remarkable.

The last molars present in the crania above referred to differ in no respect from the one just described, more than is necessarily dependent on their more advanced state of detrition. The lower down they are ground, the wider is the expansion of each disk, and the more approximated are the enamel plates of the contiguous ridges. In all of them the enamel plates are thick, deeply channelled on the outer surface, but hardly ever plaited, the inner edge being even or disposed in easy flexures.

A very fine illustration of the characters of the palate and two last true molars on either side is presented by the Monte Pulgnasco specimen discovered by Cortesi, and figured by him in the 'Saggi Geologici,' tab. 1. fig. 1. It was found at no great distance from the classic cranium of Monte Zago, upon which Cuvier founded his *Rhinoceros leptorhinus*, as an extinct species devoid of any bony partition between the nostrils. Both specimens are now preserved in the Natural History Museum of Milan, and, by the permission of Dr. Emilio Cornalia, I had an opportunity of examining them minutely. The precise identification of both is of considerable importance in the general argument of the Mammalian Fauna of the Pliocene Period in Europe. The skull of the Rhinoceros is exactly as Cuvier in the first instance, and Dr. Cornalia subsequently described it, *i. e.* without a trace of an external nasal septum. The mutilated cranium of the Elephant is a superb fragment, comprising the maxillaries and palate, with the penultimate and last true molars of *E. meridionalis*. The penultimate is nearly worn out, the disks of the last four ridges being confluent in the middle, but separated laterally by a "Dedalaean" channel-machæris, showing the thick unplaited laminae characteristic of the species. The last molar presents from twelve to thirteen principal ridges, with front and back talons. Five of these ridges are worn, the rest are intact and enveloped by cement. The crown is very broad; the thick digitations have their apices worn off into circular disks, exactly as in the Val d'Arno specimens, and the ridges are low relatively to the width of the crown. The opposite lines of teeth converge in front. The figure of this specimen, given by Cortesi, is very imperfect in execution, and inexact. Fig. 2 of the same plate, a supposed representation of the lower jaw, is made up of two fragments of opposite sides joined by their anterior ends, and therefore highly deceptive. The tusks of this cranium are of enormous dimensions, and yield an oval section with diameters of $9\frac{1}{2}$ by $7\frac{1}{2}$ inches. Other bones of the same skeleton are preserved in the Milan Collection, one of them being a sacrum of immense size.

c. *Lower Milk-molars*.—The antepenultimate and penultimate milk-molars, beautifully preserved, are present in a fine specimen of

a young lower jaw of the same age as the fragment comprising the corresponding upper teeth. The two fragments are considered by the authorities of the Museum to be upper and lower of the same individual, and they agree exactly in their mineral condition and appearance. On the right side, the antepenultimate is wanting; on the left, it exhibits a well-worn crown, composed of three principal ridges with front and back talons. It is much smaller and more compressed in front than the upper tooth, and in the general form it is somewhat cusp-shaped, like the corresponding tooth of the Sewalik *E. (Loxod.) planifrons*.

The penultimate (or second) inferior milk-molar presents six principal ridges, besides a front and back talon; the three anterior ones more or less worn, the next intact. Making allowance for the difference of upper and lower, the tooth is exactly like the corresponding penultimate above. The plates are thick, and the ridges wide apart, the vallicular intervals being but imperfectly covered with cement. On the right side, there are about six loose unconsolidated plates of the third milk-molar in the alveolar cavity; on the left side, only the empty alveolus. The principal dimensions of the specimen are—

	Inches.
United length of the two milk molars	3.0
Length of the first	0.7
Length of the second	2.4
Width of ditto at first ridge	0.8
Interval between the anterior edges of the two milk molars	1.7

The last milk-molar is beautifully preserved in an older jaw, although still young, comprising the right ramus, with the remains of the second milk-molar in front, and the empty alveolus of the antepenultimate true molar behind. The age of the interposed third milk-molar is therefore very pointedly indicated. The crown presents eight principal ridges, with front and back talons. The four anterior ridges alone are affected by wear,—the first showing two distinct, curved and reniform disks, with the convexity in front; the second, three continuous but separate disks; the third, four; the fourth barely abraded, but exhibiting the rings of five digitations. The tooth, in its longitudinal direction, has the usual curve, being concave on the outer side. The ridges are wide apart, and wrapped by an enormous layer of cement, very much as in the young teeth of *E. (Loxod.) planifrons*. In its general form, the crown differs notably from the second milk-molar, in presenting a nearly uniform width from front to rear. There is no indication of plication in the enamel of the plates, nor any outlying mesial loops. The specimen is hard and heavy, resembling in its mineral condition the hard Sewalik fossils when a little weathered. The dimensions of the tooth are—

	Inches.
Length of crown	4.6
Width of ditto at first ridge	1.6
Width of ditto at fifth ridge	1.8

Another very fine detached specimen of the last milk-molar, lower left, with the first four ridges worn, shows also eight principal ridges, besides talons. Posteriorly it is denuded of cement; the ridges are wide apart, and the enamel very deeply grooved, as in Crag specimens, the grooving being strongly marked below, and disappearing towards the apices of the ridges. Hence a corresponding difference in the edging of the enamel plates, according to the stage of detrition. This specimen is very ferruginous, and might pass for a "Crag" fossil. The dimensions are:—

	Inches.
Length of crown	4·7
Width at first ridge	1·5
Width at fifth ridge	1·85
Height of enamel plate at fifth ridge	2·3

Another smaller-sized detached specimen of the same tooth shows only seven principal ridges, with front and back talons, proving that there may be a difference of one ridge, more or less, in the ridge-formula of the last lower milk-molar. Taking the data furnished by the young jaws, upper and lower, and using *x* as a symbol for the talons, the "ridge-formula" of the milk-series in *E. (Loxod.) meridionalis* is proved to be thus—

$$\begin{array}{c} \text{Milk-molars.} \\ \frac{x3x + x6x + x8x}{x3x + x6x + x8x} \end{array}$$

This specimen is also very ferruginous and "Crag"-looking.

d. *Lower true Molars.*—The antepenultimate true molar is represented by a finely preserved detached tooth of the right side, having the crown and fangs complete. It presents eight ridges, with the usual talons. The large undivided anterior fang supports two ridges, and the anterior end bears the pit of pressure against the preceding tooth, proving the crown to be entire. The first four ridges are worn low, exhibiting thick enamel plates, more or less grooved or channelled exteriorly, and thus presenting a spurious appearance of crimping, but unplaited, on the inner border. The disk is but slightly expanded in the middle, and without angularity. The last three ridges have only the tips of the digitations abraded, showing very distinct rings of thick enamel, free from grooving or plaiting. The ridges are all well in relief from the cement, and wide apart. The fangs supporting the last four ridges are confluent into a common shell. The principal dimensions are—

	Inches.
Length of crown	5·5
Width of ditto at second ridge	2·25
Width of ditto at seventh ridge	2·6
Height of crown at seventh ridge	2·3

This tooth, though of larger dimensions and with a much greater relative width than the last milk-molar, retains the same number of plates.

The same tooth is presented, *in situ*, in a mutilated left ramus

of the lower jaw, containing the last milk-molar worn low, and the antepenultimate true molar nearly intact. Like the specimen described, the crown is composed of eight principal ridges, with talons. The anterior talon and three front ridges are a little worn, the others entire. The specimen is red and ferruginous, like molars from the "Crag." The dimensions are—

	Inches.
Length of crown	6·4
Width of ditto at first ridge.....	2·4
Height of fifth ridge	4·0

The penultimate or second true molar (fifth in antero-posterior succession, and third of the "intermediate" molars) of the lower jaw, is well shown by a detached tooth of the left side, the crown and fangs of which are complete. It presents nine principal ridges, followed by a smaller tenth, and a talon-splent behind, so that it is open to regard it as having nine main ridges, with a front and complicated rear talon, or as having ten with a small talon. All the ridges are more or less worn. The tooth, in all its leading characters, so closely resembles the others already described, except in the implied condition of larger size, that it is unnecessary to describe the crown in detail. The wide separation of the ridges, ample width of the disks of wear, thickness of the enamel plates, and their freedom from plication, are exactly as in the other teeth. In the central disks there is a tendency to an annular expansion or loop, which is directed backwards. In this specimen, also, the two first ridges are supported on a single fang, and the posterior ridges on a shell of confluent fangs. The dimensions are—

	Inches.
Length of crown	7·8
Width of ditto in front.....	2·2
Width of ditto at the seventh ridge ...	3·3

The same tooth is presented in numerous fragments of the lower jaw, but, in most instances, more or less mutilated or worn out, so as to be less adapted for a distinctive description in reference to the ridge-formula.

Of the third or last lower true molar detached specimens are numerous in the Florentine Museum, besides a quantity of lower jaws containing it *in situ*.

One mutilated mandibular fragment of the left ramus contains the entire tooth, but not of the largest size, and probably of a female. The crown presents thirteen ridges, with a talon in front and a small talon behind. Of these, the anterior ten ridges are more or less worn—the first three into continuous; the fourth, fifth, and sixth show a tendency to annular expansion (an outlying denticle) in the middle, the loop of enamel being invariably appended to the posterior plate of enamel. The seventh, eighth, and ninth ridges have each about six distinct roundish disks, indicating the same number of massive digitations, with very thick enamel. The tooth contracts very much behind. In all respects the disks of wear

agree with those of the other teeth already described. The dimensions are—

	Inches.
Extreme length of the crown	10·25
Width of ditto at second ridge	2·7
Width at third ridge where widest	3·3
Width at eighth ridge	3·0

The summits of the worn plates of enamel, in this specimen, are remarkable for projecting about $\frac{7}{10}$ ths of an inch above the cement; and, as usual (for the reason already given), the salient mæcharides recline towards the talon.

A very remarkable detached last lower molar, right side, in which the grinding-surface is somewhat contorted (as described of *E. priscus*, *antè*, p. 275), presents the unusual number of fifteen ridges to the crown, with a complicated talon. The large anterior fang and part of the first ridge are broken off. The tooth is singular in this respect, that although eleven of the ridges are worn, and the anterior ones low down, none of the disks are confluent across, the crown being traversed longitudinally by a deep fissure filled with cement, dividing it into two unequal portions, two-thirds belonging to the inner and one-third to the outer. Throughout the crown there is a great tendency to distinctness in the digital processes. The cement in this specimen is in a great measure denuded. The plates of enamel project high above the level of the cement. The enamel is very black and highly rugous at the sides of the crown, with transverse wavy grooves. The dimensions are—

	Inches.
Extreme length	13·0
Width in front	about 4·0
Greatest width near the middle	4·3
Greatest height of the plates behind	only 4·9

From the abnormal characters of this molar, it cannot be safely taken for a guide as to the "ridge-formula." The distortion of the crown may account for the unusual number of ridges. I have seen a still more remarkable case of similar malformation in a British fossil molar of *E. (Euelephas) antiquus*.

Another weathered or decomposed lower last molar of the right side is entire in front, but deficient in the posterior talon. The crown presents twelve ridges and a front talon. The enamel in this specimen is very thick and rugous. The dimensions are—

	Inches.
Extreme length of crown	about 11·5
Width of the second ridge (enamel surface)	3·5
Width of the sixth	3·7
Height of the eighth plate	5·0

The number of ridges in the last lower molar is inferred to vary from thirteen to fifteen. A similar but still greater variation is known to occur in all the species of *Euelephas*, and it in no respects throws uncertainty upon the constancy of the ridge-formula in the other teeth.

e. *Premolars*.—From the close affinity of the molar teeth in *E.*

(*Loxodon planifrons* and *E. (Loxodon) meridionalis*, I instituted a close search in the latter for the premolar teeth, which are so remarkably developed in the former; but I could detect no indication of their presence.

f. *Ridge-formulae*.—Taking the data yielded by the preceding descriptions, and using x as a symbol for the talons, the “ridge-formula” of the true molars in *E. (Loxodon) meridionalis* appears to be thus:—

$$\frac{x8x + x(8-9)x - x13x}{x8x + x(8-9)x + (13-15)x};$$

and for the whole series, milk and permanent, rejecting talons,

Milk-molars.	True molars.
$\frac{3+6+8}{3+6+8}$	$\frac{8+(8-9)+13}{8+(8-9)+13-15}$

If this is compared with the “ridge-formula” of *E. (Loxodon) Africanus* and *E. (Loxodon) planifrons* (*antèd*, pp. 265 & 266), it will at once be perceived that they agree in the hypsimerous character of the intermediate molars, here indicated as distinctive of the group from *Euelephas*—the obvious difference being that, besides a greater number of plates in the last true molars, upper and lower, the cipher 8 prevails in *E. meridionalis* and the cipher 7 in the others. In order to show how essentially distinct the Italian fossil species is in its molars from *E. (Euelephas) primigenius*, I may anticipate the results to be found in the sequel, so far as to contrast the ridge-formula of the true Mammoth, viz.:—

Milk-molars.	True molars.
$\frac{4+8+12}{4+8+12}$	$\frac{12+(16-18)+24}{12+(16-18)+24-27}$

For the manner in which this difference operates in modifying the form and relative proportions of the alternate layers of ivory, enamel, and cement, I may refer to the longitudinal and vertical sections of the molars, represented in fig. 1 of pl. 1, and fig. 5, pl. 2, of the ‘Fauna Antiqua Sivalensis,’ the former being of the Mammoth, the latter of *E. (Loxodon) planifrons*, in which the section closely resembles that of *E. (Loxodon) meridionalis*.

g. *Characters of the Tusks*.—In some of the crania the tusks are preserved entire; and the specimens are sufficiently abundant to furnish a correct idea of their form and direction. In one cranial fragment, comprising the united incisive bones, they are finely preserved in their natural position. In this case, the extruded portions diverge for some little distance in a straight line; they are then directed outwards, and curve gradually upwards and inwards, so that the points are closely approximated. When this incisive fragment is placed erect, the included area (between the tusks) gives a truncate, ovate, or lyrate outline, with the point towards the tips. Viewed sidewise, they appear to be produced forwards and upwards in a very gentle curve. On the whole, they do not differ much in this instance from varieties seen in the existing Indian Elephant.

In the majority of cases they diverge, and are produced forwards and upwards in an easy curve, with the points directed outwards, very much as in the African Elephant or in the skeleton of *Mastodon Ohioticus* in the British Museum, figured by Owen*. They never present the pronounced arc, sometimes amounting to three-fourths of a circle, which is seen in large tusks of the Mammoth, nor the double or spiral curve so characteristic of the latter species. When attached to the cranium, they are often found in the matrix, lying flat, and curved horizontally outwards like a sickle, in the *Theristocaulodon*-fashion so grotesquely represented by Koch in his fanciful restorations of the North American *Mastodon*. This I believe to be an accident †, after the decomposition of the soft parts, from torsion of the tusks within their alveoli, in consequence of the excessive weight of the extruded portions. It occurs only in the largest specimens, and the tusks have been restored in this position in some of the crania in the Florentine Museum. In one enormous skull, a late acquisition, there is but a single tusk, on the right side. On the left, the alveolus is in a great measure filled up, but not withered, which would indicate that the left tusk had been lost late in life. The borders of the incisive sheaths, in this case, diverge widely apart and suddenly. In the Indian Elephant, the tusks are sometimes broken with prodigious violence in combats between savage males, and the fracture may take place either within or outside the alveolar sheaths. My colleague, Sir Proby Cautley, has witnessed an accident of the kind in an Elephant-fight at Kotah, in Central India.

The tusks attain an enormous size, commensurate with the colossal stature and bulk of this species. In a huge male cranium, having the zygomatic arches entire, they measure outside the incisive sheaths 24 inches in girth. A detached fragment of another tusk measures about $25\frac{1}{2}$ inches; the section is nearly circular. A polished frustum of another yields upwards of 27 inches in girth, being an average diameter of 9 inches. The section varies between round and elliptical. In a finely preserved cranium, in which the tusks are entire, they measure 6 feet 9 inches, including the alveolar portion, with a diameter of 5 inches. Cuvier gives the dimensions of only a single Tuscan tusk, namely, 6 feet 8 inches long. A specimen of fossil tusk from Rome, presented to the Paris Gallery by the Duc de la Rochefoucault and M. Desmarests, measures fully 28 inches in girth (*vide* Cuv. Oss. Foss. tom. i. p. 173). It is probably of *E. meridionalis*.

In varieties of one of the living species, the tusks are known to vary so considerably in their contour and in direction that no absolute distinctive characters can safely be founded upon them. All that can be said of the Val d'Arno specimens is, that they are invariably without the double or spiral curvature and circular arc, with recurved points, which are so generally observable in the tusks

* British Fossil Mammalia, p. 298, fig. 102.

† See the frontispiece to Warren's '*Mastodon giganteus*,' Boston, 1852, and p. 88.

of the Mammoth, and that they most resemble those of the African Elephant.

h. *Cranium*.—The characters yielded by the “ridge-formula” are so pronounced, and so distinctive of *E. meridionalis* from *E. primigenius*, that the inquiry is immediately suggested, “Are they borne out by a corresponding amount of difference in the form of the cranium?” The reply is in the affirmative; but I cannot pretend to establish this part of the case with the precision and metrical proofs which I have endeavoured to adduce in regard to the teeth. This duty should devolve upon some of the anatomists or palæontologists of Italy. The time and means of access at the disposal of a mere traveller are unequal to the satisfactory accomplishment of a laborious task of this nature. But it is to be hoped that the desideratum will not continue long unfulfilled. In the remarks which follow, I shall combine the results of my own observations with those of Nesti which I was enabled to verify at Florence, and with the avowal that they are to be considered more as a contribution “pour servir” than as an exact or complete description of the subject*.

The following materials, in relation to the cranium, exist in the Museum at Florence:—

1. A very young cranium with the lower jaw attached, containing the earliest milk-teeth unworn. It is complete, but crushed. Nesti mentions that he had seen another fetal cranium in the possession of Count Bardi.
2. Another very young cranial fragment, comprising both maxillaries, palate, milk-molars on either side, and the lower jaw detached, in fine preservation.
3. The cranium C of Nesti’s description†, and represented re-

* The Grand Dukes of Tuscany long evinced the enlightened spirit of patronage of science and the liberal arts which was bequeathed to them by the illustrious Medici. But art-worship, and reverence of the relics of Galileo, have cast some branches of inquiry into the cold shade of disregard. The Grand Ducal Museum at Florence contains a collection of Mammalian remains from the pliocene deposits of the Val d’Arno, unrivalled in Europe both for their abundance and for the perfect condition in which they are preserved. Elsewhere palæontologists are compelled to grope their way by the faint light of mutilated specimens; there the fossil remains of the same forms are presented entire. A good monograph, liberally illustrated, upon the fossil Mammalia of the Val d’Arno would reflect as bright a lustre on the Italian diadem, as do the *chefs-d’œuvre* of the Tribune or the Galleries of the Palazzo Pitti. The patronage of the Court has been for centuries bestowed upon the wax models of the Museum, but withheld from the magnificent fossil remains that are laid out under the same roof. Except a few and inadequate memoirs by Nesti, nothing worthy of the subject has been brought out in Italy upon these Tuscan collections during the last half century; and it is not overstating the fact to say that the progress of research on the extinct faunas of the Upper Tertiary formation in Europe has been retarded a quarter of a century in consequence. Had these collections been yielded either by Siberia or by the northern part of the valley of the Po, the general results would have been familiar knowledge long ago. At present, a journey to Florence is the only means of becoming acquainted with them.

† Lettere sopra alcune ossa fossili del Valdarno non per anco descritte sulla nuova specie de Elefante (*E. meridionalis*) fossile del Valdarno. Pisa, 1825, 26.

versed in figs. 1 and 2 of his plate, copied in outline in figs. 19 of pls. 42 and 44 of the 'Fauna Antiqua Sivalensis,' under the misnomer of *E. antiquus*. It is nearly perfect in the frontal and occipital regions, condyles, maxillaries, and molars, but imperfect in the facial portion, the border of the nasal opening being broken, together with the terminal portion of the incisive alveoli and the zygomatic arches. Since Nesti's figures were taken, this specimen has suffered considerable damage, the upper lamina of the right incisive alveolus having disappeared, together with the salient tip of the nasals and the lateral margin including the left orbit. The last molar is present on either side, far advanced in wear.

4. The cranium A of Nesti's references, fig. 3, comprising the palatine, maxillary, and temporal regions, the inferior part of the occiput, and the zygomatic arches, the only deficiency being in the facial region. The specimen, which is highly ferruginous, has now joined on to it the entire incisive sheaths (not represented in Nesti's figure) and two enormous tusks, which are spread out horizontally in the *Theristocaulodon*-manner above noticed. Nesti, in his memoir, cites the tusks of this specimen as yielding a diameter of 0^m.26, or 10.2 inches. The last molar, much worn, is present on either side.

5. Fragments of a cranium of colossal dimensions, comprising, besides unjoined pieces, the maxillaries, palate, and the last molar on either side, with the incisive bones entire, and of enormous size. They form a plane, at the distal end, of fully a metre in width (Nesti), 39½ inches. The incisive alveoli diverge at their extremity, and contract very considerably upwards. This is cranium B of Nesti's references, unfigured. The tusks in this specimen, according to Nesti, are only 0^m.19, or 7½ inches in diameter, and the molar 11 inches long.

6. A skull, with very old molars, and the entire incisive sheaths, together with the tusks finely preserved in their natural position.

7. A cranium, mutilated as regards the incisive bones and zygomatic arches, with large tusks and much-worn molars; very white in its mineral condition.

8. A cranium nearly entire, attached to the mounted trunk, with the incisive sheaths very long, perfect, and parallel, and containing moderate-sized tusks. The upper and lower jaws of this specimen were fixed in apposition, concealing the crowns of the molars; and I am unable to say, with confidence, that it belongs to *E. (Loxod.) meridionalis*.

9. A fragment, comprising the incisive alveoli, with the perfect tusks in their natural position and of moderate dimensions.

Viewed from the front aspect, the head is more depressed, and wider behind the temporal fossæ, and the length of brow from the vertex to the tip of the nasals markedly less in *E. meridionalis* than in *E. primigenius*. In the latter, the frontal region between the margins of the temporal ridges is broad; in the former it is much narrower, being encroached upon by the temporal fossæ. The bounding ridges sweep round by a bold curve into the post-orbital processes in *E. meridionalis*, somewhat in the manner represented in

the cranium of *E. (Stegod.) bombifrons* (Fauna Antiqua Sivalensis, plate 43. fig. 13), in which the fronto-parietal region is much constricted, while in *E. primigenius* they pass into the post-orbitary processes by a gentle sigmoid flexure.

In the Indian Elephant the posterior border of the vertex is deeply emarginated by a reentering sinus, corresponding with the upper termination of the occipital fossa; in *E. meridionalis* the line is transverse, the fossa being overarched by a produced fold of the vertex (*vide* Nesti, *op. cit.*, and Faun. Antiq. Siv. plate 42).

The posterior orbitary process is very pointed and hooked; the lachrymal tubercle is also pointed, while in *E. primigenius* it is thick and prominent.

The nasals are salient, and terminate in an obtuse point; they show no tendency to becoming lunately bifid as in the African Elephant (Faun. Antiq. Siv. plate 15. fig. 17).

The nasal aperture is situated considerably nearer the vertex in *E. meridionalis* than in *E. primigenius*; the bounding margin presents a reniform outline with the cornua directed forwards, as in the latter and in *E. (Eulephas) Hysudricus* (*vide* 'Fauna Antiqua Sivalensis,' plate 43. fig. 20).

In *E. primigenius* the incisive alveoli are very much elongated and parallel. The general plane of their upper surface meets the plane of the frontal at a slight angle, from the alveoli being a little inflected towards the molars. This involves a corresponding modification in the symphysis of the mandible, the diasteme descending nearly vertically, to terminate in a short pointed beak. An equally remarkable elongation of the incisive alveoli is presented by Colonel Baker's huge cranium in the British Museum, of the form named *E. (Stegodon) Ganesa* in the 'Fauna Antiqua Sivalensis.' If the outline-profile (pl. 44. fig. 14) of this species be compared with that of the Mammoth (fig. 24), it will be seen that the plane of the incisives in the former is continuous with that of the frontal, with a tendency to obliquity forwards. The alveoli are parallel in this form, as in the Mammoth.

In *E. meridionalis* the incisive alveoli are also much elongated; but, instead of being parallel, in all the large crania they diverge from the suborbitary foramina on to their extremity, where the divergence becomes sudden and as marked as in the African Elephant.

In the huge cranium, no. 5 of the enumeration above, the width of the incisive bones at their distal end reaches the enormous spread of 39 inches (Nesti). The interalveolar fossa, deep below the nasal aperture, soon becomes shallow and disappears entirely near the extremity of the bones, where an osseous plateau is interposed between the alveoli. This divergence of the incisive sheaths is seen in the Florentine specimen, represented by Cuvier in fig. 2 of pl. 9 of the Elephants, in the 'Ossemens Fossiles.' In the Mammoth they are parallel and approximated, with an interposed fossa, throughout.

The only exception to the character here indicated that I observed in the Museum of Florence is presented by the cranium no. 9 of the above list, in which the tusks are comparatively small, indicating a female, and the specific identity of which was not well determined.

In it the incisive sheaths are long, and, if not parallel, they are but slightly divergent, although more dilated than in the Mammoth.

a. Lateral aspect.—When the head is rested on the plane of the molars, and regarded sidewise, the following points are observable:—

1. The short extent and concave arc of the surface between the vertex and the point of the nasal bones. In *E. primigenius* the brow is also concave; but the curve is gentle and distributed over a long surface, whereas in *E. meridionalis* it is shorter and more pronounced. The concavity is much greater than is represented in fig. 19 of pl. 44, copied from Nesti's side-view of cranium no. 3 of the list, and it is still more pronounced in cranium no. 4, in which it approaches the concave arc presented by *E. (Euelephas) Hysudricus* (fig. 20 A of pl. 45). The upper occipital plane, as defined by the outline of the occipital bosses, meets the frontal plane nearly at a right angle, while the lower occipital plane joins on with the former at an open angle, somewhat resembling the profile-view of the skull of *E. Africanus* (fig. 17, pl. 44).

2. According to Nesti, the plane of the zygomatic arch is inclined to that of the molars at an angle of about 35° , while the two planes are nearly parallel in *E. primigenius*. In *E. meridionalis* they are also more elongated.

3. The antero-posterior extent of the temporal fossa, in relation to its vertical height, increases progressively from *E. primigenius* through *E. Indicus* to *E. Africanus*, being round in the latter and oval in the Indian Elephant. In *E. meridionalis* the temporal fossa has a large antero-posterior expanse. According to Nesti, the proportions of length to height are in the Indian Elephant as 37:44, while in *E. meridionalis* they are as 16:17. The difference is still greater when the latter is compared with *E. primigenius*.

4. Corresponding with these proportions, the distance from the auditory meatus to the nasal border is greater, and from the same point to the vertex less, in *E. meridionalis* than in the Mammoth.

5. The incisive alveoli form elongated massive cylinders corresponding with the huge diameters of the tusks, but instead of forming an angle with the frontal plane, as in *E. primigenius*, they are produced in the same plane, or with a little outward obliquity, in *E. meridionalis*.

β. Occipital aspect.—The occipital face is chiefly remarkable for two enormous bosses stretching from a little way above the condyles up to the vertex, and leaving between them a long and deep depression for the attachment of the ligamentum nuchæ and muscles of the neck. These bosses are continued on either side into the protuberant arches of the parietals, that bound the temporal fossæ towards the vertex. Nesti describes them as “grassi tetraedri,” with parallel faces where separated by the fossa, and as pointed towards the condyles. He regarded the spacious deep fossa as a distinctive mark from *E. primigenius*. But Breyne, in his excellent description of Messer Schmidt's cranium of the Mammoth*, expressly states that there is “a peculiar and very remarkable sinus of the occipital bone, deeper than an

* Phil. Trans. vol. xlv. for 1737–38, p. 133.

ostrich's egg, serving in all appearance for the insertion of the muscles of the neck." These occipital bosses are distinctly represented by two convex lines in Breyne's profile-figure, one of which is omitted in the copy reproduced by Cuvier*. Their development varies in the Elephants, according to the age, sex, and size of the tusks in the individual. In some of the species, such as *E. Namadicus* and *E. Hysudricus*, the fossa terminates upwards in a deep concave notch of the vertex. In *E. meridionalis*, and also in *E. primigenius* in a less degree, it is overarched by a produced lamina of the vertex. I am unable to give any details as to the extent of the sphenoid *alæ* in the Italian form.

γ. *Basal aspect*.—One of the distinctive characters of the Mammoth, upon which Cuvier laid much stress, is the parallelism of the molars in the upper jaw. In *E. meridionalis*, young and old, they invariably converge, more or less, in front. In young specimens this convergence is very pronounced; in the worn-out molars of very old crania it is less obvious. It is distinctively shown in the palate-specimen, fig. 1 of pl. 6 of Cortesi's cranium, from Monte Pulgasno.

The materials for comparative description of the crania of the Elephants have been largely increased since the time of Cuvier, and chiefly with the skulls of Indian fossil species. The points here indicated clearly show that the cranium of *E. meridionalis* differs more from that of the Mammoth than does the latter from the existing Indian Elephant. The Italian form, in this respect, resembles most the cranium of *E. Hysudricus* from the Sewalik Hills, and is intermediate between it and that of the African Elephant, although widely different from both.

i. *Lower Jaw*.—Much importance was attached by Cuvier to the form of the mandible as distinctive of the Mammoth; and of *E. meridionalis* by Nesti. I have already adverted to the error committed by the latter (Part I. p. 341) in taking the lower jaw of *M. Arvernensis* as the type of his *E. meridionalis*. He adhered to this opinion to the last, notwithstanding the correction by Cuvier. The demonstration is so manifest that it would be unnecessary to discuss the point again, but that De Blainville has reproduced Nesti's figure in the 'Ostéographie', with the designation of *E. meridionalis*, thus sanctioning it in some measure with his authority.

In *Mastodon Arvernensis* the horizontal ramus anteriorly bulges out with great convexity, and the symphyseal beak is projected forwards with very little inclination of the diastemal ridges, and not as a continuation of the lower margin of the ramus, which is rounded off and curved upwards to join the beak. The latter is raised considerably above the level of the lower margin, which is convex in the antero-posterior direction. The beak forms a short, blunt, dilated spout, with raised diastemal margins. On the contrary, in all the known Elephants of the groups *Loxodon* and *Euelephas*, the beak of the symphysis is a prolongation of the inferior margin, into which the diastemal ridges descend with great obliquity; and it is attenuated towards the apex to terminate in an obtuse point (*vide*

* Oss. Foss. tom. i. *Eléphants*, pl. 2, fig. 1.

Faun. Antiq. Sival. pl. 13 B. figs. 1-8). The original of Nesti's figure yields all these distinctive marks of *Mastodon* in a very pronounced manner, and it is demonstrable that the beak is incompatible with the ascertained direction of the incisive bones and tusks of the upper jaw in *E. meridionalis*.

Of the numerous rami of the lower jaw, young and old, of this species in the Florentine Museum, the most perfect is an entire mandible attached to the cranium no. 8 of the above enumeration. There are other specimens of a much larger size. On the comparison of several, the following characters were yielded:—

1. The teeth of the opposite sides converge in front, instead of being nearly parallel, or but little inclined, as in *E. primigenius*.

Much stress was laid upon this character by Cuvier in his description of the Mammoth; but it is assuredly neither absolute nor constant. In proof of this I may refer to figs. 1, 2, and 3 of pl. 13 A, 'Fauna Antiq. Sival.,' or to fig. 1 of pl. 1 of Fossil Remains in the 'Voyage of the Blossom,' in all of which the opposite lines of molars are more or less convergent.

2. The length of the alveolar margin, from the anterior edge of the ascending ramus to the commencement of the diasteme, and the entire length of the horizontal ramus, both absolutely and relatively to the breadth of the ascending ramus, are greater in *E. meridionalis* than in *E. primigenius*.

3. In the Mammoth the rami meet in front by a very obtuse and rounded curve, from which a short, deflected, and contracted beak is suddenly given off; in *E. meridionalis* they unite by the curve of a flattened ellipse, and the symphyseal beak is given off by a broader base and less suddenly.

This obtuse and rounded outline in the Mammoth was much insisted upon by Cuvier. It is constant and very distinctive of the species. The figures above cited may be referred to.

4. In *E. primigenius* the horizontal ramus attains a great elevation in front, from which the diastemal ridges descend nearly vertically, or with an abrupt inclination, into the short beak; in *E. meridionalis* the ramus is longer, and proportionally less elevated in front, and the diastemal margins slope gradually into the symphyseal beak from a broader base; the apophysis is produced more in front, and is larger in all its dimensions than in *E. primigenius*. The symphysis is in consequence longer in *E. meridionalis*. In the perfect mandible of no. 8, the distance from the posterior surface of the symphysis to the apex of the beak-apophysis measures $6\frac{1}{2}$ inches.

5. Viewed sidewise, when the lower jaw of the last specimen is placed so as to rest on the posterior part of the ramus and on the symphysis (exclusive of the beak), the inferior margin presents a well-marked concave arc, and the beak is produced forwards, and downwards for a considerable extent below the plane upon which the symphysis rests. It attenuates to a fine emarginate point. This concavity of the lower border, and gradual slope of the diastemal ridges into the beak, are well seen in the young lower jaw which yielded the description of the earliest milk-molars. The latter cha-

racter is also finely exhibited by a superb British specimen from the Elephant-bed at Happisburgh, in the Rev. John Gunn's rich collection at Irstead; and in the Val d'Arno specimen in Dr. Buckland's collection, represented by figs. 10 and 10 *a* of pl. 14 B of the 'Fauna Antiqua,' in which, although mutilated, the long symphysis and gradual inclination of the diasteme are well marked. There is no good published figure of the lower jaw of this species which can be referred to for a visual appreciation of these differences. But an approximate idea may be had by comparing the outline of figs. 1, 2, and 3 of pl. 13 A and 13 B of the 'Fauna Antiqua Sivalensis,' representing different ages of *E. primigenius*, with that of fig. 7, representing the lower jaw of *E. Hysudricus*, which is allied in form to *E. meridionalis*; or fig. 4 of pl. 5 in the 'Ossemens Fossiles,' of the Mammoth, with fig. 8 of pl. 9, a Romagnano specimen of *E. meridionalis*. A very characteristic representation of the lower jaw in an old Mammoth, by Scharf, is given in Buckland's Appendix to the 'Voyage of the Blossom,' fig. 1 of pl. 1, above referred to.

k. *Summary of the Characters.*—On a review of the characters detailed in the preceding descriptions, it follows that in all the points connected with the form of the cranium, teeth, and lower jaw, upon which the great French anatomist rested his distinctions among the Elephants, recent or fossil, *E. (Loxod.) meridionalis* differs essentially from the Mammoth strictly so called. They have only two characters in common, namely, 1st, the great width of the crowns of the molars; 2nd, the long alveoli of the tusks. But in the former species the height of the molar crowns is low; the ridges are cuneiform in their vertical section, and limited in number, with thick enamel; and the incisive alveoli are divergent, with simply curved tusks: in the latter the height of the molar crowns is excessive, the ridges very numerous, attenuated, and closely packed together, with thin unplaited enamel; and the incisive alveoli are parallel, approximated, and inflected; the tusks spirally recurved. It will be seen in the sequel that, so far from being nearly allied forms, there are several species interposed between them.

It is no part of the design of this essay to describe the osteography of the species more than may be subservient to their ready discrimination when found fossil. I shall therefore reserve any remarks upon the peculiarities of the bones of the trunk and extremities in the Italian form for the illustration of British specimens. Bones of colossal dimensions abound in the Museum at Florence; and Cuvier inferred from remains in the Paris Museum that the fossil Elephant of Monte Serbaro, here referred to *E. meridionalis*, attained a height of at least fifteen feet.

B. *British Specimens.*—The copious details already given regarding the dentition of this species relieve me from the necessity of minutely describing a great variety of the British specimens. Having the certainty, from such cumulative evidence abroad, of the distinctness of the species, it will suffice to show where the same form occurs in England, in what strata, under what circumstances, with what associates, and where it is wanting. I shall refer only to such charac-

teristic instances as place the specific identity of the fossils beyond question, and as are accessible for comparison.

The finest British collection of the remains of this species with which I am acquainted has been gradually accumulated during the last thirty years by the Rev. J. Gunn, of Irstead, from sections along the Norfolk coast. The vast abundance in which Elephants' teeth occur upon the "Oyster-bed" of Happisburgh and Mundesley has been long known*. Mr. Gunn, favourably situated to benefit by such opportunities, has taken advantage of his position to the full measure. The interest and value of his collection are only equalled by the liberality with which he makes it available for the ends of science. I need only say in illustration that he has placed all the specimens in his possession at my disposal for this essay, even to be sawn up for sections, if necessary, or for any other use to which they could be turned. Besides a great number of detached molars, Mr. Gunn possesses huge bones of the extremities, an enormous pelvis, and lower jaws, which are only second in preservation to the Val d'Arno specimens.

In the Norwich Museum there is also a fine series of Elephant-molars from the "Crag" and various points of the coast-section, including both *E. meridionalis* and *E. (Euelephas) antiquus*. The richness of the late Miss Anna Gurney's collection in Elephant-remains is well known; and some very fine specimens from the "Crag" are in the possession of Mr. Robert Fitch of Norwich. With a single exception, up to the present time, I have not seen a fragment referable to *E. meridionalis* that has not been derived either from Norfolk or Suffolk.

a. *Molars*.—In the following descriptions of the teeth I do not consider it necessary to follow the strict order hitherto observed of upper and lower, milk- and true molars, according to their respective succession. I shall take the most characteristic specimens first.

The finest detached molar of this species that has come under my observation is a specimen which was discovered in the "Mammaliferous Crag" on the Thorpe road, near Norwich, by Mr. Prestwich. The authority of so eminent and accurate a geologist is a sufficient guarantee for the locality and the formation. It is now lodged in the Museum at Norwich, and is the specimen which first convinced me many years ago that the "Crag" yielded a species of Elephant entirely distinct from the Mammoth and from *E. antiquus*. It is represented, one-third of the natural size, by figs. 18 and 18 a of pl. 14 B, under the misnomer already explained, of *Elephas antiquus*, in the 'Fauna Antiqua Sivalensis.' It is the last true molar, lower jaw, right side, showing eleven principal ridges, an anterior talon, and a back talon limited to a single thick

* Periodic storms, during winter, scour the beach, and undermine the cliffs, causing slips. When the detritus is washed away, Mammalian remains are left in abundance upon the shore. The scouring-action of the storm-waves, at times, tears up masses of the "submarine forest" and of the "Elephant-bed," in the latter of which the Elephantine remains occur best preserved and in the greatest abundance.

digitation. The first five ridges are slightly worn, the rest being intact. The fangs are broken off, but the definition of the anterior large fang is distinctly traceable. The cement over the surface generally has been decomposed or denuded, and is replaced by a crust of Crag matrix, of a very rusty appearance, filling the interspaces. The anterior talon thins off from the outside inwards, and is considerably narrower than the first ridge, of which the inner edge is broken. The apices of the ridges, from the second to the fifth inclusive, are all more or less fractured, and the digitation present very thick enamel. The sixth, seventh, and eighth ridges show each about four thick digitations; the ninth and tenth from four to five, converging; and the eleventh four digitations, the innermost of which is fractured. The definition of the base of the crown behind is a little damaged, but nothing is wanting.

The dimensions are—

	Inches.
Extreme length of crown	11.25
Width of crown in front.....	3.3
Width at fifth ridge, where the crown is broadest..	3.8
Extreme height of ridge, ,, ,, ..	4.8
Width of ninth ridge	3.5
Height of ,, ,,	4.6

From these dimensions it is apparent that, in a length of $11\frac{1}{4}$ inches, there are eleven ridges, with talons, and the seven ridges from the fourth to the tenth inclusive, measured along the inner wall of the crown, yield a length of fully 7 inches, being an average of one plate to an inch, and fully equal to the expansion of the ridges in the African Elephant or in *E. (Loxodon) planifrons*. The terminal divisions of the ridges form stout irregular cylinders, as thick as the little finger, while in the Mammoth they are more slender and quill-shaped. The digital lobes of the ridges in *E. meridionalis* are so massive and distinct that they have occasionally been figured and described as being of *Mastodon*. The specimen now in the Norwich Museum, composed of two ridges, from the Crag of Bramerton, described by Woodward*, is of this nature. The enamel is very thick. I have in no case attempted to express this in figures, as the plates are so ragged and unequal that any linear measurement would be deceptive; but it is very obvious to the eye; and when the teeth are sawn up and polished, their distinctness is strongly marked. The surface of the enamel in this specimen is excessively rugous from transverse, wavy, parallel wrinkles, as in the Italian specimens.

A Val d' Arno lower molar of the same age, from Dr. Buckland's collection in the Oxford Museum, is represented, crown side, by figs. 17 and 17 *a* of the same plate. The dimensions of this specimen were—

	Inches.
Length of crown	10
Width ,,	3.4
Height ,,	5

* Mag. of Nat. History, 1836, vol. ix. p. 154, figs. 2, 3, *a* and *b*.

It presents eleven principal ridges, with front and back talons. The English and Italian specimens agree so entirely in their general aspect and relative proportions, that it suffices to compare the figures to be convinced that they belong to the same species, the only difference being that the latter has the ridges divided into a greater number of digital terminations—a circumstance of trivial importance, and liable to much variation.

If, on the other hand, the last lower molar of *E. primigenius* is compared with the "Crag" specimen, it will be found to comprise, in a length of 13 inches, from twenty-four to twenty-seven closely packed ridges, with all the dental materials attenuated, the enamel especially thin; so that when sawn up vertically, the section presents an appearance closely resembling the teeth of a comb.

The Crag molar from the Thorpe road is so conclusive, that, had no other specimen been met with, it would of itself have sufficed to establish the existence of *E. meridionalis* in the fossil state in England.

A superb right ramus of the lower jaw, in the Gunn collection, dug out of the Elephant-bed between Mundesley and Bacton, presents the penultimate and last true molars *in situ*, the former half worn out and exhibiting four partly confluent disks of wear, the latter having the first five ridges and talon worn, the rest covered with cement, and partly imbedded in the angle of the jaw. It comprises about thirteen ridges, exclusive of talons. The posterior ridges are not distinctly shown, in consequence of the coat of cement. In the penultimate, the disks of the last two ridges are confluent by a narrow isthmus of ivory, and they exhibit a mesial angular expansion, resembling very much that of *E. (Loxod.) priscus*. But this is simply an accident of age, from the very low stage to which the wear of the crown has been carried, close to the common base of ivory.

Of the last molar, the anterior talon is very broad at the outer side, and contracts inwards. The first four ridges exhibit wide disks, bounded by an irregularly flexuous plate of very thick enamel. The fifth ridge shows the apices of about six very thick and distinct digitations. Between the fourth and fifth ridges, but appended to the *posterior* margin of the former, there is a single outlying mesial digitation. The crown of this tooth is distinguished by its massive character and width.

The dimensions are—

	Inches.
Length of remains of penultimate	3·6
Width of crown of penultimate, approximatively ..	3·2
Length of the crown of last molar	10·0
Greatest width of the crown at the fifth ridge	3·9

The last tooth is markedly curved in its antero-posterior direction, the inner side being convex, the outer concave.

Another important specimen in the Gunn collection is a detached fragment comprising the posterior half of the last lower molar, left side, showing seven ridges and the posterior talon. It is inferred

that from four to six anterior ridges with the front talon are wanting. The first three ridges are slightly worn, presenting distinct annular disks, surrounded by a margin of thick enamel. Each of these ridges presents about five digitations converging upwards. The specimen, through its deficiency in front, is well adapted for showing one of the most distinctive characters of the species, namely, the low height of the ridges relatively to the breadth of the crown. The fracture in front passes vertically through a ridge, exhibiting the angle of reflexion of the enamel plate. The extreme height of the fourth ridge of the fragment is 4·5 inches, while the extreme width of the crown is 4·1 inches. The height of the crown is thus seen to exceed the width by barely half an inch. The proportions in *E. (Eueleph.) antiquus* and *E. (Eueleph.) primigenius*, as will be seen in the sequel, are very different. A longitudinal section of this specimen has been made, which exhibits very perfectly the relative proportions of the ivory, enamel, and cement, together with the cuneiform character of the ivory core of each ridge. It is highly desirable that it should be figured of the natural size, for the guidance of English collectors in discriminating teeth of this species.

The principal dimensions are—

	Inches.
Length of the fragment	7·5
Width of crown at the section	3·8
Height of the front plate of enamel	3·9
Width of crown at third ridge	4·1
Height of enamel plate of fourth ridge	4·5

This specimen bears such a close resemblance to the corresponding tooth of the Indian fossil species, *E. (Loxod.) planifrons*, that I question if these teeth of the two forms, in the same mineral condition, could be distinguished if found mixed in a collection.

The Irstead collection (Gunn's) contains numerous other molar teeth or fragments of *E. meridionalis*, from Bacton, Mundesley, Horsea, and Happisburgh, which have not been figured; and I, therefore, do not think it necessary to describe them on the present occasion: some of them, it is to be hoped, may appear shortly elsewhere.

The other illustrations of the species, to be noticed in the sequel, are chiefly from specimens in the Norwich Museum, which were liberally transmitted to London for identification by the managers of that excellent institution, and are figured in the 'Fauna Antiqua Sivalensis,' pl. 14 B. The citations which follow, all refer to that plate, in which the figures are drawn to one-third the natural size.

Figs. 1 and 1 *a* represent the plan and side-view of the penultimate or second upper milk-molar of *E. meridionalis*. It is a germ-specimen, without fangs, and a good deal rolled. The crown is composed of six principal ridges, besides front and back talons. It was compared with the corresponding tooth of *E. (Loxodon) planifrons*, which it resembles very closely, but it has a broader crown.

The dimensions are—

	inches.
Length	2·6
Width of crown at first plate	1·15
" " behind	1·4
Height of crown at fifth ridge	1·55

The corresponding tooth of *E. (Eueleph.) antiquus* and of *E. primigenius* yields normally eight transverse plates. The precise origin of the specimen is not recorded; but it is supposed to have belonged to Mr. Samuel Woodward, and to have been derived from the Norfolk coast.

The specimen, fig. 2 and 2 *a*, is another example of the same tooth, a penultimate upper milk-molar, right side, discovered in the Norwich Crag at Easton, Suffolk, by Captain Alexander. It presents six ridges, well advanced in wear.

The dimensions are—

	inches.
Length	2·4
Width in front	1·0
" " behind	1·6

Figs. 3 and 3 *a* represent another well-worn penultimate milk-molar, probably of the lower (?) jaw, right side. It is of a larger size than the others, but shows the same number of plates, namely six, with talons. It is very broad in the crown relatively to the length. The disks of the ridges are very wide, like the Italian specimens. This molar belonged to the collection of Mr. Samuel Woodward; it is now in the Norwich Museum. It is heavy and dark-coloured, and bears fresh patches of marine incrustation*, and may have come from the "Oyster-bed" of Mundesley and Happisburgh.

Figs. 4 and 4 *a* represent the last milk-molar of the lower jaw, left side. The crown is worn, and comprises eight ridges. The ends and sides of the crown are partly injured. In mineral condition it is black and heavy, but free from patches of marine incrustation. It is supposed by Mr. Samuel Woodward to have been procured from the coast (Norwich Museum).

The dimensions are—

	inches.
Length of crown	3·9
Width of crown in front	1·4
" " at sixth ridge	2·0
Height of crown at seventh sidge	2·1

* In this and the following descriptions the term "marine incrustation" means recent patches of existing Polyzoa, two of which have been determined by Mr. Busk to be species of *Lepralia*, or of other allied forms. Their presence determines the fossils to have been dredged out of the modern sea-bottom. This is a point of some importance in the present case, since the Mammalian contents of the "clay-beds" have been so heedlessly regarded in the geological descriptions of the Norfolk coast, that there is hardly on record a single instance of a Mammal remain precisely referred to any one distinct stratum above the "Elephant-bed" of Gunn, although the fossils, in many instances, bear palpable indications of the matrix in which they were imbedded.

The "ridge-formula" in these specimens yields the same ciphers as were found to hold in the Italian specimens; and they agree in the other characters of a broad crown, with low ridges and thick plates of enamel.

Figs. 5 and 5 *a* represent a finely preserved entire specimen of the antepenultimate or first true molar, lower jaw, left side, composed of eight principal ridges, with front and back talons. The six anterior ridges are worn. The disks of the first three ridges are wide and open, but irregularly indented, with a tendency to mesial expansion, and surrounded by margins of thick enamel, which is vertically channelled externally, and slightly crimped; the posterior ridges show the apices of six or seven digitations; the interspaces filled with cement between the ridges are open, and the ridges well apart.

The dimensions are—

	inches.
Length of crown	5·3
Width in front	1·6
" " behind	2·3
Height of the seventh plate	2·5

One of the distinctive characters of the species, namely, the low height of the crown in reference to the breadth, is well exhibited. The specimen is dark-coloured and heavy, from ferruginous infiltration. It was discovered at Mundesley, and belonged to Mr. S. Woodward (Norwich Museum).

Another left lower antepenultimate true molar of a larger individual, and more advanced in wear, is represented by figs. 6 and 6 *a*. The crown presents a front talon and eight ridges, all of them worn; the disks are wide and open, and the vallicular interspaces are also wide; the enamel-edges thick, and in some of the plates disposed to slight crimping, with irregular angular expansion. The annular disks of the seventh ridge are of large size. This tooth bears the large anterior fang. It is a very characteristic specimen of *E. meridionalis*.

The dimensions are—

	inches.
Length of crown	5·5
Width of crown at second ridge	2·2
" " behind	2·65
Height of crown at seventh ridge, barely worn	2·0

The specimen is hard, heavy, and dark-coloured, and is marked as having come from Mundesley (Norwich Museum).

Figs. 7 and 7 *a* represent a fragment, comprising the anterior two-thirds of the penultimate or second true molar of the lower jaw, right side. It includes seven worn ridges. The disks of wear are wide, and separated by broad bands of cement; the rings of the digitations are large; the plates of enamel are thick, with angular flexures and deep channelling on the outer surface, but free from crimping. The specimen is black and heavy, and bears patches of marine incrustation.

The dimensions are—

	inches.
Extreme length	5·2
Width of crown at second ridge	2·3
" " at seventh ridge	2·9

No note was taken of the height of the last ridge. The specimen is without fangs, and, although distinctly of *E. meridionalis*, the number of ridges to the entire crown is not shown. This also belonged to Mr. S. Woodward, and is now in the Norwich Museum. It has all the mineral appearance of the Mundesley and Happisburgh beds.

Figs. 8 and 8 *a* represent the anterior portion of a lower right molar, comprising the remains of six well-worn ridges. It is cited to show the angular flexures that are sometimes seen when the plates are ground down low. The side view, fig. 8 *a*, exhibits the thickness of the enamel. This specimen is too mutilated to fix its serial position with confidence. It is heavy and dark from iron-impregnation, and corresponds with the fragments from Mundesley and Happisburgh.

Figs. 9 and 9 *a* represent the posterior two-thirds of the crown of a lower molar of the right side. It is inferred to be a penultimate, but without certainty, and may be the last true molar. The crown shows six well-worn disks and a posterior talon; there are no fangs; the enamel is very thick, with large rings to the digitations; the disks are somewhat angularly expanded, and separated by wide interspaces of cement. This is best shown by the side view, fig. 9 *a*. From being worn low down, the plates exhibit a greater tendency to crimping than is usual. The specimen is dark and heavy, and bears fresh patches of marine incrustation. It is one of Woodward's specimens, probably from the "Oyster-bed" (Norwich Museum).

The dimensions are—

	inches.
Length	5·3
Width of crown at second ridge	3·2
" " at fourth ridge	3·1

This also is a characteristic fragment of *E. meridionalis*.

Figs. 10 and 10 *a* are of a specimen in Dr. Buckland's collection from the Val d'Arno. It is noticed to demonstrate how exactly the English specimens agree with the Italian form, as may be seen by comparing figs. 8 and 9 with fig. 10.

Figs. 11 and 11 *a* represent the posterior portion of a last lower molar of the right side, including six disks of wear and the back talon. The disks are broad, the interspaces of cement the same, and the enamel plates are very thick, with deep external vertical channelling, but without crimping. The specimen is black, heavy, and bears patches of marine incrustation, indicative of its having been procured from the "Oyster-bed." From Woodward's collection (Norwich Museum).

The dimensions are—

	inches.
Length	5·6
Width of crown in front	2·8
" " behind	3·1

This is also a characteristic specimen of *E. meridionalis*.

Figs. 12 and 12 *a* represent a very notable fragment of the posterior end of a last lower molar, comprising two disks of wear and a talon. The crown is ground down low, the interspaces of cement are very wide, and the annular disks of the digitations are so thick as to approach the character of the worn ridges of some of the *Stegodons*.

The dimensions are—

	inches.
Length of the fragment	2·7
Width of crown	4·2

A solitary digitation is situated at the outer side of one of the valleys. It bears the appearance of a Mundesley specimen.

Of the upper molars the figured specimens in Pl. 14 B are less numerous; but, during the twelve years which have elapsed since it was struck off, many specimens have been amassed in the Norfolk collections which could furnish complete illustrations of the upper series. I shall confine myself to the figured specimens.

Figs. 13 and 13 *a* represent a mutilated fragment of a very old molar in the collection of the British Museum (Old Palæontol. Cat. no. 7456), comprising the remains of ten disks of wear, ground down nearly to their common base. The central disks exhibit a certain amount of open crimping. The specimen is also remarkable for the breadth of the crown; it is understood to have been derived from the "Oyster-bed" of Mundesley or Happisburgh.

The dimensions are—

	inches.
Length of crown	8·2
Width	4·3

I regard it as being of *E. meridionalis*.

Figs. 14 and 14 *a* represent the crown of a fine last upper molar, left side, of a very old animal, and in an advanced stage of wear. There are nine ridges remaining, the first five of which are ground down into transverse disks; the posterior four exhibit rings that are not confluent. There is a talon behind enveloped by cement. In front of the first remaining disk there is a broad depressed surface of ivory, indicating the position of two or three worn-out disks in front. The disks are expanded, with a slight tendency to a crescentic bend, the cornua being bent forwards. The plates of enamel are very thick, and deeply channelled exteriorly, so that there is a spurious appearance of crimping on that surface; but the edges in contact with the cores of ivory are unplaited. The specimen in its mineral condition is black and heavy. It is understood to have belonged to Woodward (Norwich Museum).

The dimensions are—

	inches.
Length of crown	9·2
Width of crown at second remaining ridge	3·6

The antero-posterior convexity of the grinding-surface determines the tooth to be an upper molar.

Figs. 15 and 15 *a* represent a very remarkable fragment, of enormous width. It is worn down close to the base, the grinding-surface being somewhat convex from front to rear. The remains of seven disks of wear are visible. They are irregularly expanded, and the surrounding plates of enamel are thick and deeply channelled on the outer surface, but with only a very slight amount of crimping. The specimen is dark and heavy, and patched over with fresh marine incrustations.

The dimensions are—

	inches.
Length of the fragment	5·4
Width of crown	4·9!

The same plate, 14 B, contains a representation, fig. 16, of an entire upper molar, comprising from sixteen to seventeen ridges within an extent of 11 inches. Only three of the anterior ridges are worn, the rest being intact. I now regard it as a molar of *E. (Euelephas) antiquus*, and not of *E. meridionalis*.

Captain Alexander discovered in the Mammaliferous Crag of Easton, near Southwold, a very fine specimen, of which no figure has as yet been published, of a last upper molar, right side, of *E. meridionalis*, which I have had an opportunity of examining. The crown presented twelve principal ridges; the back talon was wanting. A small portion of the tooth was broken on one side in front, but the unfractured bend of the enamel round the opposite side proved that the crown showed nearly its entire length. This tooth resembled in every respect (making allowance for the difference of upper and lower) the specimen already described, found by Mr. Prestwich in the Crag, near Norwich. The three first ridges alone were touched by wear, the rest being intact. The ridges were broad, with wide interspaces, the enamel very thick and rugous, both from deep vertical channelling, and from close-set, transverse, wavy wrinkles of the surface. The digital processes were large and distinct. The ninth ridge presented five digitations. There were no fangs. The enamel plates of the front ridges were nearly straight, and quite free from crimping. This tooth was at once distinguishable from the corresponding upper molar of *E. primigenius* or of *E. (Euelephas) antiquus*, by the thickness and low elevation of the ridges relatively to the width of the crown.

The dimensions were—

	inches.
Length of crown	9·6
Width of crown in front.....	3·6
Height of ,, at the fourth ridge	4·5
,, ,, at the penultimate ridge ..	3·1

The only other illustration of a molar of this species which I shall adduce is that described and figured by Parkinson*, and reproduced in the 'British Fossil Mammalia,' fig. 93, p. 239. The origin of this specimen, which is now in the Museum of the College of Surgeons†, is not accurately known. Parkinson states that it was purchased at the sale of the "Calonnian Museum," by Mr. George Humphries, and that it was said to have been found in Staffordshire. It is a last upper molar of the left side, the crown presenting twelve ridges and anterior talon. The first eight ridges are worn, the rest being enveloped by cement. The pattern of the grinding-surface is somewhat abnormal. Interposed between the second and third ridges there is a demi-ridge, composed of two flattened disks, occupying only the inner half of the interspace. The next two ridges are divided each into three flattened annular and well-separated disks. The three last of the exposed ridges have the apices of the digitations barely affected by wear, but showing thick mammillary points. Parkinson describes the tooth as differing from any other that he had seen, the peculiarities of character being the great thickness of the plates, the smoothness of the sides (inner) of the line of enamel, and the appearance of the digitated points of the plates (*i. e.* the interposed demi-ridge) in the anterior part of the tooth. He adds that the width of the plates may be taken at nearly double that of the fossil teeth in general, and he infers that this tooth indicated a fossil species of Elephant distinct from the Mammoth.

The dimensions are—

	inches.
Length of crown	6·6
Width „ at second ridge	3·0
Greatest width of crown, at fourth ridge ..	3·5
Length of grinding-surface in use.....	5·0

It will be observed that all the peculiarities which struck Parkinson are those that are here considered characteristic of *E. meridionalis*. Professor Owen has described this specimen carefully, and, allowing that it unquestionably offers a great contrast to the usual form, nevertheless considers that it exhibits the characters of the thick-plated variety of the Mammoth simply exaggerated from the accidents of age and attrition. The objections, founded upon teeth of the Mammoth, which he has raised against *E. meridionalis*, will be considered with most advantage in the sequel, in the remarks upon *E. primigenius*.

Parkinson's molar differs only from the ordinary character of *E. meridionalis* in having the groups of digitations that form the flattened rings more apart than usual. The intercalation of a demi-ridge is not uncommon in the molars of fossil Elephants. This is the only "thick-plated" variety figured or described in the 'British Fossil Mammalia'; but Professor Owen states that he had seen a very similar molar of the Mammoth from the Norfolk freshwater deposits in the collection of Mr. Fitch of Norwich‡. The authority

* Parkinson's 'Organic Remains,' vol. iii. p. 344, pl. 20. fig. 6.

† Catalogue of Fossil Mammalia and Aves, p. 143, no. 599.

‡ *Loc. cit.* p. 240.

for the Staffordshire origin of Parkinson's molar being unreliable, no weight can be attributed to it as indicative of the distribution of the species over England.

b. *Cranium*.—No cranial fragment of *E. meridionalis* has hitherto been recorded from strata in England.

c. *Lower Jaw*.—A very fine lower jaw in the Irstead collection has already been mentioned (*ante*, p. 301). It consists of a right ramus, showing the whole of the body as far as the middle of the symphysis, and the contour of the posterior margin as high as the neck of the condyle; the coronoid apophysis and leafy expansion of the ala are broken off. The greater part of the diasteme is present.

The following are the principal dimensions:—

	inches.
Extreme length from the posterior margin of the ascending ramus to the broken edge of the symphysis	27·5
Length of alveolar border from the anterior margin of the ascending ramus to the diasteme	9·5
Breadth of ascending ramus in a line with alveolar border	12·0
Height of alveolar border at outer edge of ascending ramus	5·7
Height of alveolar border in front near the diasteme	7·7
Length of diasteme and symphysis remaining	6·5
Vertical height of ascending ramus to neck of condyle	12·25
Transverse diameter at bulge of ramus below the coronoid apophysis	7·2
Length of crown occupied by the two molars	14·0
Length of grinding-surface in use	7·5
Number of plates in use	11

The peculiarities distinctive of this specimen from the lower jaw of the Mammoth are—1, the comparatively low elevation of the anterior end of the ramus, both absolutely and relatively to the height at the coronoid margin; in the Mammoth the jaw attains, in old specimens, as much as $10\frac{1}{2}$ to 11 inches in vertical height; in the Irstead specimen it is but $7\frac{1}{2}$ inches; 2, the long and gradual slope of the diasteme into the beak; in the Mammoth it descends with a pitch deviating but slightly from the vertical; 3, the long symphysis; 4, the greater length of the horizontal ramus in relation to the width of the ascending ramus; 5, the less sudden curve in the contour of the posterior angle and margin of the ramus. The Irstead specimen differs appreciably also from the lower jaw of *E. (Euclerphas) antiquus* in points which will be noticed in the comparison of that species in the sequel.

The Norwich Museum contains a very fine lower jaw of *E. meridionalis*, comprising both rami; and on the right side part of the ascending ramus, the leaf of the ala being broken off. The diastemal ridges are perfect, and a part of the symphysis is present; but

the beak has been made up artificially and uncouthly with plaster, and painted to simulate the natural fossil. The last true molar is present on either side, much worn, the anterior portion having been ground away. There are ten disks of wear, presenting the usual character of the species, the enamel plates very thick and uncrimped. The tips of the posterior ridges form well-separated rings, and the digitations are seen to be massive. The diastemal ridges incline with an easy slope; the outer surface of the jaw bulges out a good deal; the height of the ramus in front, as in the Irstead specimen, does not much exceed the height behind under the coronoid process. This valuable specimen was discovered in the cliff, near Mundesley, in 1852, and presented by R. Barclay, Esq., to the Norwich Museum. It is not stated out of what stratum it came, *i. e.* whether from the "Elephant-bed," properly so called, or from the "Laminated Blue Clay" above it. It is much to be desired that figures of these two instructive specimens should be published. Some of the dimensions of the Norwich jaw are as follows:—

	inches.
Length of crown of left molar (last)	8·1
Width of crown at second remaining ridge	3·0
" " sixth remaining ridge	2·9
Length of crown occupied by six ridges, being an average of 0·77 inch to each	4·6

d. *Bones of the Trunk and Extremities.*—My remarks upon the other bones of the skeleton will be very limited, for several reasons. In the lacustrine and clay deposits of the Norfolk coast, and upon the "Oyster-bed" of Happisburgh and Mundesley, the bones and teeth of at least two of the fossil Elephants, namely, *E. (Loxodon) meridionalis* and *E. (Euelephas) antiquus*, occur intermixed in vast abundance. In consequence of the prevalent belief that they were all of one species, namely, the Mammoth, little attention has been paid to the discrimination of the precise beds and divisions of the section out of which they come, and whether from above or below the "Boulder-clay." In no instance have the bones of an entire skeleton been found together, and there are no well-determined standard examples for comparison. The identification of the species to which the bones belonged can therefore at present be little more than approximative. It will suffice to mention the principal pieces that have come under my observation from localities in which *E. meridionalis* prevails.

In Mr. Gunn's collection at Irstead there is an entire left "os innominatum" of enormous dimensions.

In the Florentine Museum there is an enormous scapula, which has been figured by Nesti (*op. cit.* fig. 6), in the finest state of preservation; it yielded the following dimensions:—

	ft.	in.
Entire length from the coracoid process to the posterior angle, measured along the spine	4	0
Transverse diameter across the spine	3	0
Greatest diameter of articulating surface	0	11

The largest perfect humerus in the same collection measured—

	ft.	in.
Length	3	11
Transverse diameter of inferior articulating head .	1	1
Girth of ditto	2	8

These dimensions are greatly surpassed by a huge humerus in the Norwich Museum, presented by Miss Anna Gurney. It is stated in the ‘British Fossil Mammalia’ that it was found in the “Cliff, composed of interblended blue clay and red gravel, near the village of Bacton in Norfolk;” and the following dimensions are attributed to it:—

	ft.	in.
Entire length	4	5
Circumference at the middle	2	2·6
” at proximal end	3	5
Breadth of distal end	1	2
From summit of condyloid ridge to end of the outer condyle	1	7

To what species this stupendous humerus belonged has not been exactly determined.

The largest entire femur in the collection at Florence was 4 feet 6 inches in length. The largest mentioned in the ‘British Fossil Mammalia,’ p. 254, attributed to a Mammoth, is stated to have been 4 feet 1 inch long.

The colossal scapula of Florence is matched by a pelvis in the same collection, which was found entire in the Val d’Arno; it yielded the following dimensions:—

	ft.	in.
Expanse between tuberosities of ilium	5	9·0
Height of pubes at symphysis	1	9·5
Transverse diameter of pelvic arch	1	8·5
Antero-posterior diameter of acetabulum	0	7·5
Transverse ” ”	0	8·5

VI. CHARACTERS OF EUELEPHAS.

1. *General Remarks.*—This group, regarded in a structural and systematic view, is the most aberrant from the ordinary Pachydermatous type of all the divisions of the Proboscidea, and it is that of which the species are the most difficult to discriminate. It is represented in the living state by the Indian Elephant, and in the fossil state by five if not six species at present known. The obvious manner in which they differ from the Loxodons is that the crown-divisions in the molars are more numerous, elevated, and attenuated. When the numerical values of the ridges in the successive teeth are regarded as a series, it is manifest that they go on augmenting by progressive increments, constituting the basis of the technical term here applied to signify the character, namely, an *anisomerous* “ridge-formula,” as distinguished from the *isomerous* formula in the Mastodons, and the *hypisomerous* formula of the Stegodons and Loxodons.

We have seen that in three out of the four groups of the Proboscidea already considered, each is susceptible of being divided into two subordinate series, namely, the "Eurycoronine," in which the molar-crowns are broad, the ridges transverse, and the valleys open, and the "Stenocoronine," in which they are narrow, and the valleys are obstructed by outlying tubercles. These two types, under peculiar modifications, are equally present among the forms referable to *Euelephas*, and the distinctive marks upon which they are founded furnish excellent help in determining the distinctness of the species. They are in some respects nice in degree, but at the same time, like all well-founded distinctions in nature, they are very constant. In order to facilitate the determination of the "ridge-formula" in the fossil forms, the characters of the teeth in the existing species will first be considered. But it is necessary to give some preliminary explanations of the modifications of the dental characters in the molars of the Euelephants, and of the terms that are here used to express them.

The folded crown of the molars in the groups *Trilophodon*, *Tetra-*lophodon**, and *Stegodon* is composed of three or more, regularly or irregularly transverse, wedge-shaped cores of ivory, arising from a common base, and covered by a shell of enamel, which is uniformly reflected over their apices and over the reentering angles at their base. These divisions are called "ridges" or "colliculi," and the interstices or valleys between them "valliculæ": though usually open in the Mastodons, the latter are in the Stegodons occupied by an enormous mass of cement, forming reversed wedges in relation to the ivory cores. The layer of enamel thus alternates with the ivory and cement, and, being of uniform thickness throughout, it is the only portion of the crown-materials to which the term "plate," "lamina," or "lamella" can with propriety be applied.

In the groups *Loxodon* and *Euelephas* these ridges go on increasing in number, without a corresponding augmentation of the length of the crown, so that the penultimate true molar (or last of the intermediate series), which in the Trilophodons has only three ridges, in the Indian Elephant presents five times that number, or about sixteen ridges. The law of compensation ("balancement" of the French, and "anamorphosis" of some German authors) comes into play to make the necessary adjustments. The ridges are compressed and close-packed, with an attenuation of the constituent ivory, enamel, and cement-materials; but as there is a limit to the lateral extension of the crown, from the disturbance which would be thereby involved in the general construction of the head, the ridges are attenuated and elongated vertically, either with no increase or in an undue proportion to the increase in the width of the crowns. But these compressed ridges are still the homologues of the massive divisions seen in the crowns of the molars of the Mastodon, and, as such, it is but correct to retain the same name for them. The obvious manner in which their elongation and compression affect the aspect of crown is embodied in the term "coronis lamellosa," and the difference of degree by the

terms "broad-" and "narrow-ridged," instead of "thick-" and "thin-plated" molars.

The mammillary divisions of the ridges in the Mastodons, when worn, form disks, *i. e.* a depressed surface of ivory, surrounded by a raised rim of enamel; and by the further progress of wear the separate disks become confluent into larger disks, that are either transverse or trefoil-shaped and alternate. In *Euelephas* the divisions of the compressed ridges form finger- or quill-shaped processes, which at first are ground down into distinct "annular disks"; two or three of these then become confluent into a compound oval disk; and at length the separate oval disks run together, forming a transverse band ("ruban" of Cuvier). Although it may not be strictly logical to apply the term "transverse disks" to these narrow bands (*tæniæ semidetritæ*), still they may be regarded as very flattened ellipses; and I have found it convenient to use the term in this arbitrary sense in order to maintain a uniformity of terms in designating the same object under different modifications.

The enamel plates furnish the most important distinctions. 1st, in regard of the thickness: in *E. primigenius* they are only half as thick as in *E. meridionalis*, and thinner than in the Indian Elephant or in *E. (Euelephas) antiquus*. 2ndly, surface-characters. The inner surface, where in contact with the ivory, is usually smooth; and the edges of the plates, in the worn disks, is even, whether the plates are straight or plaited. The outer surface is rugous and uneven in two directions:—1st, vertically from parallel or divided ribs separated by anastomosing channels, which are close-set and irregular in size, and which are most marked below, disappearing upon the apices of the digitations; and 2nd, transversely, from parallel, wavy, contiguous, and very frequent *rugæ* or superficial puckering. In the vertical section these communicate a ragged, feathered edge to the outer surface of the plates; while the transverse section of the ribs and channels, in the worn plates, produces a spurious appearance of crimping, which it is important to distinguish from plaiting or folding of the enamel upon itself. The undulated margins caused by these alternate ribs and channels multiply the triturating inequalities of the enamel, and they serve also, along with the transverse puckers, to abut the cement firmly against the enamel plates, and diminish its liability to splinter during the process of trituration. This channelling is most strongly marked in the species which have thick plates of enamel; and when the plates are denuded of cement, the ribs between the channels simulate the appearance of cords. 3rd. Flexure of the plates transversely. This is presented under two forms: first, primary flexures, where the plates are folded upon themselves by numerous minute plicatures, closely applied to each other, and communicating a continuous zigzag appearance to the worn edge of the enamel, on both sides; this is the character to which Cuvier applied the term "festooning," and here called "crimping" or "plaiting"; second, secondary flexures, caused by the outline of the ivory cores upon which the enamel plates are

moulded, and by the confluence of the disks of the separate digitations, according to the stage of wear of the teeth.

The presence or absence of the crimping is very constant in the different species, and very significant as a distinctive mark. Of all the species, fossil and recent, it is most marked in the existing Indian Elephant, in which the crowns of the molars are comparatively narrow; and ordinarily it is entirely wanting in *E. primigenius*, in which they are broad. The former belongs to the Stenocoronine type of *Euelephas*, the latter to the Eurycoronine type. The effect which is brought about in the Mastodons by the crowding of the mammillæ so as to present alternate and outlying tubercles, and in the African Elephant by the mesial rhomboidal expansion, is in the Indian Elephant accomplished by the numerous small plicatures of the enamel plates. If these were unfolded, and the plates drawn out to the extent thus gained, the molars of the Indian species would be fully as broad, if not broader than in the Mammoth. Both species, although differing so importantly in these two characters of crimping and breadth of crown, agree in one respect—that, although presenting more or less of secondary flexures, the disks of wear are of nearly uniform width across: neither of them, as a general rule, exhibits any tendency to a mesial loop or to angular expansion; whereas in *E. (Euelephas) antiquus*, which has hitherto been so generally confounded with the Mammoth, the molars present the threefold difference of narrow crowns, with crimped enamel, and a certain amount of mesial rhomboidal expansion of the disks of wear. This species, in fact, represents among the *Euelephantæ* what the existing African Elephant does among the Loxodons. The difference of *E. (Euelephas) antiquus* from the Mammoth corresponds with that of *E. (Loxodon) Africanus* from *E. (Loxodon) meridionalis*, the former in each case being Stenocoronine, the latter Eurycoronine.

Another circumstance that requires to be considered is the manner in which the plane of detrition modifies both the pattern and the antero-posterior diameter of the worn disks at different elevations. In the Mastodons, *M. (Trilophodon) Ohioticus* for example, the crowns are rectangular, with only a slight difference of height from front to back; the ridges come successively into wear, but the plane of detrition is nearly level in the same direction, and it makes no considerable angle with the vertical plane of the ridges. In the Indian Elephant, in consequence of the large increase in the number of ridges, the form of the crown is necessarily modified greatly. The upper molars, instead of being rectangular, are of a subtriangular and rhomboidal form, very high in front, and falling off behind. The anterior ridges attain in the last upper molar a height of 8 inches. In the progress of wear, the tooth moves forward in the arc of a circle. The anterior ridges of the opposed teeth are inclined in front, and, by their triturating action against each other, they are worn away obliquely, and the front part of the crown is ground down to the base before the posterior ridges come into use. The plane of abrasion intercepts the vertical plane of the ridges at an angle of about 60°. From this circumstance it follows that, as the ivory cores of the

ridges, however compressed, are wedge-shaped bodies, the disks of wear not only necessarily become wider as they get lower, but, from the obliquity of the plane that intercepts the ridges, they expose, in old teeth that are used down to the base, a broader surface than the actual width of the ridges, measured in a straight line. From not paying due regard to the cause, observers have been led to regard what is in reality only an accident of advanced wear in such cases as indicating "thick-plated" varieties, and as subversive of the specific distinction between the Mammoth and *E. meridionalis*.

2. *Indian Elephant*.—The leading features of the dentition of this species are so well known from the excellent descriptions and figures of Corse, followed up by Cuvier, De Blainville, and other comparative anatomists, and the materials are so abundant in European collections, that I shall confine my remarks, on the present occasion, chiefly to the points which affect the determination of the ridge-formula in the successive teeth. But it is necessary to enter with some detail of evidence upon this part of the subject, as the results to which I have been led differ in some important respects from those arrived at by previous observers, on what concerns the ridge-characters of the intermediate molars.

a. *Milk-molars*.—The antepenultimate and penultimate milk-molars (*d. m.* 2 and *d. m.* 3) are seen *in situ* in the upper jaw of the young cranium figured by Corse, which is now preserved in the Museum of the India House. The antepenultimate presents four ridges, and measures but 7 inches in length. This tooth is exceedingly rudimentary in form and dimensions. The penultimate is composed of eight principal ridges, with an anterior talon-ridgelet, but no posterior talon. The eighth or last ridge is as well developed as the others, showing eight distinct digital processes. The dimensions of this specimen are—length 2·4 inches, width in front ·9 inch, width behind 1·3 inch. The alveolus of the last milk-molar, separated from the penultimate by a partition, is present in this specimen, but empty.

The lower jaw of the same cranium furnishes the three milk-molars in place. The antepenultimate, like the corresponding upper tooth, is composed of four ridges, and measures ·65 inch long. The penultimate has eight principal ridges, with a small posterior talon. It is longer and narrower in proportion than the upper; it measures 2·55 inches in length. Eleven germs of the ridges of the last milk-molar are lying loose in the alveolus or cavity of that tooth.

A young cranium belonging to a skeleton in the Museum of King's College, London, and having the lower jaw attached, furnishes the next stage of dentition—namely, the penultimate and last milk-molars, *in situ*. The penultimate is much worn, the two front ridges being ground down to the base. The crown presents eight principal ridges, with indications of an anterior talon. The disks of wear are wide, and the enamel-border well crimped, but with no tendency to mesial expansion. The dimensions are—length 2·7 inches, width of crown in front 1·2 inch, behind 1·5 inch.

The last or third milk molar, left side, has a crown composed of

twelve principal ridges, with a talon in front and behind. The first ridge and anterior talon are alone worn, the two last ridges and talon being unconsolidated and separate. This tooth measures in length of crown 5·2 inches, by a width in front of 1·5 inch.

In the lower jaw of the same specimen the penultimate milk-molar presents eight principal ridges in a length of crown of 2·6 inches. The last milk-molar is partly imbedded in the alveolus, and the posterior portion concealed. Of the eight emerged ridges, the four anterior are worn. The diameter of the tusk (replaced) in this cranium is 1·1 inch.

A detached cranium, in the same museum, furnishes the corresponding teeth in the lower jaw, but a little older, and with the crown fully emerged from the alveolus. The penultimate presents eight principal ridges, with a small talon-splint behind. The crown is well worn, and measures—length 2·4 inches, width in front ·9 inch, width behind 1·2 inch. The last lower milk-molar has a crown composed of twelve principal ridges, with a posterior talon; the four anterior ridges are worn, the rest being intact, and the whole united by cement. The crown measures, in length, 4·5 inches, by a width in front of 1·55 inch. The cranium in this case, although older, is of a smaller variety than that previously described.

There are several young crania in the Museum of the College of Surgeons yielding the same teeth. In one very immature specimen (A) the antepenultimate upper is composed of four ridges and a talon, and the lower of four ridges. Of the penultimate upper and lower, each presents only seven ridges, with front and hind talons. In another (B) which is a little older, the penultimate, much worn, and the last, partly in use, are shown above and below. The penultimate upper exhibits the remains of eight ridges; the lower is worn out. The last upper milk-molar of the same specimen, and the last lower, show twelve ridges each, with a front and back talon.

Taking the data afforded by these examples and a great many others which I have seen in different collections, the ridge-formula of the milk-molars in the Indian Elephant, exclusive of talons, is ordinarily thus:—

$$\frac{4+8+12}{4+8+12}$$

In regard to the penultimate milk-molar, an exception is admitted in the case of the young cranium (A), where this tooth, both above and below, is stated to present seven ridges in addition to front and hind talons; but the hind talons in these cases may be regarded as last ridges. Cuvier adopted the numbers assigned by Corse, namely, four ridges to the tooth here designated the antepenultimate, 8 or 9 to the penultimate, and 12 or 13 to the last milk-molar. But it is to be remarked that Corse made no distinction between the talons and the ridges proper. De Blainville, in the descriptive details of these teeth, assigns to them in succession, respectively, 4, 8, and 11 ridges to the upper, and 4, 9, and 11–12 ridges to the lower. Owen describes the first or antepenultimate as having 4 plates, the penultimate 8 or 9 plates, and the last from 11 to 13 plates. Taking

the mean of the various numbers assigned, and making allowance for want of precision in some of the cases in reference to the talons, the numbers would nearly agree with those comprised in the above formula, which shows a progression by multiples of 4.

b. *True Molars*.—The exact determination of the ridge-formula of the true molars is embarrassed by greater difficulties; but it is a question of considerable importance, more especially as regards the ciphers of the antepenultimate and penultimate, in reference to the confident discrimination of the fossil species. For if, in the living species, these teeth should prove to be subject to any great variation in the number of their ridges, the same might reasonably be expected to hold good in the nearly allied fossil forms, and a reliance on the ridge-formula as a means of distinction would not be warranted. The causes of the uncertainty are these:—When the animal is adolescent or adult only two at the utmost can be present at one time, on one side of the jaw, out of the six molar teeth developed during life; and of these two, only one usually is in a perfect state. If the anterior molar is in use and complete, only a part of the posterior tooth is emerged and visible. If the latter is fully protruded, the greater part of the anterior tooth will have been worn away. It is thus impossible ever to trace the details of the dental succession throughout, in any one individual. Then there is a very great difference of size between different animals of the same age. The antepenultimate true molar of a large variety may be nearly as large as the penultimate of a small one. Again, there may be a different estimate of the number of ridges in the same tooth according to the manner in which different observers regard the talons. The same last milk-molar may be described by one as having a crown composed of twelve ridges with talons, and by another as having fourteen ridges without them. Further, a slight amount of difference in the stage of wear will make an upper antepenultimate present twelve distinct ridges at one time, and only eleven when worn lower down, in consequence of the confluence of the two anterior ridges, exclusive of the talon, into one common disk. Cuvier, in his remarks on the numerical determinations of Corse, has expressed his belief that they are not absolute. In proof, he cites a case observed by himself, in which the two consecutive teeth of a lower jaw presented each fourteen ridges; while in the corresponding upper jaw the anterior tooth had thirteen ridges in use, and the molar in germ behind it had eighteen ridges. With all deference to the illustrious French anatomist, it may fairly be asked whether in this instance the upper and lower jaws really belonged to the same animal.

In museums, it is by no means uncommon to see skulls of Elephants fitted with mandibles that do not belong to them, either imported thus from abroad, or having been subjected to some accidental misplacement afterwards. A reliable instance of the kind alleged, as a normal arrangement, has never come under my observation, after the examination of a very large number of skulls in Europe and in India. Inferring from what is ordinarily seen in the Indian Elephant, the teeth in the upper

and lower jaws in question would be regarded as belonging to distinct animals of different ages.

To revert to the numerical determinations, the antepenultimate or first true molar is that regarding which there is the most uncertainty. According to Corse, it consists of about fifteen ridges. Cuvier has not specially defined the number. De Blainville attributes to the upper antepenultimate fifteen ridges; the lower he has not characterized. Owen describes the tooth, in general terms, as having the crown composed of 15 or 16 plates (ridges), with a length of from 7 to 8 inches. The result of my observation is, that although the first true molar, in the Indian Elephant, is manifestly larger in all its dimensions than the last milk-molar, it ordinarily repeats the number of ridges shown by the latter. The following are illustrations in the Museum of King's College:—Besides the two young crania already mentioned, there is a third, of adolescent age, which contains the last milk-molar and the first true molar above and below. The third milk-molar in the upper jaw is nearly worn out; behind it the antepenultimate true molar presents a crown composed of twelve principal ridges, with a front and back talon. The six anterior ridges are worn, the rest being intact. The dimensions are—length of crown 6·3 inches, width in front 2·1 inches, width behind 1·5. In the lower jaw of the same specimen the last milk-molar is worn out; the antepenultimate true molar presents a crown composed also of twelve principal ridges, with front and back talons. The ten anterior ridges are worn: the disks of wear are well crimped, and without any mesial expansion. The dimensions are—length of crown 6·8 inches, width in front 2 inches; width behind 1·5. The cranium is well marked, for reference, by the loss of the right tusk, the pulp-nucleus of which had been destroyed, the third alveolus being nearly filled up. It bears a record of having been presented by Mr. Hammond.

In the collection of the Royal College of Surgeons there is a young cranium, nearly of a corresponding age, in which the same teeth are present. In the upper jaw, the last milk-molar is worn down to a stump, having the indistinct remains of about five ridges.

The antepenultimate true molar is in the middle stage of wear. The crown presents twelve principal ridges, with front and back talons, making in all fourteen divisions. The five anterior ridges and talon are worn, the rest being intact. The dimensions are—length of crown 6·8 inches, width of ditto in front 2·4 inches.

In the lower jaw of the same cranium, the last milk-molar is nearly worn out; the antepenultimate true molar has a crown composed of twelve principal ridges, with front and back talons, the latter of which has a small splent, appended to it. The ridges may therefore be reckoned either as 12 or 13, according to the different views of observers in regard to what ought to be considered talons. The eight anterior ridges of the crown are in full wear. The length of the crown is 7·8 inches*.

I have now before me two very instructive detached specimens,

* The other dimensions would have been inserted, but I have been unable to identify this specimen in the Museum of the College.—Ed.

belonging to the collection of my coadjutor, Colonel Sir Proby Cautley, and consisting of the right upper and lower antepenultimate true molars of the same animals. They are in the most favourable state of use for observing all the characters. The upper molar has a crown composed of twelve well-defined principal ridges, with a front and a back talon. The seven anterior ridges are in wear, presenting open transverse disks with the enamel-borders strongly crimped. The posterior talon consists of a narrow splent appended to the last ridge. The dimensions are—

	inches.
Length of crown	7
Width of ditto at second ridge	2·5
Width of ditto at eighth ridge	2·5
Width of ditto at eleventh ridge	2·2
Height of ditto at seventh ridge	6·9

The corresponding tooth of the lower jaw presents a crown also having twelve principal ridges, with a distinct front and back talon. The nine anterior ridges are in use, the front talon in this instance, as also in the upper tooth, being confluent with the disk of the anterior ridge; the posterior talon is a narrow splent. The disks of wear are transverse, open, free from mesial dilatation, and the enamel plates well crimped as in the upper molars. The dimensions are—

	inches.
Length of crown	7·5
Width of ditto at second ridge	2·1
Width of ditto at eighth ridge	2·4
Height of ditto at ninth ridge	5·6

In these two specimens the character which most obviously distinguishes the Euelephants from the Loxodons is well manifested—namely, the great height of the crown relatively to the width. In the upper antepenultimate, the height of the seventh ridge is almost equal to the length of the crown. The dimensions of these teeth render it certain that they are not the last milk-molars.

A detached right upper antepenultimate true molar, in the Museum of the College of Surgeons (no. 2802, Osteol. Catal.), shows also twelve principal ridges, with front and back talons. The dimensions of this specimen are—

	inches.
Length of crown	6·8
Greatest width of crown	2·5
Greatest height of ridge	5·5

A lower jaw in the same collection (no. 2670) shows the antepenultimate in fine preservation, presenting distinctly twelve principal ridges, with talons. The dimensions are—length 6 inches, greatest width of crown 2·1 inches. As compared with Sir Proby Cautley's specimen, it is of small size.

On the other hand, a perfect specimen of an upper antepenultimate in the same museum (no. 2803) shows fourteen principal ridges, besides front and back talons. The dimensions are—

	inches.
Length of crown	6·4
Width of ditto	2·5
Height at eighth ridge	5·5

Another illustration of the same kind is furnished by the polished section of an entire upper antepenultimate, no. 2871 of the same collection.

The specimen presents fourteen principal ridges, without a posterior talon. The dimensions are—

	inches.
Length of crown	6·8
Height of ditto at the fifth ridge	4·8

In this case if the two anterior ridges were worn somewhat lower down, they would present but a single disk, with an appearance of thirteen ridges to the crown. Although the last-mentioned specimens show that the number of ridges in the antepenultimate sometimes ranges as high as fourteen, the other instances indicate that the prevailing cipher is 12, or a repetition of that of the third molar.

The penultimate or second true molar is described by De Blainville as being composed, in the upper jaw, of seventeen ridges, and of eighteen in the lower. Owen attributes, in general terms, to the penultimate from seventeen to twenty ridges. Corse and Cuvier have not specially defined it. A vertical section of an upper antepenultimate is represented in the 'Fauna Antiqua Sivalensis,' plate 1. fig. 2, composed of seventeen ridges, with a reduced talon-splint behind, the anterior talon being confluent with the first ridge. The dimensions are—length of crown 8·5 inches, height of crown at eighth ridge 6·2 inches. The anterior eight ridges are worn. In the skull of a Malay Elephant in the Museum of the Royal Asiatic Society the antepenultimate and the penultimate are presented *in situ*, the former well worn, the latter in germ. The penultimate in this case is composed of sixteen principal ridges, with front and back talons. The typical specimen, figured and described by De Blainville*, has a crown consisting of sixteen principal ridges, with talons. The skull, no. 2659 of the Osteol. Catal. Mus. College of Surgeons, presents the upper penultimate on either side perfect, although partly worn, and the empty alveoli of the germs of the last true molar behind. The crown of the penultimate is composed of sixteen principal ridges, with a front and back talon, of which the eleven anterior ridges are worn. The dimensions are—

	inches.
Length of crown	7·5
Width of ditto in front	3·0

Of the penultimate lower true molar, the majority of specimens that I have examined have also presented sixteen principal ridges, with talons. A fine illustration is afforded by the left ramus of the

* 'Ostéographique,' "Des Eléphants," tab. 7. fig. 5 c.

mandible, no. 2667 of the Osteol. Catal. Mus. Coll. of Surgeons. The inner wall of bone is removed so as to expose the imbedded crown and fangs. The penultimate is complete, having in front the posterior fang-alveolus of the antepenultimate, and behind the empty cavity of the unformed last molar. The crown presents distinctly sixteen principal ridges, with front and back talons, the dimensions being—

	inches.
Length of crown	9·5
Width in front	2·4
Greatest width	3·0
Height at fifth ridge.....	5·0

The five anterior ridges alone are affected by wear.

This specimen is designated in the Osteological Catalogue of the Collection the last true molar; but the form and dimensions prove it to be penultimate.

A detached penultimate left lower molar in the same Museum, no. 2825, presents a crown composed also of sixteen principal ridges, with front and back talons. Eleven of the ridges are worn. The dimensions are—

	inches.
Length of crown	9·0
Width of ditto at seventh ridge	3·2
Height of ditto at eleventh ridge.....	5·5

This specimen is described in the catalogue as the last molar, but it presents all the characters of a penultimate.

No. 2824 of the same collection, a lower ramus, left side, contains the antepenultimate and penultimate *in situ*, the former well worn and reduced to the disks of the eight posterior ridges, the latter nearly in germ, the three anterior ridges alone being slightly abraded. The penultimate in this instance also presents sixteen principal ridges, with talons.

In the Ipswich Museum there is a fine specimen of a detached penultimate molar of the lower jaw, left side, presented by Mr. C. Bree, which presents sixteen ridges, besides talons, in a length of crown of 9·5 inches. Another specimen of a left inferior penultimate in the Museum at Taunton has a crown composed of sixteen principal ridges, with front and back talons. The twelve anterior ridges are worn. The dimensions in this case are—

	inches.
Length of crown	11·0
Width of ditto at third ridge	2·3
Width of ditto at eighth ridge.....	3·1
Height of ditto at twelfth ridge	6·0

It is not meant to be insisted that the cipher 16 absolutely and constantly determines the number of ridges in the penultimate molar, upper and lower, of the Indian Elephant. I believe that exceptional cases occur in which they range as high as twenty in the lower penultimate in very large individuals. But, taking the

great majority of instances, the prevailing number is seen to be sixteen.

The last true molar, both in the upper and lower jaws, is subject to a considerable difference of size in different individuals; but it is readily distinguishable, both by the modification in the form, and by the circumstance that the ridges constantly either attain or surpass twenty in number. Where the crown is complete, and all the ridges are present, the last upper molar ordinarily presents twenty-four ridges, and the last lower about twenty-seven. The posterior ridges in the upper molar are proportionally much less elevated than in the penultimate, the crown in profile, when unworn, presenting an outline that is nearly triangular, but prolonged backwards in the last lower molar; the posterior ridges, besides being very low, have their apices incurved upon the crown, and they diverge towards their bases somewhat in a fan-shaped manner; while, in the penultimate, the ridges are of a more uniform height from front to rear, and depart but slightly from parallelism in their general disposition.

As examples may be cited the cranial specimen, no. 2662, Cat. Mus. Coll. of Surgeons, which contains the last upper molar, *in situ*, in fine preservation. On the left side the alveolar wall is removed, to expose the tooth, which has a crown composed of twenty-four ridges, of which only the anterior five are worn. The dimensions are—

	inches.
Length of crown	13·5
Height at the sixth ridge	7·1
Width of ditto in front, where greatest	3·2

Another last upper, in a more advanced stage of wear, and yielding an excellent illustration of this tooth, is presented by the specimen, no. 566 of the Cat. of Foss. Mam. Mus. Coll. of Surgeons. De Blainville has given a figure (*Ostéographie*: “Des Eléphants,” tab. 7. fig. 6) of a deformed last upper molar, composed of about twenty-seven ridges.

Of the last lower molar in the Indian Elephant a longitudinal section is represented, half the natural size, by fig. 2 of plate 1 of the ‘*Fauna Antiqua Sivalensis*.’ The entire length of the crown is about 15 inches, including in all twenty-seven ridges, of which the anterior thirteen are more or less abraded. The first five or six ridges incline a little forwards, while the posterior ridges incline so much in an opposite direction that the hindermost are nearly horizontal, producing the flabelliform character that so readily distinguishes, in most instances, the last lower molar from the penultimate. De Blainville has given, in fig. 6 of plate 9 of his great work, a beautiful representation of a perfect specimen of the same tooth, composed of twenty-seven ridges. Another very fine example of a last lower molar is presented by the specimen, no. 557 of the Cat. of Foss. Mam. Mus. Coll. of Surgeons, there described as being of the Mammoth, but which I regard as being of the existing Indian Elephant, for reasons which will appear in the sequel. The crown is composed of about twenty-seven ridges. In the formula given

in the note, p. 315 of the preceding part, the numbers assigned to the true molars in the Indian Elephant are, $\frac{14+18+24}{14+18+24-27}$; and in the definition of the subgenus, the increments in the intermediate molars are expressed by $12+14+18$. The formula was framed thus to embrace the range of variation in excess which is met with in nature, and to eschew the imputation of straining facts for a numerical harmony that certainly is not absolute. But if the "ridge-formula" in this species is to be framed upon the prevailing ciphers, exhibited in a large number of teeth, it will run so—

Milk-molars.	True molars.
$4+8+12$;	$12+16+24$
$\frac{4+8+12}{4+8+12}$;	$\frac{12+16+24}{12+16+24-27}$

thus presenting two terms of progressive increments, the one ranging from four to twelve in the milk-molars, and the other from twelve to twenty-four in the true molars, the same cipher being common to the last milk-molar and to the first true molar, in accordance with what is seen in the other sections of the Proboscidea. This last circumstance is that in which my observation on the succession of the molar teeth in the existing Indian Elephant differs most from the results arrived at by previous observers.

There is no good evidence of the existing Indian Elephant having as yet, anywhere in India or in Europe, been met with in the fossil state. The specimens attributed to it by Trimmer, Mantell, and others, are referable to *E. (Euelephas) antiquus*. But undoubted fossil remains, now preserved in the British Museum, have lately been found in America, which indicate either a distinct species closely allied to the Indian Elephant, and intermediate between it and the Mammoth, or merely a well-marked variety of the former. In either view the case is one of high interest in its palaeontological and systematic relations. This form is provisionally designated *E. Armeniacus* in the Synoptical Table, p. 13 of the first part of this essay. The molar teeth combine the closely approximated and attenuated ridges of the Mammoth with the highly undulated enamel-folding or "crimping" which is so characteristic of the Indian Elephant.

3. *Elephas (Euelephas) primigenius*.—In a strictly methodical order, *E. antiquus* would follow next among the European fossil species for description. But it will better suit the objects of this essay first to dispose of *E. primigenius*, the Mammoth properly so called, since most of the disputed points involved in the question of distinct species or varieties only of a single form turn upon the exact determination of the characters of the Mammoth.

Whatever may have been the approximation previously made by Merk or Blumenbach towards a distinction of the Mammoth from the two living species, Cuvier was undoubtedly the first to characterize the extinct species with exactness, in his joint memoir with Geoffroy, under the name of *Elephas Mammoth*, in the year 1796*.

* Mém. de l'Institut, 1^{re} Classe, tom. ii.

In the same year he read a memoir at the first public meeting of the "Institute," but which was not published until 1806, in which the diagnostic marks are very pointedly expressed under the designation of *Elephas mammoreus*: "Maxillâ obtusiore, lamellis molarium tenuibus rectis," as distinguished from *Elephas Indicus*: "Fronte plano-concava, lamellis molarium arcuatis, undatis." Cuvier connected these dental and mandibular distinctions with others yielded by Messer Schmidt's figure of the skull of the Mammoth, and combined the whole in the extended specific definition of the extinct form, which appeared in his memoir of 1806—"L'Eléphant à crâne allongé, à front concave, à très-longues alvéoles des défenses, à mâchoire inférieure obtuse, à mâchelières plus larges, parallèles, marquées des rubans plus serrés." He abandoned the name *E. mammoreus* of his memoir of 1796, and adopted the designation of *Elephas primigenius*, proposed by Blumenbach* in 1803, which is that now generally accepted among palæontologists. To this normal form, as already stated, Cuvier referred all the fossil remains of Elephants found over the whole of Europe, in Northern Asia, and in North America, however much at variance with the terms of his definition; and, to the last, he clung to the specific unity of the "Eléphant fossile" with the jealous partiality of a discoverer for the earliest result from which his most cherished labours sprung.

The distinctive characters in the molars of the Mammoth, as compared with those of the existing Indian Elephant, upon which Cuvier relied, may be expressed in the following terms:—

1. Great narrowness or compression and approximation of the crown-ridges, involving both a larger number in the same length of crown and in triturating use at the same time.
2. Tenuity of, and absence of crimping in, the enamel plates.
3. Greater width of the molar crowns, both absolutely and relatively to their length.

These peculiarities, when combined, are very constant in the Mammoth. Exceptional cases have been admitted by Cuvier, and adduced by others; but, when closely examined, they have proved either to belong to other extinct species or to be disguised molars of the existing Indian Elephant.

Taking the molars of the Mammoth in succession from first to last, they yield the descriptions which follow.

a. *Upper Milk-molars*.—Of the milk-molars of the upper jaw, the antepenultimate or most anterior, from its rudimentary form, appears to have been shed at a very early period, and it is consequently but rarely observed *in situ* in the fossil state. It is inferred to have been composed of four ridges, with talons, like the corresponding rudimentary tooth of the Indian Elephant.

The penultimate milk-molar (or second in appearance) is much more common, especially in cave-collections. I observed in the Taunton Museum no fewer than eight worn penultimates, upper and lower, in the collection formed by the Rev. D. Williams, from the Mendip caverns. There are several also in Mr. Beard's collec-

* Voigt's Mag. 1803, Band v. p. 16.

tion at Banwell, and one in the collection of the Geological Society, from Kent's Hole. The displayed part of the collection in the British Museum contains a few examples of this tooth referable to the Mammoth, and it exists also in the collection of the College of Surgeons. The crown, as in the corresponding tooth of the Indian Elephant, is composed of seven or eight ridges, with talons. A fine specimen, in the Museum at Taunton, from one of the Mendip caverns, in perfect preservation, with the fangs present and the crown worn, presents seven principal ridges, besides front and hind talons.

The dimensions are—	inches.
Length of crown	2·3
Width of crown at second ridge	0·9
Greatest width behind	1·4

From the dimensions it will be seen that the crown is narrow in front and broad behind, yielding somewhat of an ovate outline. The specimen in the collection of the Geological Society, from Kent's Hole cavern, is a penultimate upper milk-molar of the right side, with the crown much worn and the anterior portion ground out. The disks of the six posterior ridges remain.

The dimensions are :—	inches.
Length	2·2
Width behind	1·3

The specimen (no. 583 of the Cat. Foss. Mam.) in the Museum of the College of Surgeons is a left upper maxillary, containing the penultimate milk-molar far advanced in wear. The crown in this case is also much worn, presenting the disks of six principal ridges and a hind talon. The specimen is reputed to be from the Drift-beds at Ilford.

The last milk-molar, or third in succession, of the upper jaw of *E. primigenius*, abounds in English collections, both from the caverns and from the Drift-beds. It is readily distinguished from the same tooth in the other species, fossil or recent, by the broad squat form of the crown and the closely approximated ridges and uncrimped enamel plates. A fine illustration of this tooth is presented by the Hunterian specimen (no. 585, Cat. Fossil Mam.) in the Museum of the College of Surgeons, from Hinton, Somersetshire. The crown is composed of eleven principal ridges, with talons, the anterior part being slightly worn, showing the disks of five or six ridges; the posterior ridges are intact.

The dimensions are—	inches.
Length of crown	3·6
Width in front	1·5
Greatest width	1·8
Height at sixth ridge	2·6

The ridges are closely approximated, and the attenuated layers of enamel free from crimping. In the descriptive catalogue (p. 140), the crown is regarded as being composed of twelve plates, the last being here considered the posterior talon.

Another illustration of the same tooth, a right upper, may be cited in a British Museum specimen, no. 156 of the Palæontol. Cat. The crown is composed of eleven principal ridges, besides talons; the six anterior ridges are worn.

The dimensions are—	inches.
Length of crown	3·7
Width in front	1·4
Greatest width	1·9
Height at sixth ridge	3·0

A third illustration is afforded by a germ-specimen of a left molar from Kent's Hole cavern, in the Museum of the Geological Society. The crown is composed, besides talons, of twelve principal ridges, of which the first alone is abraded, the rest being intact.

The dimensions are—	inches.
Length of crown	4·6
Greatest width, at second ridge	1·8
Height at second ridge	4·0

Numerous other examples of this tooth might be cited, presenting either eleven or twelve ridges, with talons. De Blainville describes it as being composed of eleven, and Professor Owen of from twelve to fourteen ridges, the talon-plates in the latter case being probably taken into the reckoning.

b. *Lower Milk-molars*.—Of the lower milk-molars, the antepenultimate, or most anterior, is exceedingly rare in collections. An illustration of it is furnished by the specimen figured and described by Kaup, under the name of *Cymatotherium antiquum*. Like the corresponding rudimentary tooth in the Indian Elephant, it is inferred to be composed ordinarily of few ridges. There is a specimen in the British Museum (no. 33,403), from Mr. Layton's collection*, which contains the sockets of the two anterior milk-molars; but the crowns are wanting.

Of the penultimate milk-molar of the lower jaw, there is a fine specimen in the Taunton Museum, from one of the Mendip caves, in perfect preservation, with the fangs present and the crown worn. It is composed of seven principal ridges, besides front and hind talons; the latter is so large that the crown may be regarded as comprising eight principal ridges without a hind talon; the grinding-surface presents no inequalities in the shape of raised machærides, the cement, ivory, and enamel being on a uniform level, as if polished.

The dimensions are—	inches.
Length of crown	2·3
Width at second disk	0·9
Greatest width, behind	1·4

From these dimensions it is seen that the crown is narrow in front and about half an inch wider behind, yielding somewhat of an ovate outline. Other illustrations might be cited, in which the

* This specimen is probably from Happisburgh, and has evidently been in the sea.

crown of the penultimate lower milk-molar presents eight ridges, besides talons.

Of the last milk-molar of the lower jaw (third in the order of appearance) a very fine example *in situ* is afforded by a cast of a mandible, in the Museum of the College of Surgeons. Both rami are complete, with the exception of the articular surfaces of the condyles. The last milk-molar, well worn but perfect, is present on either side, with the empty sockets of the penultimate in front and of the first true molar behind.

The dimensions of the last milk-molar, left side, are—

	inches.
Length of crown	3·9
Width in front	1·2
Greatest width behind	1·7

The crown is composed of twelve ridges, with talons closely approximated. The original of this specimen is reputed to have been found in the superficial deposits of the valley of the Rhine.

Another example of the last milk-molar of the lower jaw, detached, may be cited in the specimen in the collection of the British Museum, no. 21,315, from Ilford, Essex. The crown is composed of twelve principal ridges, with talons, the anterior six being worn, and the rest intact; the ridges are closely approximated, and the disks of wear form parallel transverse bands, with no tendency to expansion in the middle, and with the plates of enamel attenuated and free from crimping.

The dimensions are—	inches.
Length of crown	3·7
Width of crown in front	1·1
Greatest width, behind	1·5
Height at the seventh ridge	2·3

Numerous other examples might be cited; but these two suffice to indicate the ordinary characters of the tooth.

The third milk-molars in the Mammoth, upper and lower, are distinguishable with facility from those of *E. (Loxod.) meridionalis* and from *E. (Eueleph.) antiquus* by the duodenary cipher regulating the crown-ridges, and by the tenuity of the enamel plates; but the antepenultimate and penultimate are much less easily discriminated.

Taking the numbers yielded by the examples above given, it is seen that the ridge-formula of the milk-molars in *E. primigenius* is identical with that of the existing Indian Elephant, and liable to the same variation as regards the antepenultimate, upper and lower, as is met with in that species, namely, the ridges varying from seven to eight. The formula may be expressed thus:— $\frac{4+8+12}{4+8+12}$ exhibiting a progression by successive increments of four.

c. *Upper true Molars*.—The circumstances which render it difficult to determine with precision the ridge-formula of the true molars in the existing Asiatic form apply equally to those of the Mammoth;

and, in consequence, the ciphers of the antepenultimate and penultimate, being the two posterior intermediate molars, have heretofore been but vaguely ascertained. Cuvier had not advanced sufficiently far in the investigation of the subject to attempt to ascertain them. De Blainville attributes from fifteen to sixteen ridges to the antepenultimate, and eighteen or nineteen to the penultimate, in the upper jaw. Owen considers the antepenultimate (fourth in succession) to have been subject to considerable variation in the number and proportion of the ridges, which he estimates as ranging from twelve to sixteen, the greater number being usually in the lower molar. Of the penultimate he describes the ridges as ranging even from sixteen to twenty-four. Upon the examination and comparison of a very large number of specimens I have been led to the conviction that, ordinarily, the antepenultimate upper true molar repeats the duodenary cipher of the last milk-molar, and that the penultimate, as in the Indian Elephant, advances by an increment of four ridges.

First, in regard of the antepenultimate upper, or fourth in the order of horizontal succession. A very fine illustration of this tooth *in situ* is presented by a specimen in the Museum of the College of Surgeons (no. 620, Cat. Foss. Mam. p. 153), comprising the palate with a molar on either side, and in front of it the empty fang-pits of the last milk-molar, which had been shed. The crown of the antepenultimate is worn to the last ridge, but quite perfect, and presents the disks of twelve principal ridges, with talons; it is very broad in relation to the length, and when compared with the corresponding tooth of the existing Indian Elephant it looks short and squat; the outline is nearly a parallelogram, of which the length is less than twice the width; the disks of wear are closely approximated, forming narrow transverse bands; the enamel plates are very thin, with a slight tendency to minute irregular undulation, nowhere amounting to crimping.

The dimensions are :—	inches.
Length of crown	5·1
Width of crown in front	2·4
" " behind	2·4
Greatest width of crown	2·75

This specimen is of North American origin.

De Blainville remarks that the penultimate upper (or fifth in the order of succession) in the Mammoth is rare in the French collections. He was unable to include a figure of it in the rich series of representations contained in the 'Ostéographie.' In the descriptive details of the dentition (p. 189) he cites, as a fine illustration of it, a specimen from Warsaw on the Vistula, having a crown still composed of eighteen or nineteen ridges, although the most advanced of these are worn out; and he states that the tooth was remarkable for its large size. These circumstances throw great doubt upon the numerical rank assigned to it, which is strengthened by the fact that, in the references to the plates (p. 357), De Blainville mentions that he had no illustration of the penultimate except a bad cast, and that it was therefore omitted. The Warsaw specimen is probably a

last true molar. Perfect specimens of this tooth, furnishing the ridge-formula of the crown complete, are also rare, so far as my observation goes, in English collections, although mutilated specimens are as common as those of the other teeth. The illustrations which I adduce are chiefly taken from foreign specimens, in the the most perfect preservation. The first is a very fine molar, in the Museum of Darmstadt, which I was enabled to examine by the kind permission of Dr. Kaup. It is a detached penultimate upper of the left side, of the Mammoth, having the crown entire and all the ridges present. It is composed distinctly of sixteen principal ridges, besides a front and a back talon. The five anterior ridges alone are affected by wear, the rest being intact and perfect. The specimen yields all the distinctive characters of a Mammoth's grinder, namely, a broad crown, very high ridges separated by narrow interstices, and attenuated plates of enamel free from crimping. The dimensions of this specimen, which was yielded by the superficial deposits of the valley of Rhine, are—

	inches.
Length of crown	8·0
Width of crown	3·0
Height of the eighth ridge	7·25

From the last measurement it will be seen that the height of the ridges, in the middle of the tooth even, is nearly equal to that of the length of the crown.

Another detached penultimate upper of the left side, in the same collection, presents the crown equally perfect, and composed of from sixteen to seventeen principal ridges, with talons. It differs from the specimen just described in having a proportionally broader crown, with the ridges less elevated, the dimensions being, with a nearly equal length of crown—

	inches.
Width	3·25
Greatest height	6·25

In the Museum at Taunton there are two very instructive specimens from the Mendip caverns, the one being an upper penultimate of *Elephas antiquus*, formerly in the collection of the Rev. D. Williams, and reputed to have been procured from Bleadon Cave, the other a corresponding penultimate upper of the right side of *E. primigenius*, of which the precise cave-locality has not been recorded. These molars are in perfect preservation, and when put in opposition they show well by contrast the distinctive characters of the two species. That of the Mammoth has the crown composed distinctly of sixteen principal ridges, besides the front and back talons; of these the eleven anterior ridges are worn, the rest being intact; the crown is very broad relatively to the length, and the ridges are closely approximated, with narrow interstices; the disks of wear form narrow transverse bands, with attenuated unplaited enamel.

The dimensions are—	inches.
Length of crown	6·7
Width in front	2·5
„ at the eighth ridge	3·3
Height at the eleventh ridge	5·7

The length of the crown in this specimen is considerably less than in the first Darmstadt specimen above cited; but the difference is partly owing to the circumstance that it is in a more advanced stage of wear, involving necessarily a reduction in length.

I have seen no authentic specimen of an upper penultimate of the Mammoth presenting more than sixteen or seventeen ridges. That exceptional cases do occur, in which as many as eighteen may be seen, is not improbable; but I believe that, as holds in the existing Indian species, the prevailing and normal number is sixteen. De Blainville (*Ostéographie*: "Des Eléphants," p. 195) describes as a penultimate upper the cast of a molar in the collection of M. Duhamel de Namvilliers, of which the crown presents not more than fourteen collines; but he adds that the tooth is unusually short, and that the ridges are thick. It is therefore very questionable whether the rank which he has assigned to it as a penultimate is correct, even if the molar belongs to the species. Many of the specimens in the Palæontological Gallery at Paris, which M. de Blainville has referred to the Mammoth, have been identified by me as belonging to *Elephas antiquus* and to *E. (Lowod.) meridionalis*.

Professor Owen has given a very beautiful representation of an upper molar of a Mammoth from the Essex Till in figs. 91 and 92 of the 'British Fossil Mammalia' (p. 237), including both crown and side aspects. It is not specially described in that work; but in the "Odontography" he states (p. 666) that the fifth (or penultimate), ranging in length of crown from eight to eleven inches, is composed of from sixteen to twenty-four plates; and he refers to the figures above cited as illustrations of a penultimate upper of a Mammoth showing as many as twenty-four plates. The specimen, judging from the figures, is of an old molar in an advanced stage of wear; and the posterior ridges, although of less height than is usually seen in the penultimate, are comparatively high for a last upper molar of the Mammoth as that tooth is commonly met with; but the excessive number of the ridges is, in my view, conclusive against its being a "fifth," and equally so in favour of its being a last true molar deviating somewhat from the common form. De Blainville has figured in the '*Ostéographie*' (tab. 8. fig. 6) a last upper molar of a Mammoth, from the Canal de l'Oureq, in a more advanced stage of wear, which, allowing for this circumstance, does not differ much in form from the tooth figured in the 'British Fossil Mammalia.'

The last true molar, upper, of *E. primigenius* is subject to the same variation in the number of ridges as the corresponding tooth of the existing Indian species. They range from twenty-two to twenty-six, the prevailing number being about twenty-four. These teeth differ also very remarkably in size in different individuals; but the largest specimens have not necessarily the greatest number of ridges, the reverse being frequently seen. The tooth in outline resembles that of the Indian Elephant, being triangular, very high in front and low behind, where the last ridges gradually fall off into an angular termination; while in the antepenultimate and penultimate they are usually sufficiently high behind to com-

municate somewhat of a rhomb-shaped form to the crowns in their vertical contour. Examples of this tooth are common in all great collections. A very fine illustration from the Ohio is presented by the Hunterian specimen, a right upper (no. 615, Cat. Foss. Mam. Coll. Surgeons), presented by Dr. Caspar Wister, which yields all the typical characters of the true Mammoth. The crown is broad in front, narrow behind, and composed of twenty-six ridges, of which the anterior seventeen are ground down by wear. The disks of wear form narrow transverse bands, closely compressed, with thin unplaited machærides of enamel. The dimensions are—

	inches.
Length of crown	12·0
Width of ditto in front, third ridge	3·3
Greatest width of ditto, eighth ridge	4·0
Height of ditto at seventeenth ridge	5·3
Length of seventeen worn ridges at summit	8·2

Another fine example of this tooth, minus the fangs, is furnished by a specimen formerly in the Collection of Dr. Mantell, and now in the Jermyn Street Museum of Practical Geology. It is a last upper molar of the right side, bearing a label of "Sea-shore"; the crown is composed of twenty-seven divisions, including the posterior talon, a small portion at the anterior end being wanting, probably not more than the anterior talon or a single ridge. The vertical outline is triangular in a very pronounced degree, high in front, and low, terminating in an angle, behind. Eighteen ridges are worn into narrow parallel transverse disks, free from median expansion, and showing very attenuated enamel plates devoid of crimping. The posterior talon forms a narrow rudimentary splent. The specimen is heavy, and tinged of a reddish colour, like those dredged from the sea. The fresh fracture is very adherent to the tongue. [The author appears to have intended to give the dimensions of this tooth, but had not filled in the figures; and the deficiency cannot be supplied, as there is no tooth corresponding to the description at present in Jermyn Street*.]

d. Lower true Molars.—Of the antepenultimate (fourth in order of appearance) a very characteristic example is furnished by the Hunterian specimen, no. 622 (Cat. Foss. Mam. Mus. Coll. of Surgeons, p. 155), consisting of part of the right ramus of the lower jaw, with one molar, *in situ*, in perfect preservation. The crown is composed of thirteen principal ridges, besides front and back talon, all more or less affected by wear. The disks form transverse narrow and closely compressed bands, surrounded by thin plates of uncrimped enamel. The outline of the summit of the crown yields a short broad parallelogram, the length being less than twice the greatest width, while in the corresponding tooth of the existing Indian species the ratio is generally about three to one. The principal dimensions are—

	inches.
Length of crown	5·1
Width of ditto in front	2·1
Greatest width of ditto	2·6

* See also the footnote to p. 318.

The specimen is labelled as being from the Ohio, and when applied to the maxillary fragment, no. 620 in the same collection, containing the upper antepenultimate described *anted*, p. 328, the crown-surfaces fit so exactly, and the two specimens agree so closely in size, relative progress of wear, and in general appearance, that it is highly probable that they belonged to the same individual. They both present the black surface which is so common in the Elephant- and Mastodon-remains from the Bone-licks of the Ohio.

Another illustration of the same tooth is seen in the young mandible (Coll. Brit. Mus.) represented in the 'Fauna Antiqua Sivalensis,' pl. 13 A. fig. 2, which contains the antepenultimate on both sides, well advanced in wear, but complete, and the penultimate in germ behind. The crown of the antepenultimate is composed of twelve principal ridges, with talons, all of which, except the posterior talon, are affected by wear; it is broad relatively to the length, although in a less degree than is seen in the previous specimens; the disks of wear form closely compressed transverse bands, with attenuated plates of enamel. It is deserving of remark, that some of these plates differ from the ordinary type of the Mammoth in exhibiting a certain amount of irregular crimping, but in no degree approaching that seen in the Indian Elephant, the presence of this character being concurrent with a less than the ordinary width of crown.

The dimensions of the tooth are:—

	inches.
Length of crown	5·3
Width in front	1·85
Greatest width	2·3

In a specimen in the Museum at Turin the dimensions are:—

	inches.
Length of crown	5·2
Width in front	1·9
Greatest width	2·4

In the Museum of Taunton, so rich in remains from the Mendip caves, there is a finely preserved detached antepenultimate lower molar from "Wookey-hole," found along with teeth of the Siberian Rhinoceros, Cave-lion, and Hyæna. The crown, although worn to the extent of seven or eight disks, is complete, and composed of twelve ridges, with front and back talons; it is broad and squat-looking, with all the usual typical characters of the Mammoth, *i. e.* narrow transverse disks with thin unplaited enamel.

The dimensions of this specimen are—

	inches.
Length of crown	5·1
Width of crown in front	2·3
Height at the eighth ridge	3·5

Cuvier has given a representation* of a young lower jaw discovered near Cologne.

* Oss. Fossiles, tom. i. pl. 5. fig. 5.

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THE
QUARTERLY JOURNAL
OF
THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS
OF
THE GEOLOGICAL SOCIETY.

MARCH 8, 1865.

The Rev. T. H. Browne, High Wycombe, Berks ; Thomas Grange Hurst, Esq., Mining Engineer, Backworth, Northumberland ; and W. R. Williams, Esq., Mining Engineer, Dolgelly, North Wales, were elected Fellows.

Professor Nilsson, of Stockholm, was elected a Foreign Correspondent.

The following communications were read:—

1. A DESCRIPTION of the ECHINODERMATA from the STRATA on the SOUTH-EASTERN COAST OF ARABIA, and at BAGH on the NERBUDDA, in the COLLECTION of the GEOLOGICAL SOCIETY. By P. MARTIN DUNCAN, M.B. (Lond.), Sec.G.S.

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| 4. List of the species of Echinodermata. | |
| 5. Other fossils in the collection. | |
| 6. Description of the varieties and of a new species. | |
| 7. Remarks on the affinity and identity of the species with those | of other and remote Cretaceous strata, and on the correlation of the Arabian and Bagh beds with the typical European series. |
| | 8. The impossibility of establishing a close synchronism between the Asiatic and other Cretaceous strata. |
| | 9. Remarks on the identity, persistence, and variability of the species. |
| | 10. Conclusion. |

1. *Introduction.*—There is a small collection of Echinoderms, Brachiopods, Pectens, and Zoantharia in the Foreign Museum of the

Society, which came from Bagh on the Nerbudda. It forms a portion of that assemblage of fossils which enabled Capt. Keatinge to determine the existence of Cretaceous strata in the north-west of the Indian peninsula, and it was presented to the Society by Dr. H. J. Carter, F.R.S. The specimens from the cliffs at Ras Fartak and Ras Sharwên, in South-eastern Arabia, were collected by Dr. Carter, and include Echinoderms, Zoantharia, Foraminifera, and Pectens; they were given to the Society by their distinguished collector in the hope that they would, at some time or another, be examined and named, special reference being made to the Bagh series.

Hearing that I was studying the Bagh fossils, Dr. Carter wrote to me to direct my attention to those from S.E. Arabia; for he considers that both the localities are of Neocomian age*, and that they are along the same line of the great fault which, running parallel with the coast-line of S. E. Arabia, reaches the Vindya range on the Nerbudda.

2. *Position of the Strata.*—The town of Bagh is situated about 22 miles from the Nerbudda, 145 miles from the sea, and about 850 feet above its level. A Bryozoan limestone had long been known to exist in its neighbourhood, and the stones of Mandoo, crowded as they are with fossils, had excited the attention of Drs. Carter and Oldham †. Capt. Keatinge and Mr. Blackwell visited the caves whence the stones were quarried, and made as careful observations as could be expected under very unfavourable circumstances. Their collection of fossils was examined; and, as far as can be judged, these observers have fairly proved their Cretaceous age. Before

* H. J. Carter, 'Geological Papers on Western India, &c.,' 1857, p. 623.

† T. Oldham, 'On some Additions to the Knowledge of the Cretaceous Rocks of India,' p. 6.

‡ Kindly furnished by Dr. H. J. Carter, F.R.S.

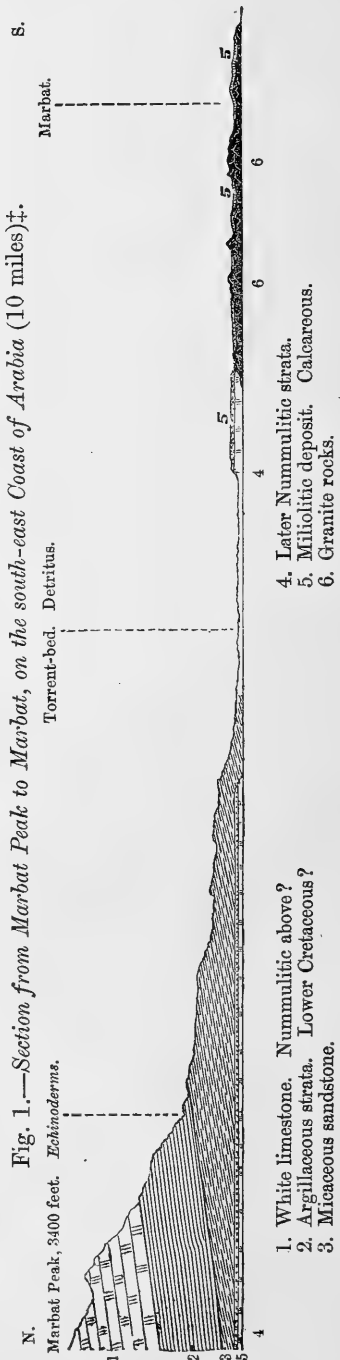


Fig. 1.—Section from Marbat Peak to Marbat, on the south-east Coast of Arabia (10 miles) ‡.

- 1. White limestone. Nummulitic above?
- 2. Argillaceous strata. Lower Cretaceous?
- 3. Micaceous sandstone.
- 4. Later Nummulitic strata.
- 5. Miolitic deposit. Calcareous.
- 6. Granite rocks.

this, both an Oolitic and a Nummulitic age had been given to this red Bryozoan limestone; but Capt. Keatinge, on the strength of the Pectens, contented himself with asserting it to be Cretaceous*. Unfortunately no stratigraphical data were obtained by Capt. Keatinge and Mr. Blackwell which were of any direct value in estimating the geological age of the Bagh limestone; but Dr. Carter recognized a similarity of arrangement between the limestone and a subordinate sandstone of Bagh and the strata on the coast of S.E. Arabia. He, moreover, recognized the identity of the Pectens at Ras Fartak and those from Bagh†.

The Arabian fossils were derived from argillaceous strata of a red colour, which are superimposed conformably on a deep, coarse micaceous sandstone, and which are succeeded by beds of White Limestone. The sandstone is unfossiliferous; but Dr. Carter asserts that the White Limestone belongs to the Upper Cretaceous series‡, and that it is succeeded by Nummulitic beds in many places.

The white sandstone of Bagh and the micaceous sandstone of South-eastern Arabia correspond, according to Dr. Carter; and the limestone and argillaceous strata which cover these respectively are also considered by him to be geologically equivalent. The parallelism as asserted is seen in the following Table:—

<i>South-eastern coast of Arabia.</i>	<i>Bagh.</i>
White limestone§ 2000? feet.	
Red argillaceous shales and coloured limestones 1000? feet	} = { Red argillaceous lime- stones and clays ... 15-20 feet.
Sandstone 1700? feet		= Sandstone ..... 100 feet.

In concluding his remarks on these strata, Dr. Carter writes ||, “On comparing, therefore, the fossils and the strata in which they are found at Bagh and its neighbourhood with those on the south-eastern coast of Arabia, we can come to no other conclusion, that I see, than that part, at least, of the coloured strata in both localities belong to the Neocomian division of the Cretaceous period. I would also add here, that there is a remarkable similarity between Mr. Blackwell’s specimens of limestone from Bagh and those from Tendu-dera, about 60 miles below Jubbalpoor, where this gentleman has also found a rich development of argillaceous iron-ore mixed with limestone. The coloured strata on the south-east of Arabia are also characterized by their ferruginous nature; so that at all three places we get similar limestones and similar developments of iron-ore, with the same kind of fossils in two, viz. at Bagh and on the south-eastern coast of Arabia.”

My observations on the fossils have led me to agree with Capt. Keatinge and Mr. Blackwell concerning their Cretaceous age, and to admit that Dr. Carter’s remarks are consistent with fact, with one exception. If that able geologist had had the advantages now offered

* Oldham, *op. cit.* p. 11.

† Carter, *op. cit.* p. 623.

‡ *Ut supra.*

§ The only fossils I have seen from these limestones are some *Echinocyami*, which cannot be distinguished from *E. Altavillensis*, Agass. (Eocene of France).

|| *Op. cit.* p. 624.

to palæontologists, he would doubtless have placed the strata he has described in the Upper rather than the Lower Greensand horizon, and would have considered them *Cénomanian* rather than *Neocomian*.

3. *The Rarity of described Prenommulitic Echinoderms in Asia.*—The Echinodermata are so numerous in both collections that they at once attract attention; this communication therefore refers especially to them.

There have been but few Echinoderms described from any strata in Asia below the Nummulitic, and only nine species have been carefully determined. Of these, two are from the Cretaceous rocks of Sinai, and the others were described by Professor Edward Forbes in his essay on the fossils of Southern India*. Generic names of the specimens from Bagh and South-eastern Arabia have been suggested by Drs. Oldham† and Carter‡ respectively; but their necessarily superficial examination did not produce satisfactory results.

The Ras Fartak and the Ras Sharwên Echinoderms add seven species to the Asiatic list; and their study is the key to the determination of the Bagh collection, which affords four species, one of which is in the Arabian collection. The united collections have a well-marked facies, and present the same general likeness to European forms from a well-studied locality, which was also noticed to occur by Professor Forbes with regard to certain Cephalopoda in Southern India. Dr. Carter having personally collected the South-eastern Arabian specimens prevents any doubt being thrown on their *bonâ fide* nature; and the same remark may be made with regard to the Bagh series, Capt. Keatinge being responsible for their having been found in the strata he termed Cretaceous. The marked nature of the facies, and the identity of most of the species with well-known forms from Western Europe, render it necessary that there should be no doubt on the subject of the localities whence the specimens were derived. The collections, as a whole, may be ascribed to an horizon comprehended between the Gault and the "chalk-with-flints" in Europe; and they refer very faintly to the Echinoderms from Southern India, and in like manner to the forms from the North American Cretaceous rocks.

4. *List of the Species of Echinoderms in the Collections.*—The following is a list of the species, with their synonyms and localities:—

Ras Fartak and Ras Sharwên, South-eastern Arabia.

- | | | |
|--|---|----------------|
| 1. <i>Cidaris Cénomaniensis, Cotteau</i> | Yvre-L'Evêque | 1 specimen. |
| 2. <i>Pseudodiadema Roemeri, Desor</i> | Plâner Inférieur of
Hildesheim | } 2 specimens. |
| <i>Tetragramma depressum, Roemer</i> .. | | |
| 3. <i>Salenia scutigera, Gray</i> | Le Mans, Martigues,
Minorca, War-
minster | } 2 specimens. |
| <i>Cidaris scutigera, Münster</i> | | |
| <i>Salenia personata, DeFr.</i> | | |
| — <i>scripta, Agassiz</i> | | |
| — <i>petalifera, Bronn</i> | | |

* "Fossil Invertebrata from Southern India," Trans. Geol. Soc. 2nd ser. vol. vii. p. 97.

† *Op. cit.* p. 11.

‡ *Op. cit.* p. 604.

4. <i>Holactypus Cénomansensis</i> , <i>Guéranger</i> } — <i>planatus</i> , <i>Roemer</i>	Le Mans, Texas	4 specimens.
5. <i>Pygaster truncatus</i> , <i>Agassiz</i>		
6. <i>Epiaster distinctus</i> , <i>Agass.</i>	Condrecieux, Ile d'Aix Villiers-sur-mer, N. } of Ireland	1 specimen.
*7. <i>Hemiaster similis</i> , <i>D' Orb.</i>		
8. <i>Cottaldia Carteri</i> , sp. nov.	Ras Sharwèn.....	2 specimens.

Bagh, on the Nerbudda.

1. <i>Hemiaster Cénomansensis</i> , <i>Cotteau</i>	Le Mans	6 specimens.
*2. <i>Hemiaster similis</i> , <i>D' Orb.</i>	Le Mans	2 specimens.
3. <i>Nucleolites similis</i> , <i>Desor.</i>	Yvre-L'Evêque.....	1 specimen.
<i>Echinobrissus similis</i> , <i>D' Orb.</i>		
4. — <i>subquadratus</i> , <i>D' Orb.</i> , sp.	Chaux de Fonds?.....	3 specimens.

It is not only convenient but necessary to refer foreign forms to those of well-known European strata, both to avoid the unnecessary multiplication of species and to obtain a definite idea of the affinities and the palæontological value of the new fossils. Collections like those under consideration will, after such a reference, be noticed to contain, usually, forms which must be arranged as follows:—

1. Species identical with those of distant localities.
2. Varieties of these species.
3. Varieties of species known in distant localities, but absent in the collections.
4. Species closely allied to those found in distant localities (representative species).
5. Varieties of these species.
6. New species without any decided affinities with those of distant localities.
7. Species and their varieties which refer to older or newer strata.

The forms from Arabia and Bagh can be arranged in the following manner under the sections:—

1. *Pseudodiadema Roemeri*, *Salenia scutigera*, *Holactypus Cénomansensis*, *Epiaster distinctus*, and *Pygaster truncatus*, from South-eastern Arabia; *Nucleolites similis* and *Hemiaster Cénomansensis*, from Bagh.
2. Two varieties of *Holactypus Cénomansensis*, from South-eastern Arabia.
3. *Cidaris Cénomansensis* and *Hemiaster similis*, from South-eastern Arabia.
4. *Cottaldia Carteri* from South-eastern Arabia.
- 5 and 6 are not represented.
7. *Echinobrissus subquadratus*, a variety, from Bagh.

5. *Other Fossils in the Collections.*—The following fossils were derived from the same localities as the Echinodermata:—

* Common to Bagh and South-eastern Arabia

I. *South-eastern Arabia.*

Pecten quadricostatus, Sow.
 — *æquicostatus*, Lam.
Neithea Alpina, D'Orb., sp.
Actinospongia, sp.
Patellina concava, Carter, sp.* }
Orbitolina concava, Lamk. }

II. *Bagh.*

Neithea Alpina, D'Orb.
Pecten quadricostatus, Sow.
Rhynchonella depressa, Sow.†
Thamnastræa decipiens, Michelin, sp. }
Centrastræa Cénomansensis, D'Orb. }
Escharina, sp. *Vincularia*, sp.
Eschara, sp. *Serpula plexus*, Sow.

The *Pecten quadricostatus*, Sow., has an immense range, and it is figured by F. Roemer from the Chalk of Texas (Kreideb. von Texas, 1852, p. 64). The coral appears to belong to the species which, under these names and that of *Thamnastræa pediculata*, De Fromentel, ranged from the Neocomian to the Hippuritic chalk of Gosau inclusive. The Upper Greensand horizon of all these forms is sufficiently distinct, and is very confirmatory of the geologic position of the Echinodermata.

6. *Description of the Varieties and of a new Species.*—I. HOLECTYPUS CÉNOMANENSIS, Guéranger. As a specimen which cannot be distinguished from the type is amongst those from Ras Sharwên, the varieties are easily distinguishable. Dr. Carter considered the species to belong to the genus *Discoidea*; but the specimens have not the internal arrangement of that marked genus. He selected the form which is considered by me to be the type of *H. Cénomansensis* as his "1st species," and ranged the others under other species recognizable by numerals‡. This *Holectypus* has been ably studied by Cotteau and Triger; and its abnormal fifth oviductal plate has, after the examination of numerous specimens, been decided to be perforated. All the Arabian specimens show the fifth generative pore. It is interesting to observe that the tendency which this species has to vary slightly is seen in the Arabian as well as in the European specimens.

Variety 1. The specimen is nearly twice as large as the type, has larger tubercles and less prominent ambulacral spaces.

Variety 2. The specimen is slightly larger than the type, and has a pyramidal instead of a rounded upper surface.

The essential structural details remain the same in both varieties, which are very closely allied. The resemblance of the species to *H. macropygus*, Agass., sp., of the Neocomian is very great; but zoologically the fifth pore necessarily places it in a subgenus; it does not, however, interfere much with the idea that *H. Cénomansensis* is a descendant by variation (probably in consequence of obeying some law of "correlation of growth") of the older type *H. macropygus*.

There is a species (*H. planatus*, Roemer) described by F. Roemer§, from Fredericksburg, which is barely specifically different from that under consideration; and MM. Cotteau and Triger||, in their admirable analysis of the species which have come before them, have detected other *Holectypi* with five generative pores. They decide that *H. Turronensis*, DeFr., sp., of the Chalk of Touraine, extends into the Upper

* Prof. T. Rupert Jones has kindly determined this species for me.

† Mr. Davidson informs me that this *Rhynchonella* resembles the variety found in the Irish Upper Greensand.

‡ Carter, *op. cit.* p. 605.

§ Kreideb. Texas, p. 84.

|| Echinides de la Sarthe, 1861.

Chalk in the form of a variety which is subconical and not so much depressed as the type, and that both have five generative pores.

The small tubercles, which are crenulated and perforated, the position of the anus, and the general form of the test are repeated sufficiently to admit the following under one species. The series will then stand thus:—*Holectypus Cénomansensis*, Guéranger. Varieties: 1. some French unnamed forms, which vary very slightly from the type; 2. var. 1, from South-eastern Arabia; 3. var. 2, from South-eastern Arabia; 4. var. *Turonensis*, from the Lower and Upper Chalk; 5. var. *planatus*, from Texas. The species follows the law, that those widely dispersed vary greatly; and its great diffusion, both in area and in depth, is very remarkable.

II. *CIDARIS CÉNOMANENSIS*, Cotteau. The variety of this species differs from the type in having the second or internal two rows of granules in the ambulacral spaces barely developed. The primary or external rows are like those of the type, and extend to the summit, occupying the interporiferous zone for some distance. This difference is insufficient to be specific; but its recognition as pertaining to a variety throws some doubt on the propriety of separating *C. Cénomansensis* from *C. vesiculosa*, these species differing only in the granulation of their ambulacral spaces.

III. *HEMIASTER SIMILIS*, D'Orb. There is a variety of this species in South-eastern Arabia, and a second at Bagh. Both have wider spaces between the rows of pores in the ambulacra than the type, and the test is generally more globular than in the European specimens; moreover the posterior ambulacral areas are a little longer than in the type, but still they are very short. The Bagh variety is broader and more globular than the South-eastern Arabian.

Figs. 2-4.—*Illustrating the structure of Cottaldia Carteri.*

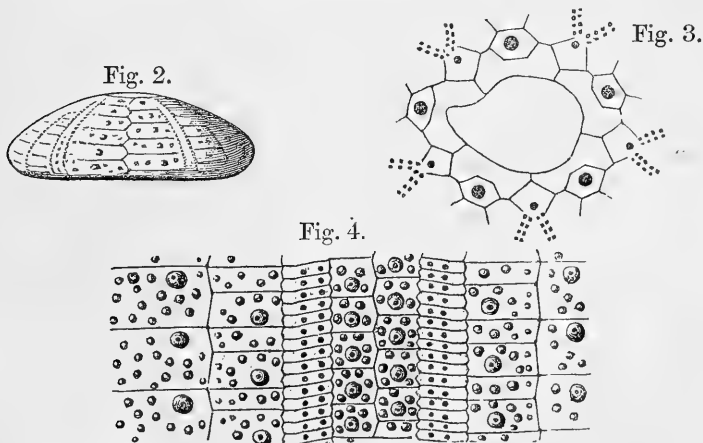


Fig. 2. *Cottaldia Carteri*: side view, natural size.

3. The same: diagram of the apical disk.

4. The same: diagram of an ambulacral space, poriferous zones, &c.

IV. *COTTALDIA CARTERI*, spec. nov. The test is circular in outline, much compressed above and below, and tumid at the sides. The tubercles are of the same size, both on the ambulacral spaces and interambulacral areas. There are two rows of tubercles in the ambulacral spaces, and from six to eight in the interambulacral areas; the tubercles are arranged moderately horizontally, are surrounded by a scrobicular circle, which is ridged and faintly granular. The generative pores are five in number. The pores of the poriferous zones are in single pairs throughout. The peristome is at the bottom of a rather deep cavity. Breadth of test $1\frac{1}{3}$ inch; height $\frac{1}{3}$ inch. The size, compressed shape, and the disposition of the tubercles distinguish this species from that nearest to it, the *C. Benettice*, Koenig, sp., which is so characteristic of the British and French Upper Greensand. *C. Carteri* is clearly the representative of its close ally.

V. *ECHINOBRISUS SUBQUADRATUS*, D'Orb., sp. This Neocomian type is represented by a variety at Bagh, of which there are several specimens in various grades of growth. The variety has all the minute details of the specific form, but the posterior margin is not incurved or emarginate; it is faintly out of the curve in the convex direction, but not more. This variety is so like the type in its other essentials, that it clearly led to the error of giving a Neocomian age to the beds at Bagh. The specimens are mineralized, like the rest of the collection; and although there is of course a suspicion of their being "derived," still there is quite as much to be said to the contrary.

7. *On the Affinity and Identity of the Species with those of other and remote Cretaceous Strata, and on the Correlation of the Arabian and Bagh Beds with the typical European Series.*—It is hardly necessary to observe that the close affinity of the Bagh and South-eastern Arabian fossils, the position of the strata with regard to the great south-west fault, and their conformability to an unfossiliferous sandstone render the parallelism of the two deposits tolerably evident. They present a remarkable assemblage of Echinodermata and some other fossils very characteristic of the European Upper Greensand and Lower Chalk. Most of the species have a wide range, both vertically and horizontally; some are restricted in their bathymetrical diffusion in certain European strata, but are not so in others; and it is one of the singularities of the collections that they should comprise many of the European Echinodermata* which have this wide range and a tendency to vary also. Mr. Darwin's generalization, that largely diffused species vary greatly, obtains much confirmation from the study of collections like these.

All the species are fairly Cretaceous, and there is no admixture of

* Much credit is due to the philosophic investigations of Messrs. Cotteau and Triger (*Echinides de la Sarthe*, 1861), who have so faithfully recorded the numerous varieties of many species which were considered very typical and stable in the French Cénomanién. The determination of the varieties of some of the species which occur in the Asiatic strata has been greatly facilitated by their researches, and by considering and acting upon the latitude which can be fairly given to variation in Europe.

those types which, foreshadowing the fauna that attained its maximum of development in early Tertiary times, complicate the palæontology both of the South-Indian and North-American Chalk.

The nearest Cretaceous strata to the south of Bagh are those which were noticed by Messrs. Kaye and Cunliffe, and whose fossils were described by Edward Forbes and Sir Philip Egerton*. The collection from Pondicherry has no species in common with those at Bagh and South-eastern Arabia, and its fossils, according to Forbes, belong to a lower horizon; but the Trichinopoly beds yielded fossils which have a slight community of facies with the northern; there are, however, no identical species. If those species which Edward Forbes considered to be unusual in the Cretaceous fauna be removed from the collections from Trichinopoly and Verdachellum, this community of facies becomes stronger, and it is evident that it is produced by the forms which are common to the European and South-Indian Cretaceous faunæ.

The varieties of *Hemiaster similis* at Ras Sharwén and Bagh are remotely allied to Forbes's *Brissus rana*†; and *Hemiaster Cénomansensis* from Bagh is allied to *Brissus expansus*, Forbes, both the *Brissi* being really *Hemiasters*.

Here the similarity ends; and the northern beds, being on an horizon inferior to those at Trichinopoli and Verdachellum, are probably the equivalents of the Ootatoor beds‡.

The other Cretaceous rocks of India, as yet described§, belong to the Upper Chalk, and their organic remains point clearly to a higher horizon than those of Bagh and S. E. Arabia. The great Cretaceous deposits of Sinai, Egypt, Syria, Palestine, Asia Minor, and the Caucasus, whose fossils are comparatively unknown, do not ally the strata under consideration with the Crimean, Russian, and Eastern European Chalk, except in a general sense. The few Echinodermata from Sinai and Egypt|| have no affinity with those just described; but the ubiquitous *Pecten quadricostatus* is common in the Chalk in Northern Asia Minor at the Kara-dagh¶. Von Buch and Abich** determined a Neocomian and an Upper Greensand, with a doubtful Gault, in the Caucasus: although there are many species common to

* Trans. Geol. Soc. 2nd ser. vol. vii. p. 97.

† The student of some of the great French works on the Echinodermata may perhaps be astonished at my referring this fossil to Edward Forbes. It is referred to Desor by D'Orbigny without any notice being taken of the original describer. The manner in which these little mistakes (which, however, are never made to the detriment of French observers) are brought about is instructive. Forbes described the species as *Brissus rana*; long afterwards Desor (Catal. Rais. p. 125) altered the generic name to *Hemiaster*, and subsequently D'Orbigny, dropping Forbes's name, calls the fossil *Hemiaster rana*, Desor. The same thing occurred with regard to Forbes's *Brissus expansus* and *B. inæqualis*. In fact, the reader of D'Orbigny's 'Paléontologie Française' naturally refers all these species to M. Desor, who honourably gives the synonyms in his 'Synopsis des Echinides,' 1858.

‡ For information about these beds, see H. F. Blanford, Memoirs of the Geol. Survey of India, vol. iv.; also *infra*, p. 407.

§ Oldham, Quart. Journ. Geol. Soc. vol. xix. p. 526.

|| Desor, Synopsis des Echinides Fossiles.

¶ Bull. de la Soc. Géol. de Fr. 2nd ser. vol. xvi. p. 398, 1850 (Tchihatzeff).

** Zeitschrift der deutsch. geol. Gesell. vol. iii. p. 15, 1850-51.

these last strata and those of the basin of the Loire and at Warminster, still none of them are found in the collections presented by Dr. Carter. The geology of Abyssinia is so little known that the existence of Cretaceous rocks has been both asserted and doubted. An *Holactypus* very closely allied to the common species at Ras Sharwên is found in the Constantine Cretaceous beds* in North Africa; and the Chalk in the Balearic Isles has yielded the *Salenia personata*. The German Pläner (doubtless, from its having been so well examined) presents the first indications of a close affinity with the Arabian and Bagh series; and this affinity becomes nearly complete in the districts of the French Cénomaniën, at Le Mans, l'Île d'Aix, and Villiers sur Mer, &c., which contains no less than thirteen out of the eighteen Asiatic species, either as identical species or as varieties. The Irish Upper Greensand contains *Epiaster distinctus* and the same variety of *Rhynchonella depressa*, Sow., which is found at Bagh; and the *Salenia personata* with *Pecten æquicostatus* are common to the English Upper Greensand and the strata in South-eastern Arabia and at Bagh.

The North-American Chalk has but a small palæontological affinity with the distant Asiatic series: a portion of it by no means well-defined has a certain similarity of facies, and in Texas there is a community of species. Roemer's *Holactypus planatus* is clearly the species previously described as *H. Cénomaniensis* by Guéranger from Condécieux, and which is also a characteristic form in the South-eastern Arabian Chalk. *Pecten quadricostatus* is also a Texan species. Here the affinity between the two series ends, as far as America is concerned; for the Arabian and Bagh series is on a higher horizon than the Neocomian of the Andes and of Trinidad †. It must be conceded that the affinity of the Asiatic species with those of the neighbouring Cretaceous deposits will most probably appear greater as new forms are collected, and that the remarkable association of so many familiar species will then become less striking, but not the less true.

8. *The Impossibility of establishing a close Synchronism between the Asiatic and other Cretaceous Strata.*—It has been noticed that the red strata of Bagh and South-eastern Arabia, whence the fossils collected by Capt. Keatinge and Dr. Carter were derived, rest on unfossiliferous sandstones. The white limestone which rests conformably on the Arabian red strata has yielded no satisfactory series of fossils; and it may be of Nummulitic age, for the only Echinoderm from it is an *Echinocyamus* allied to Eocene rather than to the Upper Cretaceous species.

The red strata thus stand alone as regards stratigraphy; but their palæontology clearly determines them to possess the homotaxis of the typical Upper Greensand strata of Western Europe.

To determine their contemporaneity is impossible, even relatively; for the vertical range of so many of the species is so great, and the parallelism of the allied European Cretaceous beds is not exact.

* Desor, *op. cit.*

† Duncan and Wall, "On the Geology of Jamaica," *Quart. Journ. Geol. Soc.* vol. **xxi.** p. 1.

The numerous natural-history provinces in Europe between the upper member of the Neocomian and the Chalk with flints, and the existence of littoral, deep-sea, and coral zones of life, prevent the possibility of a close correlation of the British, Irish, French, German, and Spanish Middle Cretaceous strata. This statement may be carried further, and it will appear that the remoter the strata are from those considered the types, the greater is the difficulty of establishing a parallelism, so that at last such distant deposits as the North American and South Indian present anomalies. The succession and parallelism of the strata do not tally in Ireland, England, and Western and Southern France; moreover there is the difficulty about the relative position of the Hippurite-Chalk of Provence, Germany, and North Africa. The restricted range of some so-called characteristic species in the French Cénomanién, and their greater range in the British Upper Greensand and Lower and Upper Chalk, have moreover tended to complicate the parallelism of the German beds containing them. It is this varying range which offers some data for reflection upon the great duration of the fauna which is considered characteristic of the Upper Greensand and its more or less definitely parallel strata. The Hippurite-limestone of Provence rests on the Cénomanién with *Exogyra columba*, *Ammonites varians*, and *Ammonites peramplus*; and these fossils are restricted bathymetrically to this Upper Greensand in France. In Saxony and in Bohemia* these *Ammonites* are found in the Pläner above the Hippurite-Chalk, but the *Exogyra* is wanting; and thus these species, which have a range in England in the Upper Greensand to well up in the Chalk-with-flints, outlived a great fauna of Hippurites and Corals, and witnessed great geographical changes of which the study of the English series gives but little trace. The same *Ammonites* are found above, but not below, the Hippurite-Chalk of Constantine†; and the great development of this zone of *Rudistes* must be remembered in estimating the time which elapsed during the changes in physical geography inferred by the existence of coral and Hippurite reefs preceded and followed by the conditions favourable for Ammonite-life. There were, in the first instance, the conditions favourable to the existence of a fauna characterized by Ammonites, Bivalves, and numerous Echinodermata. In the second these conditions were greatly altered, and an age of subsidence produced a deep sea with the essential physical geography of a coral-sea, whose Madreporaria are represented in the recent period by reef and atoll species, but which were accompanied by a great fauna of *Rudistes*. In the third instance such changes occurred as reproduced the same conditions which characterized the Prehippurite sea, and Ammonites, Echinoderms, and Bivalves migrated from the positions into which they had been driven by the alteration of the sea-depth. The duration of the second era may be estimated by the fact that a number of species of *Rudistes* arose, attained their greatest development, and probably

* Coquand, Bull. Soc. Géol. de Fr. 2d ser. vol. ix. p. 340, 1853.

† Ewald, quoted by D'Archiac, Hist. Prog. Géol. vol. v. p. 313, 1853.

died out in it, and that the coral-fauna of the period nearly equals that of the Midtertiary age. Yet during this vast lapse of time many species of Cephalopoda, Mollusca, and Echinodermata were living out of their former zone, were competing with the dwellers of the sea into which they emigrated, and finally returned to their original position. There was abundance of time for any amount of diffusion; and doubtless the strong species varied, as is their wont, and left their remains over vast areas. Now the Echinodermata and some of the other fossil remains from Bagh and South-eastern Arabia are represented in the faunæ of all the divisions of the European Chalk between the Gault and the Chalk-with-flints. They may have originated in the Asiatic Chalk, and may have emigrated to the districts referred to in Europe; the reverse may have happened; or, as is more probable, the species arose in various districts by variation from species competing strongly, perhaps under changes of physical conditions, and the Bagh and South-eastern Arabian beds may represent only one or all the European series between the Gault and Upper Chalk.

9. *Remarks on the Identity, Persistence, and Variability of the Species.*—It has been mentioned that the European Upper Greensand and its associated strata are represented in the equivalent deposits at Bagh and in South-eastern Arabia by identical species, varieties of species, and by a representative species. The common Cretaceous facies of the faunæ is thus retained, although there are forms in them which refer both to earlier and later ages. Thus the variety of *Echinobrissus subquadratus*, which is a Neocomian species, is a common fossil at Bagh, and its specimens are numerous in the small collection.

Differing from the type in having a very slight instead of a decided incurvation posteriorly, the variety presents all the other specific attributes, and it occupies the same relative position in the Bagh fauna which varieties of certain Midtertiary species do in the existing distribution of living beings. The Hemiasters, on the contrary, connect the Middle with the Upper Cretaceous, and with the Tertiary Echinodermata. The new *Cottaldia* is representative of the *Cottaldia Benettiae*, Koenig, sp., so characteristic of the Tourtia; and it is reasonable to infer, from the great similarity of their structure, an adaptation to the same mode of life. The new species clearly fills up the vacancy produced by the absence of the well-known form, which would cause a sensible gap in any series of Upper Greensand Echinoderms.

There appears to be an indisposition on the part of some distinguished geologists and naturalists to admit the occurrence of the same species in distant strata or in remote areas. The slow progression of species, and their constant competition with others during their diffusion, have suggested that greater or less variation must occur, and that the original type is never found in very remote localities, but varieties of it, some of which are sufficiently permanent to be considered closely allied species. Some naturalists assert that even if the distant forms be identical to the eye they must be specifically

distinct ; so deeply has the hypothesis of the restriction of species to definite areas influenced the judgment. It is evident, however, that direct observations must supersede hypotheses in the study of nature, and that carefully recorded facts are not to be overruled by theoretical considerations. Nearly every palæontologist who has studied foreign as well as European fossils, and the majority of those naturalists who have had a great scope of observation, determine that the whole truth is not conveyed in the opinions just mentioned, and that although the forms of distant localities are to be referred to the same families, genera, and sections of genera, and that varieties of species replace the species at a distance, still species identically the same are found separated by great distances or diffused over great areas. It is quite true that some species are restricted in their vertical and horizontal range ; but others, as Mr. Darwin remarks (*Origin of Species*, p. 381), “have migrated over vast spaces and have not become greatly or at all modified.” There are numerous examples in many families in all formations, from the Silurian to the Recent, of these wide-wandering and unchanging species, and many more of those which are more or less modified or varied. It is difficult to restrict the notion, of the influence of external physical conditions (in a state of change or not) upon specific variation, within its correct bounds. It is clearly the opinion of those who have decided against the possibility of the great range of species, that these external conditions, such as climate, position in latitude and altitude, moisture, heat, sea-depth, &c., greatly influence and enhance variation, or prevent it entirely. But the great biologist just quoted places the matter in its true light ; and his following remarks* apply in the strongest manner to the assemblage of species from Bagh and South-eastern Arabia :—“As the variability of each species is an independent property, and will be taken advantage of by natural selection only so far as it profits the individual in its complex struggle for life, so the degree of modification in different species will be no uniform quantity. If, for instance, a number of species which stand in direct competition with each other migrate in a body into a new and afterwards isolated country, they will be little liable to modification ; for neither migration nor isolation in themselves can do anything. These principles come into play only by bringing organisms into new relations with each other, and in a less degree with the surrounding physical conditions.”

The inherent power of variation which exists more or less in all animated beings irrespectively of the influence of external physical conditions, and which is shown, in the simplest form, by the so-called individual differences, is doubtless governed, restricted, and increased by definite laws. Natural selection even acts with varying intensity as the great excitant. So some species are very persistent, others vary more or less, and many are so variable as to be termed polymorphic. The simultaneous occurrence of persistent and variable species over great areas is a fact, and there is nothing abnormal in it. As the different longevities of species, and also of the individuals

* Darwin, *op. cit.* p. 381.

of species are both regulated by determinate laws, so are, doubtless, the apparently inexplicable associations of persistent, variable, nascent, and moribund species.

It would appear that every instance of wide dispersion of species in former ages is equalled, both as regards the longitude and the latitude, at the present day. From the Lower Silurian to Tertiary times, identical species have existed over vast areas of every formal formation—formal; for although the succession of forms has never ceased, still the science of geology requires some starting-points for its nomenclature, and they are either determined by apparent breaks* or more artificially by the culmination of the abundance of certain living forms. The diffusion of Arctic and Alpine species during the glacial period is considered in one of the most philosophical chapters of Darwin's work; and it testifies to the identity of species over vast areas of latitude and longitude with or without gaps. And modern investigation, the careful collection and examination of specimens, has determined that whilst some species are restricted in their areas, others have an enormous range; and these belong to many families. By considering the enormous range, with or without intermediate gaps, of many freshwater forms of Arctic and Alpine species of plants; of temperate ferns; of corals—from the Red Sea to the remotest islands of Oceania, or from the Levant to Zealand; of Bryozoa and Algæ—species being common to the European and Australian seas; and, lastly, of Echinodermata—some having a habitat of 50° of latitude †, of 30° of latitude, and 80° of longitude †, and others being found on the eastern coast of Africa and the Gallapagos ‡, at Guadaloupe and Port Essington §, at Labrador and Kamtschatka || respectively,—by these considerations it may be decided reasonably that there is no restriction to the area of the diffusion of persistent or identical species. The idea of time can only be brought to bear by noticing the rapid diffusion of species artificially introduced into oceanic islands or remote continents; but it is certain that some widely ranging species have had the opportunity for diffusion and variation from the Midtertiary age to the present day.

Amongst the identical species from South-eastern Arabia there is one, the *Pygaster truncatus*, Agass., which is a very persistent and non-varying form. It is interesting that this species should be the last known of the important Oolitic genus *Pygaster*, that it should depart somewhat from the generic attributes ¶, and that, being a rare fossil in the French Cénomaniens, it should not have appeared to vary in the distant Arabian Chalk. Another species, the *Holactypus Céno-*

* See Prof. Ramsay's Pres. Add. Geol. Soc. 1863-64.

† *Echinodiscus inaurita*, Van Phelsam, sp., Red Sea, Zanzibar, Mauritius; *Echinodiscus bifora*, Lamk., sp., Madagascar, Red Sea, Indian Ocean; *Dendraster excentricus*, Eschscholtz, sp., Kamtschatka, California.

‡ *Encope tetrapora*.

§ *Echinoneus cyclostomus*, Leske.

|| *Echinarachnius parma*, Gray. For these localities, see Synopsis of Echin. Irreg. Brit. Mus.

¶ MM. Cotteau et Triger (*op. cit.*) have some excellent remarks on this species, p. 117.

manensis, has a somewhat analogous relation to the other species of its genus. The *Holectypi* flourished in Oolitic times, and have not been found in strata higher than the Lower Chalk. *Holectypus Cénomanensis* is therefore a late species, and it departs somewhat from the generic characteristics by having a fifth generative pore; but, unlike the *Pygaster*, it is a very variable species. The *Salenia* and the *Epiaster* belong to species which vary in Europe; this is proved, in the first instance, by the difference in the published types of the species, and by comparing foreign with British specimens, and in the second instance by M. Desor's determination that the variation in the subanal projection of *E. crassissimus* is sufficiently great to render *E. distinctus* a doubtful species, and that it is identical with *E. Varusensis*. The species *E. crassissimus* and *E. acutus* have been decided to be the same. In fact all these Epiasters are varieties of a single type; but which this may be, cannot be determined. They are all found in the same strata in Europe.

10. *Conclusion.*—The ferruginous nature of the strata containing these fossils has been noticed. The iron is for the most part in the form of a dull-red sesquioxide; but here and there are traces of the sulphuret. Some specimens of the rocks are light in colour, and consist of clayey limestone, very hard and with a fine texture. This clay is the original matrix, the salts of iron and the fossils being accidental deposits having mutual relations and forming the great bulk of the strata. The fossils are usually well preserved, have been but slightly rolled, were deposited in a soft clay, and, from the comparative absence of the sulphuret of iron and of the evidences of its destructive mineralization, their details are generally very perfect.

These observations on the nature of the deposits confirm the impression produced by the study of the habits of the existing representatives of the fossil forms in estimating the bathymetrical horizon of the strata. The fossiliferous clays with *Cidaris*, with flat Echinoderms, Pectens, rugged *Ostreae*, Brachiopods, Bryozoa, and Foraminifera, could not have been deposited at a less depth than that included in the Nullipore (No. VII.) zone of Forbes. Strictly speaking they are not littoral deposits; but when considered in relation to a neighbouring very deep-sea or oceanic deposit, they may be so termed, and thus accord with the well-known theory of Messrs. Godwin-Austen and Daniel Sharp, that the Upper Greensands are littoral deposits in relation to the Lower White Chalk. Finally, it is consistent with the harmony of nature that there should be a close connexion between widely diffused species, their occasional persistency, their more frequent tendency to variation, their range in depth and in space, their belonging to a zone of sea-depth where there are great facilities for emigration and diffusion, their entombment in the fine calcareous clay of a sea-bottom removed from the regions where conglomerates and rocks can be formed, and their mineralization by a pure oxide of iron.

2. *On the FOSSIL CONTENTS of the GENISTA CAVE, GIBRALTAR.* By G. BUSK, Esq., F.R.S., F.G.S., and the late HUGH FALCONER, M.D., V.P.R.S., For. Sec. G.S.

[In a Letter to His Excellency General Sir W. J. Codrington, K.C.B., &c. &c. Governor of Gibraltar.]

(Communicated by the Secretary of State for War.)

THE circumstances which led to our visit to Gibraltar, and the objects we have had in view, are so well known to Your Excellency that it is unnecessary on our part to do more than refer to one or two incidents in the early history of the cave.

When the interesting objects contained in the upper chambers of the "Genista" cave on Windmill Hill were brought to light by Capt. Brome, Your Excellency addressed a letter to the Secretary-at-War, giving a preliminary report on the results; that communication was forwarded from the War Office to the President of the Geological Society of London, with a request for an opinion as to the importance in the interest of science of following up the exploration, and for suggestions as to the manner in which it could be best conducted. The reply led to the sanction of the Secretary-at-War for the further exploration of the cavern by means of the labour of the military prisoners, under the able superintendence of Capt. Brome; and, to pass over minor incidents well known to Your Excellency, the objects discovered were forwarded to us in London for identification and scientific examination.

Having devoted several months to the study of the cave-collections successively transmitted to us, which were so carefully classified, by means of distinctive marks, by Capt. Brome, the Governor of the Military Prison, as to place the main facts clearly before us, we were so strongly impressed with their importance that we determined, on Your Excellency's invitation, to visit Gibraltar and examine the general condition of the cave on the spot; for the discoveries in the Windmill Hill cave have not only yielded unexpected results regarding the former state and the ancient animal population of the rock itself, but they further point to a land connexion between the southern part of the Iberian peninsula and the African continent at no very remote geological epoch.

Capt. Brome's Report, dated 21st August, 1863, with the plan and section which accompany it, so clearly explains the nature of the Windmill Hill cave, that it is unnecessary for us to enter on the present occasion into any detailed description of it. The rock abounds in caves, which are of two classes. 1st. Seaboard caves at various heights above the level of the sea and horizontally excavated in the ancient cliffs by the waves. 2nd. Inland caves descending from the surface and in connexion with great vertical fissures by which the mass of the rock has been rent at remote epochs during disturbances caused by violent acts of upheavement, like the well-known cavern of St. Michael. The "Genista" cave of Windmill Hill belongs to the second class; it forms part of a great perpendicular fissure, which, by the vigorous measures adopted by Capt.

Brome, has either been excavated or traced downwards to a depth of upwards of 200 feet below the level of the plateau of Windmill Hill. It was full of the fossil remains of quadrupeds and birds, of the former of which some are now wholly extinct, others extinct in Europe and repelled to distant regions of the African continent, others either now living on the rock or in the adjoining Spanish peninsula.

The following is a list of the species which we have at present identified:—

Pachydermata.

Rhinoceros Etruscus (?). Extinct.

Rhinoceros leptorhinus (*syn.* R. megarhinus). Extinct, abundant.

Equus. Young animals only, species undetermined.

Sus prisceus (?). Extinct.

Sus scrofa. Living.

Ruminants.

Cervus elaphus, *var.* barbarus. Fossil remains abundant.

Cervus dama, or a nearly allied form. Abundant.

Bos. A large form, equalling the Aurochs in size, remains few and imperfect, species undetermined.

Bos taurus. Abundant in the upper chamber.

Capra hircus (?). In the upper chamber.

Capra Ægoceros, form A.; Capra Ægoceros, form B. Two forms of *Ibex*, probably extinct but in vast abundance throughout the fissure.

Rodents.

Lepus timidus. Rare.

Lepus cuniculus. Very abundant at all depths.

Mus rattus.

Carnivora.

Felis leopardus.

Felis pardina.

Felis serval.

Hyæna brunnea. Now repelled in the living state to Southern Africa.

Canis vulpes.

Ursus, *sp.* Not the Cave Bear, form undetermined.

Delphinidæ.

Phocæna communis.

Birds. Remains numerous, genera and species undetermined.

Tortoise. Rare, species undetermined.

Fish. Remains numerous in the upper chamber.

Apart from the still immature state of the investigations, it would be quite beyond the limits within which we are restricted in this communication for us to enter in detail upon the conclusions to which the data furnished by the fossil remains lead; we shall therefore confine ourselves to a few of the more important general points.

The rock is now bared of natural forest-trees, and destitute of wild animals, with the exception of the hare, rabbit, fox, badger, and a few magot monkeys, the last in all probability the descendants

of introduced animals. The fossil remains of the "Genista" cave establish beyond question that the rock was formerly either peopled by, or the occasional resort of, large quadrupeds like the elephant, rhinoceros, aurochs, deer, ibex, wild horse, boar, &c., which were preyed upon by hyenas, leopards, African lynx, and serval: that the remains were transported by any violent diluvial agency from a distance is opposed to all the evidence of the case. The manner in which they were introduced into the Windmill Hill cave we believe to have been thus:—The surface of the rock and its level in relation to the sea were formerly different from what we now see. The wild animals above enumerated, during a long series of ages, lived and died upon the rock. Their bones lay scattered about the surface, and in the vast majority of instances crumbled into dust, and disappeared under the influence of exposure to the sun and other atmospheric agencies, as constantly happens under similar circumstances at the present day. But a certain proportion of them were strewn in hollows along the lines of natural drainage when heavy rains fell; the latter, for the time converted into torrents, swept the bones, with mud, shells, and other surface-materials, into the fissures that intercepted their course; there the extraneous objects were arrested by the irregularities of the passages, and subsequently solidified into a conglomerate mass by long-continued calcareous infiltration. That elephants frequented the rock is proved by a valuable specimen of the molar tooth of an extinct species, which we have ascertained to be *Elephas antiquus*, discovered by Mr. Smith, of Jordan Hill, in a sea-beach on Europa Point. That the hyenas were dwellers upon the rock is also established by the fact that, in addition to numerous bones, we have discovered a considerable quantity of coprolites of *Hyæna brunnea* among the "Genista" cave relics. Some of the species must have peopled the rock in vast numbers. We infer, upon a rough estimate, that we have passed through our hands bones derived from at least two or three hundred individuals of ibex swept into the Windmill Hill fissure; in no instance have we observed fossil bones attributable to one complete skeleton of any one of the larger mammalia.

That the rock now so denuded of arboreal vegetation was then partially clothed with trees and shrubs, as the corresponding limestone mountains on the opposite side of the straits are at present, is so legitimate an inference as hardly to be open to rational doubt. It is now a pinch to find sufficient food at the end of the hot season for the flocks of goats which are reared on the promontory; while it is a matter of absolute difficulty to find fodder at all for the few cows that are kept by some of the officers of the garrison. When elephants, rhinoceros, wild oxen, horse, boar, deer, &c., &c. either peopled or resorted to the rock in considerable numbers there must have been abundant trees and more or less constant green food for them. Bare exposed masses of rock get intensely heated by a southern sun, they repel moisture by being thus heated, and raise the mean temperature of the locality by radiation; while, on the contrary, a clothing of trees and of fruticose vegetation both

tempers the heat, attracts moisture, and greatly increases the fall of rain. We are aware that Your Excellency's attention has been directed to planting-operations on the "rock." Numerous and repeated failures must be looked for at the commencement; but the facts above mentioned would indicate that success may ultimately be attained, with much benefit to the station.

The next prominent point in the case is the character of the extinct fauna of Gibraltar regarded as a group. Of the prevailing fossil forms which occur in England, Germany, and France, as far south as the northern slope of the Pyrenees and the shores of the Mediterranean, such as the Mammoth, *Rhinoceros tichorinus*, *Ursus spelæus*, *Hycena spelæa*, &c., not a vestige has been detected among the fossil remains of Gibraltar. In the latter the Carnivora are the most significant. The three species of *Felis* are of African affinities; and *Hycena brunnea*, now for the first time ascertained to have existed formerly in Europe, is at the present day chiefly found near the Cape of Good Hope and Natal. That any of these wild animals could have crossed the straits from Barbary to Europe is contrary to all probability. The obvious inference is that there was a connexion by land, either circuitous or direct, between the two continents, at no very remote period, somewhere within the Mediterranean area. To arrive at any further evidence bearing upon this very important question, from the rock of Gibraltar, becomes an object of the highest general and scientific interest.

Human remains were found in great abundance in the upper chambers. They appear to have belonged to between thirty and forty individuals. They were accompanied by stone implements of the polished-stone period, broken querns, a large quantity of pottery, marine shells of edible species, and some other objects enumerated in Capt. Brome's Report. No way of access from the surface by which these materials could have been introduced has been discovered; but, on carefully examining the ground, we believe, with Capt. Brome, that the entrance was somewhere under the southern half of the east wall of the prison-enclosure. Until the aperture from the surface is discovered, no certain conclusion can be arrived at. Considering the time and labour which have been expended on the cavern, it would be a subject of great regret if the exploration were left incomplete on this important point. We would therefore venture strongly to recommend that the excavations be continued through the ground over which the east wall runs, until the external aperture is detected. We believe that it will be found in the fissure outside the east wall, which Capt. Brome has so sagaciously and perseveringly explored.

The human bones are of high interest in consequence of certain peculiar characters which many of them present. They appear to belong to widely different epochs, although none of them perhaps of very high antiquity (*i. e.* before the historical period). That the upper chambers of the cave were ever inhabited by savage man we consider to be highly improbable. It seems more likely that they were used as places of deposit for the dead.

As regards the final disposal of the interesting and important relics discovered in the "Genista" cave, a complete series ought to be deposited in London, either in the British Museum or in the Museum of the Royal College of Surgeons. But we consider it to be of still higher importance that a collection should be retained for Gibraltar. In the progress of the vast defensive works which have been carried on during the past century, in scarping and tunnelling the rock, objects of high interest, relating either to its natural history or archæology, have been brought to light; but in the great majority of cases they have either been disregarded or lost. Instances might be cited from Col. James's 'History of the Herculean Straits,' 1771, and from Major Imrie's 'Memoir on the Mineralogy of the Rock,' in 1797. In 1844 a laudable effort was made by the late Archdeacon Burrow to establish a museum on the rock; but, after languishing some time, it failed from the want of proper support. The relics of the collection were afterwards exhibited in the Soldiers' Home; but when that institution was given up, no place remained either for displaying or taking proper care of the collection. Some of the brightest records of the military glory and prowess of our country are indissolubly connected with Gibraltar. A great nation like England cannot afford to neglect, or disregard without reproach, whatever bears on the natural history or archæology of so renowned a possession. That the naval and military services take the liveliest interest in such objects is placed beyond doubt by the United Service Museum of London, founded upon collections contributed by them from all parts of the world; but it appears to us that the formation and maintenance of a local museum at Gibraltar, illustrative of its products and relics, ought not to fall upon the garrison, who are only temporary residents, and that it is more properly an imperial obligation. The least expensive and best mode of carrying the object into effect would probably be to have a room in the Library reserved for the purpose, and under the management of the Library Committee. The only outlay would be in the construction of the apartment and in the glass cases for the objects; no establishment would be required.

In case of any proposal of this nature being entertained, we would venture to suggest to Your Excellency that the collection should be strictly limited to objects of local interest, having reference to the rock, the bay, the straits, and the immediate vicinity. Everything from beyond these limits should be excluded. A museum of reference of this nature should include:—

1. Herbarium collection of the plants yielded by the rock.
2. A zoological collection of all objects, terrestrial and marine, produced within the limits.
3. A collection of specimens of minerals of the rock.
4. A complete collection of the fossil remains yielded by the ossiferous caves and bone-breccia of Gibraltar.
5. An archæological collection of coins, pottery, and other antique relics occurring within the circuit of the bay.

In illustration of the absolute need there is of a local collection of the kind here indicated, we may mention that, being anxious to fix the age of the pottery yielded in such abundance by the Windmill Hill cave, no similar materials for comparison derived from the ancient ruins of Carteia, or from points in the Mediterranean resorted to by the Phœnicians, were to be found in the British Museum. The proof of the antiquity of the human race is one of the leading questions that occupy the attention of educated and scientific men at the present day. That human remains and other objects bearing upon it are considered of high value is sufficiently proved by the fact that a grant of £1000 was passed for the purchase of a collection of this kind from the valley of the Vézère, in the south of France, during the last Session of Parliament, for the British Museum. One of the human skulls yielded by the rock many years since appears to us to point to a time of very high antiquity. In fact it is the most remarkable and perfect example of its kind now extant. In the absence of a properly organized museum no record exists of the precise circumstances under which this interesting relic was found, and that it has been preserved at all may be considered a happy accident; it has cost us much labour, and with but partial success, to endeavour to trace its history on the spot where it turned up.

Our time has been so fully occupied by the examination of the cave collections and collateral subjects that we have only been able to make a cursory examination of the geology of the rock. We entirely agree with the opinions expressed in the excellent memoir of Mr. James Smith, of Jordan Hill, that it bears unmistakeable evidence of having undergone extraordinary disturbance, both of upheaval and depression, during the Quaternary or immediately pre-modern period; but the data are complex, and in some instances obscure. Now that a complete topographical survey of the rock has been completed on a large scale, a geological survey would be a matter of comparative ease; and we would submit to Your Excellency's consideration the expediency of an application being made for the services of an assistant upon the Geological Survey of England, to be deputed for the purpose. The area is so compact and limited that the survey, including that of the surrounding bay, need not occupy much time.

We cannot bring this letter to a close without expressing our opinion of the value and importance of Capt. Brome's exploration of the Windmill Hill cavern, under the support and enlightened countenance and encouragement which we are well aware he has uniformly received from Your Excellency during the progress of his operations, and which have led in a great measure to their successful issue. The only account of the mineralogy of Gibraltar that has been published is in the excellent "Brief Description" by Major Imrie, of the Royal Artillery, which appeared in the 'Edinburgh Philosophical Transactions' in 1797. In 1844 Mr. Smith, of Jordan Hill, brought out his valuable memoir on the Geology of Gibraltar; but the fossil mammalian remains of the bone-breccia

were only very cursorily noticed by both authors. In the latter half of the last century they attracted the attention of William and John Hunter, in papers which are to be found in the 'Royal Transactions,' but without an attempt at precise identification. Cuvier, in his great work the 'Ossemens Fossils' in 1823, gave a special chapter on the ossiferous breccias, and devoted much attention to those of the Mediterranean. From the materials derived from the rock which passed under his hands, he was able to detect evidence only of two extinct species, one of which is doubtful. He concludes his remarks on the Gibraltar remains in the following terms:—

“Voilà donc dans ce petit nombre d'os de Gibraltar que j'ai pu me procurer, au moins une espèce de lièvre et probablement une espèce de cerf, dont les pareils ne sont pas connus en Europe.

“Que seroit-ce si quelque naturaliste résidant sur les lieux prenoit la peine de recueillir et de dégager avec soin ceux qui se découvroient pendant quelques années, comme je l'ai fait pour les ossemens de nos gypses? D'après ce que nous allons voir dans les articles suivans, on ne peut douter qu'il n'y fit des récoltes abondantes et intéressantes.” (*Op. cit.* tome iv. p. 174.)

From that period down to the present day hardly any addition has been made to our knowledge of the subject, during a lapse of forty years, until Capt. Brome undertook the exploration of the “Genista” cave; and the best commentary upon the preceding citation is furnished by the fact that the materials collected by him have enabled us to determine upwards of twenty species of mammalia, above enumerated, many of them extinct, and all of them bearing importantly on the ancient condition of Gibraltar. Indeed it is within the facts of the case to say that, in the important walk of the mammalian palæontology of Gibraltar, Capt. Brome has done more than was effected by the united labours of his predecessors since the rock became a British possession. The persevering energy and vigour with which he has followed up the inquiry, and the minute and scrupulous care with which he has discriminated and arranged the objects, are worthy of the highest commendation, and more especially so as the subject was new to him. We are inclined to believe that the labour of military prisoners was never better directed in the interest of science.

We have to tender our best acknowledgments to Your Excellency for the very cordial reception which you have given us, and for the pains you have taken to forward the objects of our visit in every respect. We beg leave also, through Your Excellency, to offer our thanks to the military, naval, and civil departments of the service for their hearty cooperation. Our thanks are more especially due to Major-General Frome and the officers of the Royal Engineers, and to Capt. Ommanney, R.N., the senior naval officer of the station, who have rendered us every assistance.

MARCH 22, 1865.

Henry Turner, Esq., Mottingham, Kent, was elected a Fellow.

The following communications were read:—

1. *Notes on the CAVES of GIBRALTAR.*

By Lieut. CHARLES WARREN, R.E.

[Abstract.]

THE principal caves in Gibraltar are St. Michael's, Martin's, Glen Rocky, Genista, Asylum Tank, Poca Roca, and three on the eastern face of the rock underneath the signal-station.

The cave at Poca Roca is, in the author's opinion, a portion of the cleft in the rock which extends from the town to the village of Catalan Bay.

The strata of rock on the eastern side are usually covered over by a very recent formation, which gives a deceptive appearance to casual observers; this Lieut. Warren found to be the case while scarping at Middle Hill.

St. Michael's cave is a portion of a transverse cleft through the rock; and it is probable that at no very (historically) remote period it was open to view, as it is described by a Latin writer (Pomponius Mela) as opening up the side of the rock into an enormous cavern.

There appears to have been an idea that this cave has not been thoroughly explored since Lieut. Rich, R.A., went down it in 1840-46. Capt. Weber Smith went *halfway* down in 1840, the lengthy report of his exploit being now recorded in the R.E. office, with a plan which was completed by Lieut. Goodall, R.E., in 1858, who explored the whole cave. Since then the author has been down to the bottom more than twenty times, and has broken into new caves with crow-bars and jumpers, and he is confident that without the use of crow-bars no further passage can be discovered.

There are several bone-deposits over the rock. During the excavation of the Rosia defences immense masses were exhumed; but science was not then sufficiently far advanced to appreciate them, as those which were sent home were declared of little value. At the Europa shell-limestone quarry, and in several parts of the town, vast quantities were laid bare.

It is very probable that these bones exist in most of the clefts of the rock, as the author has come across traces of them frequently. The bone-deposit near Governor's Cottage is described by Spix and Von Martius, the Brazilian travellers, as "the well-known and remarkable osseous breccia;" and Surgeon M'Grigor found in them bones of stags, oxen, tigers, and sheep, "and works of art."

In conclusion, Lieut. Warren offers his services in case of a geological survey of the rock being made, as suggested by Mr. Busk and Dr. Falconer.

This paper also contained a few remarks on the superficial and other deposits of Gibraltar, and was illustrated by a plan and some sketch sections; but Prof. Ramsay having undertaken the above-mentioned survey renders their publication unnecessary.

2. *On the ASSERTED OCCURRENCE of HUMAN BONES in the ANCIENT FLUVIATILE DEPOSITS of the NILE and GANGES; with comparative Remarks on the ALLUVIAL FORMATION of the TWO VALLEYS.* By the late HUGH FALCONER, M.D., F.R.S., For. Sec. G.S.

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§ I. FLUVIATILE DEPOSITS OF THE NILE.

1. *General Remarks.*—The object of this communication is to bring together the few instances on record of the occurrence of Mammalian fossil remains in the valley of the Nile, and to institute a comparison between the Nilotic alluvial deposits and those of the upper part of the valley of the Ganges which have come under my own observation. Fossil human bones have, according to certain statements, been met with in both of these subtropical valleys; and it may be useful, at the present time, to consider to what general inferences the cases lead, as a guide to future observation.

The explorations conducted by the French authorities in Algeria have brought to light numerous remains of *Hippopotamus* and of other Mammalia, extinct or living, from the later deposits of that part of Africa; but it is not a little singular that the valley of the Nile has heretofore been so unproductive, considering the stream of intelligent travellers which flows up the river every season from Alexandria to the Cataracts, and the not insignificant number of accomplished explorers, German, French, and English, who have traversed the country, as high as the confluence of the “Blue” and “White” rivers, and latterly above it. The alluvial deposits along the banks appear in many places to be developed in great force; and the lowermost present characters which would refer their origin back to a high antiquity. But although fossil wood and shells of land and freshwater Mollusca have been very generally met with in these deposits, Mammalian remains have been but very rarely observed, and the instances on record only cursorily described. These will be referred to in the sequel. Any case which is calculated to direct attention to this neglected walk of observation deserves to be noticed.

2. *Fossil Hippopotamus.*—The specimen sent to the Society by Dr. Leith Adams consists of a fragment of the left maxillary, containing *in situ* the two last upper true molars of a very large Hippopotamus. Of these the penultimate is far advanced in wear, the crown-divisions having been ground down to the common nucleus of ivory, leaving only two small islets of enamel upon the

depressed disk. The last molar is but partially worn, the two pairs of trefoil comprising the crown-surface being distinct both in the longitudinal and transverse directions.

The molar teeth present the ordinary characters of the existing Hippopotamus of the upper part of the valley of the Nile and Senegal, but in size they equal those of the great extinct form of Europe, *Hippopotamus major* of Cuvier. I have compared them with the corresponding molars of the largest specimen of the living species that has come under my observation, being the huge male skull no. 3405 of the Hunterian collection, in the Museum of the Royal College of Surgeons, and with a set of specimens of *H. major* from the Val d'Arno, presented by Mr. Pentland to the British Museum.

The following are the comparative dimensions:—

	<i>H. amphibius.</i> No. 3405, H. Col.	<i>H. major.</i> No. 28790, Br. Mus.	<i>H. major.</i> No. 28789, Br. Mus.	<i>H. major.</i> A palate, Br. Mus.	Kalábshee specimen.	<i>H. major.</i> No. 28785, Br. Mus.
Joint length of the two last true molars	in. 4·0	in. 4·0	in. 4·3	in. 4·3	in. 4·3	in. 4·65
Length of penultimate	1·95	2·0	2·3	2·2	2·25	2·5
Width of penultimate	2·0	2·2	2·1	2·3	2·2	2·2
Length of last molar	2·1	2·1	2·1	2·2	2·2	2·2
Width of last molar	2·1	2·15		2·3	2·15	2·25

From these figures it will be seen that the molars in the Kalábshee specimen are as large as the majority of those of the extinct form with which it was compared, and that of the latter there is only one, no. 28785, in which the dimensions are greater, while the Kalábshee specimen slightly exceeds the proportions yielded by the existing Hippopotamus. It is at the same time to be remarked that the latter is as large as no. 28790 of *H. major*; and it has still to be shown that the bones of the skeleton of the latter form surpass those of the living species more than do the fossil bones of *Bison priscus* those of the existing Aurochs, which is generally regarded as being of the same species.

In *H. major*, the basal cingulum of the molar is commonly more salient and crenately lobed than in those of the living species. The Kalábshee specimen in this respect agrees with the latter form; but it is at the same time to be observed that the cingulum is not well preserved in the Nile fragment.

The evidence yielded in the present case is too limited to warrant any well-founded opinion regarding the species; but, notwithstanding the large dimensions of the molars, I have failed to detect any diagnostic characters which would justify the separation of the Kalábshee specimen from the Senegal variety of the living *H. amphibius*. It is inferred to have been yielded by a large and old male. In mineral condition it appears to be as well fossilized as

specimens of *H. major* from the Val d'Arno and Auvergne. The cancelli of the bone are filled throughout with matrix resembling Nile mud; the ivory of the molars has lost a large portion of its gelatine. Professor Busk, who has analyzed the specimen, found that the earthy salts of the bone yielded a very large proportion of carbonates; but he failed to detect more than a very faint trace of fluorine, so commonly met with in bones of great antiquity*. A calcareous crust covers the enamel of the teeth. Dr. Leith Adams does not indicate, in his paper, the precise stratum near Kalábshee out of which the fragment was exhumed—this being a point of much importance in the case.

Geologists may be reminded that, although rarely observed, this is not the first instance in which fossil or subfossil remains of *Hippopotamus* have been procured from the valley of the Nile. Dr. Rüppell brought to Europe, in 1827, the remains of a species of *Hippopotamus* from above the Cataracts. They were deposited in the Senckenberg Museum at Frankfort, and indicated a species in size between *H. amphibius* and the existing small *H. Liberiensis* of St. Paul's River, in Western Africa. I had an opportunity of examining them in 1849; and in the synopsis which I contributed to Dr. Morton's account of the Liberian *Hippopotamus*, the species was referred to, under the provisional name of *H. annectens*, as intermediate between the two living species†. It may prove to be of *H. Pentlandi*, the extinct species prevailing in Sicily, Malta, and Candia, which was then unknown to me.

Of *H. major*, the huge fossil form of the Val d'Arno and Auvergne, abundant remains have been found in deposits, either Pliocene or Quaternary, in Algeria. A fine series of specimens derived from that region is exhibited in the Museum of the Ecole des Mines in Paris.

3. *Asserted Discovery of Human Bones.*—The next case of Nilotic fossil remains is of still higher interest, being the asserted discovery of human bones in one of the conglomerate or older beds of the Nile-valley alluvia, at a time when the antiquity of the human race did not engage the attention of men of science as it does at the present day. In Leonhard and Bronn's 'Jahrbuch' for 1838 a series of letters appeared, in which Russegger gave some account of the results of his explorations then in progress in Nubia and Sudan. In one of these letters, dated Sennaar, 23rd March 1838, he describes the structure of the alluvial banks of the Blue Nile from Khartoom up to Sennaar, and thence to Roserres, and adds that, "In the alluvia of the Blue Nile at Duntai we found human bones.

* The following gives Professor Busk's analysis:—

Organic matter	...	...	...	...	...	7.5
Earthy carbonates	...	...	...	...	...	57.5
Phosphates, &c.	...	...	...	...	...	35.0
Iron	...	...	...	...	...	a trace.
Fluorine	...	...	...	...	...	scarcely an indication.

† 'Observations on a new living Species of Hippopotamus, *H. Liberiensis*, of Western Africa.' By Dr. Morton, Philadelphia, 1849, p. 8.

The structure of these bones was perfectly preserved, but the animal matter had disappeared. Their surface was polished and of a blackish-brown colour; the substance very hard, but not yet petrified"* (Jahrbuch, 1838, p. 403). In the second volume of his travels, published in 1843, Russegger enters at greater length into the details of the case, and states that the alluvial formation of the Blue Nile, from Khartoom to Sennaar, consists of freshwater beds thrown down by the river itself, and that, regarded as a whole, they are divisible as follows, from above downwards:—

1. Ordinary fluviatile mud, the result of modern periodical inundation, analogous in its external characters to the Nile-mud of Egypt, and containing imbedded nodules of calcareo-argillaceous concretion (nodular kankar?).

2. Friable, fine and coarse conglomerate, composed of quartz-grains and pebbles, cemented by ancient mud, forming a kind of sandstone-grit, and yielding calcareous and marly concretions.

3. Ancient Nile-mud, indurated, and containing imbedded iron-shot clay, siliceous limestone, &c., full of calcareous and marly concretions in the ferruginous portions.

4. Fine and coarse quartzose conglomerate, with the materials united by ancient Nile-mud and calcareo-argillaceous cement, very hard, used as a building-stone, and containing imbedded masses of saline clay and of ordinary clay and marl, full of clay-ironstone, ferruginous sandstone, and of calcareous and marly concretions.

5. Freshwater limestone (travertine, or slab kankar?) of a dark-grey colour, hard and sonorous, occasionally having a marly appearance, with here and there a tendency to a concentric and generally crystalline structure.

The beds are described as horizontal, of very variable thickness, attaining sometimes, in Nos. 1, 2, and 3, as much as five or six fathoms (Jahrbuch, 1838, p. 408). According to Russegger, with the exception of the uppermost deposit, they contain, very generally, fossil vegetable remains, chiefly the wood of *Mimosas* (*Mimosa Nilotica*) and stems of *Asclepia* (*Calotropis provera*): the former are either converted into lignite or have their core exhibiting a concentrically disposed and radiating crystalline structure, derived from the imbedding matrix; the latter have the bark preserved, but the spongy core occupied either by calcareous matter or conglomerate. These alluvia presented very commonly shells of the Mollusca now living in the waters of the Nile, both bivalves and univalves, together with some land species. Among the most common was *Ætheria Caillaudi*, occurring frequently in heaps or oyster-banks, together with species of *Unio*, *Iridina*, and *Anodonta*. In the alluvium of Sennaar he found *Ampullaria ovata* and a species of *Helix*. He adds, that *Ætheria Caillaudi* was also abundant in the deposits of the White Nile.

* "In den Alluvionen des blauen Flusses bei Dundai fanden wir Menschenknochen. Das Gefüge der Knochen war vollständig erhalten, der Thiermaterie aber zerstört. Die Aussenfläche war glänzend und schwarz-braun gefärbt. Die Masse sehr hart, aber noch nicht versteinert."

M. Lefèvre, writing at the same time, confirms the observation of Russegger about the occurrence of the conglomerate. "Near Khartoom, on the Libyan side, you meet on the *redans* of the White Nile with a modern conglomerate composed of fragments of sandstone united by a calcareous cement, either deposited by the water of the river or filtered through the alluvial soil. This concretionary deposit is exhibited equally on the banks of the Blue Nile, and it is well seen on either side where the banks are perpendicular." He adds that the alluvial escarpment is nowhere higher than from 50 to 56 feet.

In his 'Reisen,' Russegger describes the occurrence of the human bones at Duntai in terms somewhat different from those employed in his "Briefe" in the 'Jahrbuch.' "The freshwater alluvia occurring at Karkodije and Seru extend, with the slight modifications already indicated, up the Blue River as far as Rosserres, forming a hillocky alluvial track; and in this instance I must observe that in the ancient mud-conglomerate of Geivan we found portions of Mimosa-wood completely converted into lignite, and, at the village of Duntai, near Seru, calcined (*verkalkt*) human bones in the incipient stage of bitumenization*. A kind of bitumen, or rather highly bituminous lignite, also occurs, although sparingly, at Geivan, and, according to my observation, only in small elongated nodular pieces, which in their transverse fractures display a concentrically laminated structure, resembling the annual growth of wood, and burning with a brief flame only, but emitting a very smoky and bituminous odour." On neither occasion does Russegger specify what these fossil human bones were, nor am I aware that any detailed identification of them has been published. But the case is of sufficient importance to demand the attention of future explorers of the Nile valley to a walk of observation which may yield results of high importance. Captain Grant informs me that neither Captain Speke nor he ever met with fossil bones along their route. Besides the asserted human bones at Duntai (about halfway between Sennaar and Rosserres), Russegger mentions, cursorily, that in the conglomerate of Woadd Medineh, also on the Blue Nile, he encountered a kind of sandstone-mass containing bones, which he took to belong to the foot of a young Camel. Dr. Murie, who accompanied Mr. Petherick on his return to Soudan, has shown me specimens of an alluvial fine-grained siliceous grit or conglomerate from the White Nile, above Khartoom, which is full of shells of *Cyrena fluminalis*. The observations of Russegger, Mr. Leith Adams, and Dr. Murie agree as to the abundance of the shells of Mollusca in the Nilotic alluvia, mud, or conglomerate, from the neighbourhood of the First Cataract upwards, and along the course both of the Blue and White Rivers—oyster-banks of *Ætheria Caillaudi* occurring throughout.

* The original passage stands thus:—"Und ich glaube diessfalls nur bemerken zu müssen, dass wir in dem altern Flusschlamm-Konglomerate bei Geivan Stücke von Mimosenholz das ganz in Braunkohle umgewandelt war, und am Dorfe Duntai bei Seru Menschenknochen fanden verkalkt und im Zustande einer beginnenden Verkohlung." (Russegger, 'Reisen,' Band ii. pt. 2. p. 717.)

4. *Analogy of the Fluvial Deposits of the Nile with those of the Ganges.*—In some of the phenomena observed by all the travellers above named, there is a striking analogy between the alluvial deposits of the valley of the Nile and those occurring along the banks of the Ganges and Jumna rivers, in the great alluvial valley of Hindostan. Of these the most obvious is the great abundance of argillaceous-calcareous concretions, forming an impure kind of travertine, and in the lowermost beds horizontal deposits of more or less extent, composed of the same kind of material. Russegger constantly alludes to their frequent occurrence, both in the conglomerates and in the indurated sand- or mud-deposits, in the form of nodular concretions, varying in size from a pea up to a quarter of a cubic foot, and having their centres occasionally occupied by drusy cavities lined by crystals of carbonate of lime. The lowermost bed, No. 5 of his section, consisting of a hard dark-grey clinking limestone, appears to be a modified kind of the same calcareous deposition. The nodular form of these concretions is familiar to English observers in the "Race," which so thickly studs the sections of the brickearth-pits in many localities in the valley of the Thames.

§ II. FLUVIAL DEPOSITS OF THE GANGES.

1. *Physical Features of the Valley of the Ganges.*—The vast expanse of the plains of Hindostan consists of a fundamental deposit of very ancient fluvial sediment, which is developed in great force, but varying in its detrital characters as we follow the course of the rivers down to the sea. The valley is longitudinally traversed, after their escape from the Himalayah Mountains, by the Ganges and Jumna, which unite at Allahabad. This segment, the Doab, constituting the upper division of the plains of Hindostan, is that to which the remarks which follow apply. It is comparable in some respects to the tract through which the "Blue" and "White" Niles flow in the lower part of their course to their junction at Khartoom. The Ganges at Hurdwar, where it debouches from the Sewalik Hills, is, according to the results given by Sir Proby Cautley, 974 feet above the level of the sea, and at Allahabad 269 feet, after running a course in a straight line of 472 miles, giving an average fall of nearly 18 inches per mile. From Allahabad to Rajmahal in Bengal, near the top of the modern delta, the average fall, according to the instructive table given by Mr. Fergusson, amounts to about 6 inches along a stretch of 385 miles. The Jumna river, where it escapes from the Sewalik Hills at Rajghat, is a little more elevated; but it runs a nearly parallel course at no great distance from the Ganges, and in the inclination of its bed and other physical phenomena it resembles that river so closely that in the present sketch it is not necessary to dwell on the points of difference.

Although the average inclination of the Ganges between Hurdwar and Allahabad is about 18 inches per mile, it increases considerably as we ascend the river. Thus the fall, which in the distance of 122 miles between Cawnpore and Allahabad diminishes to 13 inches, attains in the mean of the 350 miles above it 19.3 inches, and so on

upwards as we ascend. The sedimentary deposits and transported materials vary, as a general rule, in the same ratio. The northern slope of the Sewalik Hills is overlain with a thick mass of boulder-gravel, inclined at a considerable angle, and conformable to the sandstone strata of which this Miocene range is composed. The boulders vary from a few inches to upwards of a foot in diameter; they have undergone the utmost amount of attrition, being constantly smooth and rounded into more or less of a globular form. Their origin is distinctly shown, as they are invariably composed of some of the rocks which form the intramontane portion of the nearest river-channel, transported by violent torrential action during the protracted season of flooding. Modern boulder-dejections of precisely the same character, and derived from the same rocks, are seen in progress of formation where the rivers debouch into the plains, constituting rude deltas, having a flattened conoid surface, the base of which is ultimately confounded with the plains. This gravel-and-boulder alluvium disappears from the surface and along the beds of the rivers within a short distance from the hills, and is replaced by a sand or clay alluvium, which becomes the prevailing deposit down to the confluence of the two rivers at Allahabad. It marks the boundary of the habitat of some of the characteristic vertebrate forms of the Ganges, such as the Ghavial Crocodile (*Gavialis gangeticus*) and the freshwater Porpoise (*Platanista Gangetica*), which ascend to within thirty or forty miles of Hurdwar, where the gravel-beds and rapids of the stream terminate; while the *Crocodylus bombifrons* is met with in the dhoons or longitudinal valleys which lie between the Himalayahs and the Sewalik Hills.

The rivers which traverse the alluvial plain of Hindostan have produced the usual effects of powerful fluvial action operating during a long lapse of ages, aided by movements of upheaval or depression, distinct evidence of which has been brought to light by deep borings in the delta. The two principal streams have gradually scoured their channels down through the ancient alluvium to a depth of from 100 to 150 feet below the level of the adjacent plains, thus exposing a very instructive section of great extent. At the lower part of this section the rivers, as in the case of the "Blue" and "White" Niles, have intersected horizontal beds of argillaceous or arenaceous travertine, or banks of aggregated nodular kankar, which frequently form dangerous subaqueous reefs or bars, obstructing boat-navigation. The Government of India undertook in 1828 a series of operations, which extended over seven or eight years, for the removal of these and other obstacles from the bed of the Jumna, in which they are most prevalent. These were conducted by highly instructed officers of the Bengal Engineers, one of whom, Captain Edward Smith, published an account* of the most striking facts which were observed on the occasion between Agra and Allahabad. The upper half of the section, consisting of beds of sand and clay, contained throughout, in more or less abundance, the im-

* Journ. Asiat. Soc. Bengal, vol. iii. p. 622 (1833).

pure calcareous concretions called nodular kankar. Near the base of the lower half these calcareous deposits were developed in much greater force, sometimes forming strata of rock kankar, from $1\frac{1}{2}$ foot to 2 feet thick, with a thinner bed of clay interposed. At one point, Burlót, below the junction of the Chambal river, where the bank is precipitous and 100 feet high, a stratum of rock kankar, in the form of a granular concrete 2 feet thick, was observed 60 feet above the lowest level of the stream. But the most ordinary condition of the material is the concretionary, in the form of nodular botryoidal stalactite or ramified kankar. In some places the concretions, closely compacted and connected by veins, are disposed in horizontal strata in clay, at 10 or 12 feet above the level of the stream; in others the kankar presents itself in vertical seams in the scarped front of the bank, or it ramifies in every direction through the clay, literally lacing it together; and occasionally ancient surfaces of sun-cracked clay, where denuded, are seen with the fissures filled with septarian plates of the same material. At one point, Kareem-khan, *slab kankar*, used for building-purposes, and consisting of fine sand solidified by carbonate of lime, is quarried at shallow depths from under the bed of the river. Captain Smith (from whose memoir the above particulars are for the most part drawn) has given an excellent series of highly instructive sketches, showing the various modes in which the kankar occurs along the banks of the Jumna.

2. *Mammalian Fossils*.—Fluviatile shells were either extremely rare, or they escaped the notice of individuals who were not familiar with this walk of observation. Only two instances are recorded,—one an open *Unio*, imbedded in a perforated sandy clay near the level of the river; the other, marks of shells in the granular concrete of rock kankar, found at 60 feet above the stream, at Burlót. But fossil bones were encountered in great abundance. In one case, unconnected with the operations above referred to, the skeleton of a fossil Elephant was discovered in a bed of clay deposited on a bottom of kankar, overflowed by the water of the river during the floods, about three miles above Calpee. Some of the remains were forwarded in 1828 to the Asiatic Society of Bengal. In another case the skeleton of an Elephant, forming a great mass, was observed, by Mr. E. Dean, lying amongst an immense assemblage of kankar-deposits, contained in the lowest stratum of clay intersected by the river, under the village of Pauch-kowrie, near Korah Jehanabad. The stratum forms a bank, there elevated $4\frac{1}{2}$ feet above the highest flood-mark, and 80 feet below the summit of the cliff; and abreast of it the Jumna has deepened its bed 25 feet. Numerous other organic remains occurred in the masses of other deposits surrounding the skeleton, but the precise kinds were not ascertained. In a third case, a very large tusk of an Elephant, stated to have been 8 inches in diameter, was discovered lying beneath a plate or slab of kankar in removing obstructions from the bed of the Jumna, near Adháe. The ivory was fossilized, but not petrified; and the Sepoys engaged on the work broke it up, and burnt it for pipeclay to whiten their belts.

The great mass of the fossil bones which were discovered during the first five years of the operations were unfortunately lost, having been heedlessly thrown back into the deep channel; and only those subsequently met with were preserved. They were found either imbedded in the lowest deposit of stiff clay or in the shoals of kankar. Of the latter, some were unquestionably of very modern origin, since they yielded a sword and portions of a sunken boat. Their mode of formation is obvious. Nodules of kankar and fossil bones, detached from the alluvial cliffs by various denudating agencies, are swept on by the floods until they meet with some obstruction, where they collect and get commingled with extraneous materials of modern origin, and the whole become solidified in a concrete, formed by the calcareous mud of the kankar, aided by lime derived from the waters of the river. They are therefore *remanié* deposits, wholly distinct from the original kankar and fossiliferous clay beds through which the stream has cut its way down. The difference was clearly made out by the engineer officers employed on the removal of the shoals, who distinguished the two by the names of *natural* and *artificial* kankar.

The great majority of the bones were well fossilized, and in most cases petrified*. Species of the following genera were determined:—*Elephas*, *Hippopotamus*, *Sus*, *Equis*, *Bos*, *Cervus*, *Antilope*, small Rodents, *Gavialis Gangeticus*, and freshwater Chelonians. The specimens were commonly too mutilated, and the materials then available for comparison too defective, for certain specific determination in all cases: but among them I identified molars of the extinct *Elephas namadicus*; a lower jaw with teeth, and a perfect astragalus, of the true Indian Hippopotamus, *H. (Tetraprotodon) palæindicus*; a fragment of a jaw of the great fossil Buffalo of the Nerbudda, *Bos (Bubalus) palæindicus*; and jaws undistinguishable from those of the living Ghavial Crocodile. Both Captain Smith and Mr. Dean, aided by medical officers more or less versed in anatomy, thought that they had encountered human bones among the Jumna fossils; and this opinion was published at the time in an Indian scientific journal; but the identifications were negatived by Dr. Pearson and Dr. Evans, then curators of the Museum of the Asiatic Society of Bengal; and on submitting the specimens to a close examination several years afterwards, I could discover no determinable human bones among them.

Another observation was made by Captain Smith, upon which he was professionally competent to give an opinion with authority—namely, that some of the fossil bones “were dug from depths of 6 to 18 inches in the firm shoal, which is composed of substances (*sic*),

* Mr. James Prinsep examined one of the fossil bones of the Jumna, which on a rough analysis yielded the following results:—

Phosphate and carbonate of lime	. 17.5
Water	. 6.0
Red oxide of iron with alumina	. 76.5
	<hr/>
	100.0

kankar, bricks (vitrified clay?), more or less rolled and cemented by mud and clay. The circumstance is explicable on the modern accretion of some of the kankar shoals above referred to, without involving a great antiquity to the fragments of burnt clay."

Of the fossil genera above named there are three well-determined species, which are of much significance in the history of the Doab alluvia. The first is *Elephas namadicus*, an extinct form characteristic of the Pliocene fauna of the Nerbudda. It belongs to the same group, *Euelephas*, as the existing Indian Elephant; but it is broadly distinguished from that species, and from all other known species, by a very marked peculiarity in the form of the cranium, in addition to dental and other characters. Among the vast quantity of Miocene Proboscidian remains yielded by the Sewalik Hills not a trace of *Elephas namadicus* has ever come under my observation. But I have seen perfect skulls of the species from richly fossiliferous fluviatile deposits of Southern India.

The second important species of the Doab alluvium is the huge ruminant, *Bos (Bubalus) palæindicus*, also characteristic of the Nerbudda fossil fauna. This form is closely allied to the existing wild Buffalo, or *Arnee* of the Indian forests, from which the domestic animal appears to have sprung. Not a trace of it or of any species of the same subgenus has yet been observed among the Sewalik fossil Mammalia; nor has its range in the fossiliferous beds of Southern India been as yet accurately determined. But, in indicating these distinctions of the Miocene and Pliocene faunas, it is important to remember that the rule is not absolute. I ascertained the presence of the Miocene Proboscidian, *E. (Stegodon) insignis*, of the Sewalik Hills, among the Pliocene Mammalia of the Nerbudda, where it was accompanied by a species of the Miocene *Hexaprotodon*, *H. (Hexaprot.) namadicus*. The fossil Buffalo here referred to existed in the same Nerbudda fauna along with a huge taurine species, *Bos (Urus) namadicus*, of which no close representative has been discovered among the existing Indian Bovidæ. It differs alike from the *Gaur* and *Gayal*. Of it also no trace has been detected among the Sewalik Mammalia.

The third fossil species, *Hippopotamus palæindicus*, is, perhaps, the most important in its indications. It belongs to the subgenus *Tetraprotodon*, characterized by four incisors, like the two African living species, and the European fossil species *H. major* and *H. Pentlandi*; but it is essentially distinguished by constantly having the middle incisors smaller than the outer pair, being the converse of what occurs in the other. No well-authenticated case has as yet been established of any fossil *Tetraprotodon* in Miocene strata. A quadruped so remarkable for its size, form, and habits must everywhere have forcibly impressed itself on the attention of mankind; and, struck with the close resemblance of the Nerbudda fossil Buffalo to the existing species, the question arose with me, May not this extinct *Hippopotamus* have been a cotemporary of Man? and may not some reflexion of its former existence be detected in the extinct languages or ancient traditions of India, as in the case of the gigantic

Tortoise? Following up the inquiry I ascertained from the profound Sanscrit scholar, Rajah Radhakanta Deva, that the *Hippopotamus* of India is referred to under different Sanscrit names of great antiquity, significant of "Jald-Hasti," or "Water-Elephant," in the "Amaracoshā" and "Subdaratnavah." This view is confirmed by the opinion of two great Sanscrit scholars, Henry Colebrooke and H. H. Wilson. The former, in his annotations on the "Amaracoshā," interprets the words "Graha" and "Avahara" as meaning Hippopotamus; "and the latter not only follows this version, but gives two other words, 'Kariyādus' and 'Vidu,' which he supposes to signify the same animal." It is therefore in the highest degree probable, that the ancient inhabitants of India were familiar with the Hippopotamus as a living animal; and it is contrary to every probability that this knowledge of it was drawn from the African species, imported from Egypt or Abyssinia. Assuming that the quadruped was a contemporary of Man in India, a very complex question is involved, which is beyond the scope and limits of the present communication, namely, the ancient vocables above referred to as the groundwork of the argument being of Aryan derivation, Did the Aryan immigrants see the animal living on the northern rivers of India, or was their knowledge of it derived from the traditions of the more ancient indigenous races whom they subjugated or displaced? After reflecting on the question, during many years, in its palæontological and ethnological bearings, my leaning is to the view that *Hippopotamus namadicus* was extinct in India long before the Aryan invasion, but that it was familiar to the earlier indigenous races. I may add that remains of the species have nowhere as yet been observed in recent or comparatively modern deposits in India: they have only been met with in a petrified condition, deep in the alluvium of the Jumna, or in ancient deposits in the valley of the Nerbudda.

3. *Fossil Mollusca*.—I have already stated that our information regarding the Mollusca occurring in the ancient alluvium of the Jumna is almost nil; until lately, this would have applied to the fossil shells of what I have designated throughout as the Pliocene deposits of the valley of the Nerbudda. But the operations of the Geological Survey of India have already extended to that district; and I have been favoured with a communication from Professor Oldham, dated 8th January, 1858, in which he informs me that the evidence as to the age of the formations is now becoming tolerably conclusive. A large collection of shells, comprising a considerable assemblage of species and a great quantity of individuals, all proved to be of existing forms.

But there was this remarkable in the group, that of many of the commonest living species some were exceedingly rare, or even absent. Of *Planorbis coromandelianus*, one of the most prevalent Indian species, and abundant in the Nerbudda district, only two specimens were found in the fossil state; while of *Melanidæ*, *M. variabilis* and *M. spinulosa*, also common living forms, were not met with. The species, none being marine, in all amounted to twelve or thirteen. In designating the formation as Pliocene, which I have done during

many years, I have been guided by the indications of the mammalian fauna, as intermediate between the Miocene of the Irawaddi, Perim Island, and the Sewalik Hills, and that of the existing period.

4. *General Inferences.*—I shall now briefly indicate the inferences to which the observations on the section of the Jumna lead.

1. That the Doab alluvium, intersected by the Ganges and Jumna, consists of fluviatile sedimentary deposits, the inferior portion of high antiquity.

2. That there are no indications of its being anywhere overlain by deposits resulting from marine submergence.

3. That during the progress of alluvial deposition the area now constituting the plains of Hindostan was probably subject to movements of upheaval and depression, analogous to, or corresponding with, those which have been demonstrated to have occurred in the delta of the Ganges.

4. That the fossil remains occurring in the undisturbed banks of clay and kankar, at the bottom of the section, are of the same age as the deposits in which they occur.

5. That the ancient fossil Mammalia of the Gangetic valley belong to the Pliocene fauna of the Nerbudda, as distinguished from the Miocene fauna of the Sewalik Hills.

6. That of the Jumna fossil Crocodiles, some belong to species which are now living; and that of the extinct Mammalia, some were probably cotemporaries of Man.

7. That no trustworthy cases of the occurrence of very ancient human bones, or industrial objects, have yet been established from the sections of the Jumna and Ganges, but that they may be looked for on a more careful and extended search.

8. That in the great abundance of calcareous concretionary deposits there is an analogy between the alluvial beds of the valleys of the Ganges and Nile; but that in the poverty of vertebrate remains, the latter, in so far as it has been explored, is a remarkable contrast to the former.

§ III. ANTIQUITY OF MAN IN INDIA.

1. *Introduction.*—In discussing some of the speculative points which have been raised in this paper, I have introduced topics which are not usually brought before the Society. But I make no apology. Geology has never disdained to draw upon any department of human knowledge that could throw light on the subjects which it investigates. Cuvier, in the “*Discours Préliminaires*,” exhausted the records and traditions of every ancient people in search of arguments to support the opinion that the advent of man upon the earth dates from a comparatively late epoch. At the present time the whole aspect of the subject is transformed. The science is now intimately connected with archæological ethnology, in searching for evidence of the hand of man in the oldest Quaternary fluviatile gravels of Europe. In other continents, under different physical conditions, it may be possible to interweave the indications of language and misty tradition with the more certain results of pa-

læontological research, and thus to aid us in arriving at that "speck now barely visible in the distance, which is our goal to-day, and may be our starting-point to-morrow." I shall, therefore, not hesitate to enter upon a complementary portion of the same walk of investigation which is intimately connected with the thread of the preceding speculations.

2. *Colossochelys Atlas*.—In 1835, while the interest of the Jumna exploration was still fresh, Captain (now Colonel Sir Proby) Cautley and myself, then occupied with the investigation of the fossil fauna of the Sewalik Hills, discovered the remains of the extinct gigantic Tortoise of India. This remarkable form was briefly referred to in a memoir communicated to the Geological Society in 1836, but the detailed account of it did not appear until 1844. The huge Chelonian was inferred to have had a shell twelve feet long, eight feet in diameter, and six feet high; and the anterior or episternal portion of the plastron exhibited a thickness of six inches and a half of solid bone—proportions which rendered it a fit object for comparison with the Elephant.

The following remarks, bearing upon its possible relation to the human period, are extracted from the 'Proceedings of the Zoological Society' in 1844.

"*Colossochelys Atlas*.—The first fossil remains of this colossal Tortoise were discovered by us, in 1835, in the Tertiary strata of the Sewalik Hills, or Sub-Himalayas skirting the southern foot of the great Himalayan chain. They were found associated with the remains of four extinct species of Mastodon and Elephant, species of Rhinoceros, Hippopotamus, Horse-Anoplotherium*, Camel, Giraffe, *Sivatherium*, and a vast number of other Mammalia, including four or five species of Quadrumana. The Sewalik fauna included also a great number of reptilian forms, such as Crocodiles and land and freshwater Tortoises. Some of the Crocodiles belong to extinct species, but others appear to be absolutely identical with species now living in the rivers of India; we allude in particular to the *Crocodylus longirostris*†, from the existing forms of which we have been unable to detect any difference in heads dug out of the Sewalik Hills. The same result applies to the existing *Emys tectum*, now a common species found in all parts of India. * * * * *

"This is not the place to enter upon the geological question of the age of the Sewalik strata; suffice it to say that the general bearing of the evidence is that they belong to the newer Tertiary period. But another question arises: 'Are there any indications as to when this gigantic Tortoise became extinct? or are there grounds for entertaining the opinion that it may have descended to the human period?' Any *à priori* improbability that an animal so hugely disproportionate to existing species should have lived down to be contemporary with man is destroyed by the fact, that other species of Chelonians which were coeval with the *Colossochelys* in the same fauna have reached to the present time; and what is true

* Now *Chalicotherium Sivalense*, being *Nestoritherium* of Kaup.

† *Gavialis Gangeticus*.

in this respect of one species in a tribe may be equally true of every other placed under the same circumstances. We have as yet no direct evidence to the point, from remains dug out of recent alluvial deposits, nor is there any historical testimony confirming it; but there are traditions connected with the cosmogonic speculations of almost all Eastern nations having reference to a Tortoise of such gigantic size, as to be associated in their fabulous accounts with the Elephant. Was this Tortoise a mere creature of the imagination, or was the idea of it drawn from a reality, like the *Colossochelys*?"

Reference is then made to the most remarkable cases in which the Tortoise figures in mythological conceptions that are traceable to an oriental source: first to the Pythagorean cosmogony, where the infant world is represented as having been placed on the back of an Elephant which was sustained on a huge Tortoise; next to the second Avatar of Vishnu, in Hindoo mythology, where the god is made to assume the form of a Tortoise, and to have sustained the newly created world on his back to make it stable; and, lastly, to the exploits of the Bird-demi-god *Garūda*, during one of which he was directed by his father *Kūshyūpa* to appease his hunger at a certain lake where *an Elephant and Tortoise were fighting*. The dimensions of both are expressed in figures of extravagant magnitude. *Garūda* with the one claw seized the Elephant, with the other the Tortoise, and flew to a mountain, where he regaled himself with the viands yielded by the two animals. The speculative remarks suggested by these traditions, viewed in connexion with the discovery of the *Colossochelys*, were expressed in the following terms:—

"In these three instances taken from Pythagoras and the Hindoo mythology, we have reference to a gigantic form of Tortoise, comparable in size with the Elephant. Hence the question arises, Are we to consider the idea as a mere figment of the imagination, like the Minotaur and the Chimæra, the Griffin, the Dragon, and the Cartazonon, &c., or as founded on some justifying reality? The Greek and Persian monsters are composed of fanciful and wild combinations of different portions of known animals into impossible forms, and, as Cuvier fitly remarks, they are merely the progeny of uncurbed imagination; but in the Indian cosmogonic forms we may trace an image of congruity through the cloud of exaggeration with which they are invested. We have the Elephant, then, as at present, the largest of land-animals, a fit supporter of the infant world; in the serpent Asokee, used at the churning of the ocean, we may trace a representative of the gigantic Indian *Python*; and in the bird-god *Garūda*, with all his attributes, we may detect the gigantic Crane of India (*Ciconia gigantea*) as supplying the origin. In like manner, the *Colossochelys* would supply a consistent representative of the Tortoise that sustained the Elephant and the world together. But if we are to suppose that the mythological notion of the Tortoise was derived, as a symbol of strength, from some one of those small species which are now known to exist in India, this congruity of ideas, this harmony of representation, would be at once violated. It would be as legitimate to talk of a rat or a mouse con-

tending with an elephant, as of any known Indian tortoise to do the same in the case of the fable of *Garūda*. The fancy would scout the image as incongruous, and the weight even of mythology would not be strong enough to enforce it on the faith of the most superstitious epoch of the human race.

“But the indications of mythological tradition are in every case vague and uncertain, and in the present instance we would not lay undue weight on the tendencies of such as concern the Tortoise. We have entered so much at length on them on this occasion, from the important bearing which the point has on a very remarkable matter of early belief entertained by a large portion of the human race. The result at which we have arrived is that there are fair grounds for entertaining the belief as probable, that the *Colossochelys Atlas* may have lived down to an early epoch of the human period and become extinct since:—1st, from the fact that other Chelonian species and Crocodiles, cotemporaries of the *Colossochelys* in the Sewalik fauna, have survived; 2nd, from the indications of mythology in regard to a gigantic species of tortoise in India.”—*Proceed. Zool. Soc. Lond.* 1844, part xii. p. 85.

3. *Recent Aspect of the question. Conclusion.*—More than twenty-five years have elapsed since the speculation contained in the passages above cited was briefly shadowed out in a communication addressed to the Geological Society; subsequent reflection and research have in nowise tended to invalidate it. In referring to it now, it is not meant to be urged that any weight can be rested on it, except as suggestive of further research in the palæontological direction to which it points. But it will perhaps be admitted, that the observers from whom it emanated were then occupied with the question of the remote antiquity of man in India. It is true that the expressed view is that the *Colossochelis* may have lived down to an early epoch of the human period; and not that man had lived back to be a cotemporary of the Tortoise, now proved to have been Miocene. But the two views are reciprocal; and the form of expression selected on the occasion was that which was least calculated to provoke ridicule, or to shock the strong prejudices on the subject, which were then dominant among educated men. And so firmly was, not merely the possibility, but the probability of the case impressed upon our minds, that Captain Cautley and myself were constantly on the look-out for the turning up, in some shape or other, of evidences of Man out of the strata of the Sewalik Hills, partly from considerations of a different order, to which I shall briefly allude.

The cataclysmic speculations of Cuvier and the diluvial theory of Buckland were then exploded. The wide spread of the plains of India showed no signs of the unstratified superficial gravels, sands, and clays, which for a long time were confidently adduced as evidence that a great diluvial wave had suddenly passed over Europe and other continents, overwhelming terrestrial life, and leaving the marks of its course and violent action in these enormous deposits of transported débris. Every section along the Gangetic plain in-

licated that the superficial strata there were of local origin, and the result of tranquil sedimentary deposition. Viewed in the light of a strictly physical inquiry, the chief rational argument in support of the opinion that the advent of man upon the earth dates from a very modern epoch was, first, the negative evidence in the non-occurrence of human relics, and next in the fact that, taking him in conjunction with the mammals with whom he is now associated, they appeared, as a group, to belong to a new order of things, strikingly different from that of the immediately preceding period. The Mammoth, the wool-clad Rhinoceros, the Cave Lions and Spelean Hyænas, the Irish Elk, &c., of the European Fauna were all extinct, although the carcasses of some of them had been discovered, under favourable circumstances, in the most perfect state of preservation. Facts of corresponding import were yielded, by a glance cast upon the latest palæontology of the American continent. There also the huge extinct Edentata, the Mammoth and the Mastodon, indicated a different order of life, specifically, from that now existing. But in India the problem presented itself under another aspect. There, no break was visible in the tranquil succession of deposits,—no interference of a general oceanic submergence, followed by incoherent beds of sand and gravel,—no intercalation of glacial phenomena to disturb the previous system. The present physical order of things, modified only by alterations of level, by upheavements and depressions, could be traced back in an unbroken chain, to the ossiferous strata of the valley of the Nerbudda, and of the Sewalik Hills. Results in harmony with these indications were yielded by a retrospect cast upon the system of organized life. The Mastodons, the Stegodons, and the Loxodont Elephants were extinct, as were also the *Sivatherium*, the *Chalicotherium*, the three-toed Hipparion-Horse, the *Hexaprotodon*, the *Merycopotamus*, and other peculiar forms. But they were found associated, in the same Sewalik deposits, with species of true *Equus*, of Camel, and of Giraffe, the two last being characteristic cotemporaries of Man at the present time. That the actual order of the present system of life had begun during the Sewalik period was indicated by the living Ghavial Crocodile and *Emys tectum*, referred to in the above extract as being found associated with the extinct Mammalian forms. And of the latter, some, like *Stegodon insignis*, accompanied by a species of *Hexaprotodon*, descended to the Pliocene period of the Nerbudda fauna, to be associated with a true taurine Ox, and with a Buffalo which hardly appears to differ more from the living Arnee, than does the ancient *Bison priscus* from the living Aurochs. Another fact chimed in with especial force. Among the four or five species of Sewalik *Quadrumana* distinguished by us, one was inferred by Sir Proby Cautley and myself, in 1837, to have been a large Ape, exceeding the size of the Orang-Utan, but of unknown immediate affinity. The opinion was founded upon a canine tooth of an old animal, which is figured and described in the 'Journal of the Asiatic Society of Bengal'*.

* Vol. vi. p. 359, pl. 18. fig. C.

parison between the fossil specimen and the corresponding tooth of three skulls of the Orang-Utan, contained in the Museum of the Asiatic Society in Calcutta, and found that their agreement was so close, that I conjectured that the extinct Sawalik form had been a large Ape, allied to *Pithecus Satyrus*. A quadrumanous astragalus derived from the same strata, approached in form and proportions so near to that of the existing Hoonuman Monkey, *Semnopithecus entellus*, that the help of the callipers had to be put in requisition to enable us in 1836 to discriminate them, by differences not exceeding millimetres. The distinction between the fossil and the recent bone is hardly greater than that which might be expected to occur in any two individuals of the living species. Here then was clear evidence, physical and organic, that the present order of things had set in from a very remote period in India. Every condition was suited to the requirements of man: the lower animals which approach him nearest in physical structure were already numerous; the wild stocks from which he trains races to bear his yoke in domesticity were established; why then, in the light of a natural inquiry, might not the human race have made its appearance at that time in the same region? Cuvier, notwithstanding his strong bias in favour of the modern appearance of the human race, admitted, in language which has often been overlooked in later discussions, that man may have lived before the last great revolutions which were the subject of his disquisition. "Tout porte donc à croire que l'espèce humaine n'existait point dans les pays où se découvrent les os fossiles, à l'époque des révolutions qui ont enfoui ces os: car il n'y aurait eu aucune raison pour qu'elle échappât toute entière à des catastrophes aussi généralés, et pour que ses restes ne se retrouvassent pas aujourd'hui comme ceux des autres animaux; mais je n'en veux pas conclure que l'homme n'existait du tout avant cette époque. Il pouvait habiter quelques contrées peu étendues, d'où il a repeuplé la terre après ces évènements terribles," &c. The valley of the Ganges seemed to present the exceptional conditions here demanded; it was exempt from the protracted submergence under the ocean, the effects of which in Europe suggested the idea of cataclysmic revolutions. I dwell upon the subject now, in the hope that, when the palæontological exploration of the Sewalik Hills and of the Nerbudda Valley or of other equivalent formations is resumed, these remarks may attract attention in India, and that a keen look-out may be kept up for remains of the large fossil Ape above alluded to, and for traces of Man in some form of equally remote antiquity. For it is not under the hard conditions of the glacial period in Europe that the earliest relics of the human race upon the globe are to be sought. Like the Esquimaux, the Tchukehe, and Samoyeds on the shores of the Icy Sea at the present day, man must have been then and there an emigrant placed under circumstances of rigorous and uncertain existence, unfavourable to the struggle of life and to the maintenance and spread of the species. It is rather in the great alluvial valleys of tropical or sub-tropical rivers, like the Ganges, the Irrawaddi, and

the Nile, where we may expect to detect the vestiges of his earliest abode. It is there where the necessaries of life are produced by nature in the greatest variety and profusion, and obtained with the smallest effort—there where climate exacts the least protection against the vicissitudes of the weather—and there where the lower animals which approach man nearest now exist, and where their fossil remains turn up in the greatest variety and abundance. The earliest date to which man has as yet been traced back in Europe is probably but as yesterday in comparison with the epoch at which he made his appearance in more favoured regions.

The large question which these reflections concern, is at the present time followed up with the keenest intelligence and with the closest scrutiny over a large portion of Europe. But in the tropical regions, which promise to be the most fertile of results, the ground has been barely broken. The observations of Russegger in the valley of the Nile would seem to have fallen into that oblivion which shrouded the shrewd observations of Frere on the Hoxne implements, until they were brought to light by the researches of Mr. John Evans. In India also the inquiry, begun so auspiciously nearly thirty years ago, appears to have stagnated in later days, and to require a fresh impulse. The important discoveries of Captains Speke and Grant will assuredly attract explorers, until the affluents which feed the lake out of which the White Nile flows are traced to their sources. It is incredible that that great river should run for fifteen or seventeen hundred miles, often through alluvial deposits, ancient and modern, without yielding traces of its former population. In the interest of the general investigation, I have therefore thought it might be useful to bring together the facts and speculations which are set forth in the preceding observations, as a guide to future inquiry.

APRIL 5, 1865.

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

The following communications were read:—

1. *On some TERTIARY DEPOSITS in the COLONY of VICTORIA, AUSTRALIA.* By the Rev. JULIAN E. T. WOODS, F.G.S., F.L.S., &c. *With a NOTE on the CORALS*; by P. MARTIN DUNCAN, M.B., Sec. G.S.
(Abridged.)

Tertiary Deposits of Victoria.—Some time ago (in Nov. 1859)* I had occasion to lay before the Society an account of a Tertiary formation which extends along a great portion of the south coast of Australia. That formation is characterized, as I then observed, by

* See Quart. Journ. vol. xvi. p. 253.

the peculiar white appearance of the stone, and the immense quantity of Bryozoa and Foraminifera of which it is composed. The strata are, in fact, very much like chalk-deposits. They have the same appearance when exposed in sections, and contain sheets or layers of flint, with occasionally formations like the potstones of Norwich. I have already described the extent of these beds. They are found throughout the south-eastern portion of the colony of South Australia, and they thin out, I believe, about seventy miles due east of the boundary between that colony and Victoria. Of its extent west and north less can be said. Shelly limestones occupy the whole country in those directions for many hundred miles; but whether they are united with the limestones of Mount Gambier, or whether they belong to the formation I am about to describe, cannot as yet be decided. The object of this paper is to draw attention to another deposit, which is very widely spread in the colony of Victoria. At Hamilton, a town in that colony in about lat. $37^{\circ} 45' S.$, long. $142^{\circ} E.$, there is a remarkable bed of fossils. It occurs at the junction of the Muddy and Violet Creeks, about four miles southwest of the town. Hamilton is the centre of a volcanic district which possesses several craters. Those who have read the explorations of Sir Thos. Mitchell will remember the place better in connexion with his description of the extinct volcanoes of Mounts Napier, Eccles, &c. In consequence of the extensive development of vesicular doleritic lava which flowed from them, it is only seldom that a view can be obtained of the underlying rocks. The banks of the creeks are best for the purpose, and, like all Australian streams, these have cut a deep channel for themselves. The town of Hamilton stands upon a plateau probably 300 feet above the sea-level, and rising from it by a series of terraces. The best and, as far as I am aware, the only place for viewing the beds to which I shall draw attention is at the junction just described, where, for the distance of nearly a mile, the following order is observed:—black soil 2 feet; doleritic lava 3 to 10 feet; yellow or brown clays to the bottom of the section, about 12 feet. The clay is very soft when first dug, but upon exposure it whitens and becomes hard. In the bottom of the creek one sees occasionally blocks of a very hard stone belonging to the same deposit, but much harder and more flinty from exposure than any part of the cliffs, requiring, in fact, smart blows of a hammer to break off a fragment. No beds could be richer in fossils than the whole of the clay. They bleach out upon the banks in the most conspicuous manner. They are easily extracted, but until they are dry are so brittle that the slightest touch destroys them. The shells have more the appearance of a shallow than a deep-sea deposit. The most prevalent fossils are more or less encrusted with *Bryozoa*, *Serpula*, &c., and though some of the shells are broken and worn, their general character is not such as one would expect in a strictly littoral deposit. Pectens, species of *Mitra*, *Cerithium*, *Nucula*, *Cucullæa*, and a *Corbula* are the prevailing fossils of the beds. The Bryozoa are numerous and extremely interesting, but of their character I shall speak more in detail at the close of this paper. Some of the specimens have

become glazed over with a ferruginous oxide so as to look like earthenware. The Foraminifera are large and numerous; indeed one species, *Amphistegina vulgaris*, D'Orb., is so common that the clay is principally composed of it. Its large lenticular form can be traced in almost every pinch of the débris, and what makes the individuals more conspicuous is that they have all received the ferruginous glaze which makes them look like little coins. From their numbers the strata may in truth be called an *Amphistegina*-bed, similar to that in Vienna, and probably of the same age. Other Foraminifera occur, such as *Discorbina turbo*, *Pulvinulina pulchella*, *Planorbulina Haidingerii*, *Operculina complanata*, *Poly-morphina lactea*, *Textularia sagittula*, *Miliola semihuna*, and *M. trigonula*. Prof. T. Rupert Jones has given me to understand that the above list is indicative of a recent Tertiary formation, some of the fossils being Miocene for Europe. Next in frequency to the *Amphistegina vulgaris* is the *Operculina complanata*, Bast., and though equal in size with the species found at Mount Gambier it is much more common in the latter locality. The most common of the fossil shells next to the *Pecten*, sp., is a species of *Pectunculus* (*P. laticostatus*, Lam.), large living specimens of which have been obtained by me from New Zealand*. The corals occurring fossil in these strata are numerous and peculiar. They will be found described at the end of this paper.

This fossiliferous section is, as I have observed, only traceable for about a mile along the rock, and I know of no other locality near Hamilton where it is so exposed again. But near Harrow, about sixty miles to the north-east, the deposit reappears, but in a way which renders it rather difficult to recognize. The river Glenelg runs close to the town and cuts a deep bed for itself through the coarse granite rocks of the tableland. The level country back from the banks is probably 600 feet above the level of the sea, and is much intersected by creeks which flow to form the main stream. The surface of the country is occasionally covered with what appears to be ancient lacustrine basins, because the limestone which fills these depressions has a few small fossils of existing species of *Planorbis*, *Physa*, *Paludina*, &c. Where the limestone is absent an ironstone deposit takes its place, and seems to be nothing more than a surface-gravel of rounded or glazed pebbles formed from a very ferruginous sandstone. On these pebbles one can sometimes trace the faintest outline of a shell, and sometimes a good cast of a fossil, but much too worn to enable one to distinguish even the genus to which it belongs. At a place called Reilly's Creek the following section is observed: first about six inches of the ferruginous gravel, then two feet of red loam, six inches of porcelain earth, and, lastly, about 20 or 30 feet of coarse granite with schorl, passing into mica-schist in places. The ferruginous gravel is the fossiliferous deposit, and nearly every pebble contains impressions or casts of shells—sometimes very well preserved. There are, however, none to be found except upon the surface; I have dug in many places but never

* See also Prof. McCoy's Essay prefatory to the 'Catalogue of the Victorian Exhibition, 1861,' p. 169.

could find fossils except in the first few inches of loam. After a careful examination of all the specimens, I could not detect one which does not belong to the Hamilton beds. The species prevailing are the same, but the *Nucula* is the most common. The *Cypræa eximia* appears to have been common too, and also some of the corals enumerated below, but in other respects the specimens are too broken to be pronounced upon without long and careful examination. In fresh broken pebbles the *Amphistegina vulgaris* can be readily detected in the usual abundance. It is a curious fact that though the ferruginous gravel is distributed over many miles of the neighbouring country, this neighbourhood is the only one in which I have found fossils among its pebbles. The same kind of gravel has been noticed throughout a great portion of the continent of Australia, almost, in fact, wherever an explorer has penetrated. It would be interesting to ascertain whether it was all of the same geological age. As yet we can only speculate on the subject; but as the continent is generally at so uniform a level, even a guess may be founded on strong probability. It is certain that the formation is widely distributed. It has been found in Hobarton, Tasmania, at Geelong, at Hamilton, and at Harrow, making an extent of at least six degrees of latitude and five of longitude. Add to this the fact that the fossils have strong Philippine affinities, and thence we may infer that the whole continent of Australia was then submerged, leaving a clear sea to the equator. Under ordinary circumstances we might look for similar deposits in remote parts of Australia, and it is just possible that the ferruginous gravel which is so widely distributed may belong to the same geological age.

The Hamilton beds and the Mount Gambier limestones have been regarded as belonging to the same age, yet I have now little doubt that this opinion must be modified. In the first place the character of each deposit is very different. The Hamilton beds are clays full of large fossil shells, while at Mount Gambier the formation is hard and rocky, and even in its most friable state has at least the consistence of chalk. It has also flints which are never found in Hamilton or Geelong. Then, again, the fossil contents of the beds could not be more different. At Mount Gambier the limestone teems with Bryozoa, but rarely contains a perfect shell. If they do occur they are confined to three or four genera, such as *Terebratula* (which is the only common form), *Pecten*, *Spondylus*, and *Anomia*. *Echinidæ* are also common, particularly such genera as *Echinolampus* and *Spatangus*. The stone where such fossils do not occur is made up of a kind of limestone-paste, with Foraminifera and broken Bryozoa abounding. The Foraminifera are such as exist now at a depth of from 200 to 300 fathoms, and therefore the Bryozoa may have been derived from a distance. In fact the deposit seems like a series of layers of deep-sea mud tranquilly deposited in the bottom of the ocean or brought by slow degrees from a distance.

In scarcely one of these respects does the Hamilton deposit resemble the limestone. Bryozoa are common, but do not, as at Mount Gambier, make up the principal part of the deposit. *Echinidæ* are rare, and so are *Terebratulæ*, at least in comparison with the numbers

found at Mount Gambier. In the latter strata corals never occur, but at Hamilton they are almost as common as Bryozoa. The beds of the last-mentioned place instead of being a limestone-paste are loose soft clays, and do not appear to have been deposited in anything like a deep sea. Species are common to both deposits, but not by any means all of each. *Terebratula compta*, Sow., *Pecten coarctatus*, Goldf., are the commonest fossils at Mount Gambier, but I have not been able to find them at Hamilton. The species of *Echinidæ* are different and the Bryozoa have a separate character, but the latter feature will be spoken of by and by.

It has been objected to me that the differences between the beds are not greater than might be expected in localities at least 90 miles apart, supposing Hamilton to have been the shore of an island, and Mount Gambier deep sea at the time; but the following reasons are directly against such an explanation. The Mount Gambier limestone preserves its character for a distance of more than 100 miles in a northerly direction, and 60 miles in a north-easterly direction. Wherever it is found in that interval it can be easily recognized, not a fossil is altered, and in every respect it is still like a deep-sea deposit. On the other hand the distinctive features of the Hamilton beds can be identified at Geelong, which is 120 miles to the south-east, or at Harrow, which is 60 miles to the north-west. The strata are distinguishable not only by the fossils but by the character of the clays. I may add also that the two formations have been seen by me within 10 miles of each other, that is to say, near the Wannon River, and I think no one could possibly mistake one for the other.

It may be asked, then, if the formations are distinct, which is the more modern? I think the Mount Gambier limestone. It possesses a great many more recent Bryozoa, and Dr. Busk has already expressed his opinion that the fossil contents show considerable analogy with the Lower Crag of England. This may, however, be too modern a date for this formation, which I have always regarded as identical with the well-known Murray River beds. I have so many strong reasons for believing the two deposits to be continuous, that I fancy a better acquaintance with the fossil contents will show them to be more modern than the Hamilton beds. The Murray River beds may be passage-beds between the Mount Gambier and the Hamilton strata. Indeed I have some reason for thinking that there are two deposits at Murray River; at least very different sets of fossils are collected from the River near Lake Alexandrina, and from the more northerly portions, such as the overland corner, and both are different from what we find at Mount Gambier.

Bryozoa of the Hamilton Beds.—In pointing out as I have done the difference between the two deposits at Hamilton and Mount Gambier, I have reserved any remarks on the specific characters of the Bryozoa until now. In the first place it may be stated that in one respect the Bryozoa of both deposits resemble each other, and that is in the absence of those forms, such as *Catenicellidæ*, *Menipea*, *Dimetopia*, &c., which give to the recent genera of the Australian seas so peculiar a character. It certainly may be objected that the horny joints between each cell would render them more liable to

decomposition; but then the separated cells would be easily detected by the microscope amid the dust, as they are now in nearly every pinch of beach-sand from the beach which surrounds the Australian shore. It would appear from this that *Catenicellidæ* are peculiar to the recent period. Yet some recent forms are represented at Mount Gambier, as Mr. Busk has already pointed out. Among them are *Salicornaria sinuosa*, Hassall; *Crisia eburnea*, Johnst.; *Carbasa lata*, Busk; *Membranipora ctenostoma*, Busk; *M. cyclops*, Busk; *M. bidens*, Hag.; *Idmonea Milneana*, D'Orb.; *Retepora monilifera*, Macgil. Of these none exist at Hamilton except *Salicornaria sinuosa* and *Membranipora cyclops*. The former is a very common fossil at Mount Gambier. Scarcely a fragment of the stone can be found, or a cast of a fossil on which portions of its cylindrical branches cannot be traced. At Hamilton it is not very common and is somewhat distinct in character. It is larger than ordinary, and the reflected margin round the mouth is much more clearly defined. The *Membranipora cyclops* is very similar in character in both places, but more rare at Hamilton. With reference to the extinct species, the difference between the deposits may be thus described. At Mount Gambier, as Mr. Busk has remarked, the Bryozoa are distinguished by the peculiar and characteristic forms of the genus *Cellepora*. This genus is rare at Hamilton, and the beds are, on the contrary, distinguished by the variety and peculiarity of the genus *Eschara*. No less than eleven different forms have been found by me, only three of which can be referred to the Mount Gambier limestone. A peculiar form of *Cellepora* in the latter, which has been named by Mr. Busk *C. nummularia*, is perhaps found at Hamilton and Geelong, but so very much larger in size that I fancy the species must be distinct. *Melicerita angustiloba*, Busk, is found in both localities, but more commonly at Mount Gambier. Lunulites, which are pretty common at Hamilton, are rare in the limestones, and the species are different. Finally, all the different species of *Eschara* are of singular beauty in the forms of their cells, while those of Mount Gambier are comparatively destitute of ornament. On the whole, the aspect of the Bryozoa at the Mount is much the more modern of the two.

NOTE on the FOSSIL CORALS from MUDDY and VIOLET CREEKS, SOUTH AUSTRALIA. By P. MARTIN DUNCAN, M.B., Sec.G.S.

THE Corals forwarded by the author of the preceding paper have been described by me in the 'Annals of Natural History' (No. 81, Sept. 1864); they are solitary species and probably dwelt in deep water from 80-120 fathoms. There are no reef or atoll species amongst the collection, and the evidences of luxuriant coral growth are deficient.

List of the Species.

- | | | | |
|----------------------------------|---|--|--|
| 1. Caryophyllia viola, nobis. | } | \| | 4. Placotrochus elongatus, nobis. |
| Turbinolia viola, Woods, M.S. | | | 5. Placotrochus deltoideus, nobis. |
| 2. Flabellum Victoriae, nobis. | } | \| | 6. Balanophyllia Australiensis, nobis. |
| 3. Flabellum Gambierense, nobis. | | | 7. Trochoseris Woodsi, nobis. |

The condition of the specimens is peculiar, most of them are glazed externally, are very fragile, and present no evidences of mineraliza-

tion, and a few are very hard. The usual hardening of the normal coral salts is not observed in the majority, and there are no instances of siliceous or of calcareous transposition. The specimens can hardly be said to be fossilized in the ordinary acceptation of the term; they have not been rolled, but probably were quietly covered up by sediment during a slowly progressing depression of the sea-bottom.

The species are new, and owing to our scanty knowledge of the deep-sea corals of the southern hemisphere little can be adduced respecting their affinities.

The *Caryophyllia* is a beautiful little coral and has but a remote affinity with any recent or fossil species.

The *Flabellum Victorice* belongs to the truncate division of the genus, and no species of this division have been found fossil; the existing forms are restricted to the Chinese, Philippine, and Australian seas.

Flabellum Gambierense is a pedicellate species, and has no closely allied species.

The *Placotrochi* are allied to the forms from the Philippine and Chinese seas, and remotely to those I have described from the Miocene of the Nivaje shale in San Domingo and in Jamaica.

The *Balanophyllia* is remotely allied to *B. Cumingii*, E. and H., of the Philippines, but is of the same generic section as *B. praelonga*, Mich., sp., of the Turin Miocene; it has only a generic relation with the species of the British Crag.

Finally, the *Trochoseris* is without known recent or fossil close allies.

There are no species amongst these which belong to the genera which characterize the European Miocene, and as the forms belong to genera still in existence, and represented for the most part in the neighbouring Philippine and Chinese coral seas, there are no data for assigning any particular geologic horizon to them. The facies is certainly very recent, but there are so many difficulties in deciding the correlation of Australian with typical Tertiary strata, that it is advisable to wait for further information before attempting to identify the locality whence the corals were derived by a geologic term.

2. *On the CHALK of the ISLE OF THANET.* By WILLIAM WHITAKER, B.A. (Lond.), F.G.S., of the Geological Survey of Great Britain.

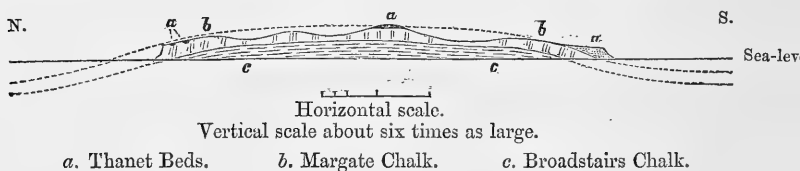
Introduction.—Besides Professor Morris's account of the faults in Pegwell Bay* the only note on the Chalk of the Isle of Thanet that I can find is by the late Rev. W. D. Conybeare, who says, "The north-eastern cape, called the North Foreland, forms the loftiest point (of the cliffs) * * * between this point and Margate the lowest strata are exhibited, the Chalk without flints making its appearance: hence the strata gradually decline, though under an imperceptible angle, towards the south-west, in which direction the upper beds of the Chalk sink and disappear beneath the more recent formations†."

* Proc. Geol. Soc. vol. ii. p. 595.

† 'Geology of England and Wales,' by the Rev. W. D. Conybeare and W. Phillips (1822), p. 90.

Unfortunately this, which, as far as I know, has never been contradicted, is in great part the reverse of the truth, as I found whilst carrying on the Geological Survey in East Kent in 1863; for there is no "Chalk-without-flints" in the island, the comparatively flintless Chalk of Margate is *above* the more flinty Chalk of Broadstairs, and the beds *rise* southwards at first, toward the middle part of the island, though they afterwards sink again further in the same direction: the island is in fact a very flat arch (or perhaps the half of a dome, of which the eastern part has been worn away by the sea), as shown by the section. The late Mr. P. J. Martin noted the fact of the Isle of Thanet being an elevated mass of the Chalk*.

Section across the Isle of Thanet from the Cliff on the western side of Margate to that at Red Cliff's End Point, westward of Pegwell.



Margate Chalk.

The higher division, or, as it may fitly be called, *The Margate Chalk*, contains but a very few nodular flints, so that the bedding is not well shown, and sometimes thin layers of flint filling the narrow vertical openings of the even joints. These joints, which are very marked and constant, in a direction about N.W. and S.E., are the cause of the peculiar form of the cliffs in many places near Margate, especially to the west, where there are parallel-sided inlets worn back from the shore, sometimes for some depth into the cliff, and here and there detached masses.

This division forms the whole of the cliff from the north-western corner of the island to White Ness on the north-east. Between the latter place and Fore Ness, a distance of about three-quarters of a mile, the face of the cliff is more or less along the joint-lines, here not quite vertical.

At White Ness there is a yellowish nodular bed at the bottom of the cliff, which must also be at or near the bottom of the Margate Chalk, although, as might be expected, there is no marked division between this and the chalk below.

I had no means of measuring the thickness, but I should think that it is not less than 80 feet.

Broadstairs Chalk.

This division is distinguished from that above by containing many layers of tabular flint and of nodular flints. One of the former, which, however, is not strictly tabular, but rather a continuous bed

* 'A Geological Memoir on a Part of Western Sussex,' 1828, p. 96.

of nodular flint, as its surfaces are very uneven, is a marked object in the cliffs southwards from White Ness; it is about three inches thick, and at no great depth below the yellowish nodular bed of chalk just noted. Other layers, though much thinner, seem to be equally constant, occurring for miles along the coast.

This more flinty and less jointed chalk forms the lower part of the cliff all the way from Kingsgate to Ramsgate, but has for the most part a capping of the higher or Margate Chalk, although sometimes the whole cliff from top to bottom is made of it, as at Broadstairs.

Along this line of cliff, which is higher and rougher than that where the Margate Chalk alone is present, the general arrangement of the beds is in the form of a very flat arch; but there are a few changes of dip, rarely at an angle of more than 3° , many small faults, and one fault of perhaps twenty or thirty feet downthrow (south) at Dumpton Stairs.

At Pegwell this division sinks below the level of the sea, and westwards the Margate Chalk alone occurs, and is soon capped by the Thanet Beds*.

Very likely the Broadstairs Chalk will turn out to be the upper part of the "Chalk with many flints" of the cliffs from Walmer Castle to Dover Castle†, and which is there the highest division; so that the Isle of Thanet section would be the upward continuation of that given by Mr. Phillips.

Conclusion.—There are four remarkable points of Chalk geology to be seen in the Isle of Thanet, the last two of which have not been noticed in the foregoing remarks, to wit:—

(a.) That the higher beds of the chalk contain a far less quantity of flints than the lower.

(b.) That they are the most affected by joints.

(c.) That large *Ammonites* are found in them, which would lead to the conclusion that the whole of the Chalk here belongs to the Lower (or Middle) division of the formation; and that therefore there is no Upper Chalk in the eastern part of Kent, for the Margate Chalk is the highest in that district‡.

(d.) That the Tertiary beds seem to be here conformable to the Chalk; for just below the unworn green-coated flints that are always present at the bottom of the Thanet Beds there is, in all sections in the Isle of Thanet, a peculiar bed of tabular flint, the upper and lower parts of which are of a whitey-brown colour and the middle black. At Pegwell Bay there are a few inches of chalk between this and the green-coated flints; at some of the small outliers of the Thanet Beds the two layers touch; and near Chislet (west of the island) the tabular flint is broken up and partly included in the bot-

* I use the name "Thanet Beds" instead of 'Thanet Sands' (Prestwich), because in these parts there is as much clay as sand in the formation.

† W. Phillips, *Trans. Geol. Soc.* 1st ser. vol. v. p. 16; and Conybeare and Phillips's 'Geology of England and Wales,' p. 90.

‡ Mr. Prestwich has suggested that the highest Chalk under the Tertiary beds of London belongs to the Middle rather than to the Upper part of the formation. 'Water-bearing Strata around London' (1851), p. 139.

tom of the Thanet Beds, though its fragments are in no case green-coated, but contrast strongly with the irregular-shaped green flints. This is the only bed of the sort in the Margate Chalk, which, as aforesaid, contains merely a few nodular flints, so that there is no chance of mistake.

I have reason to think that this conformity extends to a few miles westward of Canterbury. It is all the more extraordinary if the highest Chalk here should turn out, as I have suggested above, to belong to the Middle or Lower and not to the Upper Chalk. In the western part of Kent too (near Woolwich, &c.) the junction of the Thanet Sand and the Chalk is remarkably even in all the great sections, and it is thought that there also the Upper division may have been denuded.

3. *On the CHALK of BUCKINGHAMSHIRE, and on the TOTTERNHOE STONE* By WILLIAM WHITAKER, B.A., F.G.S.

I KNOW of but two short notices of the Totternhoe stone, and the older of these is merely to the effect that "the indurated Chalk Marle is extensively quarried at Totternhoe, in Bedfordshire*."

Prof. J. Phillips, however, has been led to class this stone and the accompanying marl with the Upper Greensand, his words being as follows:—"In Bedfordshire the Chalk Marl produces a bed of siliceous chalky stone, which may probably be analogous to the firestone of Mesterham (Merstham), in Surrey, which is determined to belong to the Upper Greensand." * * * * * "It is easy to understand how so variable a mass of sand (the Upper Greensand) placed immediately below the Chalk, and clearly in many places graduating into that calcareous rock, should in several instances become so cretaceous as to be hardly distinguishable from the Chalk itself. This happens in Bedfordshire, where the Tattenhoe (Totternhoe†) stone appears to be the representative of the Upper Greensand‡.

I would remark that the name "Chalk-marl" is, I believe, used strictly for the lowest and more clayey part of the Chalk, and therefore that bed can hardly be analogous to the Upper Greensand which occurs beneath it.

The mapping of the Upper Greensand in Buckinghamshire gave much trouble to the Geological Survey, and it was only after repeated visits, by the help of fresh sections, and from a knowledge of a great length of country along the foot of the Chalk ridge, that the difficulty was cleared up, happily, too, without leaving any room for doubt, and the Totternhoe stone and marl were found to overlies unboubted Upper Greensand.

The broad distinction of the "Chalk-with-flints" and the "Chalk-without-flints" holds in Buckinghamshire, as in most places; but the latter consists of many divisions, as shown by the section, though

* 'Geology of England and Wales' by the Rev. W. D. Conybeare and W. Phillips, 1822, p. 163.

† Tattenhoe is the name of another village some miles to the north-west, and on Oxford Clay.

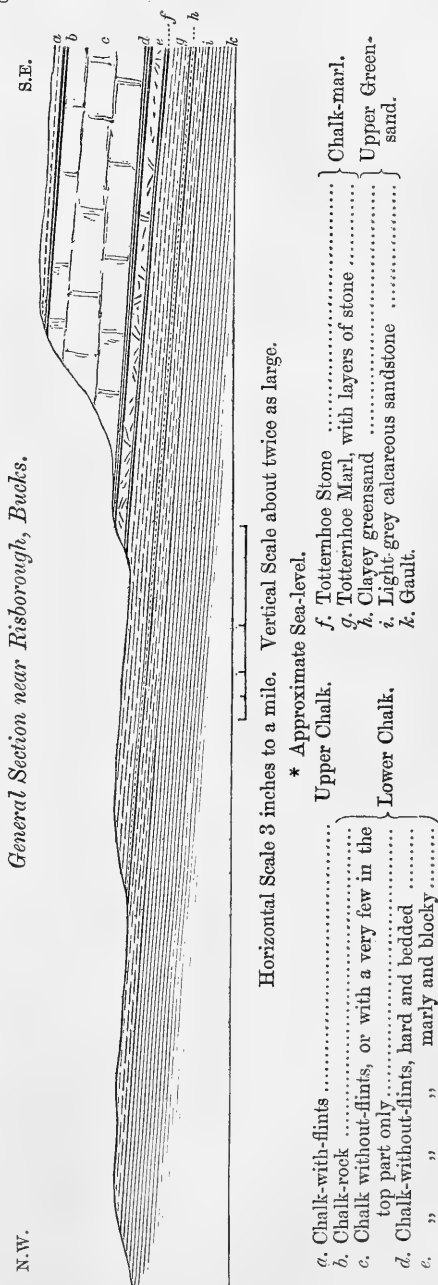
‡ 'Manual of Geology,' 1855, pp. 352 & 357.

I cannot give the thickness with accuracy. I will now give a short account of each, beginning with the lowest.

(g). *Chalk-marl*.—A rather brownish-white, slightly sandy, clayey chalk, fissile, with stony layers here and there, and often with fossils (notably fish-scales). This is perhaps 80 feet thick, and mostly causes a rise of the ground above the sloping plain of the Upper Greensand.

(f). *Totternhoe Stone*.—At the top of the Chalk-marl in this district there are generally two layers of rathersandy limestone, separated by a little marl, and which are more distinct further north-eastward (in Bedfordshire), where they are each about 3 feet thick. One bed is always here present, but I did not always see the two. This stone mostly yields fossils, amongst which *Ammonites varians* and an *Inoceramus* are abundant, and small, hard, dark-brown nodules, most likely coprolitic: it is harder and darker than common chalk, and contains many small dark grains; and was once largely quarried, for building, at Totternhoe, where there are plentiful traces of the workings. Most of the old churches of the neighbourhood were built in great part of this perishable stone, but I believe that its use has been long discontinued.

Details of the occurrence of this bed will be given in the 'Geolo-



General Section near Risborough, Bucks.

N.W.

S.E.

Horizontal Scale 3 inches to a mile. Vertical Scale about twice as large.

* Approximate Sea-level.

- a. Chalk-with-flints
- b. Chalk-rock
- c. Chalk without-flints, or with a very few in the top part only
- d. Chalk-without-flints, hard and bedded
- e. " " marly and blocky
- f. Upper Chalk.
- g. Totternhoe Stone
- h. Totternhoe Marl, with layers of stone
- i. Clayey greensand
- j. Light-grey calcareous sandstone
- k. Gault.

- Chalk-marl.
- Upper Green-sand.

gical Survey Memoir' on Sheet 46. I have traced it from near Henton (in Sheet 7 of the Geological Survey Map) on the south-west to near Ravensborough Castle (in Sheet 46, N.E.) on the north-east, along which course there is no lack of sections. I believe that it occurs further to the south-west, for in passing by train through the long cutting in the bottom part of the Chalk on the Great Western Railway north of Wallingford Road Station, I noticed a constant hard bed; and I should think that it will be found still further westward, near the foot of the Chalk range.

(e). A rather marly white chalk without flints, which breaks up into large irregular-shaped blocks with more or less curved surfaces, comes on above the Totternhoe stone, and is in turn overlain by:—

(d). Hard bedded white chalk without flints, partly yellowish and of a nodular structure, with thin soft grey marly layers. This causes a slight rise of the ground at the foot of the great ridge. I have also seen this hard chalk to the north-east, in Hertfordshire and Bedfordshire.

(c). The thick mass of the white chalk without flints, but with thin layers of soft grey shaly marl here and there, which mark the bedding. There are sometimes a few flints in the top part of this division, which forms the flank of the great escarpment.

(b). The hard and more or less nodular "Chalk-rock," often fossiliferous. Of this no further remarks are needed here, as I have described it to the Society before*, and have elsewhere noted most of the sections in Buckinghamshire†.

(a). The white chalk with flints, of which the lowermost part only occurs at the top of the escarpment, whilst the higher beds come on in succession over the table-land southwards, the thickness of the whole being possibly 300 feet.

4. On the CHALK of the ISLE OF WIGHT.

By WILLIAM WHITAKER, B.A., F.G.S.

THE following notes were made during holiday rambles in the autumn of the years 1863 and 1864, and as some of them seem to throw a little light on a formation the details of which have been hitherto somewhat neglected, I trust that they may be not unacceptable to the Society.

The divisions of the Chalk in the Isle of Wight are well enough known, but nevertheless it will be as well to mention them here before giving the details as to the line of demarcation between the first two, which is the special object of this paper. They are—

White Chalk with flints, many hundred feet thick (1200 feet or more?).

White Chalk without flints, about 200 feet?

Chalk-marl, 60 or 80 feet?

The "Chloritic Marl," which my friend and colleague, Mr. Bristow, classes as the bottom part of the Chalk ‡, I should rather look

* Quart. Journ. Geol. Soc. vol. xvii. p. 166.

† Geological Survey Memoir on Sheet 7, pp. 5-7, where the range of the Upper and Lower Chalk is also given.

‡ *Ibid.* Sheet 10, p. 25.

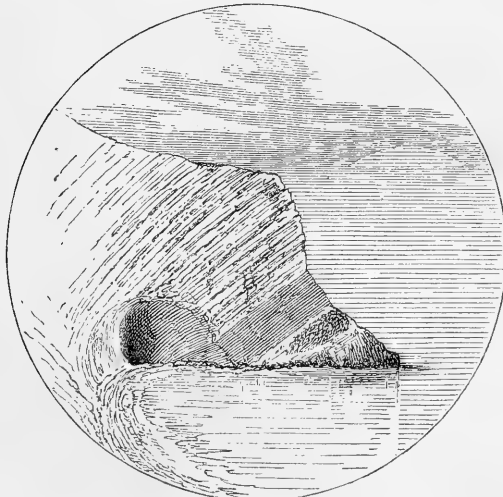
on as belonging to the Upper Greensand; for it seems to me to be the representative of the clayey greensand that forms the upper part of the latter formation in Surrey, Berkshire, Oxfordshire, Buckinghamshire, &c.*; and in taking this view I follow the late Professor E. Forbes and Captain Ibbetson †, although the last-named observer has also spoken of the Chloritic Marl as separating the Chalk-marl from the Upper Greensand, as if he doubted to which formation to refer it, notwithstanding that in the same paper he correlates it with the greensand of Surrey ‡.

I shall not treat of each division of the Chalk separately, but will give the sections in order from the west eastwards.

From the Needles to beyond Freshwater Bay only the top member of the Chalk is present, the rest having been worn away along the shore. The parallel layers of flint are very frequent, many quite continuous, some of a peculiar brown or pinkish tint, and all more or less broken up. There are also thin yellowish beds in the Chalk, which is rather hard, and weathers to a rough surface on the face of the cliffs.

At Sun Corner, the southern horn of Scratchall's Bay, there is a bed of some thickness, in which the layers of flint are so close together that they form nearly as much of the rock as the chalk itself. I could not examine this, as the tide was up when I was there. It is shown in fig. 1, in which the black lines represent the layers of

Fig. 1.—*Scratchall's Bay (looking southwards).*
(From a photograph.)



* Geological Survey Memoirs on Sheet 13, p. 18, and on Sheet 7, p. 4.

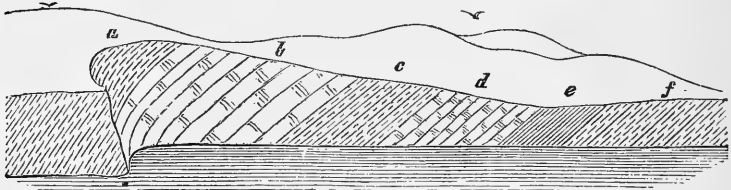
† Brit. Assoc. Report, 1844, Trans. of Sections, p. 43. Mr. Bristow tells me, however, that Prof. Forbes afterwards classed the Chloritic Marl with the Chalk.

‡ *Ibid.* 1848, Trans. of Sections, p. 69. In this paper there is a long list of the places where the Chloritic Marl may be seen.

flint, and it makes the top of the slope, or lower part of the cliff, a good example of the form called "wall above slope" by Mr. Ruskin*.

From the western side of Freshwater Bay a good view may be had of the cliffs to the east, showing all the beds from the Chalk-with-flints down to the Wealden. The diagram, fig. 2, is from a rough sketch taken from the foot of the cliff.

Fig. 2.—View of the Cliffs eastward of Freshwater Bay.



a. Chalk with flints.

b. Chalk without flints, bedded.

c. Chalk-marl, more thinly bedded.

d. Upper Greensand.

e. Gault.

f. Lower Greensand.

r. Chalk Downs.

In the higher part of *a* the bands of flints are frequent and regular, but towards the bottom they are less common and less continuous, and the chalk has a somewhat nodular look; at the bottom there is a layer of yellowish nodules, which I have been led to think is the representative of the bed, more distinct elsewhere, which I have named "Chalk-rock" †. The nodules are, like those of that bed, of irregular shapes and sometimes green-coated, and they occur here and in other places in the island (hereinafter noticed) in the same position as the Chalk-rock, that is, at the junction of the Chalk-with-flints and the Chalk-without-flints. In this section that junction is hard to get at on the top of the cliff, but the nodules may be seen in fallen blocks at the foot. The hard Chalk-marl, and the still harder Upper Greensand, stretch out as a foreshore for some way westward of their outcrop in the cliff, their even bedding being clearly shown by close parallel ridges.

A chalk-pit at the south-eastern corner of Shalcombe Down gives the following section:—

Chalk, much split up by weathering.

Line of blackish clay.

Hard and more massive chalk, 7 or 8 feet.

Hard cream-coloured bed, 8 or 10 inches. This I take to be the Chalk-rock; green-coated nodules occur at the top, which is well marked, whilst it passes down into

Chalk, without flints, but with two layers of soft grey marl.

A like section is shown by the pit, marked on the Geological Survey Map, on the southern side of Mottestone Down and due north of the village:—

Chalk, split up or weathered to a rough surface.

* 'Modern Painters,' vol. iv. p. 151.

† Quart. Journ. Geol. Soc. vol. xvii. p. 166.

Layer of hard yellowish nodules. A line of grey clay above, and two feet higher another less-marked nodular bed.

Bedded chalk.

In the large pit at the south-western end of Brixton Down there is again in the midst of the chalk a thin hard bed, like the Chalk-rock, with a clearly marked layer of green-coated nodules and lumps of octahedral iron-pyrites at its top, the bottom, on the contrary, not being defined. A foot or so above is a line of clay, which seems to show an unconformity (or false bedding?) in the Chalk*; for southwards it is further from the nodular bed, whilst northwards the latter is not seen, but seems to be cut off, the section there being as in fig. 3; at the northern and deepest part of the pit, however, the nodules come on again, and the section is:—

Chalk with a few nodular flints, the upper part weathering flaggy, the lower part with a rough surface.

Layer of nodules, &c., hard, the bottom not clear.

Bedded chalk; no flints, but lines of soft marl.

Fig. 3.—Diagram-section of a small part of a Chalk-pit on Brixton Down.



a. The line of clay above the Chalk-rock (in other parts of the section).
 b. Another line of clay. c. Chalk much split up.

A little way below this pit the hard bedded Chalk-marl is shown, and then the top part of the Upper Greensand (grey and green sand with stony layers).

In the quarry, marked on the Geological Survey Map, just east of Carisbrooke Castle there are some beds of hard nodular chalk: in one of these the nodules are cream-coloured and green-coated, as in the Chalk-rock; seven or eight feet above is a seam of black shaly clay, and another of grey clay lower down. I saw no flints here.

The new road-cutting just below, and south of, the large chalk-pit at the western end of Arretton Down is in the Chalk-with-flints; whilst an old pit still lower, and west of the road, shows chalk with a very few flints and weathering to a rough surface, and at the

* I believe that M. Hébert has observed unconformity between different divisions of the Chalk in France; and Mr. Webster has described and figured a remarkable case, in the midst of the Chalk-with-flints, at Handfast Point (Sir H. Englefield's 'Isle of Wight,' p. 164, plates 26, 27), which, however, is looked on by many geologists as a fault. I have not seen it myself.

bottom, at one part, the thin hard cream-coloured bed with green-coated nodules.

In a pit about two-thirds of a mile south-west of Brading church the section is :—

Nodular chalk, partly yellowish, weathering to a rough surface.

There is a line of whitish marl, six or seven feet below which comes a cream-coloured bed with a few green-coated nodules (Chalk-rock?—very badly marked).

Blocky bedded chalk with lines of marl.

At another pit near by, more than half a mile S.S.W. of Brading church, the beds shown are :—

Chalk with a few nodular flints (shown only at the northern end of the quarry, where it is 20 to 30 feet thick).

Thin seam of dark-grey clay.

Chalk, about 8 feet.

Inconstant layer of irregular-shaped green-coated nodules (Chalk-rock?).

Evenly and massively bedded chalk, without flints, but with seams of marl.

There is a smaller pit, just to the south, in the Chalk-marl.

Beyond this I have seen nothing of the hard nodular bed between the flinty and the flintless chalk. There seemed to be no trace of it in the cliff south of Bembridge Down, but it might perhaps be found by a very careful search. The order of the beds here is as follows :—

White chalk with flints in layers, for the most part near together.

Bedded white chalk without flints, weathering to a rough surface.

Very light grey chalk without flints.

Chalk-marl, consisting of evenly bedded alternations of lighter-coloured and harder, with darker, softer, and more clayey beds; passing down into

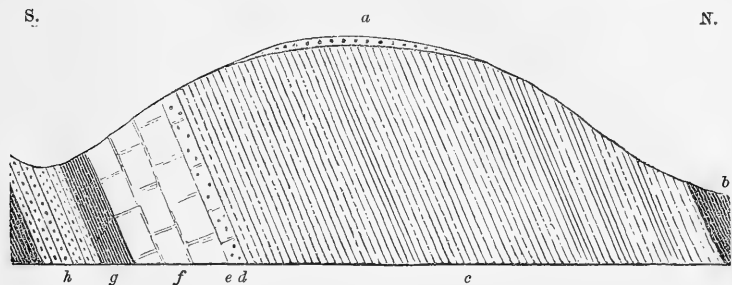
Upper Greensand: hard throughout, but the upper part more thinly bedded and cherty, and therefore harder and weathering to a rougher surface than the lower and lighter-coloured part.

The large and deep ditch of the fort on the top of Bembridge Down is of course in the Chalk-with-flints, which dips northwards at a high angle. At the northern side of the northern face, that is, where the higher beds are cut into, there are few flints, but layers of marl instead.

The great section of Culver Cliff shows something that must serve as a caution against trusting too much in nodules; for here, in the midst of the Chalk with layers of flint at every three or four feet, is a space some forty or fifty feet thick, with only one thin seam of tabular flint, but with four lines of green-coated nodules, like those of the Chalk-rock (which, if present here, must be hundreds of feet below), but perhaps of a deeper colour. These seem to take the place of the flints, the two not occurring together, and show that like conditions must have held at different times during the deposition of the Chalk. My friend Prof. T. R. Jones drew my attention to this bed some time ago.

The relative position and thickness of the divisions of the Chalk in the Isle of Wight are shown by fig. 4.

Fig. 4.—General Section across the Chalk of the Isle of Wight.



- a.* Flint-gravel, often occurring on the highest downs.
b. Woolwich and Reading Beds.
c. Chalk with frequent parallel layers of flint or flints.
d. Chalk with few flints, and of a somewhat nodular structure.
e. Position of the "Chalk-rock."
f. Massively bedded chalk without flints, but with thin marly layers.
g. Evenly bedded hard Chalk-marl.
h. Upper Greensand.

Junction of the Chalk and the Tertiary beds.—With all due respect to the opinions of other geologists who have written on the subject, I must venture to state my doubt of there being clear proof of any "eroded surface of the Chalk" at the junction of that formation with the overlying Tertiary beds*. That there is sometimes an "uneven surface" cannot be gainsaid by anyone who knows the Alum Bay section. There the junction is most irregular, the sand at the bottom of the Reading Beds filling hollows of all shapes in the Chalk; this irregularity, however, is not, I take it, owing to "erosion" of the latter, that is to say, to its having been worn away *before* the deposition of the Reading beds; but is merely a good specimen of those "pipes," or irregular-shaped funnel-like hollows, that have been dissolved out in the Chalk by the action of carbonated water *after* the deposition of the beds above.

If, after studying these pipes, the geologist will "right-about face" and look at what the sea is now doing along the chalk-coast, he will see the great difference of these two agents; for along the shore west of Alum Bay the sea is constantly attacking the Chalk, planing it down, and forming flat or slightly curved surfaces and shallow basins, but nothing like the irregular-shaped and branching pipes of the cliff.

As far as I know, it is only where the surface of the Chalk is easily got at by water that pipes occur of any great size or in any great number,—that is to say, where there is but a somewhat thin capping of Tertiary or Drift beds, or where, as in the present case, the beds are enough tilted to allow of a fairly free access of water along the junction. On the contrary, where there is a good thickness of the beds above the Chalk, and where the dip is low, pipes are both rare and small, as may be seen in the chief junction-sections of the Chalk and the Tertiary beds in the London Basin, at

* See the Geological Survey Map of the Isle of Wight, Mr. Bristow's Memoir, p. 29, and Mr. Prestwich in Quart. Journ. Geol. Soc. vol. viii. p. 256.

Newbury *, Reading †, near Maidenhead ‡, Chesham ‡, Hatfield ‡, and Northaw ‡, and at Charlton, besides very many other places.

At Alum Bay there are some very large roundish flints at or near the junction of the Chalk and the Reading Beds, sometimes, indeed, included in the pipes of the latter; and in the new railway-cutting just south of Brading station, near the other end of the island, the same thing occurs. As far as I know, the layers of flint in the Chalk are for the most part more or less tabular, and where not so, the nodules are not of this great size; and I should not be surprised if in these two places, some eighteen miles apart, the Reading Beds rest on the same bed of the Chalk. This notion, however, would hardly have entered into my head were it not that I had already found that a like thing occurs over a small area in East Kent, as shown in one of the foregoing papers (p. 398). At Whitecliff Bay the junction was quite hidden at the time of both my visits.

Of course I do not mean to deny that there may have been very large denudation of the Chalk before the deposition of the Tertiary beds; indeed, as far as we can tell at present, there must have been (see p. 397); but I have never seen, in any of the great junction-sections, any proof of unconformity. A slight unevenness of surface of the Chalk would be almost wholly destroyed by the formation of the far more irregular surfaces of pipes.

Reconstructed Chalk.—At the foot of the northern flank of the Chalk Downs there may sometimes be seen a bed, a few feet thick, made up of pieces of chalk and flints cemented together into a hard mass, as at the western end of Afton Down and both ends of Motte-stone Down. At the foot of Bembridge Down I saw two small pits in the mottled plastic clay of the Reading Beds, which was capped by chalk-rubble, compact enough to be mistaken for Chalk itself.

Summary.—This paper is not meant to be a full account of the Chalk of the Isle of Wight, for I have simply written it as a supplement to what others have observed before, and the points to which I have drawn attention are:—

1. Whether the Chloritic Marl does not belong to the Upper Greensand rather than to the Chalk.

2. That there is a fairly exact line of division between the Chalk-with-flints and the Chalk-without-flints; and that this division is marked in the Isle of Wight, as more clearly in Oxfordshire, Berkshire, &c. §, by the occurrence of a thin and peculiar bed, of a cream-colour, hard, with irregular-shaped nodules (mostly green-coated), and with its top well defined, whilst below it passes into ordinary Chalk; and that here there is generally a thin layer of dark clay a little above it. It is to be remarked also that the lowermost part of the highest member of the Chalk contains comparatively few flints.

3. That there is no proof that the Reading Beds rest on a worn surface of the Chalk; but that the very irregular junction of the two is owing rather to the formation of pipes after the deposition of the former.

* See Geological-Survey Memoirs, on Sheet 12, p. 21.

† *Ibid.*, Sheet 13, pp. 38–40.

‡ *Ibid.*, Sheet 7, pp. 44, 39, 22, 30.

§ Geological-Survey Memoirs, on Sheet 13, pp. 20, 21, and on Sheet 7, pp. 5–8.

APRIL 26, 1865.

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

The following communications were read:—

1. *On the CHARACTER of the CEPHALOPODA of the SOUTH-INDIAN CRETACEOUS ROCKS.* By F. STOLICZKA, Ph.D., of the Geological Survey of India.

[Communicated by the Assistant-Secretary.]

NEARLY twenty-five years have elapsed since the fossiliferous Cretaceous deposits of the Carnatic first received attention through the zealous labours of Messrs. Kaye and B. Cunliffe, and since this first notice of fossils in the neighbourhood of Pondicherry and Verda-chellum much has been done for the study of these rocks.

From Mr. H. F. Blanford's report* we know that the entire series of the Cretaceous deposits either rests immediately on the crystalline rocks, or is in some places only separated from them by a small thickness of plant-bearing beds. Dr. T. Oldham† identified three species of the plants from these beds with others occurring in the Rajmahal series in Bengal. From this identification he regards the plant-bearing beds of Trichinopoly as being of the same age with the Rajmahal group, which is generally believed to be at least Jurassic, the exact age, however, not being as yet settled. Above the plant-beds we have the Cretaceous deposits, which have been examined by Mr. H. F. Blanford and other officers of the Geological Survey, in the Trichinopoly and South Arcot districts, and near Pondicherry. In the two first-named districts Mr. Blanford separates them into three divisions—the Ootatoor, Trichinopoly, and Arrialoor groups. Near Pondicherry only two groups have been traced out, namely, the Valudayur and Arrialoor. The Ootatoor and Valudayur groups are the lowest and oldest among the whole series, the others being successively younger.

Since the extensive collections of South-Indian Cretaceous fossils, brought together from several localities by Messrs. Kaye and Cunliffe, and so carefully examined by the late Prof. E. Forbes‡, a vast number of fossils has been collected during the progress of the Survey of the different districts. A detailed examination of these fossils was determined on several years ago by the Superintendent of the Geological Survey of India, and began with the descriptions and figures of the *Belemnitidæ* and *Nautilidæ* by Mr. H. F. Blanford§.

Having now brought the examination of the *Cephalopoda* to a

* Mem. Geol. Surv. India, 1862, vol. iv. pt. 1.

† Mem. Geol. Surv. India, 1861, vol. ii. p. 383.

‡ Trans. Geol. Soc. Lond. 2nd ser. vol. vii.

§ Palæontologia Indica. 1st ser. 1861.

conclusion, a few general remarks will, I believe, be of some interest to European palæontologists, although I hope to be soon in a position to bring all the details of the fauna before the scientific public*. My remarks cannot of course extend beyond those conclusions which have resulted from an examination of the *Cephalopoda* alone. The examination of the entire fauna will undoubtedly give more decisive proofs, but this cannot be expected for many years to come.

As regards the number and variety of species, the fauna of the South-Indian Cretaceous rocks is equal to any of the European local faunas. In its general aspect it is truly Cretaceous, inasmuch as all the characteristic European genera are well represented. In its special character it agrees mostly with the fauna of the Middle Cretaceous deposits in Europe, as has been previously noticed by several observers. With regard to the different groups, their respective definition and age, a few detailed remarks will show how far these general conclusions are confirmed by a special examination of the *Cephalopoda*. For this purpose it is desirable to know, first, whether the fauna offers any special distinguishable characters with reference to the established groups in South India, and secondly, what relation do these fossils show to known species in Europe or in other parts of the world, whence they have been examined and reported upon.

The entire fauna of the *Cephalopoda*, as far as it is at present known, consists of 148 species, of which there are 3 *Belemnites*, 22 *Nautili*, 93 *Ammonites*, 3 *Scaphites*, 11 *Anisoceras*, 1 *Helicoceras*, 6 *Turrilites*, 2 *Hamites*, 1 *Hamulina*, 3 *Ptychoceras*, and 3 *Baculites*. Considering the Ootatoor and Valudayur groups as one, namely the lower, the Trichinopoly as the middle, and the Arrialoor as the upper, we have to note the following distributon of the species:—

By far the greatest number of the *Cephalopoda* belong to the lowest series, which contains 98 species; 10 species occur in the middle, and 19 species in the upper. The lower and middle have 4 species in common, the lower and upper 7, the middle and upper 6, and only 3 species occur throughout all the three divisions. Each of the groups has therefore a certain number of species peculiar, and comparatively few occur in two or three groups at the same time. In the middle division only the number, of species in common with the lower and upper groups is equal to those species which are exclusively confined to this group. However, it will be seen from Mr. H. F. Blanford's report, that the separation of the Trichinopoly group has been left in a few places conjectural with regard to the boundary of the Ootatoor, and in a few instances even to that of the Arrialoor group. Seeing the small number of *Cephalopoda* which the middle and upper groups have yielded, and the uncertainty of their stratigraphical and geographical extent, it will be best for the present not to take these numbers as strictly correct, because they

* Six parts of the third series of the 'Palæontologia Indica' have appeared, and the rest, concluding the *Cephalopoda*, will be (if no unexpected difficulties in printing occur) in the hands of the public in the beginning of next year (1866).

will very probably be altered during some future examination of the country.

I have previously remarked, that in its total aspect the character of the fauna is Cretaceous. Indeed, none of the genera, except *Ammonites*, are represented by species which exhibits any remarkable difference from European Cretaceous forms, even if they are not identical with already known fossils. The *Ammonites* themselves retain in general a true Cretaceous character in the groups of the *Cristati*, *Rothomagenses*, *Mammillati*, and *Ligati*, which are strongly prevalent; but there are other groups also represented, which have been only doubtfully or not at all noticed in Cretaceous deposits elsewhere. It is so far true that these foreign groups count only few species, and that even these are usually not numerous in individuals, but still they are very characteristic. I have to notice one species of the *Planulati* and four species of the *Macrocephali*, all in aspect very much resembling Jurassic forms. Of the *Fimbriati* there is, among others, one species which has the most striking resemblance to *A. fimbriatus*.

The group *Lævigati* was established by Prof. E. Forbes, and some of its members are a good deal like the smooth species of the Liassic *Falciferi*: *A. opalinus*, and others. The most striking and abnormal among the *Ammonites*, however, are three species of the Triassic group *Globosi*. When I at first examined these species, I was so much struck with their similarity to Alpine Triassic *Ammonites*, that I could not help doubting their real Cretaceous age. However, the occurrence of other unquestionably Cretaceous fossils associated abundantly with them, not only in the same locality, but some of them even in one and the same piece of rock, left of course not the slightest doubt that they are truly Cretaceous fossils. For further particulars I must refer the reader to the descriptions and figures in the 'Palæontologia Indica' (3 ser.), as I could only repeat the same here.

The next question which has to be answered is, What relation do the Indian Cretaceous *Cephalopoda* bear to the European*?

We do not need for this purpose to quote nominally all the species which have been described†; but a list of those which are identical with already noted fossils will, no doubt, prove interesting.

* There are only two species identical with American forms.

† I avoid such a complete list purposely, because I could not help mentioning names of new species without being able to give the necessary descriptions and illustrations. It is indeed very much to be regretted that even at the present time the publication of new names of species without any further references is still in use by some naturalists, whose best intention is undoubtedly to avoid confusion (*vide* Quart. Journ. Geol. Soc. vol. xx. pp. 387 & 388). Of what use are these names to the working geologist, and what to the palæontologist?

NAMES OF GENERA AND SPECIES.	GROUPS.	
	INDIA*.	EUROPE†.
<i>Belemnites semicanaliculatus</i> , <i>Blain.</i>	O.	m. c.
<i>Nautilus Danicus</i> , <i>Schloth.</i>	A.	up. c.
„ <i>Bouchardianus</i> , <i>D'Orb.</i>	A.	m. c.
„ <i>sublævigatus</i> , <i>D'Orb.</i>	A.	„
„ <i>Clementinus</i> , <i>D'Orb.</i>	A.	„
„ <i>Fleuriausianus</i> , <i>D'Orb.</i>	O.	„
„ <i>elegans</i> , <i>D'Orb.</i>	T.	„
„ <i>pseudo-elegans</i> , <i>D'Orb.</i>	O.	l. c.
„ <i>Neocomiensis</i> , <i>D'Orb.</i>	O.	l. c.
<i>Ammonites Ootacodensis</i> , <i>Stol.</i> (<i>A. colligatus</i> ,	A.	up. c.
„ <i>subtricarinatus</i> , <i>D'Orb.</i> [<i>Binkhorst.</i>])	T.	m. c. (up. c.)
„ <i>inflatus</i> , <i>Low.</i>	O.	„
„ <i>Candollianus</i> , <i>Pictet.</i>	O.	„
„ <i>Gardeni</i> , <i>Baily.</i>	A.	„ (Af.)
„ <i>Rothomagensis</i> , <i>Defr.</i>	O.	„
„ <i>navicularis</i> , <i>Mant.</i>	O.	„
„ <i>Mantelli</i> , <i>Low.</i>	O.	„
„ <i>dispar</i> , <i>D'Orb.</i>	O.	„
„ <i>Guadaloupæ</i> , <i>Röm.</i>	T.	„
„ <i>Orbignyanus</i> , <i>Geinitz.</i>	O.	„
„ <i>Largilliertianus</i> , <i>D'Orb.</i>	O.	„
„ <i>subalpinus</i> , <i>D'Orb.</i>	O.	„
„ <i>peramplus</i> , <i>Mant.</i>	T.	„
„ <i>Beudanti</i> , <i>Brongn.</i>	O.	„
„ <i>Timotheanus</i> , <i>Major.</i>	O. & T.	„
„ <i>latidorsatus</i> , <i>Mich.</i>	O.	„
„ <i>Velledæ</i> , <i>Mich.</i>	O. & A.	m. c. a. l. c.
„ <i>Rouyanus</i> , <i>D'Orb.</i>	O. & V.	m. c. & c. c.
<i>Scaphites æqualis</i> , <i>Sow.</i>	O.	m. c.
„ <i>obliquus</i> , <i>Sow.</i>	O.	„
<i>Anisoceras armatum</i> , <i>Sow.</i>	O.	„
<i>Turrilites Bergeri</i> , <i>Brongn.</i>	O.	„
„ <i>Gæsleyi</i> , <i>Pict. & C.</i>	O.	„
„ <i>tuberculatus</i> , <i>Rose.</i>	O.	„
„ <i>costatus</i> , <i>Lam.</i>	O.	„
„ <i>Brazoensis</i> , <i>Römer</i>	O.	„ (Am.)
<i>Ptychoceras Gaultinum</i> , <i>Licht.</i>	O.	„
<i>Baculites vagina</i> , <i>Forb.</i>	V. & O.	„ (Am.)

From this list we see, that the number of identical species (being in all 38) is nearly one-fourth of the total number of the *Cephalopoda*:

* O., Ootatour; V., Valudayur; T., Trichinopoly; A., Arrialoore; Am., America; Af., Africa.

† l. c., Lower Cretaceous; m. c., Middle Cretaceous (comprising the Gault, Grès-verts, Greensand, part of Aptien, Turonien, Cénomaniën, the German Flammenmergel, and Pläner, &c.); up. c., Upper Cretaceous (Danien, part of Sénonien, strata of Maestricht, Rügen, &c.).

a more conclusive result could hardly be expected. But I may take this opportunity to anticipate, after only a very cursory review of the other fossils, that they do not seem to have a smaller number of identical species, if even the resemblance be not greater.

In these 38 species already known in other countries, we have 3 of the Lower Cretaceous deposits, or Neocomian, 32 species of the middle strata, 2 species of the upper, and one occurs in the lower as well as in the middle.

In the Indian strata the same species divide themselves somewhat differently. There are 25 of them occurring in the Ootatoor or Valudayur groups, 4 in the Trichinopoly, 1 in the Ootatoor and Trichinopoly, 6 in the Arrialoor, and 1 in the Ootatoor and Arrialoor group.

I have just quoted 3 species as Neocomian; all of them are confined in India to the lower beds. In fact, there are only two decidedly Neocomian species, *Nautilus psuedo-elegans* and *N. Neocomiensis*. With regard to *Anmonites Rouyanus*, D'Orb., which species I have restricted in the original sense (in the 'Paléontologie Française'), excluding *A. infundibulum*, D'Orb., the age is not perfectly certain, as D'Orbigny quotes it only on foreign authority, which he himself afterwards (Prod. ii. p. 98) rejects.

Of the 32 European Middle Cretaceous species, 22 belong to the lower or Ootatoor, 4 to the Trichinopoly, and 4 to the Arrialoor group; 1 occurs in the Ootatoor and Trichinopoly, and 1 in the Ootatoor and Arrialoor. We have therefore a Middle Cretaceous European fauna represented in India chiefly in the lowest beds, and far less markedly in the middle and upper beds. However, even these few species of the upper groups are more numerous than those which are peculiar to one and a similar division in Europe and India.

Only two Upper Cretaceous species, *Nautilus Danicus*, Schloth., and *A. Ootacodensis*, Stol. (*A. colligatus*, Binkh.), are noticed; and both occur in India equally in the upper beds.

If we summarize all the above-quoted facts, we arrive at the following conclusions:—The lowest Cretaceous beds, known in Europe as "Neocomian," and especially well developed in the Alpine districts, are wanting in South India as a separate group. Mr. Blanford speaks in his report repeatedly of the Neocomian character of the fauna of the Valudayur group; we have seen before, however, that there are only three Neocomian species known, of which *A. Rouyanus* alone occurs in both the lower groups. It is true that the many species of *Anisoceras** of the Valudayur group near Pondicherry have a peculiar character, which recalls the Neocomian fauna; however, they are not very much less numerous in the Ootatoor group, and, except one, not identified with any known species. The fauna of the Neocomian clays, slates, sandstones, and limestones in the Alps has, in fact, a peculiar character of its own.

The lowest undoubtedly Cretaceous beds in South India (comprising the Ootatoor and Valudayur groups) are decidedly equivalent to the Middle Cretaceous strata in Europe. The greatest number of the

* Usually quoted under *Hamites* and *Ancyloceras*.

species of these rocks belongs to the Gault or Grès-verts. We find, among other species, *Nautilus elegans*, *A. inflatus*, *A. Rothomagensis*, *A. Mantelli*, *Scaphites obliquus* and *S. æqualis*, *Turritiles Bergeri* and *T. costatus*, *Anisoceras armatum*, &c.; in fact, such characteristic fossils as cannot be mistaken, and which are known from nearly every part of the globe where any Cretaceous deposits have been traced. It is equally well known from the researches of the late D.D. Owen, Meek and Hayden, Shumard, Sable, and other geologists and palæontologists, that a true equivalent of the European Neocomian does not exist in North America*, and that the lowest Cretaceous deposits there answer chiefly to the Gault. Equally is it remarked by the North American geologists, that the uppermost Cretaceous strata, known as White Chalk (with flints), and strata of Maestricht and Rügen, are either very obscurely or not at all developed. It seems to be similarly the case with the Indian deposits.

I may as well notice here that similar conclusions have been drawn from the investigations in South America by Mr. Darwin, Mr. Domeyko, M. d'Orbigny, and others, and also from the examination of Cretaceous fossils from South Africa through Mr. Baily. In North Africa, namely in Algeria, M. Coquand accounts for nearly all the European Cretaceous divisions, which within the last few years have increased to a considerable number.

So far it is certain that the lowest Cretaceous beds in South India have a Middle Cretaceous character, and that this character is strongly marked even in the two upper divisions. As already stated, the number of *Cephalopoda* from the Trichinopoly and Arrialoor groups is too small for any decisive opinion to be formed. We must leave the question until we see from the examination of the other fossils whether their indicated independence (of course within certain limits) will be confirmed, as expected, or whether it will become more obliterated. At the present moment there is no objection to the opinion that the Indian Cretaceous deposits, according to Mr. H. F. Blanford's survey, can be separated into three groups, of which the lowest is of the age of the European Gault, and of which the uppermost does not seem to answer to a higher division than D'Orbigny's Sénonien. Probably, when we have a better palæontological basis, we may be able, after a detailed survey of the country, to distinguish several divisions of the middle group, as they have been lately with some favour adopted, especially by French geologists.

* *Vide* also Dana's 'Manual of Geology,' p. 467.

2. *On the GROWTH of FLOS FERRI, or CORALLOIDAL ARRAGONITE.*
By W. WALLACE, Esq.

[Communicated by W. W. Smyth, Esq., F.R.S., Sec. G.S.]

[Abridged.]

IN giving a sketch of the physical features of the Meldon district in Westmoreland, Mr. Wallace stated that the water-shed of the Meldon range of mountains corresponds with an anticlinal axis which probably ranges at nearly equal distances from the River Tees and one of its tributaries—the Maizebeck.

The denudation of the country to the east of the Great Penine fault has evidently been regulated by the unequal elevation of the strata. The highest mountains are chiselled out of an immense mass of stratified rocks, and left standing on the ridges, or axes of highest elevation, of the beds. The denuding forces have produced the greatest effect where they have formed the valleys; or, in other words, in a general view, the greatest amount of denudation has been effected where the rocks have been the least elevated from their original horizontal position.

On each side of the Meldon hills lead-veins are found; and the formation of these veins is evidently connected with the anticlinal axis, the direction of which corresponds with that of these hills. On the north side, the principal vein of the Silver Band and Dunfell Mines dislocates the strata some 16 or 20 fathoms, the side next the axis being elevated. The veins on the contrary side probably dislocate the strata less; the amount of their throw has not, however, been exactly ascertained.

All the veins of the Silver Band Mine and the flats of the Dufton Fell Mine contain much sulphate of barytes. In some parts of the Silver Band vein I have found the width of this substance to be not less than 21 feet. Nodules of lead-ore are enclosed in the barytes; and this mineral occasionally encloses ribs of lead-ore of very irregular width. From a number of observations I am inclined to suppose that the presence of iron in the barytes has been a condition favourable to the deposition of lead-ore.

When the Great Limestone was formed, its position would be horizontal, or nearly so, throughout the whole extent of the mining districts of Alston Moor, Weardale, Teesdale, &c. It has, however, been wrenched into very unequal positions. At Nenthead it is elevated about 1450 feet above the sea; in the Silver Band Mine, and on the south side of the principal vein, 2400 feet. This difference in elevation of nearly 1000 feet is connected with very different kinds of phenomena. In the Silver Band Mine the Great Limestone is much broken by joints in which pure air circulates, so that artificial ventilation is seldom needed where mining-works are made. In the Nenthead district the Great Limestone is only jointed near the surface; and, but for the numerous veins, it would form unbroken sheets of rock in the centres of the surrounding mountains. It has been stated that "limestone strata near the summits of mountain-ranges, even when under considerable pressure, are found to contain

more joints, and those of a more open character, than the same strata lying in the valleys at a much less depth below the surface”*. The jointed character of the Great Limestone in the Silver Band Mine is therefore a verification of a law deduced from observations made in the mining districts of Alston Moor.

The formation of joints is not only affected by elevation, but also by the position of the rocks in relation to the valleys; that is to say, where the basset of the rocks forms semicircles at the heads of valleys, the rocks are less jointed than on the sides of mountains ranging in a straight direction, although the elevation in each case may be equal in amount.

Most of, if not all, the minerals deposited contemporaneously with the ores of lead and zinc are subjected to decomposing agents after the formation of joints. The sulphate of barytes is acted upon slowly; but the limestones, which by metamorphism have become impregnated with iron, and form the walls of the veins, decompose more rapidly, and by their decomposition and removal very large caverns are formed. The sulphides of lead and zinc are changed to oxides and carbonates; and occasionally the nodular masses of carbonate of lead have lost their coherence and crumble into fine sand.

If, then, the deposition of lead-ore is due to causes now in operation, it is evident that the causes brought into play by the formation of joints counteract their effects. Indeed, from the facts connected with the Westmoreland mines, it would appear that the process of the deposition of lead-ore in this district has advanced downward at a slower rate than that of the formation of joints.

The above remarks may be considered irrelevant to the subject of this paper; but I am anxious to show that the amount of decomposition in veins and in rocks is proportionate to the amount of their elevation above the sea. The progress of chemical change on minerals in veins is undoubtedly very slow. We therefore can form no adequate conception of the length of time which must necessarily transpire before atmospheric agents could effect an amount of decomposition in the Nenthead veins equal to that which has taken place in those portions of the Silver Band veins where the sulphate of barytes is not present, before the flatted or metamorphosed limestones in the former district, with all their contained minerals, could be decomposed and carried away, forming caverns to rival in extent those found in the latter mine. Yet it seems probable that, if the numbers could be comprehended, they would roughly indicate a period of time during the lapse of which the Penine mountains were raised 1000 feet.

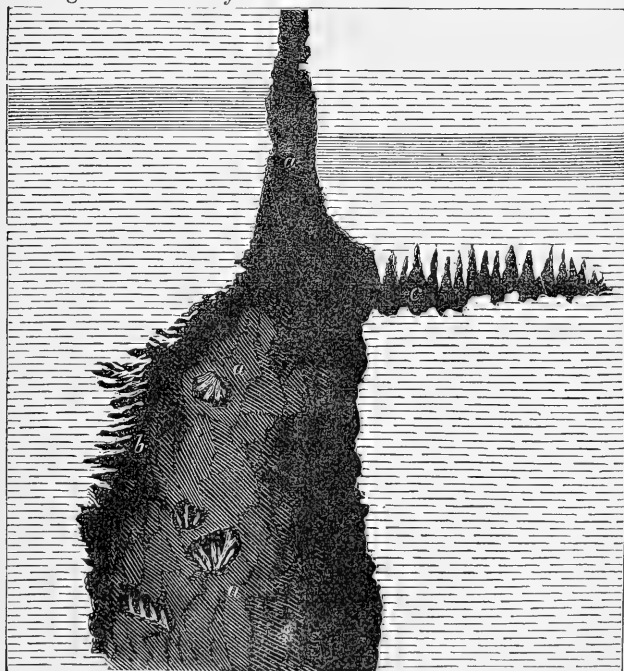
In the widely ramified works made in the Nenthead veins, where few or no joints have been formed, I have found arragonite in only one small cavern; and the few specimens it contained were not of that splendid arborescent kind found in the Dufton mines. Yet even in the Dufton mines, where stalactitic and stalagmitic masses of lime are so common, and often found highly crystalline in structure,

* Wallace, ‘The Laws which regulate the Deposition of Lead-ore in Veins, &c.’ 1861, p. 52.

semitransparent, and beautiful*, the occurrence of the branched arragonite is very rare. I have not heard of more than four or five caverns in which it has been found, except in small pieces. In the Nent-head mines stalactites are never found except near the surface, or in the old works.

Two of these caverns have come under my notice. One of them in a north vein of the Silver Band Mine, where the Great Limestone forms its walls. The vein is not strong. On the north side of a short portion the limestone was flatted for a few feet from the vein. The flats contained lead-ore and other minerals, all of them much decomposed. Nearly all the sulphide of lead was changed into carbonate, and the round lumps of carbonate, mingled with the oxides of iron, had not unfrequently crumbled into small particles, having the appearance of fine sand of a light-brown colour. Only a few fathoms west from where the arragonite was found, the vein and flat are filled chiefly with impure barytes not much affected by the decomposing agents. The cross section (fig. 1) will enable me to describe more clearly the phenomena connected with the cavern.

Fig. 1.—Section of a Cavern in the Silver Band Mine.



1. Sandstone. 2. Shale. 3. Great Limestone.

That part of the cavern marked *a* was filled with rubbish and pieces of sandstone; without doubt the latter had fallen through the

* The transparent stalactites exhibit double refraction.

hole in the roof from the stratum of sandstone which lies above the Great Limestone. The decomposed stuff in which the sandstone was embedded contained detached pieces of carbonate of lead.

The remains of the flat were situated on the north side (*b*) of this rubbish. It consisted chiefly of impure hydrated oxides of iron mixed with sulphide of lead, partially, and not unfrequently altogether, changed into carbonate. The oxide was evidently derived from limestone which had been impregnated with carbonate of iron, as nodules of the latter remained unchanged in the centre of detached masses of the oxides. It appears probable that this limestone was ferruginized about the time when the sulphide of lead was deposited in the flat. Small caverns lined with snow-white arragonite occurred in this mass of oxidized matter.

On the south side of the vein there was an open cavern (*c*) partially filled with broken limestone, not much mineralized with iron. The roof of this cavern was lined with stalactites, and the rough lumps of jagged limestone lying at the bottom were covered with corresponding stalagmites. In one or two small caverns near or in the roof some beautifully branched arragonite was formed upon hard limestone, from which it could not be detached without breaking.

Below the larger lumps of sandstone, &c., which had fallen into that part of the cavern (*a*), small openings had remained unfilled with the soft clay and rubbish. In these openings arragonite was formed upon the clay; and in one instance it had shot horizontally across one of the small caverns from the oxides of iron and entered the clay at *a*, which formed the opposite side of the cavern. The clay was hardened around the place where it was pierced with the arragonite, and small crystals of the latter were formed upon it pointing in an opposite direction.

From these facts the following inferences may be drawn:—

1. That the limestone rocks forming the sides of this vein and flat were metamorphosed by agencies of the same kind as those which have effected a similar change upon the limestone strata forming the sides of veins and flats in the Nenthead Mines.

2. That, after the formation of joints, this limestone (partially metamorphosed into carbonate of iron, in which were formed caverns lined with galena and other minerals) was subjected to decomposing agencies, and a large cavern formed, which ultimately was filled with clay and rubbish by the falling in of the roof.

3. That after the roof had fallen in, stalactites and stalagmites were formed in the cavern (*c*), all of which were more or less coloured by chalybeate waters flowing over them; and in some places crystals of pure white arragonite were formed upon these congealed masses of lime, and also upon clay and impure oxide of iron.

4. That after the roof had fallen in, the cavern had never been filled with water; for, had this been the case, the clay would have softened and settled down like a sediment, whereas the contents of the cavern appeared like a mass of rubbish just filled in by a navy, and clay not unfrequently forming a portion of the sides of the interstices between the detached pieces of limestone and sandstone.

5. That water could not have flowed over the surface of the arragonite; for as it was found pointing in all directions, it could not rise against gravity to the ends of the arborescent varieties pointing upwards, which were occasionally of considerable length.

6. Now, as the interstices of the loose rubbish had evidently at no time been filled with water; and from the position in which some of the arragonite was found, it was impossible for water to flow over its surface; it therefore necessarily follows that the growth of this mineral is due to a circulation of fluids through its pores.

I may observe that after the formation of arragonite, in some places water had flowed slowly over its surface and stained it with various shades of the sienna-browns. In other places clay had been washed over its surface; but in both instances the arragonite was more or less decomposed, and ordinary stalactitic congelations were in the process of formation.

Such were the conclusions arrived at after repeated and most careful inspection of the phenomena connected with the presence of arragonite in one of the Silver Band veins.

A few months afterwards, another opportunity occurred of investigating the conditions connected with a cavern of greater magnitude, most splendidly lined with snow-white arragonite.

This cavern was found near one of the principal veins of the Duffon Fell Mine, at a depth of about 80 fathoms from the surface. Flats have been formed in the Tyne Bottom Limestone in connexion with this east and west vein, and these flats contained much lead-ore near the outcropping of the limestone. Extensive works have been made to prove this vein in the Melmerby Scar Limestone directly below this rich ore-deposit. While prosecuting these works in this limestone, a large joint was met with, which in some places was filled with very soft rubbish, the result of decomposition; in other places it was open, and afforded pure air for the workmen, so that artificial ventilation was not needed. When first discovered, it was considered to be a cross vein; but a rise made at its intersection with the east and west vein proved it to be a large joint existing only in the Melmerby Scar limestone; for it terminated altogether at the top of this limestone, and no trace of it can be discovered in Robinson's limestone, which at this place is separated from the former only by a bed of very soft and fine sandstone some 18 or 20 inches thick. In its direction northward, towards the centre of the mountains, it gradually closed; and no trace of it could be detected, though works were made in its direction to an extent of 20 or 30 fathoms in the very close and compact limestone.

Excepting in the upper portion, where the arragonite was found, no water trickles down the sides of this joint, nor are there any stalactites formed, neither does it contain any of the minerals found in the lead-veins of the north. A great portion of the rubbish it contains might be due to decomposition when the joint was filled with water; but a portion of the very loose stuff near the top of the joint is undoubtedly the remains of limestone which had been slowly decomposed by a moist atmosphere, and in consequence had fallen

from the sides. As might be expected, the unfilled portion is near the top of the joint.

The greatest amount of decomposition had taken place at the intersection of the joint with the east and west vein. At the time when this vein was mineralized its walls in the limestone strata had undergone a considerable degree of metamorphism, rendering it more susceptible of decomposition than ordinary limestone. Hence at this intersection the joint is of considerable width; it contained chiefly hydrated peroxide of iron and a little carbonate of lime. I could find no sulphate of barytes, though directly above, in the Tyne Bottom limestone, the vein and flats contained very large quantities of this mineral.

I have said that the joint was cut off by a bed of soft sandstone, which separates the Melmerby Scar limestone and Robinson's limestone. On the north side of the vein a thin post of limestone, however, remained uncut through, upon which the arragonite was formed. Except at the intersection with the vein the joint was generally about 1 foot wide; here it widened out to about 5 feet; but towards the north end of the cavern it was not more than $1\frac{1}{2}$ foot wide, and this space was almost blocked up with a growth of arragonite.

The sides of the cavern were damp; but there was sufficient moisture in only two places to form drops, and it was there where the greatest thickness of arragonite was formed. At the north end of the cavern the water descended through a small tube in the arragonite and formed a stalactite, from the end of which it dropped slowly, and a thin stalagmite (the only one in the cavern) was formed by this drop on the soft floor. The stalactite was covered with small crystals of arragonite, but there were none upon the stalagmite.

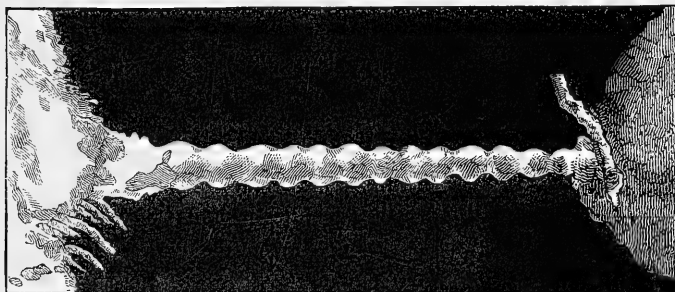
At the south end of the cavern the moisture had very slowly streamed down a portion of the west end. Here the arragonite was formed at the roof and about $2\frac{1}{2}$ feet down the end and west side; below, in a narrow strip, the side was encrusted with lime, which was most thickly deposited near the arragonite, and thinned off to nothing before it reached the bottom of the cavern. This incrustation was much discoloured. The most splendidly branched arragonite was formed in this part of the cavern. Some of the slender branches were 6 or 7 inches long, and pointed from the roof and sides in all directions. At one place it had grown horizontally from the side, and the points of the branches were incorporated into a mass of arragonite formed on a projecting corner; indeed the interlacing at this place resembled a tangled underwood.

There was the least arragonite formed on the east side of the cavern; that little, however, was exceedingly beautiful. In two or three small cavities in this side, the branches had grown in a slanting or horizontal direction, and touched the opposite side, where each one split into two or three flattened points, which in their direction conformed and slightly adhered to the opposing side. This phenomenon is represented in fig. 2.

At one time stalactites of considerable length hung from the roof of the cavern. From some unknown cause these had been subjected

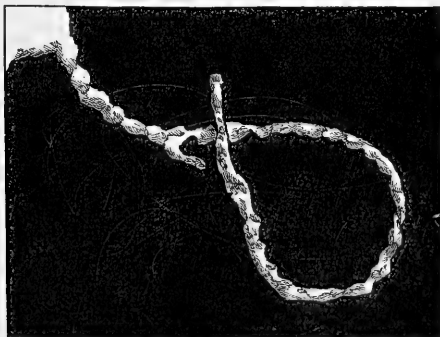
to a considerable amount of decomposition; for a great portion of them had a corroded appearance. It seemed, however, that before the decomposition commenced, the points of the stalactites had been violently broken off. Some of the corroded lime was thinly covered with a fine clay; and upon nearly the whole of it beautiful crystals of arragonite were forming, and in some places the clay was incorporated half an inch or so below the crystals. I may observe that no stalagmites were formed on the bottom of the cavern to correspond with these stalactites; or if they had once been there, they must have been entirely dissolved without leaving any trace of their existence.

Fig. 2.—*Sketch of a horizontal stem of Arragonite in the Dufton Fell Mine.*



It is scarcely necessary to point out the impossibility of stalactites being formed in a cavern filled with water. The arragonite must therefore have grown in some kind of air or gas. The fact of its crystals covering a stalactite in the course of formation with a corresponding stalagmite on the floor of the cavern sets this point entirely at rest. Indeed a glance into the cavern would have been sufficient to convince a reasonable mind that the arragonite was formed after the water was drained from the large joint.

Fig. 3.—*Sketch of a bent stem of Arragonite in the Dufton Fell Mine.*



But if the arragonite could not have been formed in water, as in the Silver Band cavern, so also in this cavern it was impossible for

water to flow over its surface to the ends of the branches of the arborescent kind pointing from the sides in all directions. In many instances the branches were bent; and in the one which is drawn full size in fig. 3 it had grown into the form of a ring—undoubtedly the result of the stem which had first shot from the side horizontally being unable to sustain its own weight. It is impossible for water to flow over the surface of such a figure to the point or end of the stem. Besides, had the water flowed over the surface like ordinary stalactites, the stems would have been thickest at the base. Nor is it possible that any of the long stems could have been knobbed. Again, in the branched varieties which hung from the roofs of the cavern there were no phenomena to warrant the conclusion that those pure white and elegant forms could result from water streaming very slowly over the surface.

We are therefore compelled to adopt the theory of a circulation, through the pores of the spar, of fluids holding its component parts in solution, as the only one which will harmonize with the varied phenomena found connected with the two caverns in which this mineral was formed in the Dufton Fell and Silver Band Mines.

In connexion with this theory there is one fact too remarkable to be passed over, which occurred in both caverns, namely, that after an *isolated* piece of arragonite was broken off the *hard* rock, a thinly spread gush of water flowed over the fractured part for a few minutes, gradually blended with the moisture on the damp sides of the cavern, and then totally disappeared. It would appear that some force attracted the water to the root or base of the arragonite; and when the connexion between the arragonite and the rock was broken the water flowed from the fracture like sap from a wounded tree.

From an examination of a great number of cases of arragonite in an inceptive state, it appeared that carbonic acid had been evaporated from the sides of the cavern, leaving a very thin deposit of lime; and that to this thin deposit the moisture is drawn or attracted to circulate through its pores, effecting the development of either the curiously rounded masses or stems. It may be asked, Why is not this mineral always found growing on the damp sides of limestone-caverns or joints? Perhaps this question cannot be satisfactorily answered at present. I have already observed that all the places where I have found arragonite were in or near veins in which the minerals deposited at a former period were undergoing decomposition. And if it be still further questioned why arragonite is not formed wherever decomposition of vein-minerals is being effected, I can only reply, that its growth may be promoted by a number of causes very delicately balanced; and I am inclined to suppose that common air and carbonic-acid gas, combined in proportions which rarely continue in nature through long periods of time, constitute an atmosphere essential. It is difficult or impossible to ascertain the exact constituent parts of this atmosphere; for the openings made by mining operations admit a purer air, or one containing a less quantity of carbonic acid. A large quantity of this gas was evidently present in the Dufton Fell cavern, for when it was first opened into the candles were with difficulty kept lighted.

Of the forces which have impelled the fluids through the pores of the spar I can give no satisfactory explanation. It is certain that both in the Silver Band and Dufton Fell caverns, the moisture oozing out of their sides contained iron, at least in solution, for the arragonite was discoloured wherever the water had slowly streamed over it. It is only when their elements combine chemically that bodies crystallize. So far, however, as arragonite is concerned, a separation of the unsuitable elements must be effected before the fluids are drawn or forced into the pores of the spar. It has been suggested to me by a friend that this separation may be effected by *osmosis*; and it is possible that the fluids may circulate in the pores by capillary attraction, and that, when these reach the surface or points of the stems, and the superfluous portion of carbonic acid evaporates, the crystallization of the lime is then effected in definite proportions with the remainder.

Such are the conditions connected with the growth of arragonite. Most of the minerals found in the lead veins traversing Mountain-limestone in the north appear to be deposited from fluids filling up and slowly circulating through the openings or interstices in the veins. Arragonite growing in an atmosphere may be considered a type of vegetation, the forms of which it more especially mimics.

3. *Notes accompanying some RHOMBOIDAL SPECIMENS of IRON-SANDSTONE, &c. presented to the Society.* By Sir J. F. W. HERSCHEL, Bart., K.C.H., F.R.S., F.G.S., &c. With a Note by Captain T. LONGWORTH DAMES.

[Communicated by Sir C. Lyell, Bart., F.R.S., F.G.S.]

(Abstract.)

Most of these specimens came from a quarry at Clanmullen, near Edenderry, King's County, and the remainder from the Collingwood Quarry, in the Weald of Kent. The Irish specimens are siliceous, containing some oxide of iron and a little manganese, and are homogeneous throughout. They all agree in the sharpness of definition and the exact parallelism and evenness of the flat surfaces; but, like those from the Weald, they are not constant in form or size, and sometimes are very irregular in angle and in the parallelism of opposite sides. The Wealden specimens, however, are all closed boxes, each containing a rhomboid of hardened sandstone, the outer case being highly ferruginous—in fact, the “Ironstone of the Weald.” Sir John Herschel endeavoured to account for the formation of the boxes, and Captain Dames added a Note stating the circumstances under which the Irish specimens occur.

MAY 10, 1865.

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

The following communications were read:—

1. *On the AZOIC and PALÆOZOIC ROCKS of SOUTHERN NEW BRUNSWICK.* By G. F. MATTHEW, Esq.

[Communicated by J. W. Dawson, LL.D., F.R.S., F.G.S., Principal of McGill University, Montreal.]

[PLATE XII.]

CONTENTS.

I. Introduction.	V. Upper Silurian.
II. Laurentian Formation (Portland series).	VI. Middle and Upper Devonian.
III. Huronian Formation (Coldbrook group).	VII. Lower Carboniferous.
IV. Lower Silurian (St. John's group).	VIII. Carboniferous.
	IX. General Remarks and Conclusions.

I. INTRODUCTION.

It is now twenty-two years since Dr. Abraham Gesner made a geological survey of this province.

The grand features recognized by him were the existence of a great interior coal-basin, flanked on either side by more elevated tracts of metamorphic and igneous rocks, and of a large Upper Silurian area, coterminous with the northern boundary of the province.

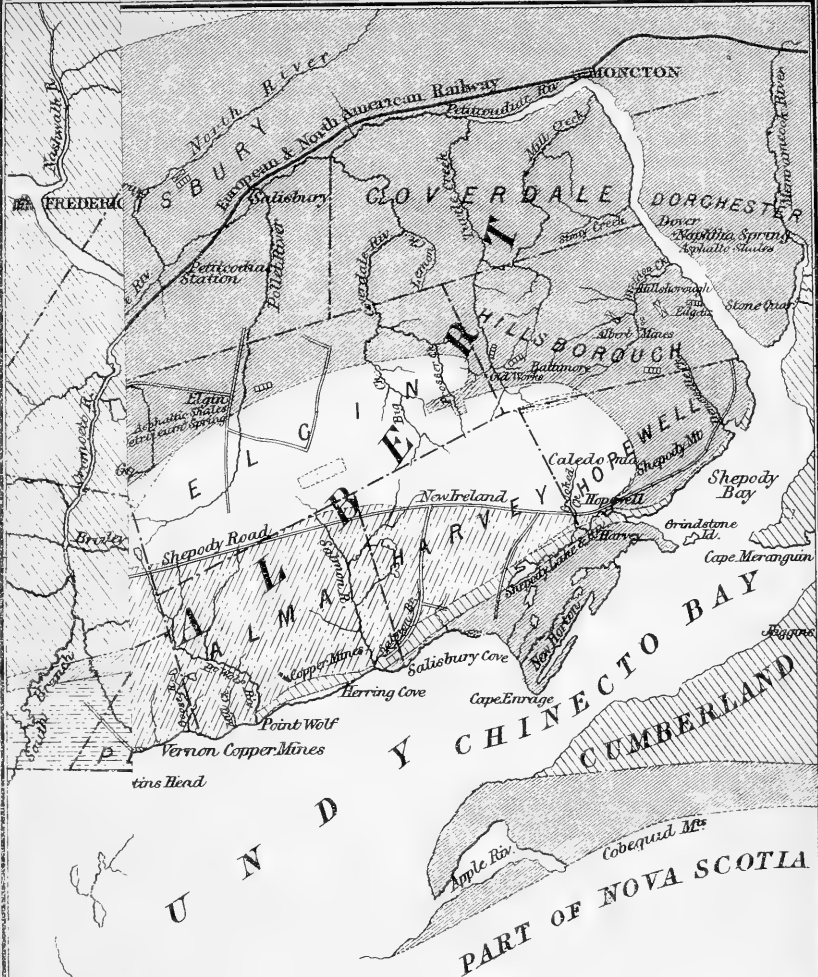
Among the later observers who have laboured in New Brunswick may be mentioned Principal Dawson, of McGill University, Montreal, Dr. James Robb, Prof. C. H. Hitchcock, late State Geologist for Maine, and Prof. L. W. Bailey, of the University of New Brunswick*.

At the time when Dr. Dawson's memoir on the Devonian Flora was written, the sediment underlying the Devonian beds had been examined only in the vicinity of the City of St. John, and, supposing that they formed a connected series, he called them the "St. John Series," without attempting to fix their precise age.

When my own paper (Observations on the Geology of St. John co., New Brunswick) was written, we had learned to distinguish the "Portland" (nos. 7 and 8 of Dawson's List) as an independent series. But although a break was suspected to exist between the St. John and Bloomsbury groups (no. 4, and nos. 5, 6, in part, of Dawson), a careful examination along the base of the latter did not reveal its occurrence. Subsequent explorations further west confirmed the suspicion, and, with the nearly simultaneous discovery of Trilobites, threw new light upon the relations of the series in which they occur; but, until the study of these organisms was undertaken by Mr. Hartt, the exact position of the series in the Lower Silurian formation was not ascertained.

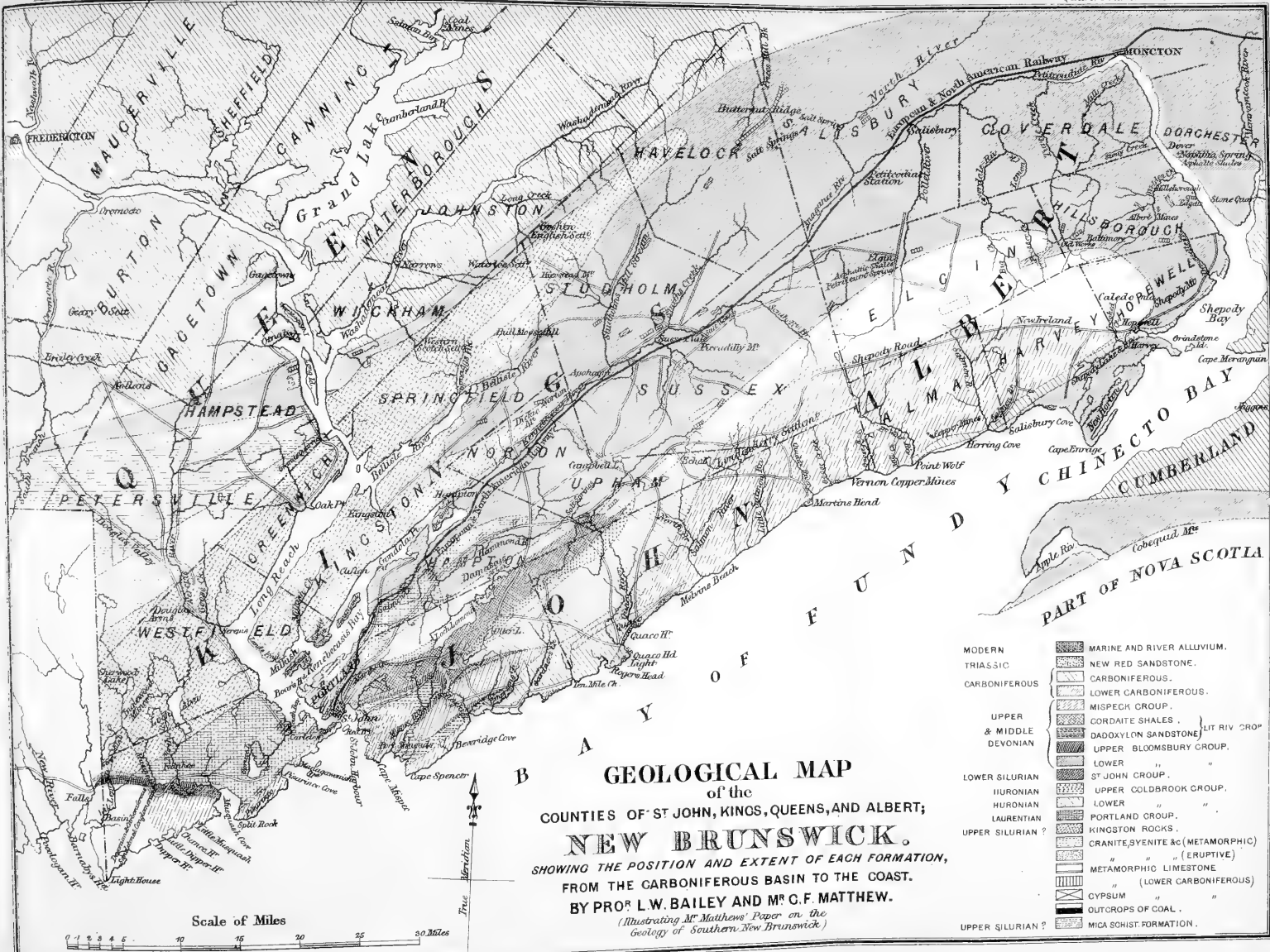
This point having been determined for the base of the upper of

* See Gesner's five Reports to the Legislature of New Brunswick; a chapter by Dr. Robb in Johnstone's Report on 'Agricultural Capabilities of New Brunswick;' Dawson's Acadian Geology and Supplement; Hitchcock's Report on the Nat. Hist. and Geol. of the State of Maine; Dawson's 'Precarboniferous Flora of New Brunswick, Maine, and Eastern Canada,' Can. Nat. 1861; Dawson's 'Flora of the Devonian Period in North-east America,' Quart. Journ. Geol. Soc. 1862; Bailey's 'Geology and Botany of New Brunswick,' Can. Nat. 1864; Dawson's 'Flora of the Carboniferous Period in Nova Scotia,' Can. Nat. 1863, &c.



MODERN		MARINE AND RIVER ALLUVIUM.
TRIASSIC		NEW RED SANDSTONE.
CARBONIFEROUS		CARBONIFEROUS.
		LOWER CARBONIFEROUS.
UPPER & MIDDLE DEVONIAN		MISPECK GROUP.
		CORDAITE SHALES.
		DADOXYLON SANDSTONE.
		UPPER BLOOMSBURY GROUP.
		LOWER " "
LOWER SILURIAN		ST JOHN GROUP.
		UPPER COLDBROOK GROUP.
HURONIAN		LOWER " "
		PORTLAND GROUP.
LAURENTIAN		KINGSTON ROCKS.
		GRANITE, SYENITE &c (METAMORPHIC)
UPPER SILURIAN ?		" " (ERUPTIVE)
		METAMORPHIC LIMESTONE
		" " (LOWER CARBONIFEROUS)
		GYPSUM " "
		OUTCROPS OF COAL.
UPPER SILURIAN ?		MICA SCHIST FORMATION

AND ALBERT;
 ICK.
 EACH FORMATION,
 THE COAST.
 TTREW.



"Diagrams & Notes," 22, "Index to 5th Geol. Card"



the two groups, a recasting of the divisions, and radical changes in the only geological map of New Brunswick published (by Dr. Robb), became necessary.

This has been effected in the Report on the Geology of the Southern Counties, by Prof. Bailey, and the Geological Map which accompanies it (see also Pl. XII.).

It is proposed now to give in the succeeding pages a summary of the more important facts ascertained respecting the Palæozoic and so-called Azoic * strata of this part of Acadia.

II. LAURENTIAN FORMATION (PORTLAND SERIES †).

The surface-area occupied by these rocks is about forty miles long and from two to eight miles wide. To the south-west they are overlain by Devonian, and in an opposite direction by Lower Carboniferous beds. They approach within half a mile of the City of St. John.

Owing to faults and overturn dips the sequence at the middle and on the north-western side of this area has not yet been made out; but the beds on the south-western side present the following succession ‡:—

1. Grey limestones and dolomites (?) of great thickness, with beds of clay-slate, occupying the middle of the peninsula which separates Kennebeckasis Bay from the Bay of Fundy.

2. A mass of syenite and protogene, probably metamorphosed sediment.

3. Grey and white limestones, and beds of syenitic gneiss.

4. Grey and reddish gneiss, conglomerate, and arenaceous shale, altered, resembling syenite and granulite.

Arenaceous shale and grey quartzite.

Dark flinty slate, with oval grains (black).

5. Graphitic shale and pyritous slate, frequently alternating with grey and white limestones and dolomites (?). The beds thinner, and alternations more frequent, towards the top.

A study of this series will probably throw much light upon the history of the Azoic rocks, which, thanks to the laborious investigations of Sir Wm. Logan and others, are now emerging from obscurity.

Nor are traces of organic life absent; for while the upper section (no. 5) abounds with an impure graphitic shale (in which fragments of Fucoids (?) have been observed), a group of arenaceous shales at Sand Point §, which resemble the strata of section 4, holds numerous worm-burrows, and gives other evidence of deposition in shallow waters.

* This term is becoming unhappy in its application to those ages which preceded Palæozoic time. *Eozoic*, as suggested by Dr. Dawson in his description of *Eozoön canadense*, would express better the opinions which begin to prevail among geologists respecting them.

† Names in parentheses are those which have been applied in the article on the Geology of St. John co., New Brunswick, mentioned in a previous note.

‡ This, like all the following tables, is in ascending order.

§ Referred to the St. John group in 'Observations on the Geology of St. John county.'

To what portion of the *Azoic* ages this series is to be referred we cannot yet say. Palæontology gives little aid in solving the question, and the composition of the felspars, &c., is not known. But that it is older than the Huronian series seems, to say the least, highly probable; for,

1. In the varied character of its deposits and the abundance of limestones, together with the extreme alteration of many of the beds, it resembles the "Laurentian" of Canada, and the Azoic region lately separated from the Silurian system in Southern New York and New Jersey *

2. It is unconformably overlain by a great thickness of deposits similar to the "Huronian" series, and subordinate to those which in this quarter represent the Potsdam period †.

III. HURONIAN FORMATION (COLDBROOK GROUP ‡).

Between the Azoic or Laurentian and the Lower Silurian sediments a thick series of beds intervenes, differing in character from both. These rocks extend in two bands, one north-east from the City of St. John, the other parallel to it, but further south, each about thirty miles long and three or four wide. They consist of—

Lower Division.

1. Coarse red conglomerate (with an abundance of quartz pebbles) and red sandy shale.

2. Dark porphyritic slates and trap, with slate, conglomerate, trap-ash, and tufa.

3. Grey and ferruginous arenaceous shale and sandstone, becoming, when altered, a laminated compact felspar or feldspathic quartzite.

4§. Pale-green (weathering grey) slate, stratification very obscure [apparently an indurated volcanic ash, *Dawson*], with slate-conglomerate, ash-beds, and tufa.

Upper Division.

5§. Red and grey conglomerate and red shale. Red and purple grit and sandstone.

Of these beds, nos. 1, 2, and 3 do not extend so far west as St. John, and no. 4 diminishes very much in bulk in the rear of the city, where it fills inequalities in the uppermost beds of the Portland series. While further west, at the head of the harbour, the remnants of this Huronian series (nos. 4, 5) are only 150 feet thick, yet at Loch Lomond, ten miles eastward, the whole formation measures vertically not less than 7000 feet!

These figures indicate that the ancient continent, previously ele-

* See 'Silliman's Journal,' 1865, p. 96.

† Further details respecting this series, and all the overlying formations found in the counties of St. John, King's, and Albert, will be given in the Report on the Geology of Southern New Brunswick, already alluded to, written and arranged by Prof. Bailey, and published by the Provincial Legislature.

‡ This and the succeeding division (St. John group) have such a variety of members, and represent so great a lapse of time, that they deserve to be called formations rather than groups.

§ These are equivalent to nos. 1, 2, 3, and 4 of the section given in 'Geology of St. John county.'

vated above the sea, sank under the accumulated weight of Huronian sediment to the extent of one mile and a half or more in that short distance, and that a coast-line near the position now occupied by the city limited the Huronian sea to the eastward during a great part of this period.

Its opening, if we may judge by the lowest number known, was marked by the accumulation of littoral sediment. To this succeeded an epoch when igneous eruptions commingled molten matter, scoria, and fragments of rock with the fine mud resulting from the wearing of the Azoic continent. After an interval of time, during which the arenaceous shales of no. 3 were formed, these conditions were again repeated in a still greater accumulation of volcanic ashes, tufa, &c., which, as the preexisting land sank beneath the waters, spread as a thin deposit further west.

The whole was eventually covered by the red and purple sediments of the Upper Division, which are more uniformly distributed, and are *conformably* surmounted by the lowermost strata of the Lower Silurian formation, thus becoming, like the Cambrian of Britain, the "basement segments of the Silurian System." And although Prof. J. D. Dana classes these fundamental rocks of the Palæozoic series as Azoic, he remarks, that "should the Huronian rocks be hereafter found to contain any fossils, they will form the first member of the Silurian."

In general characters there is a remarkably close resemblance between this formation and the Huronian of Canada, notwithstanding the wide extent of country which intervenes. Both are largely composed of erupted materials, diorites, tufas, and volcanic mud: hardness and obscurity in the lamination of the slates is a feature in common; and here, as in Canada, slate-conglomerates may be seen of a texture so compact and uniform that the enclosed masses are distinguishable only by a difference of colour. There is even a parallelism in the different members between the Acadian series and that at the Bay of Mamainse, on Lake Superior, and at Thessalon River, Lake Huron, at which latter place the whole Huronian series is supposed to be present:—thus, nos. 3, 4, 5, and 6 of the section given at pp. 55–57, 'Report Geological Survey, Canada,' 1863, indicate the prevalence at succeeding periods in the region of the great lakes of conditions similar to those which obtained in Southern New Brunswick during the formation of nos. 1, 2, 3, and 4, or the lower division of the Coldbrook; while the higher members at Thessalon River are an accumulation of sediments on a larger scale, but resembling those of the Upper Coldbrook, and the passage-beds to the Lower Silurian formation. I may also add that the passage-beds in their eastern extension are overlain by igneous rocks, which intervene between them and the Primordial shales.

Considering, therefore, the origin of these deposits as well as their position relative to the more ancient series and the Lower Silurian beds above, we have little hesitation, notwithstanding that the latter are conformable to them, in assigning these semivolcanic sediments to the "Huronian series" of Logan.

IV. LOWER SILURIAN (ST. JOHN GROUP).

In my article on the geology of St. John county allusion was made to the discovery of Trilobites in the slates of the St. John group. A collection of more perfect forms, made later in the same year, together with those collected by our party last summer, were placed in the hands of Mr. C. F. Hartt for study and determination. By means of these fossils he was enabled to fix with precision the geological horizon of the basal portion of this formation, and thus furnish a datum-line by which the underlying formations and superior sediments have been approximately co-ordinated.

A preliminary notice of these organisms will appear in Professor Bailey's report, and descriptions of the species in a paper by Mr. Hartt, which will form an appendix to the same. Of Trilobites there are four genera, namely:—*Paradoxides*, 5 species, *Conocephalites*, 7 species, *Agnostus*, 1 species, and a new genus (?) allied to *Conocephalites*, 1 species. There are also six species of Brachiopoda, of the genera *Orthisina*, *Discina*, *Obolella* and *Lingula*. Mr. Hartt remarks that all these species are apparently new.

Geographically the St. John series or formation occupies a narrow valley, about thirty miles long and four miles wide, having Azoic and Huronian rocks on the north-west, and limited on the south-west by Huronian and Devonian ridges, with a spur passing into a valley which separates the former from the latter series.

By the following section it will be seen that but a small part of this formation is yet known to be of Primordial age:—

	feet.	feet.
1. <i>a.</i> Grey sandstone or quartzite.....	50	
<i>b.</i> Coarse grey arenaceous shale.		
[This and the preceding are passage-beds from the Coldbrook or Huronian group.]		
<i>c.</i> Grey argillaceous shale, rich in fossils: <i>Paradoxides</i> , <i>Orthisina</i> (?), <i>Conocephalites</i> , <i>Obolella</i> .	150	
<i>d.</i> Black carbonaceous shale, full of fossils: <i>Paradoxides</i> , <i>Conocephalites</i> , <i>Orthisina</i> , <i>Discina</i> , <i>Orthoceras</i> , and a thin, subtriangular shell resembling <i>Theca</i> , all much distorted		200
2. <i>a.</i> Dark-grey shales, with thin seams of grey sandstone..	220	
<i>b.</i> Coarser grey shales, with grey flagstones	200	550
<i>c.</i> Grey sandstone and coarse shales: <i>Lingula</i> , &c.	130	
3. <i>a.</i> Dark-grey shales, finely laminated	450	
<i>b.</i> Black carbonaceous and dark-grey argillaceous shales, more compact than the last	300	750
4. Shales and flags resembling 2 <i>a</i> & <i>b</i>		800 (?)
5. Black carbonaceous shales, resembling 3 <i>b</i> , but finer and softer		450
6. <i>a.</i> Shales and flags like 2 <i>a</i> & <i>b</i> : <i>Lingula</i> , a Conchifer, Coproliques, Worm-burrows, and Crustacean markings	700 (?)	
<i>b.</i> Grey and ferruginous sandstones and beds of coarse shale: <i>Lingula</i>	400	1100 (?)
7. Black carbonaceous shales, finely laminated		650
		4500

[N.B. The thickness of 4 & 6 *a* is apparently much greater than this; but it is supposed that the beds are repeated by folding. This may also be the case with some of the other divisions.]

The Primordial forms of no. 1 have been met with at a number of localities within the area covered by this formation, but always near its base; and they show that this portion of the formation is equivalent to the Potsdam of New York, the Olenellus-shales of Vermont, and those schistose beds which at Braintree (Massachusetts) hold *Paradoxides Harlani*, and in Newfoundland contain *P. Bennetii* and a *Conocephalites*; while the cotemporary deposits in Europe would be the Lingula-flags of Britain, the alum-schists of Scandinavia, and "Étage C" of Barrande in Bohemia.

While there is therefore no longer doubt regarding the age of the fundamental part of this Lower Silurian series, a degree of uncertainty still hangs around those slates and flags which form its principal mass.

That a portion of it is equivalent to the Calciferous (with perhaps the Chazy) formation of the west seems highly probable. But the series differs both from it and the Quebec group in lithological characters, approaching more nearly the cotemporaneous deposits of Europe.

The old coast-line of the Huronian period in this quarter left its impression upon that which succeeded. For, while deposits of great thickness are found at St. John and a few miles to the eastward, the series is much attenuated west of that city. In the easterly exposures of the formation it also decreases in bulk, and the sediments become finer.

In appearance they present a marked contrast with those of the formation on which they rest. Coarse fragmental beds and volcanic products are common in the latter; but among the former no conglomerate nor even a grit has been detected, or any evidence of synchronous igneous action.

Two wide belts of slate, admitted by all observers to be of great antiquity, traverse the central portion of the province, and represent a mining region of some importance. They were denominated "Cambrian" both by Dr. Gesner and Dr. Robb. But as this term is now by some restricted to a series of deposits, which Sir R. I. Murchison and others consider equal to the Huronian of Canada, if we limit the base of the Silurian by the Potsdam formation, it will not be sufficiently accurate, provided they prove (as we suppose they will) to be of the latter age. They do not assimilate in appearance to the known Acadian representative of the Cambrian or Huronian, namely, the Coldbrook formation; but they *do* resemble the St. John or Lower Silurian.

The more southerly of the two slate districts in question extends through the counties of York and Charlotte into the State of Maine, coming out upon the Atlantic at Columbia (Hitchcock). A provincial collection in the University Museum of the rocks in this quarter closely resembles those of the Lower Silurian slates of St. John, and differs essentially from the Upper Silurian and Devonian deposits which have been recognized in this region*; and since the

* The greater width of these slates is no objection to their being equivalent with those of St. John, since Professor Hitchcock states that they are folded on fine synclinal and anticlinal axes along the St. Croix river.

base of the St. John series is known to be on the horizon of the Potsdam, while the middle and superior portion probably represents the Calciferous or the Llandeilo of Britain (and perhaps higher formations), it does not seem likely that Professor C. H. Hitchcock's surmise will be substantiated. He says, "It would not be strange if the name Cambrian, which was applied to both these belts of mica-schist in New Brunswick many years ago, and is now generally discarded, should ultimately prove to be their correct appellation."

In the alternations of arenaceous and dark-coloured clay-slate with intercalated quartzite, this formation, which is also auriferous, resembles the gold-bearing series of the Atlantic coast of Nova Scotia, long ago recognized as Lower Silurian by Dr. Dawson*. If both prove to be on the same horizon geologically as the St. John series, namely, the lower part of the Lower Silurian, our knowledge of the age and relations of the older metamorphic rocks of Acadia will be placed on a firmer basis than heretofore.

So far as our knowledge goes, they differ from cotemporaneous deposits to the westward in being conformable to the Huronian series; and also in the rarity of calcareous and magnesian sediments, there seeming to be little else than shales of various degrees of fineness, flagstones, and quartzites.

V. UPPER SILURIAN.

The strata noticed under this head may prove to be in part either above or below the horizon I now place them in; for they are for the most part highly metamorphosed, and organic remains are rare.

They cover an area of about seventy miles long and twenty wide, stretching north-eastwardly from Passamaquoddy Bay, and including the highest eminences in the southern counties.

The evidence bearing upon their age may be summed up as follows:—

1st. Dr. Dawson, to whom a suite of the metamorphic rocks was submitted, remarks—

"In comparing them with Nova Scotia I have no hesitation in saying that they are unlike our Atlantic-coast series, which I believe to be Lower Silurian; but they are very like the rocks of the Cobequid Mountains, and of the inland hills of east Nova Scotia, which I believe to be Middle and Upper Silurian."

2nd. There is a district in the south-east part of Maine, about twenty miles wide, occupied by Upper Silurian rocks, which extend through the islands of Passamaquoddy Bay into New Brunswick.

3rd. Fragments of shale occur in the "drift" at St. John, holding *Chonetes*, *Pterinea* or *Avicula*, *Clidophorus*, *Orthis*, *Rhynchonella*?, *Leptodomus*?, &c., which appear to have been derived from a band of grey shales on the north-west side of the supposed Upper Silurian district.

It would thus appear that the highest and most broken tracts in this and the neighbouring province are composed of the metamorphic

* See also 'Can. Nat.' vol. v. p. 134.

rocks of this age, such as the Nepisequit region, Ncrepis Hills, Cobequid Mountains, the inland hills of east Nova Scotia, northern Cape Breton, &c.

Of the Nova Scotian equivalents of this series Dr. Dawson remarks—

“We can recognize among the partially metamorphosed sub-carboniferous rocks of Nova Scotia formations ranging from the Middle Silurian to the Lower Devonian inclusive, but of a more argillaceous and less calcareous character than the series occupying this position in the mainland of America.”

Such is the character also in southern New Brunswick, the only limestones known being those of Lubec and their apparent continuation at L'Etang, New Brunswick. In the northern part of this province, as in northern Maine (where Lower Devonian strata occur), the series is more calcareous, and fossiliferous limestones are frequently met with.

In this region Prof. Hitchcock found the Upper Devonian series reposing upon it unconformably at a number of places. A similar break seems to be indicated at St. John, where Middle and Upper Devonian rest directly upon the Lower Silurian, without the interposition of the Middle and Upper Silurian, although semi-metamorphic beds, which I am disposed to refer to this age, occur in force only six miles north-west.

VI. MIDDLE AND UPPER DEVONIAN.

(Bloomsbury group—No. 4 of Dawson's list.)
 (Little River „ —Nos. 2 & 3 „)
 (Mispeck „ —No. 1 „)

This series has undergone a more critical examination than any of the preceding, owing to the exceedingly rich Devonian flora which appertains to it, described in Dr. Dawson's article in the 'Quarterly Journal of the Geological Society,' Nov. 1862. Its more general characters being so well delineated in that paper, and details being given in my own, it is only necessary to add a few general remarks upon its extension to the north-east and south-west. In the former direction the lower group and the inferior members of the Little River group diminish in volume; but the higher portion is largely expanded, and, in the form of a metalliferous series of altered rocks, occupies a great part of the hilly district towards the head of the Bay of Fundy. Westward of the City of St. John, in the county of the same name, Devonian rocks cover much of the surface, and, by means of several detached areas in the county of Charlotte, examined by Professor Bailey, are connected with the well-known plant-beds of Perry, Maine. In this direction they rest unconformably, first, upon *Laurentian* and then on *Upper Silurian* strata.

On mature consideration of the affinities of the plants which they yield, and which were collected from a few hundred feet of strata at the junction of the two members into which the Little River group is divided, Principal Dawson has expressed the opinion that the

plant-remains combined the features of the Hamilton and Portage groups of New York. In this case the Middle as well as Upper Devonian should be represented at St. John, seeing that there are 5000 feet of Devonian sediment beneath the plant-beds.

Besides the area along the north shore of the Bay of Fundy, over which this series extends, another is reported by Professor Hitchcock in northern Maine, but the series has not yet been met with in the neighbouring province.

The metalliferous strata of this age in New Brunswick are largely charged with ores of copper, which occur not only in veins, but in fahlbands. One of these (at Black River) holds also the remains of Devonian vegetation, which, as Dr. T. Sterry-Hunt suggests respecting the origin of similar deposits in the Quebec group, may have given rise to the metalliferous layers by causing the decomposition of metallic salts held in solution.

If the lower members of this series at St. John are equivalent to the Middle Devonian, the phenomena attendant upon their deposition are in strong contrast with those which prevailed in the middle States and North-east Canada during the same period. As we rise in the series, however, a greater resemblance is established, and at the summit sediments are found closely resembling the deposits to the west and north.

Prior to its formation great changes had occurred in the condition and relative positions of the older series. For the Devonian rocks are found to repose successively upon Lower Silurian, Huronian, Laurentian, and Upper Silurian formations, westward of St. John, showing that these had been uplifted and folded, and had to a certain extent assumed the geographical parallelism which they now present, previously to the existence of the first-named series.

Nevertheless, wherever these younger deposits are voluminous or widely spread, they are involved in the grand folds impressed upon all the formations which are of earlier date than the Lower Carboniferous. The Devonian and the older formations are distinguished from those which succeed by a semi-metamorphism which has expelled from all deposits preceding those of the Carboniferous age that bituminous matter with which many of them were once charged. I am therefore disposed to think that these Middle and Upper Devonian deposits witnessed many of those changes which accompanied the grand period of upheavals in North-east America, and that the close of the age is in Acadia a limit as strongly marked, so far as physical features are concerned, as that which divides the Azoic from Palæozoic formations, or the New Red Sandstone from the Post-tertiary.

VII. LOWER CARBONIFEROUS.

In southern New Brunswick this formation covers a large extent of surface in King's, Albert, and Westmoreland counties (100 miles in length, and of very varied width). From this quarter it extends in a narrow margin around the southern and north-western sides of the great coal-field, being at one point within twenty miles of

the United States frontier. And in another (south-east) direction a belt of Lower Carboniferous deposits, bending around the metamorphic hills of the coast, passes beneath the waters of the Bay of Fundy, being connected, however, with the western termination of the larger area in Kennebeckasis Bay by isolated patches along the shores of the Bay of Fundy.

The lowest members of the formation, which I have examined, are thin beds of conglomerate and bituminous limestone, gypsiferous beds, and heavy masses of grey limestone. In connexion with these there are grey shales towards the western part of the Kennebeckasis valley, which may represent the Albert shales (pyroschists) placed by Dr. Dawson at the base of the series in Albert county. Rich deposits of manganese occur at the summit of this portion of the series.

Heavy beds of coarse conglomerate ("Kennebeckasis conglomerate") overlie the limestones, and, with the associated brownish-red sandstones and shales, form conspicuous ridges in various parts of the valley and along the coast. Limestones appear in connexion with this part of the series; but whether they are a portion of the older beds brought up by a fault, or are of later origin, has not been ascertained.

According to the observations of Messrs. Bailey and Hartt, the grey flags and shales, observed by myself and others on the lower courses of the Kennebeckasis, extend through Sussex, Elgin, and Dover, nearly to the Gulf of St. Lawrence, having associated with it a mass of pyroschists similar to those of the Albert Mines, and yielding *Lepidodendron corrugatum*, *Cyclopteris Acadica*, and other Lower Carboniferous forms. This group, so far as I can judge from the imperfect data in my possession, is at or near the summit of the series.

The Lower Carboniferous rocks which underlie the western part of the great coal-field, and crop out along its margin, present features somewhat different from those of the district just sketched. This difference consists in the addition of claystones, amygdaloids, tufas, and trap-beds, resulting from igneous eruptions, the (apparent) absence of bituminous shales, and the diminution of coarse fragmental deposits*.

The history of this epoch, as shown by the deposits to which reference has been made, appears to have opened with a period of comparative quiescence, during which extensive limestone beds and gypsiferous strata were laid down in the southern part of the province. The later part of this period, during which the coarse and massive conglomerates of the Kennebeckasis were accumulated, was marked by greater disturbances and the abrasion of the great folds into which the Præ-carboniferous formations had been thrown, and was also accompanied by extensive and long-continued igneous outbursts in the more central districts. To the time of this or a similar disturbance may be attributed the auriferous Lower Carboniferous drift of Gay's River, Nova Scotia, observed by Mr. Hartt†—a discovery of some interest.

* Dr. Jas. Robb and Prof. L. W. Bailey. † See Can. Nat. 1864, p. 459.

The shales and sandstones formed at the close of the epoch approximate in appearance to those of the Coal-measures, but are not known to extend beneath the great coal-field.

VIII. CARBONIFEROUS.

Grey sandstones and shales of various shades, from grey to black, are spread in nearly horizontal layers over the central and eastern parts of New Brunswick. Coarse red shales and grits are found resting upon the sandstones at Grand Lake and elsewhere.

After an examination of plants from various parts of this extensive basin, Dr. Dawson remarks, "In this coal-basin there is a mixture of the floras of several different horizons, possibly due to the comparatively small thickness of the Carboniferous beds." The plant-remains he believes to be on the horizon of the "middle Coal-formation, though tending to the upper." His view regarding the thinness of these measures seems to be corroborated by the presence, towards the central and eastern part of the basin, of *low islands* of Silurian and Devonian strata, projecting through the horizontal sandstones of this series.

Professor Bailey's observations on the southern border of this basin, at Hampstead, would seem to indicate that a want of conformity to the extent of about 15 degrees may be found to exist between the Coal-measures and the Lower Carboniferous formation.

South and east of the large area covered by this latter series, the Coal-measures again appear in Westmoreland county ("North Joggins"), and extend in a narrow interrupted belt along the north shore of the Bay of Fundy, where a flora similar to that of the Millstone-grit is present*. In this quarter they suffered extreme dislocation at some period prior to the Trias†.

IX. GENERAL REMARKS AND CONCLUSIONS.

From the preceding observations and the publications to which reference has been made, we may gather that nearly all the principal Palæozoic formations have now been recognized in Acadia. Thus the Huronian exists in St. John county, New Brunswick.

Lower part of	}	St. John county, New Brunswick (Hartt.)
Lower Silurian		Central New Brunswick.
"	"	Atlantic coast, Nova Scotia (Dawson).
Middle Silurian	"	Central and North-eastern Nova Scotia (Dawson).
"	"	? Southern New Brunswick.
Upper Silurian	"	Northern New Brunswick (Henwood and
"	"	Southern New Brunswick. [Gesner).
"	"	Northern and North-eastern Maine (Hitchcock).
"	"	North-eastern Central, Nova Scotia (Dawson).
Lower Devonian	"	Northern Maine (Jackson and Hitchcock).
"	"	N. Central Nova Scotia (Dawson).

* See Report, page 94.

† Page 94 *et seq.*

Middle Devonian	„	Southern New Brunswick (Dawson).
„	„	? Northern Maine (Hitchcock).
Upper Devonian	„	Southern New Brunswick (Dawson).
„	„	South-eastern Maine (Jackson and Rogers).
„	„	Northern Maine (Hitchcock).
Lower Carboniferous		widespread in Nova Scotia and New Brunswick (Lyell, Dawson, &c.).
Carboniferous	„	with the last (Lyell, Dawson, &c.).

Thus the only important hiatus now remaining is that wherein the Trenton limestones and Hudson-river shales should appear. As great physical changes occurred along the line of the Appalachian chain at the close of the latter period, these formations, if they exist in Acadia, will probably be found to form a part of the Lower Silurian already known, possibly the upper beds of the St. John shales or of their equivalent.

It is now a well-established fact that throughout Palæozoic time the centre of the North American continent was comparatively stable, the whole series of formations being found in continuous and conformable succession from the base of the Silurian to the summit of the Permian. To the northward the Huronian series had been uptilted before the Potsdam period. In Acadia, however, the Primordial shales appear to overlie the Huronian without any appreciable discordance between the two.

Throughout New England and on the borders of Canada East, disturbances occurred at the close of the Lower Silurian age: they appear to have affected all Acadia as well. Dr. Dawson suspects the existence of a break at this point in the continuity of the Silurian sediment of Nova Scotia, and the same also seems to be indicated in the rocks of southern New Brunswick.

At the junction of the Upper Silurian and Lower Devonian with the higher portion of the latter system, another discordance appears in northern and south-eastern Maine (Hitchcock) and southern New Brunswick.

But the broadest and most strongly marked line of division in this region, as already stated, is that which separates the Lower Carboniferous from the underlying formation.

There are thus three breaks and possibly a fourth (between the two sections of the Carboniferous system) in the Palæozoic chain noticeable in Acadia. But while this country has been the theatre of great physical disturbances and heavy accumulations of sediment during those long ages in many parts of it, yet as the strata have to a great extent been exempt from extreme metamorphism, their study will not only add many interesting facts to those already known, but is calculated to throw much light upon the geology of that region.

NOTE.—Since writing the above I have seen a collection of fossils lately discovered at a locality within the limits of the district noticed under the head of “Upper Silurian;” they tend to confirm the views herein expressed regarding the age of the series thus designated.

The genera are *Dalmania*, *Phacops*, *Orthoceras* (2 species), *Murchisonia* (2 species), *Loxonema*, *Holopea* (?), *Lucina* (?) or *Anatina* (?), *Avicula* (?), *Leptodomus* (?), *Spirifer*, *Chonetes* (?), *Atrypa*, *Rhynchonella* (?), *Retzia* (?), *Strophomena*, *Orthis*, *Discina*, *Favosites*, *Zaphrentis* (2 species), *Syringopora* (?), and other corals. The material at hand is limited, and many of the shells are much distorted. Joints of an Eocrinite with a smooth column are common.

2. RESULTS of GEOLOGICAL OBSERVATIONS in BADEN and FRANCONIA.

By Dr. F. SANDBERGER, For. Corr. G.S., Professor at the University of Würzburg.

[Communicated and translated by W. J. Hamilton, Esq., F.R.S.,
Pres.G.S., &c.]

Introduction.—The great interest which the Geological Society of London has for many years taken in my labours renders it imperative on me to make known to them, from time to time, those results of my observations which have any claim to general importance. I therefore propose, in the following pages, to communicate as briefly as possible the more important results of the study of the Palæozoic, Triassic, and Jurassic beds in Baden and Franconia, which I have recently made, both at Karlsruhe and at Würzburg.

Palæozoic beds.—In 1856 I ascertained that the so-called Transition formation in the southern portion of the Black Forest did not deserve this name; but that from its containing *Calamites radiatus*, Brongn., *C. transitionis*, Göpp., *Sagenaria Veltheimiana*, Göpp., and other typical plants, it should be considered as Lower Carboniferous (Culm). This conclusion has been recently confirmed to its full extent by Schimper's beautiful monograph on the extension of these beds into the Vosges ('Le terrain de transition des Vosges,' Strasbourg, 1862), founded chiefly on a comparison with the Baden specimens which I had communicated to him. The Transition formation in the Black Forest is therefore only represented by black unfossiliferous slates in the south, and by green slates alternating with red limestone in the northern portion of the mountains near Baden, the precise geological age of which cannot for the present be ascertained.

The next division of the Coal-formation, in ascending order, is the deposit of Berghaupten, near Offenbourg, which also occurs in Alsace; it contains, together with some forms of the lower division, a large proportion of such as are peculiarly connected with the Flora of the principal Coal-formation. I hope that Schimper will also give us a monograph of these beds. I have carefully examined, for the Baden Government, the detached deposits of the Upper Coal-ormations which occur near Baden, Oppenau, Hinterohlsberg, and Geroldseck, and have published an account of them in two works which I have recently forwarded to the Society, namely, 'Geological Description of the neighbourhood of Baden,' 1861, and 'Geological Description of the Smoke-baths (Rauch-Bäder), with the Geological Maps' (1 : 50,000).

Whilst in Baden we find *Sigillaria* and other coal-producing plants, accompanied by very thin beds of coal, the floras of the other places contain no *Sigillaria*, no *Lepidodendron*, and no beds of coal; but, on the other hand, besides the well-known species of the true Coal-formation (*Neuropteris Loshii*, *Sphenopteris irregularis*, *Annularia longifolia*, *Cyathites Miltoni*, &c.), we find some new species of great interest, namely, at Oppenau, a *Pterophyllum* (*P. Blechnoides*, Sand.), three feet long, and at Geroldseck a Palm, which is closely allied to the living genera *Trithrinax* and *Carludovica* of tropical America. The great *Pterophyllum* is a new proof of the close connexion between the Triassic and Palæozoic Floras, to which may properly be added the discovery of a true *Schizopteris* in our Letten-coal, near Würzburg*. I have frequently had occasion to observe that this connexion is perceptible in the Triassic Fauna to a much greater extent than has hitherto been supposed.

The New Red Sandstone (Rothliegende) of the Black Forest has also been fully described in all its details in the two memoirs above mentioned. I divide it into three series (étages), as follows:—

1. Lower beds: granitic or gneiss-conglomerate, without pebbles of quartz or porphyry, but, on the other hand, with intermediate layers of black, green, or red clays (*Estheria tenella*, *Ganychonyx*?, *Odontopteris obtusiloba*, *Cordaites Ottonis*, and *C. Rösslerianus*, &c.).

2. Porphyry, breccia, and conglomerate.

3. Granitic or gneiss-conglomerate, with nests or beds of brown dolomite, and deep red Cargneule (Karneol).

On the borders of the middle and upper series I have also found, after many years' search, fossil plants near Baden Baden—*Walchia piniformis* and *Odontopteris obtusiloba*. From these observations we may conclude, that in the Black Forest only the lower member of the Permian or Zechstein formation occurs, whilst near Heidelberg higher members are also developed.

Trias.—I had for many years, both in Carlsruhe and in other places, explored the Swabian development of the Trias, so accurately represented in Alberti's excellent monographs, and particularly in the last †; and I had made many detailed sections, when I was compelled to remove to Würzburg. Here I came upon the widely different Thüringer type, which, as far as I am now able to judge, completely thins out in the lower Tauber valley. I do not know anywhere in Germany a richer and more perfect development of the Wellenkalk, the Muschelkalk, and the Letten-coal group than in Franconia. Moreover, the great clearness of the stratification leaves no doubt respecting the sequence both of the beds and the faunas. I have thus been enabled in a short time to complete a comparison of the Thüringian and Swabian types by my observations near Würzburg, which the Society will shortly receive.

The most important result is the discovery of the Fauna of Reo-caro and Mickelschütz in the middle Wellenkalk, the true position

* I have given a description and engraving of the plants in a notice of them already forwarded to the Society (1864).

† Sketch of the Trias of Stuttgart, 1864.

of which has recently been worked out in Silesia by M. Eck*. Now, as the rocks of the Alpine so-called Muschelkalk (Guttensteiner Kalk of the Austrian geologists, and particularly Virgloria Kalk of Richthofen) entirely agree with our Wellenkalk, this rock ought henceforth to be called Wellenkalk; and no representative of the true (upper) Muschelkalk has hitherto been observed in the Alps. I will not at present allude any further to the Flora of the Trias, which is developed in Franconia with greater richness than anywhere else, because my colleague, Professor Schenk, is about to publish two works on the subject, accompanied by excellent illustrations, one of which will give the Flora of the Keuper, which, near Würzburg, contains about thirty species, the other, that of the Bone-bed (Rhætic formation), from all the materials to be found in Bavaria, with 25 plates.

Jura.—During the last few years my studies in Baden were particularly directed to the Middle Jura, which, at the western extremity of the Black Forest, belongs entirely to the Swiss-Burgundian type. This latter formation has been but slightly studied in Germany, and it could only be superficially alluded to in the valuable work of my friend Oppel. I have followed up all the beds, from the brown Oolite with *Ammonites Humphriesianus*, Sow., to the uppermost limit of the Cornbrash, in Breisgau, with great detail, and have found the following order of superposition:—

- | | |
|--|-------------------|
| I. Fine-grained white Oolite, with <i>Ostrea acuminata</i>
and <i>Echinobrissus Renggeri</i> | Feet.
450–500. |
| II. Hard limestone, with oolitic masses, in which <i>Nerinea Bruckneri</i> is inclosed | 8. |
| III. Marly oolite, argillaceous at the base, with <i>Ammonites Parkinsoni</i> , <i>A. ferrugineus</i> , Opp., <i>Hybochypus gibberulus</i> | ca. 10. |
| IV. Cornbrash, ash-grey and yellow decomposing marl, without oolitic grains | ca. 40. |

The bed No. I. was formerly considered identical with the English "Great Oolite." I disproved this in 1857, by finding *Ammonites Parkinsoni* in bed No. III. whereas in England it always underlies the Great Oolite. On the whole, I have now found forty-seven species in No. I., of which thirteen had hitherto been referred exclusively to the Inferior Oolite (zones of *Ammonites Humphriesianus* and *A. Parkinsoni*), fourteen in these and in the Bath group (Forest Marble, Great Oolite, and Cornbrash), and sixteen only in the Bath group. To the latter belong the very common *Terebratula intermedia*, Sow., *Avicula echinata*, Sow., *Apiocrinus elegans*, &c. The Faunas of the Inferior Oolite and of the Bath group are by no means so sharply separated as has been hitherto assumed, and in the Swiss-Burgundian Jura-formation the horizon of *Ammonites Parkinsoni* acquires a development and extent of stratification such as never

* *Rhynchonella decurtata*, Gur., *Spiriferina fragilis*, Schloth., *Sp. hirsuta*, Alb., *Waldhemia angusta*, Schloth., and *Pentacrinus dubius*, Goldf. are characteristic forms.

occurs in Swabia. I can already add, founded on the friendly communication of MM. Oppel and Schlumberger, that the White Oolite occurs near Nancy under identical conditions, and contains there also *A. Parkinsoni* together with the other forms which I have mentioned above. The Nerinæa-bed has also been traced by Oppel and myself as far as the Bernese Jura. The bed No. III. is well developed in the neighbourhood of Basle and Aargau; it contains a large proportion of the Gasteropods (*Pleurotomaria ornata*, Sow., *P. conoidea*, Desh., *P. Sauzeana*, D'Orb, &c.), which, in the neighbourhood of Bayeux, accompany *Ammonites Parkinsoni*, and will hereafter undoubtedly prove of great importance in instituting a special comparison with France.

The Cornbrash, containing sixty-four species of fossils, a number which no doubt will be increased, is the same as the English.

3. *On the CHANGES rendered necessary in the GEOLOGICAL MAP OF SOUTH AFRICA by recent Discoveries of FOSSILS.* By R. N. RUBIDGE, M.B. Lond., F.G.S.

IT may be necessary to remind those not specially interested in the geology of the Cape of Good Hope, that in a paper read to this Society in 1854, on the metallic deposits of Namaqualand*, I pointed out a peculiarity in the relation of the quartzose sandstones with the gneiss of that district—namely, the occurrence of horizontal beds of sandstone resting on the upturned edges of gneiss, and continuous with inclined sandstone, of like kind, interstratified with the gneiss.

In 1857† I gave reasons for thinking that this relation of the quartzose sandstones existed on a much greater scale in other parts of the Colony, and that it had misled geologists; that, for instance, the separation of the schists of the Bokkeveldt from the Clay-slate formation was an error of this kind.

The section published in 1856 in the Society's Transactions ‡ I believe, from personal observation, to be nearly correct. The quartzose sandstones of Table Mountain rest unconformably on the edges of the slates and granites, which are generally believed to be of the same age as the above-mentioned gneiss, as they do at Cape Town and at Bain's Kloof; but at this place, Mitchell's Pass (or rather in the last range through which the pass winds), the sandstone is found highly inclined, and passing under the Bokkeveldt schists, which rest on it.

On account of this relation, the schists were supposed to be much newer than the clay-slate. Their fossil contents seeming to Mr. Bain to be Upper Silurian, he called the sandstones "Lower Silurian," and the rocks of the Cape district "Primary Clay-slate."

In the paper mentioned I gave some reasons for doubting this conclusion, while admitting the facts from which it was drawn. I thought it probable that the clay-slate and the Bokkeveldt schists belonged to one formation, and that the Carboniferous rocks of the

* Quart. Journ. Geol. Soc. vol. xii. p. 239.

† *Ibid.* vol. xv. p. 194.

‡ Second Series, vol. vii. pt 4, pl. 21. fig. 1.

Eastern Province were not separable from the clay-slate. It would follow from this that the horizontal quartzite resting on the edges of the clay-slate, must, if the latter proved to be Devonian, be much more recent; and, in an article in a local Magazine*, I conjectured that it might turn out to be an outlying mass of the Dicynodon-formation.

All these conjectures, the verification of which would involve a complete change in the Palæozoic geology of all but a small portion of the Colony, were founded mainly on the belief in the extensive prevalence of the relation mentioned, due, as I thought, to a metamorphosis of rocks of widely different ages into masses of the same character.

Acting on this faith, I commenced to search, and I stimulated others to search, for the evidence which has now established the truth of most of my conjectures, and rendered them all so far probable that they may be fairly assumed as true until disproved. I will very briefly lay this evidence before the Society.

1. In the Map published by this Society ten years ago† the "Primitive Clay-slate," separated from the Devonian schists ("Upper Silurian" of the Map), as shown in the section (pl. 21, fig. 1.), extends eastward to near Gamtoos River. To prove the Devonian character of these schists, I have the fossils that were sent to England some years ago from St. Francis Bay; also specimens of *Orthis* and *Spirifer* from Humansdorp, and some *Encrinites* from near Kropme River, all pronounced Devonian by Mr. Salter and other competent authorities. And Mr. Thomas Bain writes me that he has found *Orthis palmata*, the *Spirifers* and *Strophomenas*, and some of the *Trilobites* of the Bokkeveldt rocks in the schists near the Knysna, about eighteen miles from the granite, where they dip at an angle of 80°. The specimen of *Knorria* now exhibited was found by Dr. White in the clay-slate of Zwellendam; and Mr. Fairbridge tells me that a *Trilobite*, which he believes to be *Homalonotus*, was found at the Buffeljagts River, near Riversdale. Now Lichtenstein, Bain, Krauss, and Wilie all agree in making the Cape Town slate and that of Zwellendam and the Knysna belong to one formation; and the gneiss of Namaqualand is considered by them to be a metamorphic condition of the same rock. Having then proved the Devonian character of a large part of this formation, it is clear that we must colour as "Devonian" that portion of the clay-slate which extends as far west as Zwellendam, and that there is no reason to doubt that the rest of the old rocks, including the gneiss, are of the same age.

2. I believed the "Carboniferous rocks" of preceding geologists to be Devonian, because they have the same relation to the quartzite as some of those just described; and I had clear evidence that they had undergone the siliceous metamorphosis. The discovery of Devonian fossils in immense numbers (and among them several new genera and species), at Winterhoek, Uitenhage, Chatty, Olifantshoek, and Port Francis, has established this beyond a doubt. The

* Eastern Province Monthly Mag. vol. ii. 1857.

† Trans. Geol. Soc. (2nd ser.) vol. vii. pt. 4, p. 20.

interval of country left doubtful between the Devonian ("Upper Silurian") and the "Carboniferous" by Mr. Bain may, by the discovery of fossils at Willowmore and Antoniesberg, be safely referred to the same formation.

3. It follows that, having proved the clay-slate to be Devonian, the sandstone which rests unconformably on it must be something considerably newer; and I had a suspicion that it might represent altered conditions of the great lake-formation of the interior, in which the *Dicynodon* and his numerous congeners lie fossilized. Mr. Salter tells me that a Calamite which was found at Riquetberg, and kindly sent to me by Mr. Layard, proves the Table-Mountain sandstones, in which it occurred, to be not older than the Carboniferous epoch. It is very much like some of the same genus that I found near the Orange River in the *Dicynodon*-rocks.

4. I did not see any reason for placing any rocks between the Devonian and the *Dicynodon*-rocks. I have found the same kind of stems as those which occur in the Devonian rocks near Salem, at Wolve Kraal and at Pickel Vontein, in Ecça Pass, and at the Vander Merwes River, in inclined rocks not far from the almost horizontal *Dicynodon*-strata, which appeared to be unconformable to them. I am not, however, quite so certain of this correction as of the others. I am safe, I think, in saying that the evidence for any intermediate strata is not satisfactory.

By making the corrections here pointed out as necessary, it will be seen that, in the Map published by the Society ten years ago, only that portion of the Palæozoic rocks coloured "Upper Silurian" (since called "Devonian," on the authority of Messrs. Sharpe and Salter) rests where it did. I laid before the British Association at Bath the evidence, in a condensed form, on which these changes are made, in hope that the proof of work done would draw the attention of geologists to a matter which I conceive to be of infinitely more interest,—namely, the principle which led me to predict so many years ago the changes I have since made. I will not go into the evidence of this principle; it may be found elsewhere by those who would seek it*. Suffice to say here, that the quartzose sandstones, of which the Zeurbergen and other great ranges are formed, are regarded by all geologists who have examined them as interstratified with the Devonian rocks, which they cross at such angles that a section of ten miles across the strike may be all schists at one place, and at another ten miles distant all quartzites.

MAY 24, 1865.

James Philip Baker, Esq., Wolverhampton; George William Clive, Esq., 38 Albemarle Street, Piccadilly; James Coutts Crawford, Esq., Wellington, New Zealand; Theodore H. Hughes, Esq., of the Geological Survey of India; and Charles Ottley Groom Napier, Esq., of Bristol, were elected Fellows.

* See 'Geologist,' vol. v. p. 147, &c., and p. 366, &c.

The following communications were read:—

1. ADDITIONAL OBSERVATIONS on the RAISED BEACH of SANGATTE with reference to the DATE of the ENGLISH CHANNEL, and the Presence of LOESS in the CLIFF SECTION. By J. PRESTWICH, Esq., F.R.S., Treas. G.S.*

IN my paper on the Loess and Quaternary beds of the north of France and south-east of England, I expressed an opinion that the break in the land between France and England was not the result of the last geological change †, but that the Channel existed at the period of the formation of the low-level gravels of the Somme and Thames valleys, and probably at the period of the high-level gravels. The argument was based upon the position of analogous beds at places on both sides of the Channel, upon the contour and slope of the land, and the direction of the Sangatte and Brighton raised beaches. I was not then able to give more positive evidence. I am, however, now in possession of facts which enable me to do so, and these I will briefly lay before the Society.

On my return last Easter from an excursion in Belgium with several Fellows of this Society, I took the opportunity of revisiting the Sangatte section in company with Mr. Godwin-Austen. The winter storms had cleared the beach and bared the cliff, and we found a long and very interesting section exposed. Our visit was short. It enabled me, however, to recognize some beds very loess-like in character, and to detect traces of shells in some of them. We also again noted in the underlying old sea-bed layers of a green sand, which might have been derived either from some Lower Tertiary beds or from the Greensands.

We thence proceeded round Cape Blanc-nez, where Mr. Godwin-Austen wished to see the peculiar structure of the Lower Cretaceous series, whilst it gave me the opportunity of ascertaining whether the old beach extended round that chalk promontory into Wissant Bay. So far as we went we saw no trace of it there, but, owing to the extent of the dunes around Wissant, such a beach might be entirely hidden by the sands.

On my return through Calais from Bethune a few days later, I took the opportunity of paying another short visit to the cliff at Sangatte for the purpose of making both a larger collection of shells from the chalk rubble and loam beds and a closer examination after rock specimens.

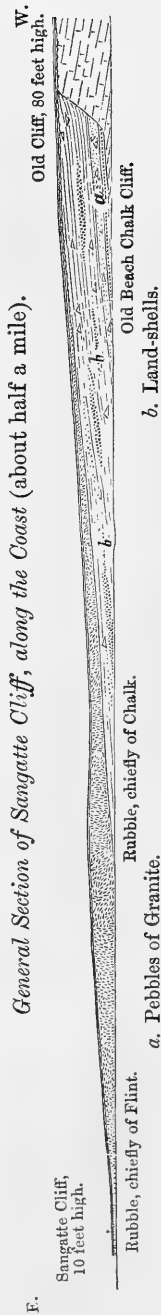
The old beach, as I have before described, consists almost entirely of much-worn large flint shingle, with a few rolled blocks of chalk fallen from the old cliff, and with some pieces of worn Tertiary iron-sandstone. Above the shingle, and at some short distance from the foot of the old cliff, are some light-coloured sands, with seams of green sand above mentioned, and subordinate beds of shingle.

* The first notice of this beach was given by the Author in the Quart. Journ. Geol. Soc. vol. vii. p. 274, 1851.

† Phil. Trans. for 1864, p. 301.

It was desirable to determine, if possible, the origin of these materials, as some interesting points of ancient physical geography hinged upon this point. I therefore again closely examined these sands and the subordinate shingle, and succeeded in finding a not inconsiderable number of subangular fragments of chert of distinct Lower Greensand origin, together with a few pebbles of Lydian stone, derived probably from some of the Portland beds, and some pebbles of sandstone which might also have come from the Boulonnais. I also found two pebbles of a red granite, which may have been derived from the granitic districts either of the Contentin or of the Channel Islands. Still it is possible that these granite pebbles may have been derived indirectly from the Lower Greensand, which we know to contain in places pebbles of granite and of other older rocks, or from the more distant Boulder-clay or beds of that age. I unfortunately lost my specimens in returning to Calais before I had had the opportunity of carefully examining them. The presence, however, of chert from the Lower Greensand, and of pebbles of Lydian stone and of other rocks from the Boulonnais district, suffices for our object, which is to show the additional probability these facts afford of the existence of a channel between France and England anterior to the low- and possibly the high-level valley-gravels. For to the eastward of a line drawn between Cape Blanc-nez and the South Foreland there is no coastline whence this Lower Greensand chert could have been derived—the area consisting of Tertiary strata—whilst a channel open to the westward would, after passing through the belt of Chalk, intersect the Lower Greensand of Folkestone and the Portland and Purbeck beds of the Boulonnais, although that channel might have been much narrower than the one now existing. At the same time there is another explanation possible, although I consider it much less probable.

I have mentioned in my last paper in the 'Phil. Trans.' that the old rivers of the Wealden area debouched, as do those of the present day, outwards into the Thames valley, but that they were of much greater size and extent. I have evidence to show that in the very centre of the Wealden area there are remarkable cases of valley-excavation and old river-action. I have even there found beds of high-level gravel. Now these rivers, in their passage across the Lower Greensand, always took up considerable quantities of chert and ragstone fragments,



E.

which they carried out into the valleys traversing the North Downs and into the valley of the Thames. It is therefore possible that somewhere between Calais and Dover there may have been an old river flowing eastward from the Wealden area, and debouching in this part of the English Channel, into which it might have transported the chert and other pebbles we find in the old beach at Sangatte. I am disposed, however, to consider the transport by sea-action along a channel open from west to east, as at present, although much narrower, the more probable.

Above the old beach is a mass, from twenty to eighty feet thick, of angular flint and chalk-rubble, identical in general characters with that in the same position at Brighton, in which Dr. Mantell discovered the remains of the Elephant, Horse, &c., but presenting some features of much interest, that have not yet been observed at Brighton. At both places irregular seams of fine chalk-rubble and marl are intercalated with the flint débris, but at Sangatte there are in addition some beds which are not to be distinguished from ordinary Loess. Not only do they resemble that deposit in general characters, but I likewise discovered in some of these loams, as also in some of the more marly beds, several species of land-shells common in the Loess. I found also, what I before discovered in the Loess of the Somme valley, numerous small, semitransparent, calcareous concretions, the probable remains of land-slugs. The following is a list of the shells from the Sangatte cliff, revised by my friend Mr. Gwyn Jeffreys:—

<i>Helix concinna.</i>	<i>Pupa marginata.</i>
— <i>pulchella.</i>	<i>Arion ater.</i>
<i>Succinea oblonga.</i>	<i>Limax agrestis.</i>

I found no freshwater shells, or Mammalian remains.

There is no intercalation of sea-beach or sea-bed in this mass of overlying rubble. The two beds are perfectly distinct, and the old beach must have been raised so as to form dry land before the accumulation of the land débris above it. It is an interesting problem how it could have been formed in such a position—whether by the mere melting of the winter snow on the adjacent range of chalk hills, or by the flooding of some adjacent river. It is not, however, my intention on this occasion to discuss this subject, but merely to make known additional facts which I consider of importance in their bearing on a very interesting theoretical question, and again to direct attention to a remarkable section—one requiring further examination—with the view especially better to determine the old rock-pebbles and the organic remains that are to be found in it.

2. *On the SUPERFICIAL DEPOSITS of the VALLEY of the MEDWAY, with REMARKS on the DENUDATION of the WEALD.* By C. LE NEVE FOSTER, B.A., D.Sc., F.G.S., and WILLIAM TOPLEY, F.G.S., of the Geological Survey of Great Britain.

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INTRODUCTION.

DURING the last few years the subject of river-gravel has so much occupied the attention of geologists, that a short description of the gravel and brick-earth of the valley of the Medway will not be without interest, especially as those deposits have a most important bearing on the denudation of the Weald. In the present paper we propose, firstly, to describe the superficial deposits of the valley of the Medway, and, secondly, to show what light those deposits throw on the theory of the denudation of the Weald.

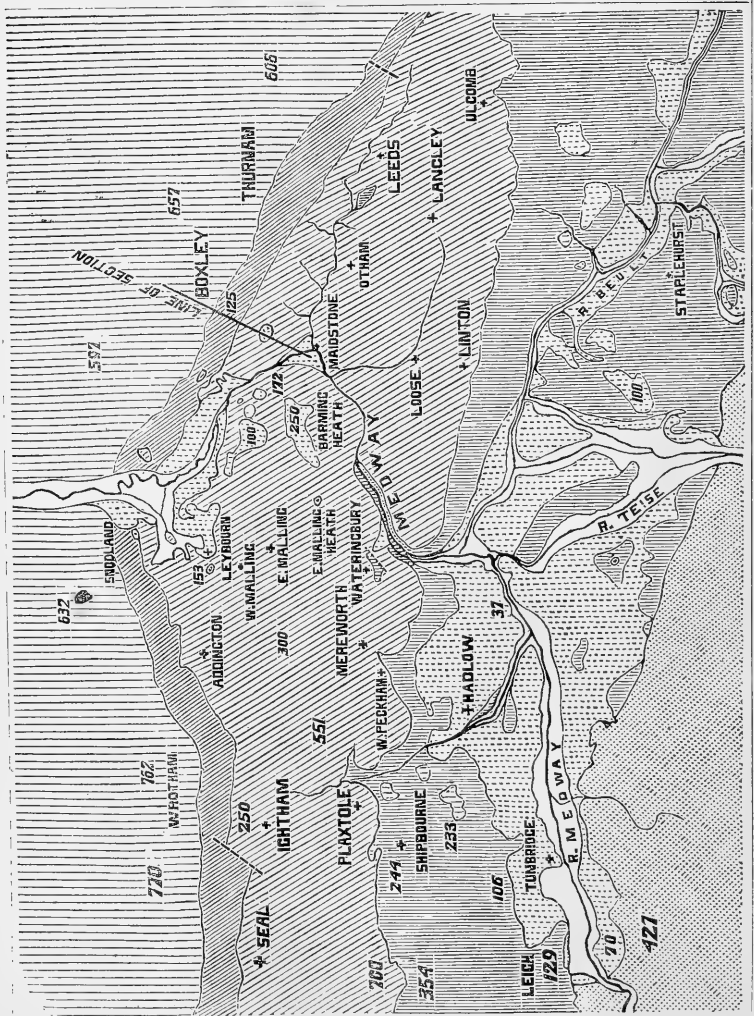
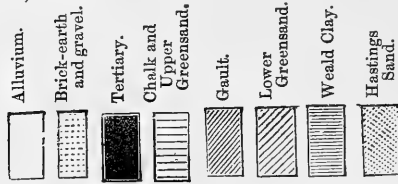
PART I. DESCRIPTION OF THE SUPERFICIAL DEPOSITS.

a. *General Description of the Valley of the Medway.*—Before describing the superficial deposits it will be well to devote a few lines to a concise account of the basin of the Medway; the position of the beds will then be more readily understood. As we intend to treat of only so much of the basin as lies within and south of the Chalk escarpment, we can confine our description to that part. The escarpment of the Chalk forms on the north a well-marked boundary to our district. On the east the line of watershed separating the valley of the Medway from that of the Stour passes south from the Chalk by Lenham to Pluckley and Shadoxhurst; thence the watershed turns westwards, and, passing Cranbrook, Ticehurst, Wadhurst, Crowborough, and West Hoathly*, divides the waters of the Medway from those of the Rother and the Ouse. From West Hoathly a line passing northwards by Copthorn Common and Bletchingley to the Chalk escarpment, north-west of Godstone, separates the Medway basin from that of the Mole; the boundary of our basin then follows the Chalk past Titsey, turns south-east and runs eastwards along the high ground of the Lower Greensand to Ightham Common, and then

* This high ground forms part of the prominent chain of hills known as the Forest Ridge. The highest point, Crowborough Beacon, is 804 feet above low-water mark.

Fig. 1.—Geological Sketch-map of the Valley of the Medway and adjacent District.

(Reduced from Sheet 6 of the Map of the Geological Survey of Great Britain: the Cretaceous beds surveyed by Mr. F. Drew, the gravels by Messrs. Foster, Topley, and Dawkins.)



Scale $\frac{1}{4}$ inch to 1 mile.

northwards to the Chalk near Wrotham, and is thus separated from the basin of the Darent.

The Chalk forms a steep escarpment facing the Weald to the south, but to the north and north-east the grounds lopes down gradually; the dip is everywhere into the escarpment, lower beds rising to the south. Through this escarpment the Medway flows at Burham. To the west of the transverse valley thus formed the strike is E. and W.; on the eastern side it is nearly S.E. and N.W. South of the Chalk we come upon the Gault, forming a flat of low ground averaging three-quarters of a mile in width. The Upper Greensand is here very thin, and makes no feature on the ground; springs often flow out at the base of the Chalk. The Lower Greensand rises gradually from beneath the Gault, and ends, like the Chalk, in a steep escarpment to the south. The upper part of the Lower Greensand is sandy (Folkestone Beds)*; this division is underlain by a thin bed of clay and sandy clay with fuller's earth (Sandgate Beds); and the lower part of the Lower Greensand (Hythe Beds) consists mainly of beds of limestone and sand, known as "Kentish Rag" and "Hassock." Here the valleys, which do not reach down to the Atherfield Clay, are often *dry*, like those of the Chalk. The Kentish Rag country east of the Medway is known as the Quarry Hills. Springs flow out at the junction with the Atherfield Clay below. This clay is the lowest member of the Lower Greensand, and rests immediately on Weald Clay, which occupies a low and broad plain, varying from four to seven miles in width. The Hastings Sand†, subdivided into beds of clay and sand, rises up on the south from beneath the Weald Clay towards the high land of the Forest Ridge. All the streams to the north of this ridge run into the Medway, those to the south drain into the Rother and the Ouse; the former enters the English Channel at Rye, and the latter at Newhaven.

The Medway is formed by the junction of a number of small brooks coming down from the high land near East Grinstead; it flows down past Hartfield to Penshurst, where it receives a large tributary, the Eden, and passing Tunbridge, arrives at Yalding. Here the Beult and the Teise fall into the Medway, which now enters the gorge cut in the Lower Greensand; it soon reaches Maidstone, receives the Len, and then flows on in a general north-north-westerly direction towards Snodland, where it is joined by the Snodland Brook. The Medway now takes its course along the gorge through the Chalk, passes by Rochester, and finally reaches the Thames at Sheerness.

β. *Superficial Deposits.*—The following different kinds of superficial deposits are found in the Medway valley:—

1. Subaërial beds.
2. Modern alluvium.

* For a description of the subdivisions of the Lower Greensand, see Fitton, *Trans. Geol. Soc.* 2nd ser. vol. iv. 1836, p. 103, and Drew, 'Memoirs of the Geological Survey,' Sheet 4, 1864.

† For a description of the northern part of the Hastings Sand country, see Drew, *Quart. Journ. Geol. Soc.* vol. xvii. 1861, p. 271.

3. River-gravel and brick-earth (Loess).

1. *Subaërial Beds**.—Under this head we class those beds which are formed by rain before it has collected into streams.

In our area they are of two kinds—

(1.) Rainwash-brickearth and chalky wash.

(2.) Unstratified flint gravel and beds of angular chert.

(1.) The action of the weather is always degrading rocks, and the matter thus detached is carried down the hill-sides by rain. In some places this accumulates to a considerable thickness, and may then be conveniently termed "rainwash." When carried down into the streams it goes to form true alluvial deposits, or is carried away to sea.

It is frequently difficult to distinguish between rainwash-brickearth, and true alluvial loam. Both may contain land-shells, and the former is sometimes roughly stratified, but rarely, if ever, so distinctly as the latter.

(2.) Beds of chemical origin left as the result of the chemical action of rain on the strata come under this head. The "dry valleys" of the Chalk have usually a considerable thickness of flints in their lowest parts. These flints are entire, or, if broken, are sharply fractured by weather, never rounded or water-worn. These valleys are probably due to the dissolving away of the Chalk along lines of underground drainage†. Deposits of flints also occur frequently on the top of the chalk downs, mostly mixed with clay (clay-with-flints); and this clay, too, is in most cases probably the residue of the chalk which has been dissolved away‡.

The beds of unstratified flint gravel that are met with in many places on the Lower Greensand, Gault, and lower slopes of the Chalk are probably the residue left, as the Chalk escarpment was gradually worn back by subaërial denudation. This gravel may be seen on Pennenden Heath, near Maidstone, for instance; it differs entirely from the river-gravel by its want of stratification, and by the absence of Wealden pebbles; and it consists of angular and subangular flints, with occasionally a few Tertiary pebbles, the interstices of the gravel being often filled up with clay. This gravel is sometimes very chalky, as is the case at a place about a mile N.E. of Aylesford, where the deposit is 15 feet thick and rests on the Gault.

2. *Modern Alluvium*.—The modern alluvium does not differ in any important respect from that of other rivers, and does not need any very particular description. It consists of loam and gravel. About Tunbridge and Yalding the alluvium forms broad meadows; between Yalding and Teston it gets quite narrow, and then disappears altogether until you have passed Maidstone. At Aylesford alluvial meadows are once more met with, forming a broad plain near Snodland.

3. *River-gravel and Brick-earth (Loess)*.—River-gravel§ occurs

* See Godwin-Austen, *Quart. Journ. Geol. Soc.* vol. vii. p. 1851, 118.

† Whitaker, 'Mem. Geol. Survey,' Sheet 7, 1864, p. 96.

‡ *Ibid.* Sheet 7, pp. 63, 66, and Sheet 13, 1861, pp. 54, 55.

§ We have used the term "river-gravel" instead of "valley-gravel," in order to prevent the gravel of true river-origin from being confounded with the subaërial gravel which also occurs in the Medway valley.

at all heights, from the present alluvial plain up to 300 feet above it. It is not possible to draw any exact line between the higher and lower gravels. They form, as Mr. Prestwich says, "the extremes of a series." Much confusion has arisen in consequence of some observers employing the term "high-level gravel" to designate the higher terrace- or river-gravel of a country, whether occurring on the flanks of a valley or capping the neighbouring hills, whilst others restrict the term to the still higher gravels, which have no obvious connexion with the present drainage of the country.

The following table shows at a glance the terms used by some of the most recent writers on the subject:—

Prestwich, 1862*, 1863†. Lyell, 1863‡.	Prestwich, 1863†, 1864§. Lyell, 1865||.	Whitaker, 1864¶.
Upland loams and gravels (Lyell).		High-level gravels.
High-level gravels	High-level valley-gravels	Valley-gravel. { Terrace-gravels. Low-level gravels.
Low-level gravels	Low-level valley-gravels	

River-gravel and brick-earth are found overlying all the formations over which the Medway passes, sometimes forming broad spreads, in other cases existing only in small isolated patches. The most convenient way of treating the subject will be, in the first place, to describe the gravel and brick-earth of the Medway and its tributaries; then, to pass on to a special description of the pipes of gravel and brick-earth that occur in the Kentish Rag; and finally to notice a few interesting cases of disturbance.

a. *The Medway*.—The lowest gravel is seen at many places along both banks of the Medway. In the Hastings Sand country it generally consists entirely of pebbles of Wealden sandstone, but in other parts it often contains angular and subangular flints, Tertiary pebbles, and Wealden pebbles.

In some gravel at Maidstone, a few feet above the river, Professor Morris has found numerous species of land shells**.

The higher river-gravel of the Medway valley is far more interesting and important than that which occurs at a low level; it often lies in terraces, and is found at various levels above the river up to 300 feet; and, like the lower gravel, it always consists of rocks which occur within the Wealden area.

In following the Medway from its source we do not meet with any gravel of great importance until we reach the neighbourhood of

* Proc. Royal Soc. vol. xii. p. 38.

† Quart. Journ. Geol. Soc. vol. xix. p. 497. ‡ 'Antiquity of Man,' p. 107.

§ Phil. Trans. vol. cliv. 1864, p. 247.

|| 'Elements of Geology,' 6th ed. p. 114.

¶ 'Mem. Geol. Survey,' Sheet 7, p. 68.

** Mag. Nat. Hist. vol. ix. 1836, p. 593.

Tunbridge*. Here, on the north of the Medway there is a plateau, several square miles in extent, covered by a deposit of gravel and brick-earth. About Hadlow the brick-earth predominates, and forms a rich soil of much value for the cultivation of hops. At Hadlow the level of this plateau is 40 or 50 feet above the river, and north of Hadlow it is nearly as much as 80 feet. A little east of Hadlow the ground slopes down gradually to the Medway, and the higher river-deposits join on to the lower without any distinct line of separation. In places the gravel and brick-earth have been cut through by small streams, which expose the Weald Clay beneath.

A good section of the gravel is seen at Goose Green, near Hadlow, where a pit shows 15 feet of gravel, which consists of pebbles of Wealden sandstone, angular and subangular pieces of flint and chert, besides Tertiary pebbles. False-bedded coarse sand is found interstratified with the gravel.

Brick-earth is dug at a place marked *Pottery* on the Ordnance Map; on the southern side of the pit stratified brick-earth 13 feet thick is seen, with scarcely a single pebble; a little further north false-bedded sand and gravel are interstratified with the brick-earth, and in one place there is an interesting case of disturbance, to which reference will be made later. Few other sections of brick-earth are to be had, as it forms such a good soil that it is more profitable to cultivate hops than to dig the earth for bricks.

North of Tunbridge several patches of gravel occur of considerable interest.

The outlier north-east of Starve Crow Farm is, at its highest part, 180 feet above the river at Tunbridge. This gravel has been much dug for roads: it appears to be 14 or 15 feet thick; the springs on North Fright Farm are at that depth. Other patches of gravel are found near here at about the same level.

Junction of the Plaxtole and Medway Gravels.—Just east of the village of Plaxtole the Greensand range is broken by a valley running northwards up towards the Chalk escarpment, which, however, shows no corresponding feature. Along this valley a stream runs southward to join the Medway.

About half a mile south-east of Plaxtole is a patch of gravel about 60 feet above the stream, in which we can clearly trace the junction of the old Medway with the old stream that flowed through the Greensand escarpment. Along the south of this outlier Wealden and Tertiary pebbles, with pieces of flint and chert, occur. The gravel is well seen resting on clay on the road going south from Plaxtole. A brickyard just east of this gave, in August 1864, the following section:—

	ft.	ins.
Gravel not well bedded	2	6
Good gravel interbedded with coarse sand and a little clay	4	0
Blue clay (Wealden)		

* There are beds of gravel higher up the Medway than Tunbridge, but not of sufficient importance to claim notice here. They will be described in the Memoir on Sheet 6 of the Geological Survey-map.

Wealden pebbles are less numerous here than in the road-cutting to the west. This deposit is certainly an old river-gravel of the Medway. On the east side of this outlier a different gravel occurs, and is seen along the road going north from Dunks Green. It contains flints and Tertiary pebbles, but *no Wealden pebbles*; at one point a fragment of *chalk* was found embedded in the gravel; many of the flints are rather angular and large.

It must be particularly observed that this deposit, which differs materially in its character from that on the south side of the outlier, overlooks the transverse valley before mentioned. The stream which comes down this valley from the north traverses only Greensand and the beds above; it can therefore only bring down materials contained in those beds. In this small patch of gravel, then, we have abundant evidence, in the absence of Wealden pebbles, in the large size of the flints, and the presence of *chalk* itself, that in former times, when the stream ran at some distance above its present level, it then, as now, came from the north, bringing down only materials belonging to beds found along its course. We have here preserved the exact junction of the small transverse stream with the main river, which then, as now, brought down débris from the west and south.

It may be well to notice a similar junction occurring further down the Medway. Between Allington and Aylesford we have, on both sides of the river, evidence of the junction of a stream with the Medway, when both were running 20 or 30 feet above their present level. Just under the railway-bridge, half a mile north-west of Allington Church, 8 feet of gravel is seen in the railway-cutting. The gravel is well stratified, and contains flints and chert with Tertiary and Wealden pebbles, besides numerous rounded fragments of chalk, which have been brought down by the stream which rises at the foot of the chalk hills near Boxley. From this gravel were also obtained fragments of concretionary Wealden ironstone containing small *Paludina*, also a piece of shelly ironstone*, with great numbers of *Cyclas* (or *Cyrena*). These specimens, were the Wealden origin of the pebbles disputed, would be sufficient to prove that materials derived from the central districts of the Weald are found in the gravels of the Medway†.

Similar interstratifications of chalky gravel, with gravel containing Wealden pebbles, are met with along the road just south-east of Cob Tree, near Maidstone. Prof. Morris, in the paper already alluded to‡, has noticed the above section, and says that it is remarkable as containing pebbles of chalk, "although it occurs two miles from any chalk *in situ*."

Further down the Medway valley we come to an important spread of gravel, which forms a well-marked terrace near Aylesford.

* A bed of shelly ironstone, not to be distinguished from this, is found almost universally at the base of the Wadhurst Clay. Similar beds, perhaps, occur in the Weald Clay.

† This fact, obvious enough to any one acquainted with the Weald, was first published, we believe, by Mr. Prestwich, Phil. Trans. 1864. p. 267 and Map.

‡ Mag. Nat. Hist. vol. ix. (1836) p. 595.

The top of the terrace is rather more than 40 feet above the level of the Medway. The gravel-pit a little north-east of Aylesford Church will be known to many geologists, as it has yielded such an abundant harvest of Mammalian remains.

The gravel here is from 18 to 20 feet thick, and rests on the top-most part of the Lower Greensand (Folkestone Beds). It consists of angular and subangular bits of flint, Tertiary pebbles, pieces of chert and Kentish Rag, and pebbles of Wealden sandstone, and large lumps of sandstone resembling "Greywethers." It is interstratified in places with beds of coarse sand, and beds of loam are occasionally met with.

Bones or teeth of the following Mammals have been found in the Aylesford gravel:—

Elephas primigenius,	Equus.
Rhinoceros,	

The teeth of the Elephant are very common; and occasionally very fine tusks are found.

The next well-marked terrace on this bank of the Medway occurs on the top of the hill half a mile north-west of Maidstone Gaol, at a height of 200 feet above the river. Its position is shown in fig. 2, p. 451. It consists of angular and subangular bits of flint and chert, with Tertiary pebbles and pebbles of Wealden sandstone: it is distinctly stratified. On the left bank of the Medway, near Maidstone, there is a good deal of gravel, occurring in three or more terraces up to the level of 300 feet above the river*. The gravel exactly resembles that found on the opposite bank, and we need only notice that which occurs at the higher levels. About half a mile east of East Malling Heath, gravel is found at a height of 300 feet above the Medway; it contains pebbles of Wealden sandstone, flints, chert, and Tertiary pebbles, and resembles undoubted river-gravel. At East Malling Heath, at a height of 275 feet above the Medway, there are some beds of brick-earth with a little gravel, which have been proved to be 36 feet thick in places. One of the pits shows a beautifully stratified deposit, which few persons would deny to be of true river origin. This brick-earth probably lies in a "pipe," like those to be described hereafter.

b. *Tributaries of the Medway: River Eden.*—The first tributary of any importance is the River Eden. Sir R. I. Murchison, in his paper "On the Flint Drift of the South-east of England" †, has described some gravel at Hever Lodge, on the left bank of the Eden, and gives a section showing its position. The gravel resembles that of Aylesford, and in appearance and lie seems to be a true river-gravel. Sir Roderick, however, in his paper, will not admit that this

* These terraces, except the highest (of which little now remains), appear, in tracing them down the valley, to fall to a *lower relative level* as compared with the river beneath. The cause of this is not at all clear. Mr. Prestwich (Phil. Trans. 1864, p. 252) has noticed the same fact in the valley of the Waveney. Mr. Bristow informs me he has also observed it in the terraces of gravel in the Thames valley.—W. T.

† Quart. Journ. Geol. Soc. vol. vii. (1851) p. 381.

Fig. 2.—Section from Maidstone to Boxley.

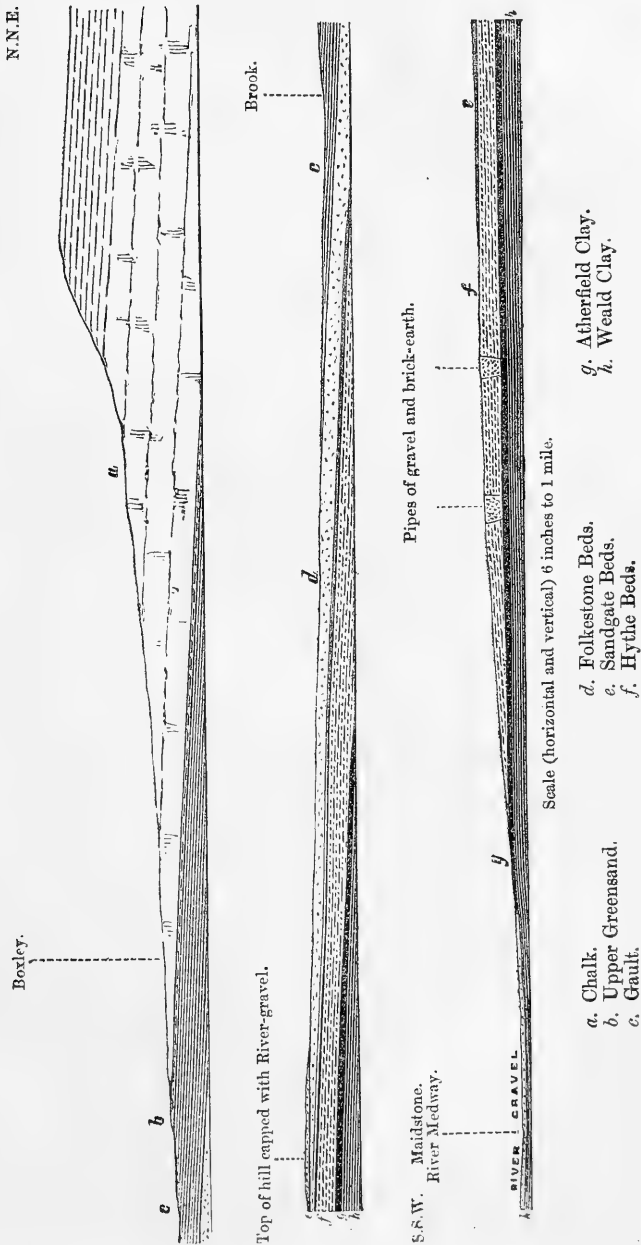


Fig. 2.

gravel was deposited by any "ancient river following the direction of the present streams," because it contains Chalk-flints which are not found in place until we have crossed the high Greensand escarpment, and at a distance of seven miles. It must be recollected, however, that tributaries of the Eden rise at the Chalk near Titsey and Godstone; and the old gravel found near them is composed, as we are informed by our colleague, Mr. W. Boyd Dawkins, of flints and chert, brought down, no doubt, by the tributary streams. These streams, then, probably furnished the Eden with the flints and Tertiary pebbles* which are now found in its old alluvia. Again, the Plaxtole Brook doubtless helped to furnish the flints and Tertiary pebbles found in the Hadlow gravel. On the eastern side of the Medway basin, in the Weald Clay valley, where there are no streams coming in from the Chalk, flints are very rare, and the river-gravel is almost entirely composed of Wealden pebbles. This fact is in favour of the theory that the flints at Hever and Hadlow were brought down by tributaries coming from the Chalk. Mr. W. Boyd Dawkins, who mapped the gravel at the eastern and western ends of the Medway basin, has arrived at the same conclusion †.

Rivers Beult and Teise.—Deposits of gravel are found along the banks of both these streams, and in the angle formed by the junction of the two streams a considerable spread of gravel is met with. There are four patches of gravel lying at about the same level, (50 or 60 feet above the rivers Beult and Teise), which appear to have been once united, forming a broad plateau. Gravel was no doubt deposited at the junction of the Beult and the Teise when these rivers were at a much higher level and their junction further south-east. As these rivers worked their way to the west and to the north, the spread of gravel increased. The rivers at the same time gradually cut their way down deeper; their old beds were left high and dry, and were at once attacked by the denuding agencies of the atmosphere. Little valleys, some 20 feet deep, have been cut through the gravel and the underlying clay, and all that remains of the broad plateau are the four above-mentioned patches.

Sections of the gravel are seen at Marden and at Wantsuch Green. It consists almost entirely of pebbles of Wealden sandstone; a few quartz-pebbles ‡ also occur, and occasionally a few flints are met with. Sir R. I. Murchison, in his paper just alluded to, mentions the fact that remains of the Mammoth were found in the gravel at Marden §.

* Beds of pebbles are found capping the Chalk escarpment near Godstone, believed by Mr. Prestwich to be unconformable Tertiaries ("On the Thanet Sands," *Quart. Journ. Geol. Soc.* vol. viii. (1852), p. 256).

† This is also shown by Mr. Prestwich in the map appended to his *Memoir in the Phil. Trans.* for 1864.

‡ Pebbles of quartz, as big as a hen's egg, are sometimes found on the Weald Clay about Marden and other places, as well as being found in the gravel. Whence these pebbles are derived is somewhat uncertain.

§ I may add here that I found the pointed end of a flint-implement, of the spear-head shape, in a field at Marden: part of the field was on the river-gravel. I also found an oval-shaped flint hatchet on the surface of a field near Maidstone, though at some distance from any existing deposit of river-gravel. Both implements resemble those that have been found in gravel.—C. L. N. F.

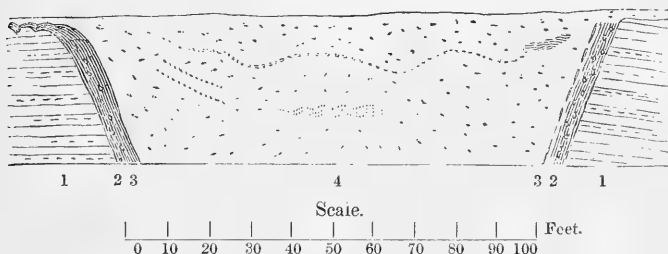
In the foregoing description we have spoken only of those sections especially worthy of notice. It is needless on this occasion to enter more fully into the subject, as the whole area will be more minutely described in a forthcoming Memoir of the Geological Survey.

4. *Pipes of Gravel and Brick-earth.*—Where the gravel and brick-earth rest on the Kentish Rag they are generally let down into “pipes” or “pot-holes,” which sometimes attain a very large size. As these pipes not only show the great thickness of the gravel and brick-earth, but also give proof of a considerable lapse of time since the deposition of these old alluvia, we will proceed to describe them in detail. The best sections are seen in some brick-fields to the north of the town of Maidstone. The section (fig. 2, p. 451) will show how the beds occur. The brick-earth is found in long deep pipes, one of which has been proved to go through the entire thickness of the Kentish Rag to the Atherfield Clay beneath. The direction of many of the pipes is a few degrees west of north. They gradually dwindle away and die out at their north and south extremities; but some can be traced for the distance of a quarter of a mile.

The largest pit, which is in Mr. Goodwin’s brick-field, is 50 yards broad, and is worked to a depth of 40 feet; it has been dug 10 feet lower, but the running sand which is then met with prevents further working.

The accompanying section (fig. 3) across the large pit in Mr. Goodwin’s brick-field will show how the brick-earth lies:—

Fig. 3.—Section across a Brick-earth pit, Maidstone.



1. Kentish Rag.
2. Clay with angular and weathered lumps of Rag.
3. Sandgate Beds: fuller's earth interstratified with beds of sand.
4. Brick-earth distinctly stratified. In the lower part of the pit, the strata are contorted.

A little gravel is interstratified with the brick-earth. It contains pebbles of Wealden sandstone, angular and rounded flints, and pieces of chert. Similar pipes are seen in the same brick-field and in another to the south-west; all are characterized by the lining of Sandgate Beds.

On the opposite side of the Medway, about half a mile south of Allington Church, there is a small railroad leading from the river to a Rag quarry. Along the cutting which has been made, as many

as seventeen pipes may be counted, as shown in fig. 4. They vary in width from 6 feet to 50 feet. Some of them in the quarry are seen to be 30 feet deep; and of course as no signs of their ending off are seen, they go down deeper: one has been proved to be at least 50 feet deep.

In the Iguanodon-quarry, belonging to Mr. Bensted, some good examples of small pipes are seen, one of which is shown in fig. 5.

The organic remains found in the brick-earth resemble those obtained from the gravel. Remains of the following Mammalia have been found* :—

Elephas primigenius,
Rhinoceros tichorhinus,
Cervus,
Equus.

The brick-earth † has also been found to contain the following shells, kindly determined by Mr. Etheridge :—

Helix fulva (Müller),
 — *hispida* (?), Linn.
Pupa muscorum, Pfeiffer.
Succinea oblonga, Drap.
Zua subcylindrica, Linn.
Pisidium or *Cyclas*.

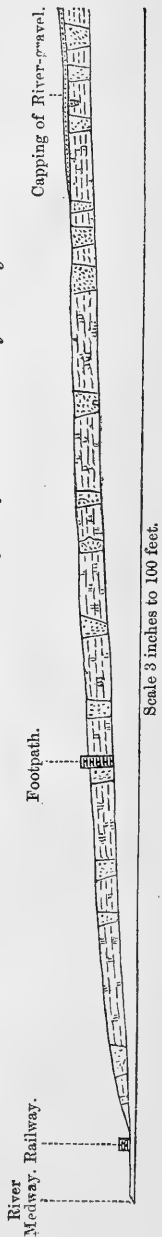
This *Pisidium* or *Cyclas* was found by our colleague, Mr. T. M^cK. Hughes.

Pipes similar in character to those of our district are of frequent occurrence in limestone strata. To account for them, two theories have been brought forward. Mr. Trimmer, in numerous papers in the Society's Journal, argued that the pipes had a mechanical origin. Dr. Buckland, Sir Charles Lyell, Mr. Prestwich, Mr. Kirkby, and others have upheld the notion that the pipes were produced by the slow dissolving action of water charged with carbonic acid. This view is now so generally adopted, and is so entirely consistent with observed facts, that it is unnecessary for us to enter very minutely into the matter. We will therefore content ourselves with referring for

* Mr. Bensted ('Geologist' for 1862) mentions *Hippopotamus* as occurring in the brick-earth; and Prof. Owen gives *Hyaena spelæa* (Brit. Fos. Mam. 1846, p. 151).

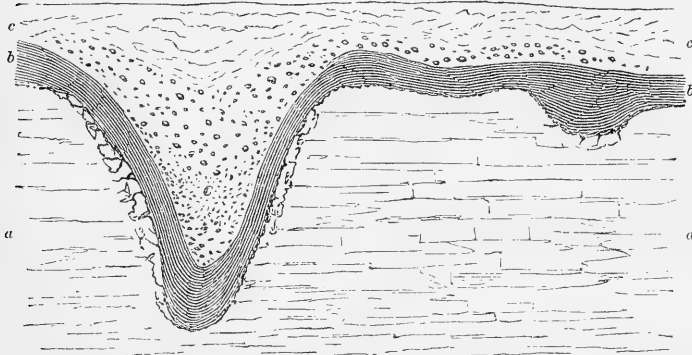
† See also the paper by Prof. Morris, Mag. Nat. Hist. vol. ix. 1836, p. 593, where lists of fossils are given.

Fig. 4.—Section of Brick-earth pipes and Kentish Rag, half a mile south of Allington Church.



a full account of this subject to Mr. Prestwich's admirable paper "On the Origin of the Sand and Gravel Pipes in the Chalk of the London Tertiary District" *.

Fig. 5.—Section of "Pipes" in Iguanodon Quarry (May 1864).



a. Kentish Rag.

b. Sandgate Beds

c. Gravel.

In the case of the pipe shown in fig. 5, few persons would hesitate to admit that the following was the mode of its formation:—Gravel was deposited on the surface of the Sandgate Beds, then resting horizontally on the Kentish Rag; afterwards part of the Kentish Rag was dissolved away by the percolation of water charged with carbonic acid, and the Sandgate Beds and gravel sank down to fill the vacant space. In many of the quarries we find every gradation between small pipes and large ones; and if it is admitted that the small pipes were formed in the manner described above, the same mode of formation must be allowed for large ones.

It seems at first not a little remarkable that where beds have been let down in pipes into limestone, they are generally separated from the limestone by a bed of clay. The only exception of which we are aware is in the case of some pipes in the Magnesian Limestone, described in the 'Geologist' for 1860, by Mr. Kirkby, who says (p. 297), "The pipes are found in the limestone beneath the sand beds. I have never noticed them where the sand is absent; and though they are sometimes filled with clay, or a mixture of clay and sand, yet in these instances a thin layer of sand is always the immediate cover of the limestone; nevertheless, the quarrymen assert that pipes have occurred in other parts of the hill where the limestone is immediately covered by the Boulder Clay."

The clayey covering of the Chalk ("clay-with-flints"), and also the clay lining the Chalk pipes, may be the direct result of chemical action upon the chalk; but facts about to be described render it at least probable that a horizontal covering of clay, whether formed by chemical action or actual deposition, may help the formation of pipes.

* Quart. Journ. Geol. Soc. vol. xi. 1855, p. 64.

Dr. Fitton, in his paper "On the Strata below the Chalk"*, describes pipes and furrows in calcareous beds, lined with clay which also caps horizontally the limestone. In these cases the clay is certainly not the result of chemical action upon the subjacent beds, as it forms part of the Purbeck and Portland series. At p. 276, Dr. Fitton figures and describes a pipe in the Portland Beds at Great Hazeley, in which "dark brown clay like fuller's earth" overlies the calcareous beds and passes round the pipes. Speaking about Oxfordshire, Berkshire, &c., Dr. Fitton says (p. 279), "in a great number of the quarries in this part of the country, the ferruginous sands at the upper part (Lower Greensand) are separated from the rubbly stone beneath (Purbeck) by a dark tough clay, 4 to 9 inches thick, which follows the irregularities of the mass below, and coats the bottom of cavities like the 'gulls' of Hazeley" †.

Mr. Conybeare describes similar appearances at the junction of the Kimeridge Clay and Coral Rag ‡.

In most of the cases mentioned by Dr. Fitton, the clay is stated either to consist of, or to contain, "*fuller's earth*." It is worthy of note that the Sandgate Beds, which universally, as far as we know, line the Maidstone pipes, are of this nature.

Mr. Prestwich, in his paper on "Pipes" already alluded to, notices the effect of a bed of clay in the cases of the pipes in the Chalk. He says (p. 79), "As the gravel is generally without any such partially impermeable seam at its base as occurs in the Tertiary sands, the underlying chalk surface seems to have been liable to be attacked by the acidulated waters in a greater number of places, and to present a larger proportion of pipes and indentations than when overlain by the sands," with the clayey band at their base. The effect of the Sandgate Beds is no doubt similar: they hold up the water which sinks through the porous bed above, and thus protect the limestone beds below *in most places*. At those points, however, where the clay is in any way permeable, much water passes down, and chemical action goes on rapidly. The clay therefore serves to concentrate at particular points or along particular lines that action which, were no clay present, would be distributed pretty equally over the whole area. Here we may add that, in the case of the harder limestones, Mr. Prestwich suggests (p. 80) that the pipes are likely to have resulted from the water-wear "being directed into given channels by pre-existing cracks or fissures;" he adds, "some gravel-pipes at Maidstone afford excellent illustrations of such results." The marked parallelism of the long pipes at Maidstone is an argument in favour of their having been originally started along joints or fissures.

Mammalian Remains at Boughton.—In the year 1827 Mr. Braddick found some Mammalian bones in what appear to have been small

* Trans. Geol. Soc. 2nd series, vol. iv. 1836, p. 275 *et seq.*

† These pipes are also noticed by Mr. Hull, 'Mem. Geol. Survey,' Sheet 13, p. 11 (1861).

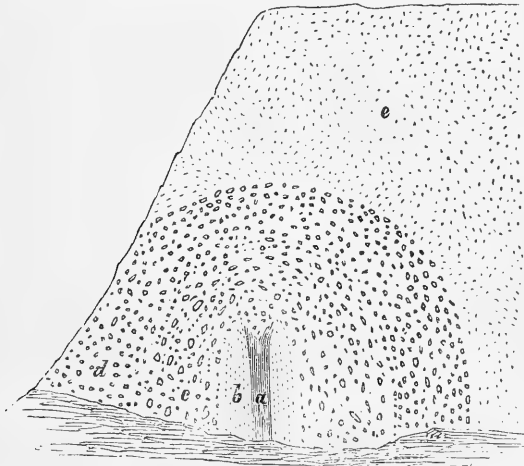
‡ 'Outlines of the Geology of England and Wales,' p. 189 (foot-note), 1822.

pipes in the Ragstone at Boughton, near Maidstone. Dr. Fitton* describes them as “irregular fissures or cavities, approaching to a conical figure called ‘vents’ by the workmen, filled with loose rubbly stone and sandy clay.” Sir R. I. Murchison, who visited the place with Dr. Buckland, says †, “the bones had been preserved under a copious accumulation of impervious loam and clay.” Prof. Morris has also noticed these remains ‡. Mr. W. Boyd Dawkins has favoured us with the following list of the bones found at Boughton, and deposited in the Society’s Museum, and described as from a cavern:—

Hyæna,	} Prof. Morris.	identified as <i>H. spelæa</i> by Mr. Dawkins.	} Mr. Dawkins.
Wolf.		Young Rodent’s jaw.	
Fox.	<i>Cervus elaphus.</i>		
Water-rat	<i>Rhinoceros tichorhinus?</i>		
	<i>Equus.</i>		

5. *Disturbances in the Gravel.*—Attention has frequently been drawn to the occurrence of faults and contortions in superficial de-

Fig. 6.—Section of a Brick-earth pit, near Hadlow.



- a. Shaly Weald Clay.
- b. Sandy Brick-earth.
- c. Gravel, consisting chiefly of pebbles of Wealden sandstone, but containing also numerous Tertiary pebbles and angular pieces of Chert.
- d. Fine gravel and coarse sand, with a little coarse gravel.
- e. Brick-earth.

posits. † Many instances have been quoted by Sir Charles Lyell §, Mr. Trimmer ||, and more recently by our colleague Mr. Green ¶.

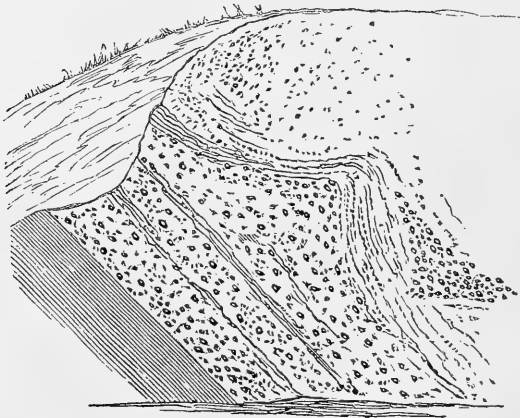
* Trans. Geol. Soc. 2nd series, vol. iv. (1836), p. 132.
 † Quart. Journ. Geol. Soc. vol. vii. (1851), p. 383.
 ‡ Mag. Nat. Hist. vol. ix. (1836), p. 595.
 § Phil. Mag. New Series, vol. xvi. 1840, p. 345, and Proc. Geol. Soc. vol. iii. 1840, p. 171; also ‘Antiquity of Man,’ 1863, chaps. 12. and 17.
 || Quart. Journ. Geol. Soc. vol. vii. (1851), pp. 22-30.
 ¶ Mem. Geol. Survey. Sheet 45 (1864), p. 55.

Disturbances in true river-deposits are described by Mr. Godwin-Austen * as occurring in the gravel of the Wey valley. In one section figured by Mr. Godwin-Austen, gravel is seen *faulted* against Neocomian clay. Mr. Prestwich † has also figured and described disturbances in the river-gravel of the Somme: they are stated to occur chiefly in the higher gravels. Mr. Trimmer, Sir Charles Lyell, and Mr. Prestwich look to ice as the cause of these phenomena.

Disturbed gravel has occasionally been met with in the basin of the Medway. At a brick-earth pit, near Hadlow (marked *Pottery* on the Ordnance Map), some gravel beds have been bent into a sharp anticlinal, enclosing in the centre a little of the Weald Clay, which underlies the gravel. The sketch on the last page (fig. 6) will give a better idea of the section than any verbal description. One way of accounting for the disturbance is by supposing that the gravel was bent up by the grounding of some large mass of ice. This explanation is in accordance with the theory that the climate, during the deposition of the older gravels, was colder than at present.

In September 1864 a considerable section of loam and gravel was open at Leney's Brewery, Watlingbury. The gravel resting on Atherfield and Weald Clay was seen distinctly dipping 25° to 30° to the N.E. This appearance was certainly not due to false-

Fig. 7.—Section in a Gravel-pit north of Maidstone Gaol.



bedding, as all the beds, both fine and coarse, showed it equally well. The gravel, therefore, must have been disturbed since its deposition.

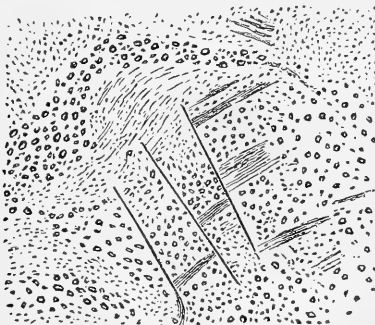
* Quart. Journ. Geol. Soc. vol. vii. (1851), p. 285.

† Phil. Trans. vol. cl. (1860), p. 299, and vol. cliv. (1864), p. 269.

In the gravel already described as occurring half a mile north of Maidstone Gaol, some of the deposit has plainly been disturbed since its deposition (fig. 7). The gravel is resting on Folkestone Beds: both dip at an angle of about 40° . The pebbles have their longer axes in the same direction, while the finest gravel and sand dip just as much as the coarser kinds. Here it seems plain that the gravel was deposited on horizontal Folkestone Beds, and that the whole has subsequently been disturbed.

It does not seem probable that *ice* should have produced this result; it is more likely that some of the underlying Rag has been dissolved away, causing a subsidence of the overlying beds. Fig. 8, from another part of the same pit, shows some small faults produced by the disturbance.

Fig. 8.—Section in another part of the same pit as Fig. 7.



Disturbed Gravel at Preston Quarry, Aylesford.—Mr. Bensted, of Maidstone, has published* an account of the strata at Preston Quarry. He describes and figures a sharp anticline affecting both the Greensand beds and the overlying gravel. Sir R. I. Murchison, in his paper “On the Flint Drift of the South-east of England” †, also alludes to this section. Mr. Bensted considers certain perforations by marine shells in the topmost bed of Rag to be of recent origin. A careful examination, however, will prove, we think, that the bed in which Mr. Bensted has found perforations is overlain by Sandgate Beds and Folkestone Beds; therefore the perforations must belong to the Greensand period. It certainly seems, however, that the gravel has been disturbed since its deposition. May not this be due to a dissolving away of the Rag, producing a subsidence in two places, which has caused the strata to dip down on both sides of the quarry in the manner described by Mr. Bensted?

* ‘Geologist,’ 1862, p. 450.

† Quart. Journ. Geol. Soc. vol. vii. (1851), p. 383 (foot-note).

PART II. ON THE DENUDATION OF THE WEALD.

Having now described the chief phenomena connected with the superficial beds of the Medway valley, we will pass on to consider the light which they throw upon the much-disputed question of the "Denudation of the Weald." We think it will be conclusively shown that "rain and rivers" have been the main agents in producing the present form of the ground.

We propose to treat the subject in the following manner:—

- a. Short sketch of previous theories, with objections to the theory of fracture, and to the marine theory.
 - 1. Theory of Fracture. 2. Marine theory.
- β. Bearing of the river-gravel on the question.
- γ. On the mode of deposition of beds of gravel and loam, and on the action of streams and rivers in modifying their channels.
- δ. On the origin of escarpments.

a. *Short Sketch of previous Theories, with Objections to the Theory of Fracture and to the Marine Theory.*—In the Introduction prefixed to Conybeare and Phillips's 'Outlines'*, Mr. Conybeare gives an account of the combination of longitudinal and transverse valleys, or those running respectively along and across the strike, of which the Weald is an excellent example. He attributes their formation to running water; but adds, "it is easy to show that the phenomena attendant on valleys are very commonly of such a nature that to believe them to have been formed by their actual rivers, however long their action may have endured, involves the most direct physical impossibilities." Mr. Conybeare also points out (p. 145) that, if the transverse valleys were filled up, the whole drainage of the country would pass out by Romney Marsh and Pevensey Level.

Mr. Scrope †, in 1825, in speaking of the results of volcanic action, alludes to the Weald as the result of upheaval, during which "a longitudinal crack opened across the beds parallel to the axis of elevation. The chalk, resting on beds of clayey marl, slipped away on either side from the axis, leaving bare the lower strata of green-sand. Again, the partial subsidence of this formation upon the slippery beds of the Weald Clay disclosed in turn the iron-sand, which forms the visible axis of this ridge." Such valleys the author proposed to call "valleys of *elevation and subsidence*, or *anticlinal valleys*"‡. He considers that they may have been "subsequently enlarged and otherwise modified; and many others, perhaps indeed a far greater number, wholly and entirely excavated by the slow but constant and powerful action of the same causes which are still continually in force; amongst which the fall of water from the sky, and its abrasive power as it flows over the surface of the land from a higher to a lower level, is the principal" (p. 214).

* 'Outlines of the Geology of England and Wales,' 1822, p. xxiii.

† 'Considerations on Volcanos,' chap. 10, p. 213.

‡ Dr. Buckland, in 1825, proposed to call the Weald and similar valleys, "valleys of elevation" (Trans. Geol. Soc. 2nd series, vol. ii. p. 119).

Mr. Martin *, in a series of publications extending over thirty years, taught that the Weald was denuded "by the joint operation of earthquakes and diluvial currents." The results of these violent actions he found in the various "drifts" with which the country is in places covered.

Mr. Hopkins †, in 1841, submitted a paper to the Society, "On the Structure of the Weald," in which some of the chief lines of disturbance were traced, and their supposed bearing on the physical geography of the Weald pointed out; also the connexion between transverse and longitudinal fractures. We shall allude more fully to this subject immediately.

Sir Charles Lyell ‡, in 1833, brought forward the marine theory of denudation, which, with little alteration, has held its place until the present time.

Sir Roderick Murchison §, in 1851, published his paper "On the Flint Drift of the south-east of England." He described with great care the drift of the Wealden area generally, and considered it to be owing to great rushes of water which mingled the débris of the various beds into the present drift deposits, burying the remains of Mammalia. This took place when "the country had to a large extent assumed its present form."

Col. Greenwood ||, in 1857, published his views upon the question of denudation with special reference to the Weald. He maintained that the valleys were wholly formed by "rain and rivers."

In 1862 Mr. Jukes ¶ read before the Society a paper on the river-valleys of the South of Ireland, in which he advocated the theory that these valleys were formed by atmospheric denudation. In a postscript (p. 400) he adds, "My acquaintance with the Weald of Kent is too superficial to allow me to express an opinion; but perhaps I may venture to ask the question, whether the Chalk, when once bared by marine denudation, which perhaps removed it entirely from the centre of the district, has not been largely dissolved by atmospheric action; and whether the lateral river-valleys that now escape through ravines traversing the ruined walls of Chalk that surround the Weald may not be the expression of the former river-valleys that began to run down the slopes of the Chalk from the then-dominant ridge that first appeared as dry land during or after the Eocene period?"

Prof. Ramsay, in 1863, while admitting that considerable ma-

* 'Geological Memoir on Western Sussex,' 1828; Phil. Mag. (1829), p. 111; Phil. Mag. 4th series, vol. ii. 1851 (pp. 44 *et seq.*), containing a paper read before the Geol. Soc. in 1840; Phil. Mag. (1854), p. 166; Phil. Mag. (1856), p. 447; Quart. Journ. Geol. Soc. vol. xii. (1856), p. 134.

† Trans. Geol. Soc. 2nd series, vol. vii. (1845) (read in 1841).

‡ 'Principles of Geology,' 1st edit. vol. iii. (1833), chap. 21.

§ Quart. Journ. Geol. Soc. vol. vii. p. 349.

|| 'Rain and Rivers; or Hutton and Playfair against Lyell and all Comers,' 1857.

¶ Quart. Journ. Geol. Soc. vol. xviii. (1862), p. 378. See also a letter by Mr. Jukes, in 'The Reader' for 12th March 1864.

rine denudation may have taken place, says* that the Weald was denuded "probably to a great extent also by the influence of atmospheric agencies." In 1864 he further explained † his views, and gave many arguments against the marine theory.

1. *Theory of Fracture*.—Mr. Hopkins, and other writers on this subject, dwell much upon the longitudinal dislocations of the Weald, and draw the inference that the well-known longitudinal valleys are the direct results of these dislocations. But, if this be so, the valleys and the faults ought to coincide, not only in direction, but absolutely. This they rarely or never do.

The longitudinal valleys run along the outcrop of the softer beds, or those most easily eroded. This of itself is some evidence of their formation by erosion. But the strike of the beds of any area necessarily corresponds in direction with its lines of disturbance, being alike due to elevatory forces acting from beneath. Hence we see that the strike and the faults are effects of the same cause; while the longitudinal valleys are determined by the strike alone, and may be seen to be so in districts where faults are altogether absent.

Against Mr. Hopkins's mathematical deductions we neither presume nor wish to contend. It is quite certain that longitudinal disturbances have taken place, and it is certainly possible that transverse fissures may have been formed which gave the original direction to the rivers which now run through deeply eroded valleys. Such dislocations, however, must have been mere fissures, and nothing more. There was no possibility of the beds slipping away on either side, nor has any vertical displacement taken place. Therefore the transverse valleys are still "valleys of denudation." Moreover, it is somewhat surprising that the Geological Survey has been unable to find any very important dislocations in any other parts of the Chalk escarpment. The Gault and Greensand lines have been drawn with care, but no marked disturbances are known; nor, as Mr. Hopkins admits, is there any *proof* that dislocations of any kind occur even in the transverse valleys themselves.

2. *Marine Theory*.—The view held by many geologists upon the denudation of the Weald is that, during a long course of time, the waves of the sea have formed the long lines of escarpment passing round the Weald, which are likened to sea-cliffs, such as are now being formed by the action of the sea on the Chalk of Kent and Sussex.

We think the commonly received marine theory untenable for the following reasons:—

(1.) The foot of the Chalk escarpment ‡, and also that of the Lower Greensand, are not at the same level all round the Weald, as every sea-cliff must necessarily be. This inequality of level can hardly be explained by unequal elevations during the last rise of

* 'Physical Geology and Geography of Great Britain,' 1st edit. 1863, p. 64.

† *Op. cit.* 2nd edit. 1864, p. 75.

‡ See Ramsay, *op. cit.* 2nd edit. p. 77.

the land, as the lowest parts are at the river-gorges. This would necessarily be the case if these transverse valleys were cut down by running water, as hereafter described.

(2.) The escarpments follow only the *strike of the beds**, changing their direction as the strike changes. The British islands, from the number of formations exposed, and their great extent of coast, should furnish some examples of long lines of cliffs following the outcrop of beds, if any ever occur †. But we find, on the contrary, that the sea cuts across all formations alike, quite independently of the strike. It sometimes forms bays and indentations where the strata are soft and easily worn away, but never runs up the country along the outcrop of the beds.

(3.) We never find accumulations of shingle or any other marine deposit at the foot of the escarpments. Sir Roderick Murchison has used this argument against the marine theory. In his paper before alluded to, he says (p. 393), "There is not a single rounded pebble along the lower edges of any of the escarpments that flank the central Wealden; still less does the tract contain any fragments of marine shells; whilst by far the greater part of the detritus is just that which must have resulted from an action which left the shattered débris in positions and conditions which no ordinary sea could have done." "Again, all the fossils found inland are terrestrial."

The gravel at Barcombe, cited by Sir Charles Lyell ‡ as an example of marine drift, is undoubtedly a river-gravel of the Ouse. It occurs near the junction of two streams, and contains Wealden pebbles. In this gravel Mammalian remains have been found §.

Sir Charles Lyell, however, does not seem now to lay much stress on the gravel at Barcombe as being proof of marine action, as he omits any mention of it in his last edition. He also suggests|| that marine deposits may have existed, and have since been swept away by atmospheric denudation, without conceding a very considerable power to atmospheric agencies; but as we shall show that "rain and rivers" have effected a very great amount of denudation, there can be no reason, in the absence of positive evidence, for appealing to the action of the sea for the formation of the escarpments, especially as the other objections to the marine theory which we cite still hold good.

(4.) Prof. Ramsay has well pointed out that, if the Weald were now submerged so as to convert the escarpments into cliffs, we should have an arrangement of sea and land in which denudation could act but very feebly. There would be a central group of islands surrounded

* See Rev. O. Fisher "On the Denudation of Soft Strata," Quart. Journ. Geol. Soc. vol. xviii. (1861), p. 3.

† Mr. F. Drew, who mapped a large part of Kent, Surrey, and Sussex, had remarked these facts, and in 1861, if not earlier, had rejected the theory that the Chalk and Greensand escarpments are due to marine denudation.—C. L. N. F.

‡ 'Manual of Elementary Geology,' 5th edit. 1855, p. 287.

§ Mr. Godwin-Austen, Quart. Journ. Geol. Soc. vol. vii. (1851), p. 288.

|| 'Elements of Geology,' 6th edit. 1865, p. 372.

by a strip of water in the Weald Clay valley, then a long ridge of Greensand country; beyond this a second strip of water washing the foot of the Chalk escarpment. "This form of ground would certainly be peculiar, and ill-adapted for the beating of a powerful surf, so as to produce *on one side only* the cliffy escarpment that forms the inner edge of the oval of Chalk"*.

β. *Bearing of the River-gravel on the question.*—We have endeavoured to show that there are many objections both to the "fracture theory," and to the "marine theory," and we will now proceed to discuss the arguments in favour of the "atmospheric theory" which may be derived from an examination of the superficial deposits, described in the first part of our paper.

We have shown that deposits of river-gravel occur at various heights, sometimes even 300 feet, above the level of the Medway. All this gravel we consider as having been deposited by the River Medway, when its bed was at a much higher level †, and the following are the reasons for this supposition. No one would hesitate to say that the Aylesford gravel is a former bed of the Medway, or, in other words, that the Medway once flowed 40 feet above its present level. When we find similar gravel and brick-earth of river origin, and containing similar fossils, gradually creeping up the hills, we find that we cannot stop at 40 feet, and we are constrained to admit that the Medway flowed at 100, 200, and even 300 feet above its present level, *and in the same direction as at present*; for the river-gravel lying on the Lower Greensand and Gault contains pebbles of Wealden sandstone which must have been brought from areas south of the Greensand escarpment. As the gravel is found at all levels from the 300 feet to the present level of the Medway, we must suppose that the river deepened its bed gradually, and that since the Medway flowed at the 300-foot level no agents, except rain and rivers (and possibly river-ice), can have been working at the denudation of the rocks contained within the basin of the Medway. The next question is, What is the amount of denudation that has been effected since the Medway flowed at the 300-foot level at East Malling? The area shaded on the Map (fig. 9) represents roughly ‡ what part of the Medway basin *south* of East Malling is below the 300-foot level. When the Medway was depositing the East Malling gravel, of course all this area must have been above the 300-foot level. Therefore, since the Medway ran at the 300-foot level at East Malling all this area has been denuded. When we add that a large part of this area is 200 and even 250 feet below the gravel at East Malling, the vast amount of the denudation will be perceived.

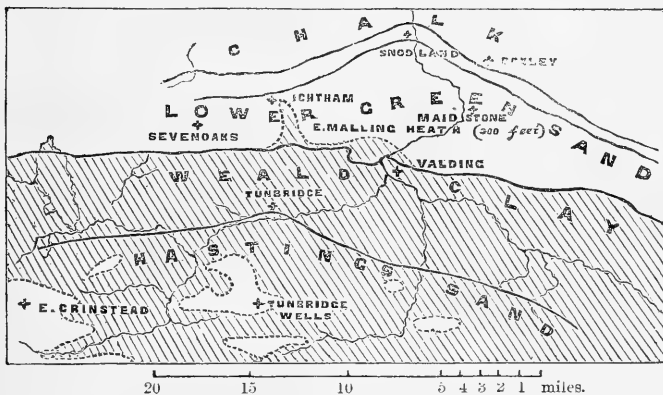
* Ramsay, 'Physical Geology and Geography of Great Britain,' 2nd edit. p. 79.

† Relatively to the strata it was flowing over, though not necessarily higher above the sea-level than it is at present; for, if the river worked its way downwards as fast as the Wealden area was raised upwards, no alteration of its position with regard to the sea-level would take place.

‡ Until the New Ordnance Survey of Kent is completed, it will be impossible to show *exactly* how much of the country is below the 300-foot level; but a rough map is sufficient for our purpose.

And all this denudation has been due to the action of rain and rivers; for we have shown that the Medway deepened its valley gradually; and not only are there no traces of marine action, but had the sea had access since the gravel was deposited, surely it would have swept away such loose and incoherent deposits. If rain and rivers could do so much, if they could cut out a valley 250 feet deep and seven miles broad, surely we may allow that by giving them more time they could scoop out valleys 500 feet deep; in other words, that, making every allowance for slight superficial inequalities produced by marine denudation, all existing inequalities in the basin of the Medway, including the Greensand escarpment and the Chalk escarpment, are entirely due to atmospheric denudation, that is to say, to the action of rain and rivers*. If this holds good for the basin of the

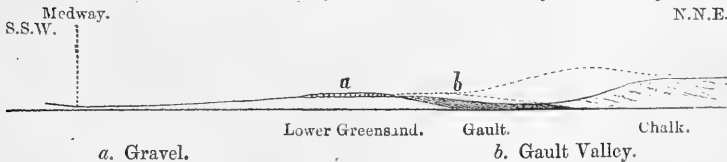
Fig. 9.—Map of the Basin of the Medway.



The area shaded shows that part south of East Malling Heath which is below the 300-foot level.

Medway, it may be applied to the whole of the Wealden area. The reason why we have no traces of river-action at the higher levels is that in the long lapse of time these old alluvia have themselves been removed by subaërial denudation.

Fig. 10.—General Section from Maidstone to beyond Bowley.



It is not only the gravel at East Malling that gives proof of vast denudation. Fig. 10 (see also fig. 2) shows the position of the river-

* The Wealden district does not appear to have been under water at all during the Glacial period. Of course throughout this period frost and land-ice must have had an immense effect in wearing down the surface of the country.

gravel between Boxley and Maidstone. It is clear from the position of the gravel at *a* that the Gault valley (*b*) could not have existed at the time of the deposition of the gravel; for when the bed of the Medway was at *a* this must have been the lowest ground of the neighbourhood. Since the deposition of the gravel at *a*, the Gault valley has been eaten out to a depth of 120 feet, and breadth of $1\frac{1}{4}$ mile, and the main Medway valley to a depth of 200 feet, and breadth of two miles. But this is not all; for when gravel was deposited at *a*, the sides of the valley very likely began to rise a little to the east of *a*, as shown by the dotted line; the place of the hill is now occupied by a valley, and what was the bottom of a valley now caps the top of a hill.

The gravel at Marden is another interesting case. This gravel lies about 50 feet above the level of the Teise, and is surrounded on nearly all sides, in some directions for miles, by lower ground. As before, this gravel, which once occupied the bottom of a valley, now forms the tops of hills. These cases (though on a much smaller scale) are exactly similar to that of the basalt-capped hills of the neighbourhood of Clermont, so well described by Mr. Scrope*. Both the lava and the gravel were once in the very bottom of the valleys, whilst now they cap the hill-tops. The denudation implied by this fact is very great; for not only must everything below the level of the present gravel-plateau have been denuded since the deposition of the gravel, but also the very walls of the valley which confined the river at the time of the deposition of the gravel must themselves have been washed away.

γ. On the Mode of Deposition of Beds of Gravel and Loam, and on the Action of Streams and Rivers in modifying their Channels.—Before proceeding to the discussion of the origin of escarpments, it may be well to say a few words on the mode of deposition of beds of gravel and loam, and on the action of streams and rivers in modifying their channels.

Gravel occurs and is now being formed in the bed of the present river Medway. It probably underlies the modern alluvium in most places, usually rising from beneath it to join the old river-gravels at the edge of the modern alluvium. Gravel is being constantly brought down by the river, but chiefly of course when the rush of water is greatest; and, as a rule, it is deposited only in the river-bed. No doubt during floods there will be exceptions; but even then only the finer gravel will be swept over the banks, and that will quickly come to rest, while the finer loam will remain much longer in suspension.

During dry weather, or such times as the river is confined within its banks, no permanent deposit of loam will be formed. At times the river may run comparatively clear, the matter held in suspension being small. Of the little it contains, the larger portion will be carried out to sea; some may settle down in sheltered portions

* Mr. Scrope (*Volcanos of Central France*, 2nd edit. 1858, p. 203) speaks of basaltic lava occurring 1500 feet "above the water-channels of the proximate valleys."

along its course, but these deposits will generally be swept away by the next rush of water; occasionally they are preserved, as proved by lenticular beds of sand and loam interstratified with gravel.

During floods much matter is carried down in suspension by the water. This is deposited by the flood-waters, when, having overflowed their river-banks, their velocity is lost or diminished.

Rivers are constantly changing their courses. This is accomplished by the undermining of one bank, accompanied by a gradual silting-up of the channel on the opposite side. A river may in this way, if the land continues stationary, travel many times across its plain, rearranging and depositing gravel as it goes*. It is interesting to notice that a river, in undermining its banks in the way just described, lays bare gravel deposited long before, and now mixes this with other gravel that it has just brought down. Thus fossils of very different ages (as measured in years) *may be* found imbedded together.

It is also important to notice that the width of an alluvial plain does not depend entirely upon the size of its river, as is frequently assumed in reasoning upon old river-alluvia. This is well shown in our area; and from the description already given (p. 446), it will be seen that the alluvial flat, like the general valley, is broader where passing over the softer beds.

It is manifest too that when the river is not deepening its channel the valley must be growing broader, because rain running down the hill-sides washes down material which, when it reaches the river, is carried away. The river, too, often reaches the edges of the alluvial plain, and then undermines the rocks that bound it. Each successive flood adds to the thickness of the alluvial deposits, and these gradually creep up the sides of the valley. Thus, if no elevation occurs, the alluvial plain will gradually widen. This effect will be produced much more rapidly if a *depression* occurs; the river will then raise its bed and thicken the deposit of gravel.

The greatest floods occur now a little way within the Chalk escarpment near Snodland, and just within the Lower Greensand escarpment at Yalding, which has been called the "Sink of Kent." At both these places the drainage of a considerable area is concentrated into a narrow gorge, and this is doubtless the cause of the floods. *It is probable that these cases are analogous to the former condition of the country, when the great deposits of brick-earth at Maidstone and Hadlow were formed.* Thus, when the brick-earth, now let into pipes on both sides of the river at Maidstone, was deposited, the Chalk escarpment was further south than at present, and the gorge was much nearer the brick-earth beds. The proximity of Maidstone to the then-existing gorge may very likely be the reason why the old alluvium was subject to those often-repeated floods, which have produced the thick deposits of brick-earth which now remain. A similar explanation may be offered to account for the

* See Fergusson "On the Delta of the Ganges," Quart. Journ. Geol. Soc. vol. xix., 1863, p. 321.

Figs. 11-14.—Plans and Sections illustrating the formation of Escarpments.

Fig. 11.

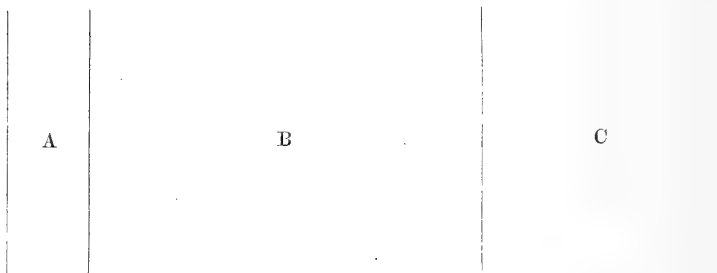


Fig. 12.

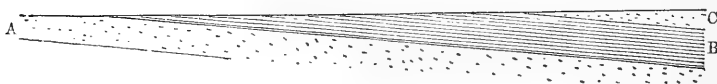


Fig. 13.

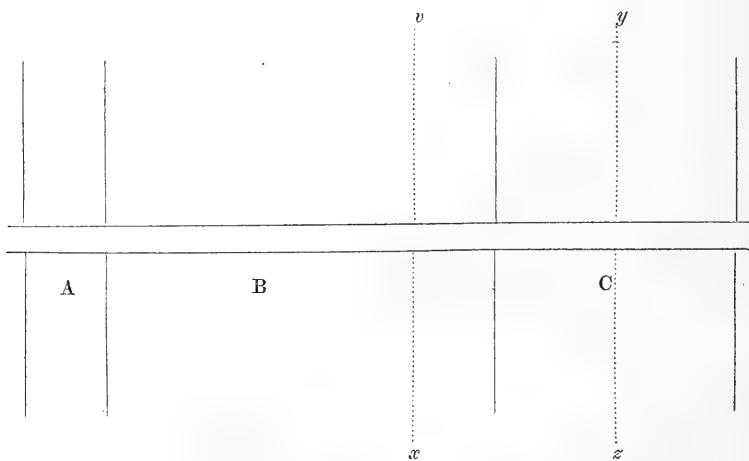


Fig. 14.—Section along the line y z.



Figs. 15–18.—Plans and Sections illustrating the formation of Escarpments.

Fig. 15.—Section along the line $v x$.

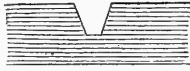


Fig. 16.—Section along the line $y z$.

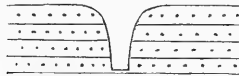


Fig. 17.—Section along the line $v x$.

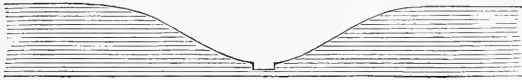
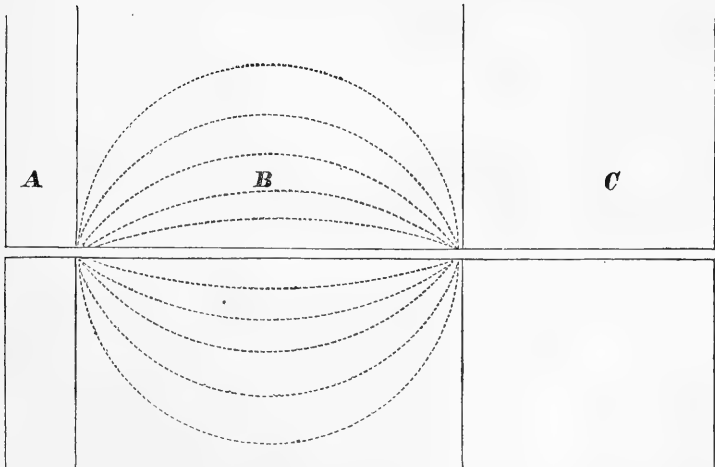


Fig. 18.



great spread of brick-earth round Hadlow. The brick-earth there is not let into pipes, because it rests on clay.

The occurrence of great floods, as suggested by Mr. Prestwich*, may also be due to the probable low winter-temperature during the deposition of the higher gravels. The effect of a low winter-tem-

* Proc. Royal Soc. for March 1862, p. 47; Phil. Trans. vol. cliv. 1864, p. 290.

perature would be the storing up of snow and ice, the sudden melting of which in the spring would bring about floods.

We have thus far been speaking of the rivers when the land is stationary or sinking. If, however, an elevation takes place, the river will commence deepening its channel. The elevatory action may be so slow as to allow the river to travel all over its alluvial plain, reducing all alike to a new level; but more commonly "terraces" of the old alluvium will be left, which, unless completely removed by atmospheric action, will remain to show the former position of the river. This process we conceive to have been going on during a long period of time in the Medway valley, the gravel at the 300-foot level being the oldest river-bed remaining; between which and the nearest point of the Medway there is no higher ground intervening.

δ. *On the Origin of Escarpments.*—In treating this subject we will first take a hypothetical case, and then apply the principles there explained to the area under consideration*.

Let fig. 11 represent in plan, and fig. 12 in section, three beds, A, B, and C,—A and C being sandstone, and B being clay; and let us suppose the plane formed by the denuded edges of the beds to slope down in the direction from A to C; let rain fall on this sloping surface, slight inequalities of the ground will make the rain flow into a number of small rivulets, and, as the principal slope is at right angles to the line of strike, the rivulets will take the same general direction, and begin cutting out channels or small transverse valleys. In plan, the channel would be shown as in fig. 13. If we had nothing but sandstone of uniform hardness, the stream would merely cut itself a gorge, the breadth of which would be the same all along. When we come to rocks of different hardness, however, the case is otherwise. The stratum B, being of clay, will suffer much more from atmospheric denudation at the sides of the gorge than the strata A and C. Each shower of rain, each frost, will do its part in degrading the soft clayey walls of the valley; slips, too, may come to our aid, and the transverse stream will carry off the débris and rain-wash. In this manner the valley will be widened where it passes through the bed B. Figs. 14 and 15 will show sections, along the lines *vx* and *yz*, through the sandstone bed and through the clay bed, before the atmospheric agencies have had much action. Figs. 16 and 17 show similar sections through the two beds, after the denuding powers of the atmosphere have produced some effect. The valley on the clayey strata is widened considerably, whilst the walls of the valley where formed by sandstone have scarcely suffered any change. The result of atmospheric action will be that the walls of the valley will get less and less steep where they are formed by the bed B. A sort of amphitheatre will be formed on each

* We would here again refer to the excellent paper by Mr. Jukes, in which the connexion between longitudinal and transverse valleys was first clearly explained, "On the River Valleys of the South of Ireland," *Quart. Journ. Geol. Soc.* vol. xviii. 1862, p. 378. See also Mr. Geikie's 'Scenery and Geology of Scotland,' 1865, p. 138.

side of the transverse valley, and these amphitheatres will extend themselves backwards along the strike, as shown by the dotted lines, fig. 18. Soon we shall have sufficient area to support a brook, and thus we shall get two brooks at right angles to the transverse valley, fig. 19. Fig. 20 shows a section from *r* to *s*, and fig. 21 a section from *p* to *q*. Of course, rain running down the slope, *b a*, will gradually wear off the face of the clay, and undermine the sandstone. In time the end of the sandstone, *b*, will succumb to the never-ceasing atmospheric agencies, and an escarpment will begin to be formed. An escarpment will be formed, and not an even slope, on account of the difference in hardness between the clay and the sandstone; and the latter will project, because it will suffer less from the action of rain than the clay. In the case we have assumed, there is another element to be taken into consideration, besides hardness. The sandstone will soak in a great deal of the rain that falls upon it, whilst every drop that falls upon the clay will produce a certain amount of mechanical erosion. However, where there is a steep slope on the sandstone the rain may produce considerable mechanical erosion, and the face of the escarpment will gradually be worn back, as shown by figs. 22 and 23. The sandstone-plain will also suffer to a certain extent, and its general level will be lowered slightly; but it will suffer much less than the face of the escarpment, as its slope is but small.

The rate at which the escarpment is worn back will depend on the rate at which the river deepens its valley. It must not be inferred from this that the escarpment would not go on wearing its way back, if the stream merely performed the office of carrying the rainwash down into the transverse valley. The escarpment would continue to wear its way back, but the difference in level and, consequently, the slope between the edge of the escarpment and the bottom of the valley would constantly be getting less; if the level of the land remained stationary, the amount of rainwash would get less and less, and in time the slope would get so small that rainwash would not be carried down, and the formation of the escarpment would cease. If, however, the stream at *a* has an excavating power, which enables it to preserve a certain slope between itself and the escarpment, then the wearing back will always go on. The excavating power of the stream in the longitudinal valley will depend on that of the transverse valley; and if the sea-level remains constant, the transverse stream will go on deepening its bed and lessening its excavating power, until at last it ceases to have any at all. A slight elevation of the land would once more give the transverse stream an excavating power, which in time would be communicated to the longitudinal streams.

From what we have said it will be seen that we consider escarpments to be due to the difference of waste of hard and soft rocks under atmospheric denudation. When once a transverse valley has been formed, longitudinal valleys will be formed along the strike of the soft beds, and escarpments will be formed by the hard beds on the side on which the beds dip away from the valley, as in fig. 23.

Figs. 19-23.—Plans and Sections illustrating the formation of Escarpments.

Fig. 19.

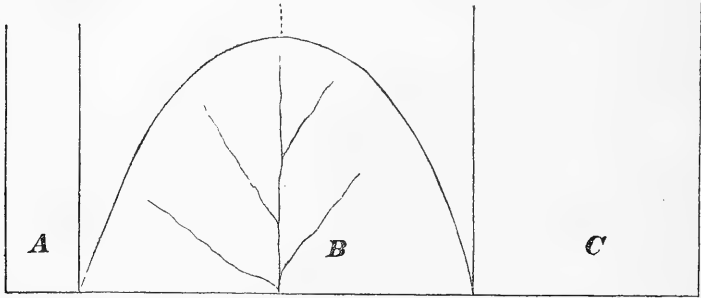


Fig. 20.

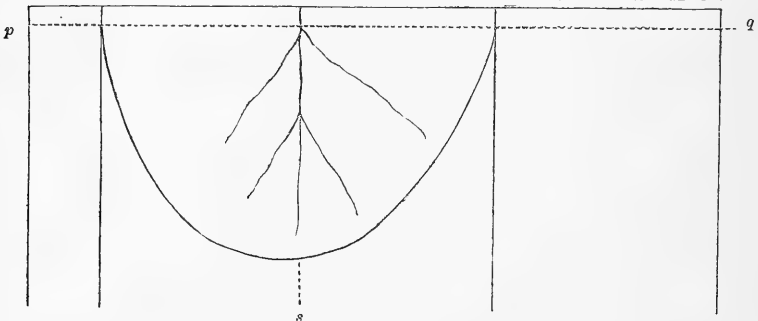


Fig. 21.



Fig. 22.

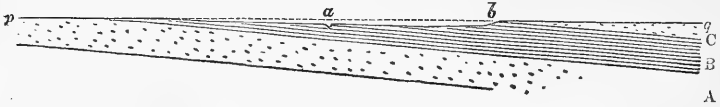
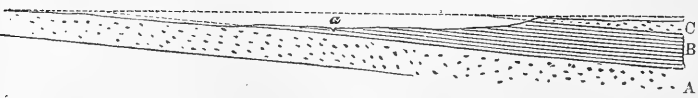


Fig. 23.



In the case of the Weald we have a long escarpment formed by the Chalk, and another by the Lower Greensand. We have already spoken of the many objections to their marine origin. There remains then only pure atmospheric denudation to account for these escarpments; and as we have what we consider *proof* that the Medway has deepened its valley 300 feet, we are not afraid of ascribing great effects to such a cause as atmospheric denudation. It must not be inferred, however, that we consider the escarpments to be *river-cliffs*. The longitudinal streams, though running parallel to these escarpments, do not run directly below them, but often, as with the Medway itself, at a considerable distance. No river-gravel in this area is ever found on *the face* of the escarpment; nor can we discover thereon any traces whatever of river-action. We have no reason then to ascribe them to the immediate action of the streams.

The manner in which we consider the denudation of the Weald to have taken place is as follows. After a large portion of the Tertiary and Upper Cretaceous strata, with some of the Lower Cretaceous beds, had been removed by marine denudation*, a comparatively plane surface was formed, which gradually appeared above water; probably the centre of the Wealden area rose out first, forming an island, and then as the land rose a spread of country was formed sloping down to the north and south from an east and west ridge. The central ridge determined the flow of the water that fell upon the area, streams began to flow to the north and to the south, and in this manner the transverse valleys of the Wey, Mole, Darent, Stour, Cuckmere, Ouse, Arun, and Arun were first started. At the same time the longitudinal valleys along the strike were formed, on account of the difference in hardness between the various rocks. The moderately *hard porous* Chalk has suffered less than the *soft impervious* Gault, and the *hard porous* Lower Greensand has been less denuded than the *soft impervious* Weald Clay. As we are dealing with limestone beds, we must take into consideration the chemical action of the rain charged with carbonic acid. The top of the Chalk and Kentish Rag certainly suffer from this action, and their general level is gradually being lowered. The mechanical atmospheric denudation, however, exceeds the chemical denudation, and, in spite of the general lowering of the Chalk and Kentish Rag, they still form escarpments.

CONCLUSION.

In conclusion, we will revert to the main points discussed in this paper.

After describing the gravel of the Medway valley, we have endeavoured to prove that an old river-gravel of the Medway occurs 300 feet above its present level. We have then shown that, if this fact be admitted, it follows that so large a denudation has been effected by rain and rivers that there can be but little difficulty in

* The term "plane of marine denudation" was first used by Prof. Ramsay (see Brit. Ass. Rep. 1847, Trans. Sects. p. 66).

supposing the present form of the ground in the Weald to have been produced entirely by these agents.

With regard to the time which has elapsed since this denudation commenced, nothing can as yet be said with certainty save this, that the plain of marine denudation was formed *after the deposition of the Eocene beds*, and that, therefore, the present valleys of the Weald have been formed since that period. Should the doubtful beds occurring at intervals along the top of the North Downs turn out to be Crag*, as believed by some geologists, "then," to quote again Prof. Ramsay †, "the bay-like denudation of the Weald has probably entirely taken place since that epoch; implying another lapse of time so long that, by natural processes alone, in rough terms, half the animal species in the world have disappeared, and been as slowly replaced by others. This may mean little to those who still believe in the sudden extinction of whole races of life; but to me it signifies a period analogous to the distance of a half-resolved nebula—so vast that if it were possible to express it in figures the mind would refuse to grasp its immensity."

JUNE 7, 1865.

The following communications were read:—

1. *Note on OVIBOS MOSCHATUS*, Blainville. By Mons. E. LARTËT, For. Mem. G.S.

[Translated by the late H. Christy, Esq., F.R.S., F.G.S.]

CUVIER has given the history of three skulls of *Ovibos moschatus* discovered in Siberia, and figured by Pallas and Ozeretskovsky‡.

In 1846 M. Giebel§ noticed the existence, in the Museum of Halle, of part of a skull found in the neighbourhood of Merseburg.

In 1852, Sir John Richardson, in the 'Zoology of the Herald,' gave a list and some figures of some remains of *Ovibos moschatus* brought from the Bay of Eschscholtz, with bones of Elephants, Reindeer, and other Mammals.

In 1855 Professor Owen|| described, under the name of *Bos moschatus*, a fine fragment of skull of *Ovibos moschatus*, discovered by the Rev. Mr. Kingsley and Mr. Lubbock at Maidenhead, in Berkshire, on a bed of low level-gravel, of which Mr. Prestwich gave at the same time a description¶, with a sketch of the bed, in which he afterwards found an Elephant's tooth.

In the third edition of the 'Antiquity of Man' Sir Charles Lyell further cites a skull of *Ovibos moschatus* found by Mr. Lubbock, near

* Prestwich, 'Quart. Journ. Geol. Soc.' vol. xiv. 1858, p. 322. Sir Charles Lyell (Elements of Geology, 6th edit. 1865, pp. 232 and 368) considers these beds to be Upper Miocene. In the last edition of Mr. Greenough's Map (1865) they are coloured "Crag."

† 'Physical Geology and Geography of Great Britain,' 2nd edit. p. 84.

‡ Oss. Foss. 4to, vol. iv. p. 155-159.

§ Leonhard and Bronn's Neues Jahrbuch, 1846, p. 460.

|| Quart. Journ. Geol. Soc. 1856, vol. xii. pp. 124-31.

¶ *Ibid.* pp. 131-33.

Bromley, Kent, in the valley of a small affluent of the Thames; and also two other skulls, male and female, discovered in the drift of the Avon, near Bath Easton, by Mr. Charles Moore*.

In the same page of the 'Antiquity of Man' Sir Charles Lyell further mentions a skull of *Ovibos moschatus* preserved in the Museum of Berlin, and which Mr. Quenstedt had determined in the year 1836; but I have failed, even with the indications given by Sir Charles Lyell, to find the description of this skull.

In 1859 Professor Hébert communicated to me a molar tooth found by the Abbé Lambert in the diluvium of the Oise at Viry-Nouveau, near Chauny (Aisne), in association with remains of *Elephas antiquus* and *E. primigenius*, *Rhinoceros tichorhinus*, *Hyæna*, a small Bear, Reindeer, &c. This tooth I ascertained to be a molar of *Ovibos moschatus*.

In 1863 Professor E. E. Schmid, of the University of Jena, described, under the name of *Bos Pallasii* (De Kay.), a portion of skull of the same species discovered in 1862 in the ancient alluvium of the Saale‡.

In 1864 Dr. Eugene Robert sent me a very fine piece of the skull of *Ovibos moschatus*, discovered by him in the diluvium of the Oise at Precy, near Creil (Oise), in the same spot where he had collected the remains of an Elephant's tusk. I announced this discovery to the Academy of Sciences at its sitting on the 27th of June, and I addressed to the Geological Society of London an extract from my communication, with a plate, in which were figured this skull and the molar teeth found at Viry by the Abbé Lambert§.

Further researches at one of our stations in the Gorge d'Enfer (Dordogne) have produced a hoof phalange exactly identical, both in form and dimensions, with the corresponding bone of the existing *Ovibos moschatus* (*Bos moschatus*, auct.). It was found, in association with remains of the Great Cave Bear (*Ursus spelæus*), Lion (*Felis spelæa*), Wolf, Reindeer, and Aurochs||.

It is to be noted that in the three localities where the bones of *Ovibos moschatus* have been observed in France, there have been also gathered the products of human industry.

At Viry-Nouveau worked flints were found by l'Abbé Lambert, of which two specimens were sent to London. At Precy was found, in 1860, an axe of the St. Acheul type, which was presented to the Geological Society of France by M. de Verneuil at its sitting of the 21st of May, 1860, and of which Sir Charles Lyell makes mention in pp. 152 and 153 of the 'Antiquity of Man.'

At the Gorge d'Enfer worked flints have also been found, as well as Reindeer-horn unbarbed lance-heads of a type differing from

* 'Antiquity of Man,' 3rd ed. p. 156.

† Ann. des. Sc. Nat. 8vo. 4ième série. Zool. vol. xv. p. 224.

‡ Leonhard and Bronn's Neues Jahrbuch, 1863, p. 541.

§ Comptes rendus de l'Acad. des Sci. Séance 27 Juin 1864.

|| Since this paper was communicated to the Geological Society, the author has discovered among the fossil remains of the same station in the Gorge d'Enfer, seven new bones of a hind leg and foot of *Ovibos moschatus*; the long and marrowed bones being split and broken like those of the other herbivora used for food by the ancient indigenous tribes of Perigord.

those found in any other of the Dordogne caves, but identical with those of Aurignac (Haute Garonne) and of Chatelperron (Allier).

The discovery of this fragment of *Ovibos moschatus* in the Gorge d'Enfer gives us the most southern spot where this species has been observed*, and by it its Quaternary habitat is carried down 15° to the south of its existing limit in North America, where it is known that this animal is rarely found below the sixtieth degree of latitude.

The Reindeer, whose migrations are still more extensive, was advanced yet further south during the Quaternary period, as I have found its remains on the northern slopes of the Pyrenees.

2. *On some ADDITIONAL FOSSILS from the LINGULA-FLAGS.* By J. W. SALTER, Esq., A.L.S., F.G.S. *With a NOTE on the GENUS Anopolenus*; by HENRY HICKS, Esq., M.R.C.S.

In my last communication, of March 1864, I described all the fossils then known from the Lower Lingula-flags of Pembrokeshire. There are now several more forms to communicate, some of which are generically new, and others are new species of old and well-known genera. I must confine myself in this paper to one or two species of which a better knowledge has been obtained, and the description of which it is desirable to amend, as the forms differ in some marked peculiarities from any of the Trilobite-group hitherto described.

The new genus *Anopolenus* (see vol. xx. p. 36) was supposed, and with good reason, to be a blind Trilobite allied to *Paradoxides*, without facial sutures or head-spines, and with truncate body-segments not produced into spinous appendages as in most of its congeners (see pl. xiii. of the vol. above quoted, figs. 4, 5). All this was true so far as I then had materials; but the subjoined description, by my friend Mr. Hicks, of a new species of the genus will show that I then only had a part either of head or body of this curious animal, which turns out to be more truly intermediate between *Paradoxides* and *Olenus* than was before supposed, while it also presents characters contradictory to those of either genus. It possesses eyes, facial suture, and expanded pleuræ; but the arrangement of these is abnormal, as Mr. Hicks's description will show.

Before giving his description of them, however, I would call the attention of the Society to a new fact of some importance with respect to the fauna of the Lower Lingula-flags. As noticed in the paper above quoted, the fossils occur in a band, but a little distance above the base of the Lingula-flag series, in fact only one hundred feet or so from the grey Cambrian rocks. Having faith in the continuity of the band, I had begged Mr. David Homfray, of Portmadoc, to employ his first leisure in examining the same horizon in the Ffestiniog country, a locality which had hitherto been neglected. He met with his usual good success; and found not merely the same genera, but many of the species which we had discovered at

* The supposed skull of *Bos Pallasii*, De Kay, from the alluvium of Mississippi at New Madrid, has been recognized by Mr. Leidy as referable to his genus *Bootherium*.

St. David's. I think hardly any of the forms are distinct. There are *Anopolenus*, *Conocoryphe*, *Microdiscus*, *Holocephalina*, together with *Theca* and *Agnostus*, all, or nearly all, of the same species as those described in our paper. There is also a new genus of Trilobites, which we have called *Erinnys*, distinguished by the great number of the body-rings; and this is also found in both North and South Wales.

This identity of forms between localities so widely separated and on the same horizon, gives us great reason to believe that the fauna is a marked and persistent one over larger areas. And we have large seen that it is distinct specifically both from the fauna of the Middle and from that of the Upper Lingula-flags. Curiously enough, however, the great *Paradoxides*, which is the conspicuous fossil in South Wales, has not yet been found in the North Welsh locality. But at an intermediate spot (the famous gold-mines of Dolgelly) fragments of this large fossil were found about the same time by Mr. Readwin, and by his assistant-chemist, Mr. Ez. Williamson, the superintendent of the lead- and silver-mine at Tyddyn-gwladys. I examined this ground critically last autumn, and found that the position of the "Paradoxides-beds" (*Theca* also accompanied the Trilobites) was the same as in South Wales, namely, a short distance above the Lower Cambrian Sandstones, in bands of uncleaved black slates mixed with trappean ashes. The facts above cited show that we are justified in recognizing the Lower Lingula-flags as a separate formation, quite as distinct from the upper portion as the latter is from the Tremadoc Slates which overlie it. All the species in the three separate groups, with very few and, indeed, trifling exceptions, are peculiar; and there are many distinct genera in each*.

Note on the GENUS Anopolenus. By HENRY HICKS, Esq., M.R.C.S.

NEW specimens having been found during my search at St. David's, I have been enabled to reconstruct the form of this very curious fossil, of which two species are known. My friend Mr. Salter did me the favour to name the first one after myself, when defining the genus so far as then known. The second and larger species is more common than the first, and he allows me to name it after him, in memory of pleasant days spent together on the cliffs of St. David's.

GEN. CHAR.—Elongated and depressed. Head occupying a fourth of the whole length, semicircular, with prolonged spines, and a clavate glabella having four pairs of furrows; large, punctate, and strongly margined fixed cheeks, each a quarter of a circle in shape, and reaching nearly to the front of the glabella, against which the extremely long eyes abut; thence the facial suture curves outwards, and is marginal in front. The long eye-lobe which forms the margin of the fixed cheeks reaches quite to the glabella in front, and very nearly to the posterior angle below. The free cheeks are a narrow band, margined, and reaching only three-fourths down the

* We have now (October 1865) in all 33 species, distinct and confined to this formation, for which the new term "Mænevic Group" was proposed, Sept. 1865, at the Meeting of the British Association at Birmingham.

fixed cheek! Labrum —? Thorax more than as long again as the head, somewhat narrower in its upper three-fourths than the width of the free cheeks; but the width of the lower fourth, in consequence of the greatly increased length and thickness of the three or four hindmost pleuræ, is much greater, and nearly equal to that of the whole head. The tail is wide and expanded, but narrower than the body. It is widely marginate, and serrated by six or eight marginal spines.

ANOPOLENUS SALTERI, sp. nov. (Hicks).

AN. $4\frac{1}{2}$ *unciæ longus, axe lato; capite magno, margine frontali lato, longispinoso. Glabella angusta, genis æqualibus, frontem attingens, sulcis quatuor brevibus. Oculi longissimi, anticè glabellam, posticè cervicem attingentes. Thorax segmentis 14 (an plures?). Pleuræ anteriores axe angustiores, spinis brevibus recurvis; posticè 3 vel 4, spinis longissimis, curvatis. Cauda semicircularis, emarginata, serrata, axe 5- vel 6-annulato, margine lato, sex-dentato.*

Description.—The head—not including the long slender spines, which extend backwards to opposite the ninth or tenth pleuræ, and at a slight angle to the general axis—is semicircular, with an even outline, and bounded by a strong wide margin, which is only slightly narrower in front. The glabella occupies about a third of the width of the head, being broadest across the frontal lobe. It reaches far forward, where it is slightly contracted, and separated from the front margin only by the deep furrow which surrounds the head. It is raised a little above the level of the cheeks, having rather deep axial furrows intervening. Well marked glabella-furrows divide it into a frontal lobe, three lateral lobes, and a neck lobe, but are not complete across in this species, which thus differs at a glance from *A. Henrici*. The frontal lobe is large, wide, and bounded below by the supplementary or first pair of furrows*. These are short, less distinct than any of the others, and sinuate, arising from the sides of the glabella at its broadest part, and reaching to about one-fourth of its width; their inner extremities nearly touch the second pair of furrows, thus forming small triangular lobes on either side. The third or median furrows are well marked, equal to the fourth or ocular pair, but less strong than the basal and neck furrows; they arch gently forwards and stretch equally across with the ocular and basal, leaving centrally an intervening, narrowed, elevated space, which extends in this species all down the middle of the glabella. The ocular and basal furrows run inwards nearly in a straight line (the former being perhaps a little curved); but the latter is much deeper and wider than the former, and equal to the neck furrow, which is the only one continued direct across. The neck and basal lobes are of equal breadth; both exceed the middle lobe, which again is broader than the upper or third lobe.

* There are only a few genera in which the anterior or supplementary pair is found.

The cheeks are divisible into two portions, which must be separately described. The fixed cheeks are wide, nearly triangular, bounded at the base by the posterior margin, and on the outer side by a broad rim or margin, which continues of the same breadth all the way up, and is the upper covering of the eye*. Outside this the linear free cheek is continued backwards by its strong margin to form the long curved slender spines, whilst the limb is contracted and does not reach to the posterior margin of the fixed cheek; in consequence of this contraction occurring about $\frac{1}{4}$ of an inch above the line of the posterior margin, the outer angle appears to be suddenly and abruptly emarginate and to have two posterior angles. A rather narrower border (eye-lobe) surrounds the fixed portion of the cheek, dividing it from the outer, extending from opposite the frontal lobe of the glabella to the posterior margin, and including within it a spherico-triangular space. This surface is flattened, rugose-punctate, and rises into a sharp narrow ridge on its inner border, from opposite the middle glabella furrow down to the neck furrow. The neck furrow is strong and wide, and continuous at the outer angle with the equally strong furrow which runs inside the strong border (eye-lobe) of the fixed cheek. The facial suture curves outwards and upwards above the eye, and cuts across the outer margin; also downwards and outwards below the eye along the broad margin or eye-lobe of the fixed cheek to the posterior border, terminating just above and to the outside of its short acute angle. The outer cheeks are, as above said, long and narrow, and terminate in the long tapering head spines, which, though moderately wide at the base, are for the most part slender, and extend backwards to opposite the ninth or tenth pleuræ. The outer cheeks are, moreover, very loosely attached to the head, and are very seldom found *in situ*.

The labrum is large, much compressed and expanded at the base; the apex truncate, with short spinous angles; a deep sulcus runs along the inner border of the apex, and a little within this on either side a small tubercle is seen. (No perfect specimens of the labrum have yet been found.) The thorax, comprising more than a half of the whole length, has a broad axis consisting of 14 or more segments, the upper seven or eight being wider than their pleuræ, including their short spines, whilst the last three or four are from $\frac{1}{2}$ to $\frac{1}{4}$ shorter than their attached pleuræ, the spines of which are greatly and suddenly increased in size and length. The axis is gently raised above the pleuræ, and is separated from them by rather deep axial furrows; the segments of the axis curve slightly backwards, and have a strongly sculptured surface. The pleuræ are broad, much flattened, and marked by a rather distinct lineation running parallel with the upper and lower borders, grooved deeply and obliquely from their upper inner angle to their outer margin at the base of the spines. The spines

* This remarkable border, which at first sight appears so anomalous, running across the cheek as if there were two borders to it, is in reality the eye-lobe! The eye is thus of immoderate length. We have only lately seen it in the true light; and I find that Prof. Angelin has figured a very similar fossil under the name of *Paradoxides Loveni*. It has a somewhat shorter eye.—J. W. S.

are very small and scarcely perceptible in the upper pleuræ, and are still short in the middle ones, but become suddenly increased in size in the five hindermost—the third upwards from the tail being longest, reaching as it does for nearly a fourth of its length beyond the extremity of the tail; the two hindermost pleuræ again shorten gradually, the last one terminating just above and in a line with the foremost serration of the tail, to which it is, moreover, for its inner two-thirds, closely compressed. The spines in each case turn sharply backward from the fulcrum, and have tapering extremities; the upper and middle thinning gradually from the fulcrum, whilst the hindermost first swell out, attain their greatest breadth about midway, and then taper regularly.

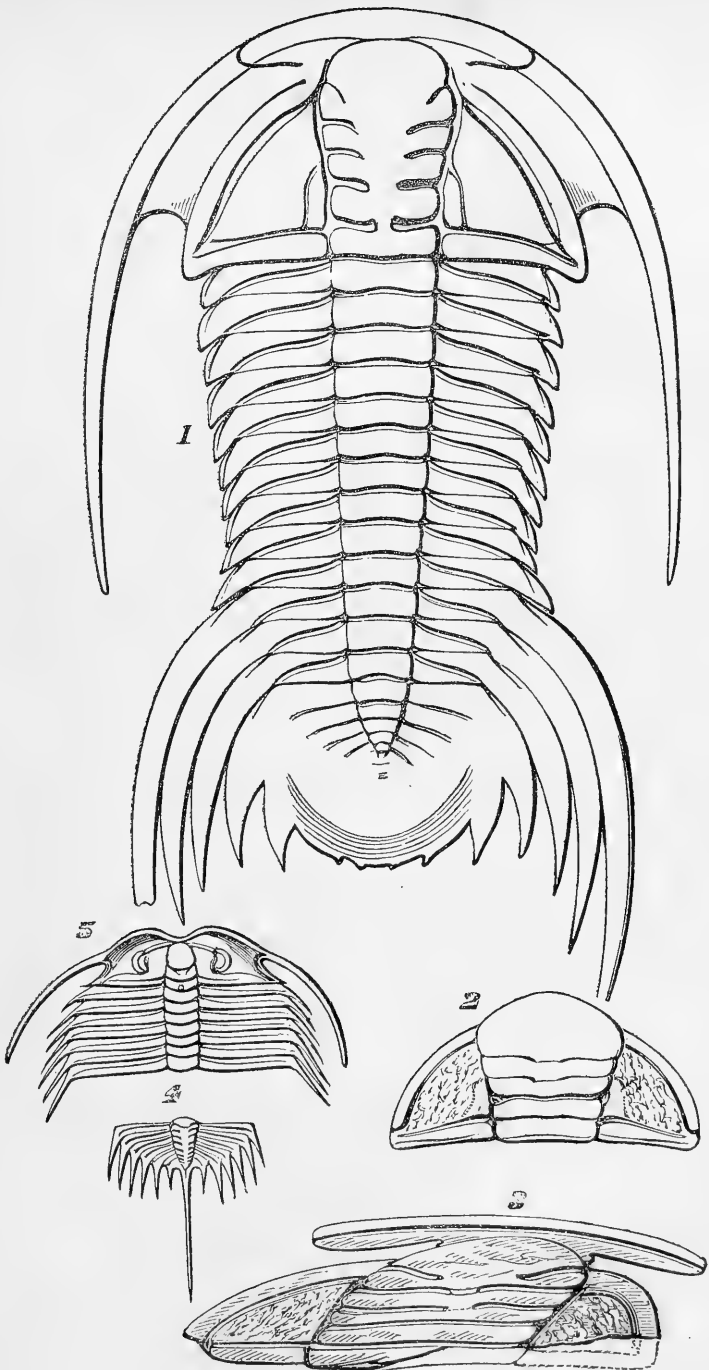
The tail consists of a raised axis of five or six segments, with a broad nearly semicircular serrated limb, and is much narrower than the thorax. The axis reaches backwards nearly to the posterior margin, its last segments, however, being in most cases ill defined. The sides are distinctly marked by furrows and ridges which pass from the central segments to the lateral serrations, and are bounded by a broad raised margin, having concentric lines, and moreover marked by transverse elevations where the lateral ridges (or pleuræ) are continued into their terminal spines. There are always three distinct serrations on either side, which diminish gradually backwards, the last being a little on one side of the line of the axis; in some cases, however, another is seen still further back, but in all cases the terminal part of the limb is quite free from them.

HENRY HICKS.

We may now compare this species, which has long been recognized as distinct by my friend and myself, with *A. Henrici*, Salter, published in vol. xx. p. 236, from specimens which, wanting the marvellous free cheeks, did not afford us scope for characterizing the genus fully.

A. Henrici has the glabella twice the proportional width of that of *A. Salteri*, and the three lower furrows complete across. It has the facial suture reaching even further out in front, so as to include a wider stretch of the margin; and we do not know of any spinous tips to the front pleuræ. The tail is less expanded, more triangular, and has a much broader axis.

In no genus that I have ever seen do the two portions of the cheeks show so clearly the distinctness of the two segments, anterior and posterior, which form the head of a Trilobite. Separate the anterior one with the long eyes in this genus, and you have, to all appearance, a complete head left, with a true border to the cheek, such as is possessed by numerous Trilobite genera. I naturally thought that we had in *Anopolenus Henrici* (*l. c.*) a blind Trilobite, and so described it. But further researches in the rocks of St. David's showed us, first fragments, then heads, then bodies, of a form unlike any other Trilobite, but clearly enough belonging to the family *Olenidæ*. I described the genus briefly from these more perfect materials at the Meeting of the British Association at Bath, in 1864, and a short



1. *Anopolenus Salleri*, restored. St. Davids.
 2. ———— *Henrici*, imperfect head.
 3. The same, obliquely pressed. Tafarn
 Helig, North Wales.

4, 5. *Olenus (Spharophthalmus) Pecten*. Upper
 Lingula flags of Malvern. Tail natural
 size, body and head enlarged.

notice of it will be found in the Geological Magazine for December, 1864.

With it, and illustrating the remarkable character of the abbreviated outer cheek, was noticed, but not described, a new species of *Olenus* which had been found at Malvern, the *O. Pecten*. This belongs to the section *Sphaerophthalmus* of that genus. As it has been fully described, and only imperfectly figured, in the Decade 11, Geol. Survey, pl. 8, figs. 12, 13, there is no need to give a full description here, but I figure the very perfect head in connexion with some body-rings and the tail-piece (figs. 4 & 5). Both exhibit the very extreme of anomalous and extravagant characters in the appendages, and might have prepared us to expect some such form as *Anopolenus*, in which the characters of *Paradoxides* are reversed as regards the pleuræ.

3. *On some NEW SPECIES of CRUSTACEA belonging to the ORDER EURYPTERIDA.* By HENRY WOODWARD, F.G.S., F.Z.S. (of the British Museum).

(Plate XIII.)

HAVING last year visited, in company with Mr. James Powrie, F.G.S., certain localities in the vicinity of Forfar, Arbroath, and Dundee, noted for the occurrence of Devonian Crustacea, I am now enabled, through the kindness of my friend, to describe some interesting remains of two new species of the genus *Stylonurus*.

This genus was proposed by Mr. David Page in his paper read before the British Association, at Glasgow, 1855, and the name was published in his 'Advanced Text-Book of Geology,' 1856, where he also figured and named the then only known species belonging to that genus—*Stylonurus Powriei* (after its discoverer), but without giving any description.

Since that date much better materials for the illustration of this genus have been afforded by the labours of Messrs. James Powrie and Robert Slimon.

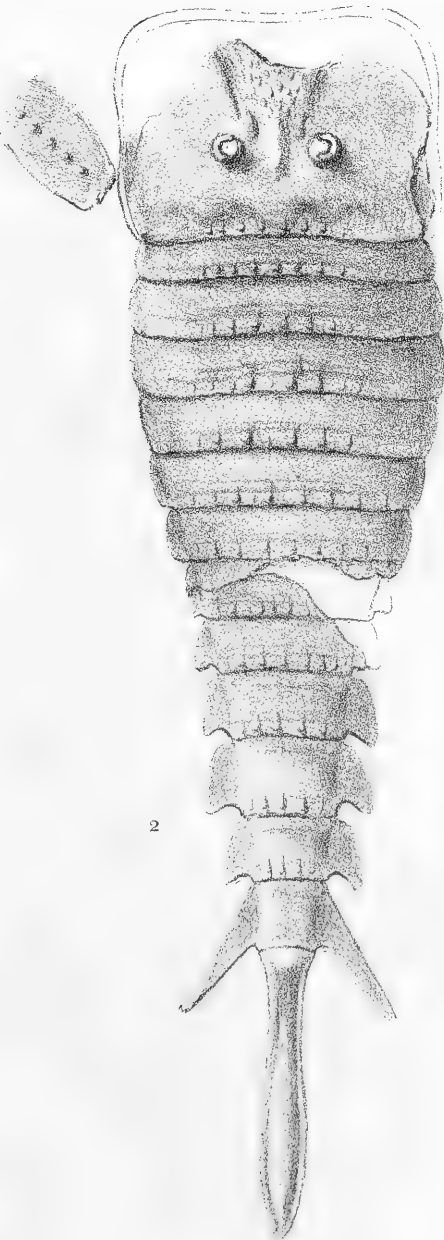
1. *STYLONURUS POWRIEI*, Page.

This species occurs in the Old Red Sandstone of the Turin Hill range, near Pitscandy, in Forfarshire. The most important characters by which the genus is distinguished are the peculiar form of the carapace, the great length of the telson or terminal joint (in *S. Powriei* one-third the length of the entire animal), and the substitution of two pairs of long, slender, oar-like jaw-feet, instead of the single pair of broad, short natatory organs more usually met with in this group.

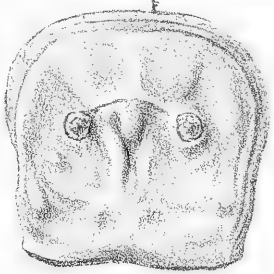
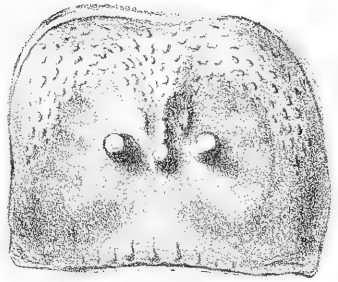
The impression and counterpart of *S. Powriei* (Page), being only on sandstone, and, in all probability, the interior side of the upper surface, do not afford such good material for description as the specimens of the other species to be hereafter mentioned.

Dimensions.—The carapace measures 2 inches 3 lines across at its posterior border and 2 inches 7 lines in its greatest breadth, and 2 inches in length. It is bordered in front by a deep groove $\frac{1}{8}$ th of an inch from the external margin, which gradually unites with it halfway

8



2



4

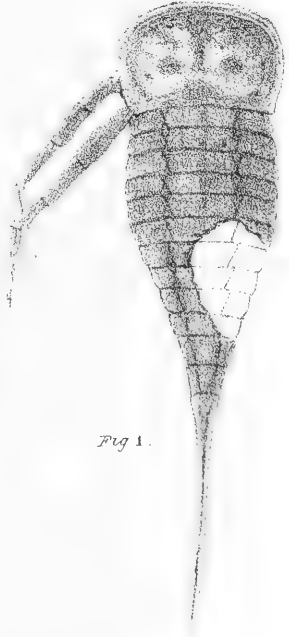


Fig 1.

up the sides, which rapidly contract for one-fourth of their length before reaching the posterior angle.

The eyes are placed $\frac{3}{4}$ ths of an inch apart on either side of a median furrow, which, passing forward, divides into two semicircular arches, and is lost in a series of minute tuberculations. On either side of the median line are two small oblong tubercles, placed between and slightly in front of the eyes. The eyes themselves can hardly be said to be preserved in this specimen, but their position is clearly indicated.

Only two pairs of long appendages in *S. Powriei* are known. The basal joints of these were furnished with palpi, as in *Pterygotus*, *Eurypterus*, and *Slimonia*. They appear to have been eight-jointed, the first joints being broad and flat, and no doubt precisely like that of *Stylonurus Loganii*, mihi*; the second, a short articulation not clearly seen; the third, about one inch in length, and having a keel down the centre; the fourth, 10 lines in length, also keeled; the fifth and sixth, 7 lines; the seventh and eighth, 6 lines each. The third and fourth joints seem to have been about 5 lines in width, and the others slightly narrower to the eighth, which terminates in a fine slender point slightly incurved. The two pairs of limbs on either side appear to have been about equal both in length and breadth.

The body-segments, twelve in number, increase gradually in breadth to the fourth, when they as gradually decrease to the eighth, whilst the four remaining segments rapidly decrease in breadth and increase in length.

Dimensions.—Thoracic segments: first, 2 inches 3 lines broad, 3 lines long; second, 2 inches 5 lines broad, 5 lines long; third, 2 inches 5 lines broad, 5 lines long; fourth, $2\frac{1}{2}$ inches broad, $\frac{3}{4}$ ths of an inch long; fifth, 2 inches 3 lines broad, 5 lines long; sixth, 2 inches broad, 5 lines long; seventh (or first abdominal), 5 lines (about) long, 1 inch 7 lines broad (about); eighth (or second abdominal), 5 lines long, $1\frac{1}{2}$ inch broad; ninth (or third abdominal), 9 lines long, 17 lines broad; tenth (or fourth abdominal), 5 lines long, 14 lines broad; eleventh (or fifth abdominal), 6 lines long, 10 lines broad; twelfth (or sixth abdominal), 5 lines long, 9 lines broad, forming a semicircular curve into which the anterior margin of the tail is inserted.

The telson, or tail-spine, is 3 inches 10 lines in length, nearly 3 lines broad through its entire length, having a deep groove down its centre $\frac{1}{16}$ th of an inch in width. Two zigzag lines of plicæ pass down $\frac{1}{16}$ th from the head on either side of the thoracic segments, about $\frac{3}{4}$ ths of an inch from their lateral margins. These markings appear to be due to compression, and, as they are also noticeable in the Lanarkshire specimen, are probably lines along which the muscular attachment within was strongest.

The thoracic segments are slightly spinose along their posterior margins. *S. Powriei* had, probably, epimeral pieces to its abdominal segments: but, being as before stated a cast, these pieces would not

* See 'Geological Magazine,' vol. i. p. 197, pl. 10. fig. 1.

be shown attached, but remain upon the exterior slab, as is the case both in *Pterygotus anglicus*, in the Arbroath Museum, and *Stylonurus Scoticus*, described herewith.

2. STYLONURUS SCOTICUS, spec. nov.

Although not so large as *Pterygotus anglicus*, this new species is perhaps the most remarkable of all the Palæozoic Crustacea. It was found in an Old Red Sandstone Quarry in Montroman Muir, near the Forfar and Montrose Pike.

It is represented by a separate carapace (the relievo side of which is in Lady Kinnaird's cabinet, and the intaglio in the British Museum collection), and by an almost entire example which Mr. Powrie has been so fortunate as to obtain. The latter is lying on a slab of Old Red Sandstone, at full length, with its dorsal aspect exposed, and the five last body-segments detached entire, so as to show both the ventral and dorsal surfaces. The impression of the upper surface of the same on a separate slab exhibits in the most perfect manner the epimeral portions of each of the last four segments, and also the remarkable spatulate telson 9 inches in length.

The entire specimen is 3 feet 4 inches in length. The margin of the carapace is much injured; but fortunately the separate carapace is well nigh perfect, so that we are at no loss to ascertain its contour. The posterior margin of the head is at its narrowest point $9\frac{1}{2}$ inches in breadth and about 12 at its widest central portion, and (about) 8 inches in length.

There is an oblong median ridge in the centre of the carapace, terminating in a smooth rounded prominence 3 inches from the posterior margin, and extending forward about 2 inches. On either side of this central line are two smaller oblong prominences, rising more in advance of the central ridge ($4\frac{1}{4}$ inches from the posterior margin and about $\frac{3}{4}$ ths of an inch in length), broader in front than behind, and curving away from the median line, from which they are distant half an inch on either side. The central ridge and lateral prominences are carried forward in a V-shaped elevation which spreads out laterally as it advances; the whole of the front and antero-lateral portion being coarsely tuberculated, a single irregular row running down the median ridge.

The eyes are situated parallel to the median ridge, and arise exactly 1 inch on either side.

They are almost identical in form with those of *Phacops* and *Asaphus*, being arranged in a semilunar or horseshoe shape around a raised prominence. The cornea of the eye measures 22 lines, and is disposed outwards and forwards, the centre being directed towards the latero-anterior angles. The eyes are elevated about 5 lines above the surface of the carapace; probably they may have been even higher, but are somewhat compressed.

Very minute scale-like markings are seen on the lateral and posterior margins of the carapace and body-segments.

The margin of the head is double around the frontal and latero-anterior portion, as in *S. Powriei* and *S. Logani*, &c.

Thoracic Segments.—The first segment is $1\frac{1}{16}$ of an inch in length, and 10 inches in breadth; the lateral portion is rounded and curved upwards; the surface is minutely scale-marked.

The second segment is 17 lines in length, and 10 inches in breadth: a series of long tubercles borders the posterior margin, and the surface is covered with minute scale-markings. The lateral portion is rounded and slightly expanded.

The third segment is 2 inches wide, and $10\frac{1}{2}$ broad: three principal prominent tubercles mark the posterior margin, pointing backwards, and also several smaller ones.

The epimeral portion of all the thoracic segments is widely rounded, and a broad margin of each segment overlaps the succeeding one.

The fourth segment exposes 1 inch and 10 lines of its length.

The tubercles upon this and the third segment are the most strongly marked of any. It is 11 inches in breadth. The fifth segment (thoracic) is $1\frac{3}{4}$ inch in length, and 9 inches broad. The sixth segment is 19 lines in length, and (about) 8 inches in breadth. The seventh (or first abdominal) is 2 inches in length, and from 5 to 6 inches in breadth. (Here the specimen is fractured across, and the margins of this segment are wanting.) Each of the abdominal segments has large epimeral pieces, which have been well preserved upon the surface of the overlying slab.

The eighth (or second abdominal) is 14 lines in length, and 5 inches in breadth, including the epimeral portion, which is clearly shown. The ninth (or third abdominal) is $2\frac{1}{2}$ inches long, and $4\frac{3}{4}$ in breadth. The tenth (or fourth abdominal) is $2\frac{1}{5}$ inches in length, and $4\frac{1}{2}$ inches broad, including the epimeral portion. The eleventh (or fifth abdominal) is $2\frac{3}{4}$ inches long, and 3 inches 10 lines in breadth, including the epimeral portion. The twelfth (or sixth abdominal) is $2\frac{1}{4}$ inches in length, and $3\frac{3}{4}$ inches in width. From this segment two elongated epimeral pieces are developed, measuring $4\frac{1}{2}$ inches in length by about 5 lines in width, and terminating in a broad rounded point.

The telson ($9\frac{1}{4}$ inches in length) is somewhat broad at the point of attachment, and becomes slightly narrower in the first quarter, gradually widening to $1\frac{1}{2}$ inch. The central depression is $\frac{3}{4}$ inch in width. The termination is rounded, and the border does not appear to have been ornamented. Of the appendages, there remains only the single joint of a swimming-limb attached to the left margin of the carapace, measuring 4 inches in length by two in breadth, and having a row of tubercles upon the centre.

In a letter dated 9th February, 1865, Mr. Powrie writes—

“Mr. Salter has expressed his conviction that *Stylonurus Powriei*, and *S. Scoticus* are specifically the same—the larger one a full-grown male, and the smaller a young female, the longer and narrower body, shorter tail and epimeral appendages being all characteristics of the male; in other respects the resemblance is most marked.”

But if *S. Powriei* and *S. Scoticus* be identical, then the determination of the sexes in the British and American species of *Eurypterus*, *Pterygotus*, and *Slimonia*, by Prof. Hall and myself, is of no avail.

symmetrical or bilineal rows of plates being unknown (see Plate XIV. fig. 6).

More than 200 species are known, occurring in all climates throughout the world, from low water to 25 fathoms; and it is interesting to find that upwards of forty species of Chitons are recorded by palæontologists in a fossil state, extending back in time to the epoch of the Lower Silurian.

During the past month I have had my attention drawn by Messrs. E. J. Hollier and Charles Ketley to the two species of fossil Chitons which were described and figured by M. L. de Koninck ('Bulletins de l'Académie Royale des Sciences, &c., de Belgique,' 26^{me} année, 2^{me} sér. t. iii. 1857*, p. 199, pl. 1. fig. 2), and are from the "Wenlock Shale" and Limestone of Dudley. The only specimens then known were in the cabinet of Mr. John Gray, of Hagley, and are now in the British Museum. The species are named respectively *Chiton Grayanus* and *C. Wrightianus*; but it is to the last of these that I wish to direct attention. I have already stated the prevailing characters of the valves of the genus *Chiton*, namely, that they never exceed eight in number, that the series is always unilinear, and that the sides of the valves are symmetrical and divided into three areas.

From the specimens furnished me by the kindness of the before-mentioned gentleman, I am now able to state that the so-called *Chiton Wrightianus* of M. de Koninck is not a *Chiton*, seeing that it does not conform to any one of the above characters; and scanty as was the material at the disposal of M. de Koninck, I am enabled to prove from the very specimen on which the species was founded and the actual figure which he has published, that it is not a *Chiton*, but a Cirripepe.

The specimens show,

1st. That *Chiton Wrightianus* had probably as many as four rows of plates.

2ndly. That the two sides of each principal row of plates are unsymmetrical, and are somewhat different both in form and sculpture.

3rdly. That the series exceeds eight in number.

4thly. That the plates have a uniformly sculptured surface, and are not divided into three areas as in *Chiton* proper; and,

5thly. That the separate plates are without lateral processes (apophyses).

In M. de Koninck's plate is given a figure of the original specimen, which consists of two detached plates embedded in shale (Plate XIV. fig. 1 a). In this figure (fig. 2 a, *op. cit.*, reproduced in our plate, fig. 1 b) the plates are seen to be unsymmetrical; but in the restoration of the series which he gives (fig. 2 c.) they are represented as symmetrical, and the series is completed with terminal plates to match.

His description is as follows:—

* M. de Koninck's paper, with the original figures reproduced, appeared in the 'Annals and Magazine of Natural History,' ser. 3, vol. vi. p. 91. Translated by W. H. Baily, Esq., F.G.S., &c.

“The form of the dorsal plates of this species is subtriangular, the posterior edges making very nearly a right angle. The lateral angles are rounded, and the anterior edge is very sinuous. All the plates are supplied with a well-marked median carina, and appear to have been without apophyses. The surface is covered with a small number of equidistant striæ. The test is slender. The median area is larger than the lateral ones.

“This *Chiton*,” M. de Koninck adds, “resembles *Chiton Loftusianus*, King, but differs from it in the regularity of the striæ of the median and lateral areas, and by the more marked sinuosity of the anterior edge of its plates.”

From an examination of the figures of the very beautiful specimens (Plate XIV. figs. 1 *a-h*) it will be seen that we have evidence of two principal rows of inequilateral plates (Plate XIV. figs. 1 *i,k*), each with a strong median carina, and having their edges intersecting each other. Upon the two external margins can also be traced the remains of two other rows of much smaller plates, without a keel, but similarly ornamented with delicate lines of elevated striæ, which follow, as in the larger valves, the contour of the plate (see Plate XIV. fig. 1 *l*). Two specimens show as many as eleven plates in one series, and one about fifteen.

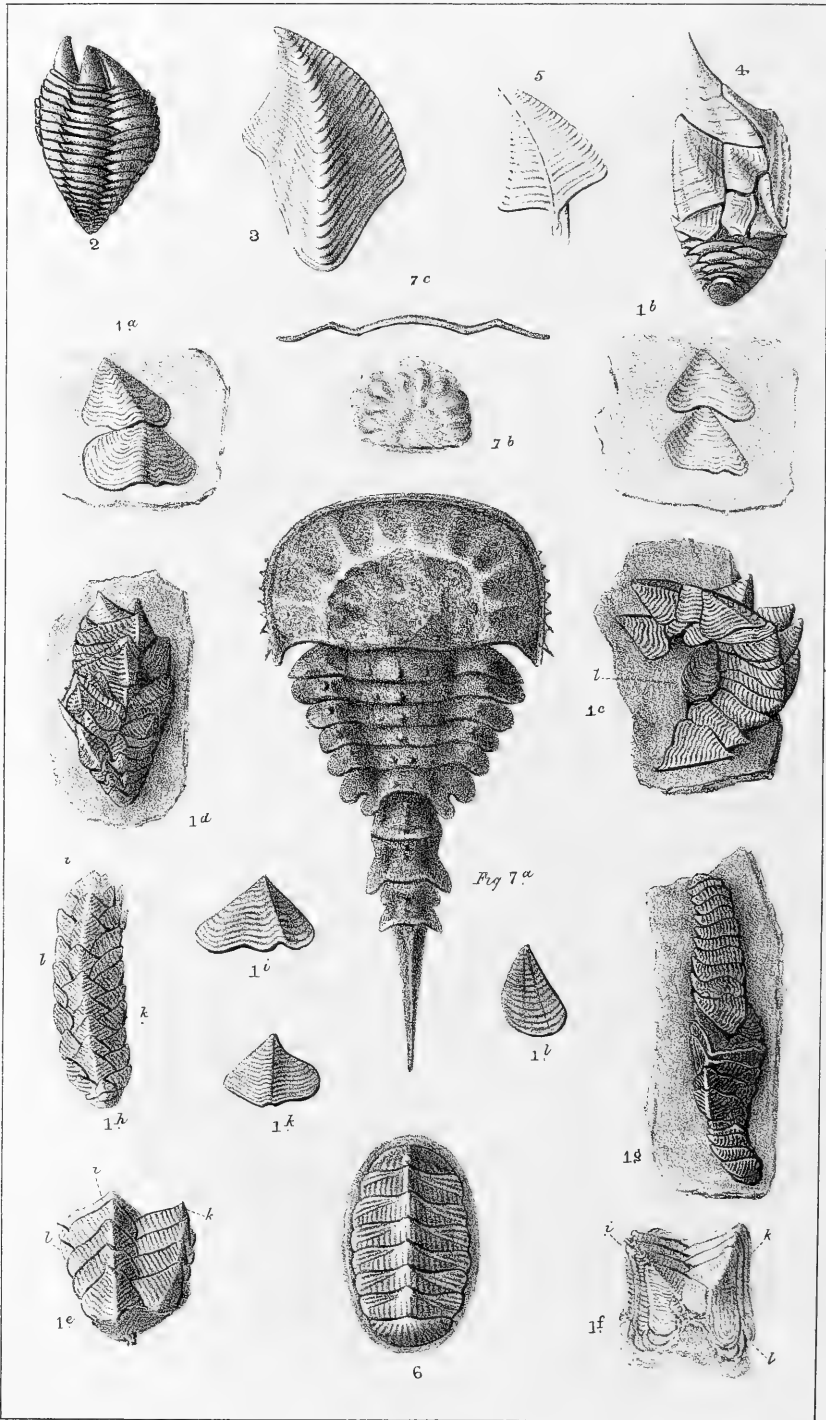
Having pointed out the objections to *Chiton Wrightianus* being accepted as a *Chiton*, it devolves upon me to show my reasons for considering it a Cirripede.

The first point of affinity is the ornamentation of the valves. This becomes at once apparent by comparing them with the opercular valves of *Balanus* (especially the tergum (Plate XIV. fig. 5), or of *Pollicipes* (Plate XIV. fig. 3).

Secondly, the plates have their overlapping points directed upwards, or towards what I believe to have been the aperture of the shell. This agrees with the structure of the *Cirripedes*, for Mr. Darwin has demonstrated that they are attached by their anterior extremity, the peduncle in the *Lepadidæ* being the cephalothorax greatly produced,

Thirdly, the rows of imbricated plates, with their intersecting edges, cannot be compared with any other order except *Cirripedia*, unless it be the Echinodermata, from which they differ in the absence of any trace of crystalline structure, and in the sculpturing of the valves; whereas the peduncles of *Scalpellum ornatum* (Plate XIV. fig. 4), *Loricula pulchella* (Plate XIV. fig. 2), *Pollicipes Redtenbacheri*, and *P. cornucopia* all indicate an analogous arrangement of the plates. Indeed, the shell of every *Balanus* is composed of a series of intersecting plates arranged around the soft body of the animal.

From the imperfect condition of the specimens, it is probable that the animal was attached by its side as well as its very slender base, as appears to have been the case in *Loricula* and in several Upper Silurian Cystideans. The opercular valves we do not know at present; but they were no doubt small, as the size of the scales would indicate that (as in *Loricula* and the recent genera, *Lithotrya*



5. *On a new GENUS of EURYPTERIDA from the LOWER LUDLOW ROCK of LEINTWARDINE, SHROPSHIRE* By HENRY WOODWARD, F.G.S., F.Z.S.

(PLATE XIV. figs. 7a, 7b, & 7c.)

THE specimen which forms the subject of this paper is in the Museum of Practical Geology, Jermyn Street, and through the kindness of Professor Huxley I have been permitted to describe it.

Its discovery was referred to by Mr. J. W. Salter, in 1857 (under the MS. name of *Limuloides*), in the 'Annals and Magazine of Natural History,' in a paper "On some New Palæozoic Starfishes," but the genus has never yet been described (except by myself at the British Association, Bath, 1864). The great interest attached to this new Crustacean is, that it appears to offer just the link we needed to connect the *Xiphosura* with the *Eurypterida*.

Limuli, apparently differing but little as regards the carapace from the recent species of China and America, occur as early as the deposition of the Solenhofen limestone of Bavaria; and in the Coal-measures of England and Ireland several species of *Bellinuri* occur, in which the cephalic shield is composed of the cephalo-thorax; and the segments of the abdomen if not anchylosed in all, are so in most.

But in the specimen under consideration we have the cephalic, thoracic, and abdominal divisions still remaining distinct, and apparently capable of separate flexure. This important character at once separates it from *Limulus* and *Bellinurus*.

I have on this account (*with the concurrence of Mr. Salter*) considered his MS. name of *Limuloides* inappropriate as a generic appellation, and adopted the name of *Hemiaspis* (from ἡμισος, *half*, and ἀσπίς, *a shield*), reserving Mr. Salter's name of *Limuloides* for the specific title of the most perfect specimen of the genus (see Plate XIV. fig. 7a).

But it will be observed that *Hemiaspis* is also, *in general appearance*, strongly severed from the other species of *Eurypterida*, as well as from the *Xiphosura*, in structure.

The three divisions into head, thorax, and abdomen are more strongly marked. The abdomen is reduced to very slender proportions (less than one-third the breadth of the thoracic plates). The telson is nearly one-third the length of the animal (the entire specimen measuring $2\frac{1}{2}$ inches in length by 1 inch in width).

The carapace in general outline resembles *Limulus*, but is more dilated laterally. There is a faint indication on one side of the shield of a facial suture, with a small aperture upon its border, as if to indicate the position of the eye, but it is by no means clearly defined.

The glabella (when perfect) appears from a second specimen to have been ornamented with a semicircle of nine tubercles, and a tenth immediately within the circle upon the elevated front, and two small tubercles at the posterior margin.

Four ray-like corrugations descend on either side of the glabella towards the margin of the shield, and the whole surface of the carapace is minutely tuberculated. The lateral margins of the shield are ornamented with minute spines, and the two posterior angles of

the carapace terminate in a broad triangular point directed backwards. Two lesser spines arm the lateral border of the glabella.

The thorax is composed of six strongly trilobed plates, the epimera being equal in breadth to the central portion of each segment (see Plate XIV. fig. 7b).

The first segment is the largest, being 1 line in depth and $7\frac{1}{2}$ lines in breadth, including the epimera, which are pointed at their extremities and slightly overlap the following segment. Three minute tubercles ornament the median portion of each segment. The four following segments have the borders of their epimeral pieces rounded, and gradually decrease in breadth downwards from 9 lines to 7, and increase in depth from $\frac{1}{2}$ line to 1 line.

A section of one of the segments would present an outline like that of *Phacops* among the Trilobites, namely a triple corrugation (Plate XIV. fig. 7b).

The sixth thoracic segment is more strongly arched than the preceding ones, and the lateral borders are divided into two rounded lobes on each side: breadth 5 lines, depth 1 line.

The abdomen consists of only three segments each, 2 lines in breadth and $1\frac{1}{2}$ line in depth. The first has no epimera, and appears to move freely at its articulation with the sixth thoracic segment. The second and third segments have small epimeral pieces, which are bilobed with the posterior lobe more pointed. A line of small tubercles runs down the centre of these three joints, which are somewhat raised at their articulations.

The telson is 12 lines in length and $1\frac{1}{4}$ line in breadth where it articulates with the abdomen. It tapers gradually to a fine point.

If we regard the first six body-rings from the head as thoracic, and the remaining three segments as abdominal, we must presume that each of these latter is a double segment, as compared with the segments of the *Eurypterida* proper.

On the other hand, the presence of these three segments precludes our considering the head to be the cephalothorax and the succeeding segments the abdomen, as in the *Xiphosura*.

The smallness of the abdomen, and its reduction from the assumed normal number of six to three, seems to indicate a form by which, with the help of others, we may bridge over the interval that has hitherto existed between these two groups, the *Eurypterida** and the *Xiphosura*.

There are several peculiarities about *Hemiaspis* which seem to offer analogies with the Trilobites, but we know so little of the structure of that very isolated group that we cannot venture to speculate on its affinity to this order.

Note.—Mr. Salter is acquainted with several species of *Hemiaspis*, which have been marked with MS. names by him in the Jermyn Street Museum. They are, however, *extremely fragmentary*. The species are as follows:—

* Among the *Eurypterida*, perhaps *Stylonurus Powrici* comes nearest in general form; but *Hemiaspis* will be seen to differ widely even from this genus.

1. *Hemiaspis limuloides*, H. W.
2. *Hemiaspis tuberculata*, Salter, MS.
3. *Hemiaspis optata*, Salter, MS.
4. *Hemiaspis sperata*, Salter, MS.
5. *Hemiaspis Salweyi*, Salter, MS.

These will be noticed in the Monographs of the Palæontographical Society.

PLATE XIV. figs. 7a, 7b, and 7c.

(*Illustrative of New Silurian Eurypterida.*)

Fig. 7a. *Hemiaspis limuloides*. Entire specimen: Lower Ludlow Rock, Leintwardine, Shropshire (enlarged one-third).

Fig. 7b. ———. Centre of shield (nat. size).

Fig. 7c. ———. Section of one of the thoracic segments.

JUNE 21, 1865.

Samuel Bailey, Esq., Mining Engineer, The Pleck, Walsall; William Keene, Esq., Sydney, New South Wales; and the Rev. Benjamin Waugh, Newbury, Berks, were elected Fellows.

The following communications were read:—

1. *On the CARBONIFEROUS ROCKS of the VALLEY of KASHMERE*. By Capt. H. GODWIN-AUSTEN. *With NOTES on the CARBONIFEROUS BRACHIOPODA*, by T. DAVIDSON, Esq., F.R.S., F.G.S.; *and an INTRODUCTION and RÉSUMÉ*, by R. A. C. GODWIN-AUSTEN, Esq., F.R.S., F.G.S.

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

(The publication of this paper is unavoidably deferred.)

[Abstract.]

THIS paper was a continuation of one read before the Society last year, in which the Carboniferous, Jurassic, and Post-tertiary deposits and fossils were described by Capt. Godwin-Austen, Mr. Davidson, and Mr. Etheridge. In this communication Capt. Godwin-Austen confined himself to the Carboniferous formation, which was shown by him to have, in the Valley of Kashmere, a thickness of more than 1500 feet. The upper portion of this mass contained but few fossils, except in one particular bed near the entrance of the ravine above the village of Khoonmoo; but the lowest portion, or Zèwan bed, is made up chiefly of the remains of Brachiopoda and Bryozoa; and a higher stage, though still near the base of the formation, contains abundant remains of *Producta*. The position of a limestone containing *Goniatites* is not very clearly determined, but it is probably a member of the Zèwan series.

The sections in which the relative positions of the different beds were exhibited were described in detail, and plans and a map were given showing their geographical relation.

Mr. Davidson described the Brachiopoda forwarded with the paper, stating that they abound particularly at Barus and Khoonmoo, but are rarely in a very good state of preservation. Among them are several common and wide-spread European and American

species, with a few that have not hitherto been noticed. They appear to be of Lower Carboniferous age.

In the introduction Mr. Godwin-Austen gave a synopsis of the more remarkable facts brought forward in the paper, and in a *Résumé* he gave lists of the fossils which had as yet been determined. These were forty-six in number, forty-two of which had specific names, and twenty-two of which are well-known forms; eight are common to the Punjab and Kashmere, seven of them being also European species. Of the Kashmere list, full half the species are found in British Carboniferous beds; and Mr. Godwin-Austen remarked on the support given to the notion of the approximate contemporaneity of distant formations containing the same fossils by the occurrence of these European Lower Carboniferous species near the base of the Carboniferous formation of Kashmere.

2. *On the MAMMALIAN REMAINS found by E. WOOD, Esq., near RICHMOND, YORKSHIRE.* By W. BOYD DAWKINS, Esq., M.A. (Oxon.), F.G.S., of the Geological Survey of Great Britain. *With an INTRODUCTORY NOTE on the DEPOSIT in which they were found.* By E. WOOD, Esq., F.G.S., and G. E. ROBERTS, Esq., F.G.S.

[Abstract.]

IN the introduction to this paper Messrs. Wood and Roberts state that a large assemblage of Mammalian and other bones was discovered, during the autumn of last year (in making excavations for a new sewer), on a terrace of blue clay mixed with limestone-débris, on the north bank of the River Swale, and at a height of about 130 feet above it. The bones lay at a depth from the surface of from 4 to 7 feet, in ground previously undisturbed; and it is supposed that the accumulation of clay and limestone-pebbles was derived from the limestones northward and westward by pluvial action, extending through a considerable period of time. Many of the bones have been cut and sawn by human hands, and the authors express their opinion that the deposit is made up of the commingled contents of several "kökken-möddings."

Mr. Boyd Dawkins also remarks that the condition of the bones proves them to have been derived from one of those heaps of kitchen-refuse that are of various ages, and that railway-cuttings have proved to be by no means so uncommon as is generally supposed. Most of the bones, except the solid and marrowless, are broken; and of the numerous skulls there is not one that is perfect. The great bulk of the remains exhibit unmistakeable evidence of being cut or sawn, and some are stained black as if from being imbedded in an old cinder-heap. The patches of blue colouring-matter visible upon a great many of the specimens are owing to a deposit of phosphate of iron, consequent on the decomposition of the animal matter contained in them in contact with oxide of iron.

The remains of the Carnivores, as one would naturally suppose, bear a very small proportion to those of the Herbivora. Two species however have been determined. One right scapula which belonged to an aged individual is indistinguishable from that of the Brown or

Black Bear—*Ursus arctos**. It is indeed very remarkable that the remains of *Ursus arctos* should be so very rarely found, as the range of the species in Britain extends as far back as the period of the great Carnivora.

Its remains have been found in the caverns of Wookey Hole, and in the low-level brick-earth of the Thames valley at Crayford, in Kent. A fine skull preserved in the Woodwardian Museum, at Cambridge, and portions of skulls and jaws in the collections of the Earl of Enniskillen and Sir Philip M. G. Egerton were obtained also from the peat of the Manea Fen in Cambridgeshire (see Owen, Brit. Foss. Mam. pp. 77–81). Professor Owen cites it also from a cavern at Arnside Knott, near Kendal. During the Roman occupation of Britain it was sufficiently abundant in this country to be exported to Rome for the gladiatorial shows, unless Martial's allusion to the *Ursus Caledonius* be merely a flight of poetical imagination—

Nuda Caledonio sic pectora præbuit urso,
Non falsâ in cruce laureolus.

The family of the Gordons are said to derive the three bears' heads upon their banner from the fact of one of their ancestors, in the reign of King Malcolm III., having killed a great and fierce bear in Scotland, in the year 1057, and being ordered thereupon by the king to bear this cognizance in memory of his deed of daring. This would appear to be good evidence of the Bear having lived in North Britain in a wild state, at least up to the middle of the 11th century. The importation of Bears (*Ursus arctos*) into Britain for the barbarous practice of bear-baiting, only rendered illegal by an Act of Parliament in the reign of William IV., would be an additional reason for their remains being more abundantly discovered; and yet, so far as I know, this specimen from Yorkshire is the only one, with the exception of that of Wookey Hole Cavern, that has been found associated with traces of Man in Britain. The extensive range of the species in time prevents its being cited in evidence of the antiquity of the Richmond kitchen-heap.

The remains of *Cervus dama* in Britain have not yet been proved to be of higher antiquity than the first Roman invasion. M. Lartêt suggests in a letter to me that the species may have been introduced to this country by the Romans. No trace of it has been found in a Pleistocene deposit.

The following bones were also determined by Mr. Dawkins:—

Canis familiaris.—Femur and humerus.

Sus scrofa.—Seven small lower jaws, of young individuals, all more or less cut or broken.

Equus.—Two metatarsals and two lower jaws.

Cervus elaphus.—Skull, fragment of an antler, a tine, and two metacarpals.

Cervus dama.—A small antler, with the palm broken off.

Bos longifrons.—Numerous teeth and bones, and upwards of forty-five horn-cores.

* The portion of the paper relating to the occurrence of bones of *Ursus arctos* is printed in full.

Ovis aries.—Two horn-cores and a skull.

Capra ægagrus.—Fifteen horn-cores.

Ægoceros Caucasica? A horn-core.

Concerning the two latter species, Mr. Dawkins expresses himself as follows:—

Fifteen horn-cores, recurved, carinated in front, very convex on the outer, nearly flat on the inner side, are indistinguishable from a small *Capra ægagrus* of Pallas. Their maximum and minimum length is 9·5 and 6·3 inches, their maximum and minimum circumference 5·4 and 5 inches.

A third form of recurved horn-core belonging to *Capra*, slightly compressed parallel to the median line, and much more slender than that of *Capra Ægagrus*, more closely resembles that of *Ægoceros Caucasica* than any recent form with which I am acquainted. For its specific determination there are no materials in British osteological collections. Its occurrence, however, in a bone-cavern explored in 1863 by Mr. W. A. Sanford and myself, associated with a skull of *Bos taurus* and one of *Sus scrofa*, and with the remains of Wolf, Fox, Mole, *Arvicola*, Badger, Bat, Reddeer, and a small *Felis*, makes this discovery at Richmond particularly interesting. I detected also the same form among the organic remains from an Irish crannoge, on a visit to the Museum of the Royal Dublin Society in February last. Their maximum length and basal circumference is 8·0 and 3·4 inches, their minimum 6·0 and 3·6 inches.

The presence of this animal in the Richmond kitchen-heap is, indeed, my only apology for bringing these few osteological notes before the Geological Society; for it is by no means improbable that the same parallelism that exists between the contents of some of the older caverns and the remains found in the old river deposits may also be found to obtain in some of the more recent caverns and the kitchen-heaps of a date possibly within the reach of history.

On sending some of the doubtful horn-cores to the most eminent European authority, M. Lartet, he writes me, "As to the horn-cores which Mr. Christy has brought me, and which I return, I am able to see nothing in them but specimens of the diversified forms that are the results of domestication and sometimes of hybridity. I have received lately from M. Troyon two horn-cores very closely resembling yours, of which the larger (more keeled and less compressed than the largest of yours) appears to have belonged to a hybrid between the Bouquetin and the Goat. I have seen similar ones in caverns relatively of very recent date in the Pyrenees."

The jaw of a large fish that closely agreed with that of the Hake in the British Museum, and a fragment of the claw of a large Crustacean, were also found.

There is nothing in the presence of any one of these species to stamp the age of this "kitchen-heap;" but the association of the Bear, Deer, and Fallow Deer with the remains of the Horse, and the short-horned Ox, and the Sheep, points in the direction of the similar deposits in the Swiss Lakes.

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Goeppert.—Ueber versteinte hölzer Sachsens.

——. ———, No. 571. December 6, 1863.

Goeppert.—Ueber lebende und fossile Cycadeen.

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Cohn.—Reise nach Italien.

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——. Mémoires de la Société Linnéenne de Normandie. Vol. xiv. 1863-64.

E. E.-Deslongchamps.—Études sur les étages Jurassiques Inférieurs de la Normandie (3 plates).

Morière.—Note sur deux espèces nouvelles de Mytilidées fossiles trouvées dans le Calvados (plate).

E. de Fromental.—Polypiers coralliens des environs de Gray, considérés dans leurs rapports avec ceux des bassins coralliens de la France, et dans leur développement pendant la durée de cet étage.

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J. C. Brooke.—Mines of Khetree, 519 (8 plates).

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TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On some FOSSILS from SPAIN. By Dr. ZITTEL.

[Proceed. Imp. Geol. Instit. Vienna, September 13, 1864.]

A LARGE collection of fossils has been transmitted by Don Juan Vilanova y Piera to the Imperial Museum of Vienna; most of them are from the Jurassic and Cretaceous strata of the provinces of Castellon and Teruel (Valencia), where these strata predominate, while the Triassic series is but imperfectly developed, being represented only by a few specimens, amongst which is a well-preserved *Neoschizodus*. The Lias of Obon (Teruel) is represented by *Spirifer rostratus*, Schl., *Lima gigantea*, Sow., *Nautilus late-dorsatus*, d'Orb., and *Ammonites bifrons*, Brug.; the Jurassic strata of the same locality being characterized by the presence of *Lima proboscidea*, Sow., *Ceromya inflata*, Ag., *Rhynchonella Lycetti*, Dav., *R. concinna*, &c. The beds of Red Iron ore of Sannion (Teruel) have afforded specimens of *Ammonites macrocephalus*, Schl., *A. lunula*, Ziet., and *A. anceps*, Rein., all characteristic of the "Kelloway Rock." The whole of the north-western portion of the province of Castellon, and an extensive area of the neighbouring province of Teruel, are occupied by sandy, argillaceous, calcareous, and marly deposits of the lower (and locally, perhaps, also of the *middle*) horizons of the Cretaceous period. The lowermost of them are fossiliferous, easily decomposed, and more or less glauconitic Greensands. These are overlain by compact marble-like Caprotina-limestones, clays, and marls, locally containing small seams of Lignite. The environs of Manella (North Castellon) abound in organic remains, nearly all more or less identical with ascertained Neocomian forms, and are as follows:—

Nautilus lacerda, Vilanova.

Natica Sueuri, Pictet et Rén. Neoc.

Fusus, spec. nov.

Cerithium Favrinum, Vil.

— Hoernesi, Vil.

Omphalia Pizcuetiana, Zitt.

Pleurotomaria Pizcuetiana, Vilan.

(Mem. Cast. t. 2. f. 12.)

Rostellaria simplex, d'Orb. Gault.

Pholadomya elongata, Minst. Neoc.

Panopæa Ligeriensis, d'Orb.

Fimbria cordiformis, Desh., sp. Neoc.

Lucina Vendoperana, Leym. Neoc.

Circe discus, Math. (*Astarte Buchi*,

Pict. et Rén.; *Arcopagia*, d'Orb.)

Trigonia, spec. nov., allied to *T. carinata*, Sow.

Trigonia, spec. nov., allied to *T. crenulata*, Lam.

Hinnites Favrinus, Pictet et Roux. Gault.

Lima Cottaldina, d'Orb. Aptien.

Janira atava, Roem. Neoc.

Terebratula praelonga, Sow. Neoc.

— sella, Sow. Neoc.

Rhynchonella Gibbsiana, Sow. Neoc.

Galerites gurgites, Pict. et Rén. Gault.

Pygaulus ovatus, Agass. Gault.

Diplopodia (*Tetragramma*) *variolare*, Désor.

Holctypus similis, Désor. Neoc.

— *Neocomiensis*, Grat. Neoc.

Heteraster (*Holaster*) *oblongus*, d'Orb. Neoc.

Omphalia Pizcuetiana stands next in size and beauty of form to

the Alpine *O. Giebeli*, Zek.; the *Trigonia*, *Fimbria cordiformis*, and the Echinoderms are remarkable for their fine state of preservation. The beds at Aliaga (Teruel) are evidently coeval with those of Morella, and are represented by *Omphalia* (*Cerithium*) *Luxãni*, Vern.; *Punopœa irregularis*, d'Orb.; *Cyprina cordiformis*, d'Orb.; *Protocardia Toseptrina*, Vil.; *Trigonia ornata*; *T. Verneuli*, Vil.; *Trigonia*, spec. nov. (allied to *T. crenulata*, Lam.); *Cucullœa Moutoniana*, d'Orb.; *Avicula*, spec. nov. (allied to *A. anomala*, Sow.); *Plicatula placunea*; *Ostrea Aquila*, Brongn.; and *Caprotina Lonsdalei*, Sow. Other species from the same provinces, as *Ammonites consobrinus*, d'Orb.; *A. subfascicularis*, d'Orb.; *Natica Coquandiana*, d'Orb.; *Protocardia Hillana*, Sow.; and *Artacon Studeri*, Vil., may be referred to well-known Lower Cretaceous types. Two new and beautiful species of *Trigonia*, *T. Baylei* and *T. Deshayesi*, come from the "Aptien" of Tosa. *Cyprina Ligeriensis*, d'Orb., and *Omphalia*, spec. nov., nearly allied to *O. Kefersteini*, seem to indicate comparatively more recent strata. The fauna represented by the collection in question bears on the whole a Neocomian, Aptien, and Gault facies, like the Cretaceous faunæ of the North of France and of England, and of the South of France and South-west of Switzerland. The Gosau strata, the Hippurite-limestones, and generally the Upper Cretaceous deposits of the Austrian Alps, with their analogues on the south-west margin of the Pyrenees, in Guadalajara and Zaragoza, as well as the Portuguese deposits described by the late Mr. D. Sharpe under the denomination of "Suberetaceous" strata, seem to be completely wanting in the provinces of Castellon and Teruel. [COUNT M.]

On FOSSIL LEPADIDÆ. By Professor REUSS.

[Proceed. Imp. Acad. Vienna, February 18, 1864.]

THE number of living pedunculated *Cirripeda* described in Mr. Darwin's monograph does not exceed 48 species, belonging to 11 genera; and only 52 fossil species have at present been described, of which 51 belong to the living genera *Scalpellum* and *Pollicipes*, and but one to the extinct genus *Loricula*. The *Lepadidæ* seem to rank first in geological antiquity among the *Cirripeda*, three species of *Pollicipes* appearing as early as the Jurassic period. Perhaps even they could be traced to a far more remote period, if *Plinnulites*, Barr., occurring in the Silurian rocks of Bohemia, prove to belong to the *Lepadidæ*. In the Cretaceous period the *Lepadidæ* reached their maximum development, 44 of the above-named 52 species appearing in strata of that age. Only 5 species (3 of *Scalpellum* and 2 of *Pollicipes*) have been found in Tertiary deposits, and only 12 species (6 of *Scalpellum* and 6 of *Pollicipes*) are now living, while all the other species described belong to genera not represented in a fossil state. In general, the fossil *Lepadidæ* are of rare and local occurrence, and are seldom found well preserved.

Three new species have recently been discovered in the Middle

Oligocene strata of Söllingen, near Brunswick, namely, (1) *Scalpellum robustum*, Reuss, closely related to *S. Nauckanum*, Reuss, from the Upper Oligocene of Crefeld (Westphalia), and specifically distinguished by its lobe, above the vertex of the carinal valve, forming with the longitudinal axis of the main portion of the carina an acute (or, at most, a right) angle; (2) *Pollicipes interstriatus*, Reuss, known only by a scutal valve of remarkably elevated, trigonal form; and (3) *Pœcilasma dubium*, Reuss, founded upon a carinal valve differing from those of *Scalpellum* and *Pollicipes* by its exclusive upward growth, and from those of *Anatifa* by the breadth of its upper end not allowing its insertion between the two lateral tergal valves, as also by its truncated inferior extremity; it is allied to *Pœcilasma*, Darwin, a genus not before known to occur in a fossil state. *Lepadidæ* have hitherto only been found in Oligocene, Eocene, and Pliocene deposits; but Professor Reuss has found 4 species in Miocene deposits. One of them is *Scalpellum magnum*, Wood, known to occur in the English Crag, and lately found at Galle, near Bordeaux: two other species, *Pollicipes decussatus*, Reuss, and *P. undulatus*, Reuss, are known only by detached but well-preserved scutal valves; both are allied to *P. interstriatus*, Reuss, are analogous to *P. Guascoi*, Bosq., and have been found in the Miocene plastic clay of Niederlois (Lower Austria). A single tergal valve from the Miocene strata of Podjarkow (Galicia), described as "*Pœcilasma miocenica*, Reuss," is of considerable interest, as being the first undoubted fossil remains of the genus *Anatifa* yet discovered; it should probably be ranked with Mr. Darwin's subgenus *Pœcilasma*, on account of its very short and inflected interior margin. Three species of *Lepadidæ* prevail among those of the Bohemian Cretaceous deposits; *Pollicipes glaber*, Roem., is the most frequently diffused among them, and nearly the whole of its valves have been found. *P. conicus*, Reuss, is only known by a well-preserved carinal valve; *Scalpellum quadricarinatum*, Reuss, by the same valve, just sufficiently preserved to admit of generic and specific determination. Isolated tergal valves, occurring in the "Pläner" of Hundorf, may, with some doubt, be referred to *Pollicipes Bronni*. The Upper Senonian Marls of Nagorzano (Galicia) contain remains of *Lepadidæ*, among which *Pollicipes fallax*, Darw. (a species of extensive range, as it has been found in contemporaneous strata of Limburg, Belgium, England, Hanover, and Sweden), seems prevalent. Nearly the whole of its valves have been found. *Pollicipes glaber*, Roem. (a species of still wider range, as it has been met with also in Westphalia, Bohemia, and Saxony), is associated with *P. fallax*, although of scarcer occurrence. A new species, *Pollicipes Zeidlereri*, Reuss, only known by a scutal valve very analogous to that of *P. Darwinianus*, Bosq., also seems to be very rare.

[COUNT M.]

On FOSSIL ALGÆ of the VIENNA and CARPATHIAN SANDSTONES.
By PROFESSOR VON ETTINGSHAUSEN.

[Proceed. Imp. Acad. Vienna, Dec. 17, 1863.]

SINCE Count Sternberg's time (1820) these Algæ have not been made the object of special investigation. Their variations in form and in the development of the *thallus* are as numerous and diversified as they are in existing *Algæ*, and consequently many forms hitherto accepted as distinct species are in fact but varieties of a very limited number of real species. It may be inferred from the condition and mode of preservation of these vegetable remains that the strata containing them must have been deposited at a short distance from the sea-shore, in shallow and well-protected bays and lagoons whose quiet waters offered conditions favourable to the accumulation of *Algæ*. [COUNT M.]

On the COAL-DEPOSITS in the ALPINE REGIONS of LOWER AUSTRIA.
By HERR D. STUR.

[Proceed. Imp. Geol. Instit. Vienna, June 16, 1863.]

By a careful investigation of the fossil flora of the carboniferous sandstones of the North-eastern Alps, M. Stur has found that these sandstones form two distinct groups of very different geological ages. One group, characterized by the occurrence of *Equisetites columnaris*, is of Lower Keuper age; the other, the flora of which is identical with that of Fünfkirchen (Hungary), is equivalent to the Liassic Sandstone, the "Gnosten strata" of the Austrian geologists. The Keuper Sandstones rest on dark-coloured slates with *Ammonites Aon*, overlying black ("Guttenstein") limestone resting on Werfen Slates; and it is overlain by a stratum very rich in organic remains, which, however, are not easily obtainable well enough preserved for specific determination. These fossils belong to the genera *Corbula*, *Perna*, and *Myophoria*, and may therefore be considered as representing the Raibl strata, although *Myophoria Kefersteini*, the truly characteristic form of this horizon, has not yet been identified among them. The Liassic sandstone rests immediately on Kössen (Rhætic) strata. Immediately above it, in a stratum of at most three feet in thickness, are found numerous Gnosten fossils, namely, *Gryphæa arcuata*, *G. cymbium*, *Rhynchonella Austriaca*, *Pleuromya uniooides*, &c. The interval between the Kössen beds and the supposed Raibl strata is occupied by the Great Dolomite. Over the Lias-sandstones are found in ascending order: (1) Variegated Marls, (2) Vils and Klauss strata, (3) Jurassic *Aptychus*-limestones with *Terebratula diphya*, and (4) a sandstone with intercalated layers of coarse conglomerates with *Orbitolites* (?). The large granitic blocks around Waidhopen (perhaps also the huge one in the "Pechgraben," selected as a monument to Leopold von Buch) belong to this conglomerate. *Terebratula diphya* has lately been discovered, associated with *Ammonites*, by Dr. Madeung in the Ips valley, in a red and white limestone overlying the Klauss strata. [COUNT M.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

The FLORA of the UPPER COAL-FORMATION of the BLACK FOREST in BADEN. By Dr. F. SANDBERGER, Professor of Mineralogy in the University of Würzburg.

[Die Flora der oberen Stein-Kohlenformation in Badischen Schwarzwalde. 4to. Carlsruhe, 1864; 7 pp., three plates.]

THIS memoir, published in the 'Transactions of the Karlsruhe Natural Sciences Society,' vol. i., commences with a notice of the researches of W. P. Schimper and the author respecting the Lower and Middle Coal-formation of the Grand-Duchy of Baden; and, after an enumeration of the several Palæozoic floræ found in the Black Forest (namely, 1. that of the Lower Coal-formation or "Grauwacke," at Badenweiler and Lenzkirch; 2. the Middle, at Berg-hampton; 3. the Upper, at Baden, Oppenau, Hinterohlsbach, and Geroldseck; and 4. that of the Rothliegende or lowest part of the Zechstein-formation, at Durbach, Oberkirch, and Baden), proceeds to treat of the geological conditions of the Upper Coal-formation at different places:—1. Baden-Baden; 2. Lierbach Valley, near Oppenau; 3. Hinterohlsbach, between Oppenau and Gengenbach; and 4. Hohengeroldseck by Lahr; and then enters on the description of some species; namely, *Pterophyllum blechnoides*, Sandb., *Palmacites crassinervius*, Sandb., and *Neuropteris Loshii*, Ad. Brongn., which have three good plates devoted to their illustration. *P. blechnoides* is the second species of this genus known in the Coal (*P. gonorrhachis*, Goepp., being the other); whilst *P. Cotteanum*, Gutb., is found in the Red Permian Marlstone near Zwickau. No Palm, besides the *Palmacites* here noticed, has been known for certain in the Coal; but Geinitz had his *Gulielmites Permianus* from the next succeeding formation.

Of *Neuropteris Loshii*, Prof. F. Sandberger remarks that the great variation in the terminal leaflets of the frond in this important species, not well figured by Brongniart, and its wide geographical range, have induced him to illustrate it. The earliest (seedling) fronds, though rare and imperfect, are evidently the same as *Cyclopteris reniformis*, Brongn. *N. Loshii* is found, with *Pterophyllum blechnoides* and *Cordaites borassifolius*, in great abundance at Holzplatze; but it ranges throughout the Coal-measures of different regions.

The species of plants catalogued by the author as occurring in the Upper Coal-formation of the localities mentioned above are:—

Alethopteris pteridoides, *Brongn.*

— *marginata*, *Brongn.*

— *aquilina*, *Schl.*

Cyatheites arborescens, *Schl.*

— *Miltoni*, *Artis.*

— *unitus*, *Brongn.*

Odontopteris Britannica, *Gutb.*

— *Reichiana*, *Gutb.*

Neuropteris tenuifolia, *Brongn.*

— *rotundifolia*, *Brongn.*

— *Loshii*, *Brongn.*

Sphenopteris irregularis, *Sternb.*

— *anomala*, *Presl.*

Schizopteris lactuca, *Presl.*

— *anomala*, *Presl.*

Asterophyllites equisetiformis, *Schl.*

— *longifolius*, *Sternb.*

— *rigidus*, *Sternb.*

Sphenophyllum longifolium, *Sandb.*

Calamites cannæformis, *Schl.*

Calamites Cistii, *Brongn.*

— *Suckowii*, *Brongn.*

Annularia sphenophylloides, *Zenk.*

— *longifolia*, *Brongn.*

Sigillaria Brongniarti, *Gein.*

— *lepidodendrifolia*, *Brongn.*

Lepidostrobis variabilis, *Lindl.*

Pinites densifolius, *Sandb.*

Noeggerathia palmæformis, *Goëpp.*

Rhabdocarpus Bockschianus, *Goëpp. & Berg.*

Cordaites borassifolius, *Sternb.*

Palmacites crassinervius, *Sandb.*

Pterophyllum blechnoides, *Sandb.*

Trigonocarpum Parkinsoni, *Brongn.*

Cardiocarpum marginatum, *Artis.*

— *Kuenssbergi*, *Gutb.*

Carpolithus clypeiformis, *Gein.*

— *ellipticus*, *Sternb.*

The relative abundance and range of these species in the Black Forest and Saxony are indicated in the author's tables. [T. R. J.]

On the CORALS of the TRIASSIC, RHÆTIC, and KÖSSEN STRATA of the ALPS. By PROFESSOR REUSS.

[Proceed. Imp. Acad. Vienna, July 23, 1864.]

THE corals of the Alpine Trias and of the Rhætic beds, although of extremely frequent occurrence in some strata (as in the Dachstein or Lithodendron-limestone), are still but very imperfectly known, owing to their bad state of preservation. All the determinations hitherto established, some of which were made when even recent corals were very imperfectly known, require to be thoroughly revised: and, above all, those of the Palæozoic genera *Cyathophyllum*, *Catenipora*, *Syringopora*, *Calamopora*, and *Chaetetes*, which seem to have no genuine representatives in the Trias and the Rhætic beds. The general aspect of the Upper Alpine Triassic Corals is rather uniform; they include about thirteen species (still wanting revision) of *Montlivaltia*, and seven species of free-branched *Astræideæ* (*Cladophyllia*, *Rhabdophyllia*, *Calamophyllia*, and *Thecosmilia*). Next to them come two or three species of *Latomæandra*; *Thamnastræa*, with five species, still wanting rigid determination, is the only genuine Astræan having some influence on the general type of this fauna. The species of *Isastræa* and *Astræa* are very isolated, as also is a *Goniocera*, the only representative of the *Cladocoraceæ*. One *Fletcheria* and one *Coccophyllum* (a new genus) are the only undoubtedly tabulate Corals connecting the Triassic fauna with the Palæozoic.

The Rhætic Anthozoa, although less abundant in species, are more diversified than those of the Trias; but their determination is still more uncertain, especially as to the few species occurring in the Dachstein. Not one of the many specific names applied to the

“Dachstein-coral” is really acceptable. The genus *Lithodendron*, into which it has been ranked, is, in itself, inadmissible, and must be abandoned. The free-branched *Calamophyllideæ* are prevalent; next to them stand the *Thamnastræa*; then follow species of *Stylina*, *Isastræa*, *Convexastræa*, *Confusastræa*, *Plesastræa*, *Astræomorpha*, and one *Microsolena*, a genus subsequently well represented during the Oolitic periods. No Palæozoic forms have yet been found among the Rhætic Corals.

Among the Corals of the Kössen (Rhætic) strata, ten forms could be generically and specifically determined; five others admitting only of generic determination. Seven of these species (*Rhabdophyllia bifurcata*, Reuss; *Isastræa Suessi*, Reuss; *Confusastræa delicata*, Reuss; *Plesastræa tensus*, Reuss; *Thamnastræa Meriani*, Stopp.; *Convexastræa Azzarolæ*, Stopp. sp.; and *Astræomorpha Bastiani*, Stopp. sp.) come from the “Voralpe,” near Altenmarkt; the three last having been found in the Lower Lias of Azzarola by Abbate Stoppiani, the other four being new species. Three species (*Thecosmilæ cæspitosa*, Reuss; *Calamophyllia Oppeli*, Reuss; and *Cocconema Sturi*, Reuss) come from the Upper Trias immediately overlain by the Hallstatt limestone. The last-named of these species is the type of a new genus of tabulate Corals, and probably of a new group, allied to the *Chætetinæ*, but differing from them in the imperfect, but fully distinct, development of its septal system. [COUNT M.]

On the CORALS and BRYOZOA of the MAYENCE BASIN.

By PROFESSOR REUSS.

[Proceed. Imp. Acad. Vienna, July 21, 1864.]

IN 1859 Professor Reuss described 6 species of these fossils from the Mayence Basin, the first ever published from this locality. Among them were 3 *Balanophyllia*, 1 *Caryophyllia*, 1 *Cænocyathus* (a genus not known before to occur in a fossil state), and the typical species of the new genus *Placopsammia* of the group *Eupsammideæ*. A second collection of Anthozoa and Bryozoa from the lower marine sands of the same locality was (with the exception of *Cænocyathus costulatus*) entirely composed of new species. The Anthozoa among them are—*Caryophyllia Weinkauffi*, *Stereopsammia granulosa*, *Blastocyathus indusiatus*, and *Haplohelia gracilis*; the last two being representatives of new genera. The *Caryophyllia* much resembles the younger Tertiary Sicilian species—*C. elegans* and *C. arcuata*. Only one species of the extinct genus *Stereopsammia* has been described before; it is from the London Clay.

The Corals of the Marine Sand of Mayence number at present 10 species: 5 *Eupsammideæ*, 4 *Caryophyllideæ*, and 1 *Acutinideæ*; the *Astræideæ*—so abundant in other localities—seem completely wanting there. The *Caryophyllia*, *Cænocyathus*, and *Balanophyllia* bear a decidedly Mediterranean facies. The extinct genera, as *Haplohelia*, *Blastocyathus*, *Stereopsammia*, and *Placopsammia*, occurring all in small-sized individuals, it may be inferred that the sea in which they lived was rather of a subtropical than of tropical temperature;

this also Prof. Sandberger has concluded after a careful examination of the molluscan fauna of the Mayence Basin. Six species of the Mayence Bryozoa, all undescribed, could be determined; they are—*Cellepora lobato-ramosa*, *Hornera sparsa*, *Radiopora Sandbergeria*, *Defrancia monosticha*, *Eschara tetrastoma*, and *Bicupularia lenticularis*; the last being the type of a new and very interesting genus. [COUNT M.]

On the CORALS and BRYOZOA of the UPPER OLIGOCENE STRATA of GERMANY. By PROFESSOR REUSS.

[Proceed. Imp. Acad. Vienna, December 15, 1864.]

ONLY 7 species of Corals (3 *Caryophyllideæ*, 3 *Turbinolincæ*, and 1 *Madrepora*) are known to occur in these strata; and of them, only *Caryophyllia granulata* (rarely completely preserved) is either widely diffused, or abundant in individuals. *Sphenotrochus intermedius* ascends to the Crag of Suffolk and Antwerp. *Cryptaxis alloporeoides* occurs chiefly in the Lower Oligocene, only a few individuals range upwards into the Upper Oligocene. The other species, one of them of the new genus *Brachytrochus*, are of very rare occurrence; so that the Corals do not distinctively characterize the Upper Oligocene fauna. The Bryozoa number already 73 species, and a thorough investigation of each locality may add still more to them. The number of species in each locality is distributed thus:—Astrupp, 37; Luithorst, 28; Bünde, 16; Klein-Freiden, 15. The other localities have hitherto proved rather unproductive. Of these 73 species, 53 are *Cheilostomata*, and 20 are *Cyclostomata*. As to the families, their distribution is thus:—*Membraniporidae*, 22; *Escharidae*, 21; *Ceriodoridae*, 8; *Celleporidae*, 4; *Salicornariidae*, 3; *Selenariidae*, 2; *Vincularidae*, 1; *Crisidae*, 1; *Tubuliporidae*, 1. The genera richest in species are—*Lepralia*, 19; *Eschara*, 16; *Idmonea*, 4; *Hornera*, 4. With the exception of *Salicornaria rhombifera*, Goldf. sp.; *Biflustra clathrata*, Phil. sp.; *Myriozoum punctatum*, Phil. sp.; *Lunulites Hippocrepsis*, F. A. Römer; *Hornera gracilis*, Phil. sp.; and *Spirapora variabilis*, v. M. sp.; all the other species are but of scarce and local occurrence. Thirty-three species (45 per cent. of the total) have not yet been met with above or below the Upper Oligocene; 21 species are common to the Upper Oligocene and to the Middle Oligocene Saptarian Clay; 14 species descend into the Lower Oligocene; 18 reach upwards into the Middle Tertiaries. It is a new proof that a considerable number of Bryozoa have passed through several divisions of the Tertiary period. Professor F. A. Römer's assertion, that each of the Tertiary species of Bryozoa is confined to only one subdivision, and is characteristic of its fauna, ceases, therefore, to be absolutely admissible. The Upper Oligocene Bryozoan fauna, in its general features, as in those of nearly all its species, offers distinct analogy with those of other Tertiary deposits, and possesses but very few striking forms; so that the Bryozoa are of but limited use for characterizing and discerning Upper Oligocene deposits.

[COUNT M.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On the FOSSIL MOLLUSCA of the VIENNA BASIN.

By Dr. MORIZ HÖRNES.

[Die fossilen Mollusken des Tertiärbeckens von Wien. Von Dr. Moriz Hörnes. Lief 15 & 16. Noticed in the Jahrbuch der k.k. geol. Reichsanstalt, 1864, pp. 509-514.]

THESE parts contain the families *Lucinidae*, *Erycinidae*, *Solenomyadæ*, *Crassatellidae*, *Carditidae*, *Naidæ*, *Nuculidae*, and *Arcaceæ*. The species are distributed in the following manner:—

Diplodonta rotundata and *D. triyonula*, both now living in the Mediterranean, and on the coasts of Madeira and the Canaries occur in Tertiary sands. *Lucina* (including the genus *Codakia*, Scop., which has been merged into *Lucina*, on account of its structure) 19 species. The species which most frequently occur, and sometimes abundantly, are *L. Columbella*, Lam., and *L. ornata*, Ag. The former of these is confined in Europe to the Miocene (Lower Neogene) deposits. Some specimens of it, together with some other characteristic forms, found by Prof. Doderlein in the Subapennine deposits near Modena, prove this formation to be of Miocene age, but so intimately connected with the Upper Pliocene beds that they are scarcely separable.

Lepton, 2 sp., and *Erycina*, 5 sp., all of them very minute, mostly in the yellow sands of Potzleinsdorf.

Solenomya Doderleini, Mayer, very much resembling the living Mediterranean *S. Mediterranea*, Lam., extremely scarce, and exclusively confined to the Plastic Clay of Ottning (Upper Austria).

Crassatella Hardeggeri, Hörn., *C. Moravica*, Hörn., and *C. concentrica*, Duj., all of them occurring in the coarse and loose sands of Gnusbach, in the Moravian portion of the Vienna Tertiary basin. This genus, the 34 living species of which are eminently tropical, after having reached a high degree of development during the Eocene period (24 species occur in the Eocene beds of the Paris basin), nearly disappeared in the course of the Miocene period.

Cardita, 14 species, most of them in the marly strata of the Leithakalk (Neogene). Among them *C. trapezia*, *C. calycu-*

lata, and *C. elongata* are still tenants of the Adriatic and Mediterranean coasts; the others are of a Senegalian type; and one of them, *C. crassicosta*, Lam., is still living in this region.

Astarte, 1 species, *A. triangularis*, Mont. This genus, which begins with the Mountain Limestone, occurs frequently in certain Jurassic strata, and also existed during the Cretaceous period, is completely wanting in the Eocene deposits, those of North America excepted. It is represented, however, but feebly, in the Neogene strata. Its species are of frequent occurrence in the Oligocene of Belgium, Central and North Germany, in the Neogene beds of Lüneburg, Sylt, North Sleswick, &c., and, most strikingly, together with many recent species, in the English and Belgian Crag, proving thus a former connexion of the Crag Sea with the North Atlantic, the present habitat of nearly all the living species.

Unio, 9 species, all in the Congerian (Neogene freshwater) strata, and mostly of decided North-American type.

Nucula Mayeri, Hörn., *N. nucleus*, Lam., mostly in the sands, the latter species occurring in almost all European seas.

Nucinella ovalis, Wood, identical with the form from the Crag.

Leda, 7 species, in the marls and plastic clays of the Leithakalk.

Limopsis anomala, Eich., is of frequent occurrence in the same localities as *Leda*, and also in the Lower Plastic Clay of Baden, &c.

Pectunculus, 3 species, *P. Fichteli*, Desh., is extremely frequent in the coarse sands of Leobersdorf (basin of Vienna), as also in those of Korod (Transylvania). *P. pilosus*, Linn., occurs as frequently in the Marls of the Leithakalk as in the existing Adriatic and Mediterranean fauna, but is very scarce in the "Lower Plastic Clays"; *P. obtusatus*, Partsch, seems scarcely to have extended beyond the Vienna basin.

Arca, 15 species, among them are *A. umbonata*, Lam., *A. Breislacki*, Bast., *A. Tichteli*, Desh., *A. cardiiformis*, Bast., and *A. Turoonica*, Duj., found in an arenaceous deposit of comparatively most ancient date; *A. Noë*, Linn., *A. barbata*, Linn., *A. clathrata*, Dfr., and *A. lactea*, Linn., belong to the existing Adriatic and Mediterranean fauna; *A. Hungarica*, *A. Rollei*, *A. dichotoma*, and *A. Pisum* are new forms.

General Results. Relative Age of the Strata in the Vienna Basin.—The lowest strata in this basin are not those of most ancient date, which are really represented by the sand-deposits around Korn (north of the Danube), containing *Cardium cingulatum*, Goldf., and other shells not to be distinguished from those of the Oligocene fauna. Next to them come the sand-deposits of Grusbach, Grund, Ebersdorf, Weinstein, Poetzteinsdorf, &c., with a fauna perfectly identical to those of the Swiss Molasse, the beds of Bourdeaux, Dax, Perpignan, &c., and—as a contemporaneous formation—the calcareous reef-deposits (Leithakalk, or Nullipore Limestone), frequent along the coast of the old Tertiary sea, Steinabrunn, Nikolsburg, Gainfahn, Nussdorf, Grinzing, &c., their subordinate beds of marls including plenty of shells, denoting a fauna remarkably analogous to the fauna

of the Tertiaries near Turin. The "Lower" or "Baden Tegel," hitherto considered as the most ancient deposit on account of its situation, has a fauna perfectly analogous to that of Tortona and Saubrigdes, near Dax, and therefore standing next to the Subapennine period, and approaching the living Mediterranean fauna.

2. *Subdivisions of the Tertiaries.*—The Eocene fauna is eminently characterized by forms of tropical type, but which gradually disappear subsequently to the Oligocene period. The fauna of the Lower "Neogene" strata bears a subtropical ("Senegalian") aspect, gradually giving place to Mediterranean forms, which become decidedly prevalent in the uppermost strata. As the tropical fauna has its origin in the Eocene seas, so the subtropical fauna, which gradually passes into the Mediterranean fauna, has its origin in the seas of the Neogene period. The term "Neogene" is, in the first place, intended to remind us of the strict delimitation between Eocene and Miocene deposits, as it can be traced through the eastern half of Europe, at least; nor is it an obstacle against any further subdivision of these two chief systems of Tertiary deposits. In Europe, violent disturbances undoubtedly took place between the Eocene and the Neogene periods, the strata of the former being constantly unconformable to those of the latter, the Eocene beds being generally inclined, the Neogene strata always remaining in a horizontal position. This subdivision of the Tertiaries into two great systems has been lately confirmed by the investigations of the late Professor Bronn and Dr. Keferstein, who both examined the question from a zoological point of view, by comparing, as a whole, the faunæ of these two systems and of the Tertiaries in general.

[COUNT M.]

On the RED CLAYS of the TERRITORY of KRAKAU. By Prof. E. SUESS.

[Proceed. Imp. Geol. Institut. Vienna, December 6, 1864.]

THESE clays are of very different geological ages, and their careful distinction is absolutely necessary for getting an accurate insight into the strata overlying the Carboniferous Sandstone with workable coal-seams. This sandstone is grey, yellowish, and occasionally light-red, and frequently becomes arkose-like by containing numerous minute particles of felspar. Where it is not overlain by other strata, it passes immediately into the moveable sand of the heaths, by means (as it appears) of local weathering. Near Jaworzno it is overlain by a series of arenaceous and argillaceous strata, representing the Varigated Sandstone, and again covered by a deposit of shell-limestone. Beneath these strata dips a rather thick layer of dark-red clay; and a dark-yellow laminated sandstone, with siliceous cement, appears beneath this clay, which seems to rest on another of light-green colour; then follows a stratum, 4 feet thick, of very coarse-grained sandstone, passing gradually downwards into a fine-grained, loose, light-yellow and red-coloured sandstone, with veins and oval-rolled pieces of light-green clay, and with light-

coloured stripes and round spots strikingly resembling typical specimens of the variegated sandstones of North Germany. This rests again on alternating layers of yellow and dark-red sands and red clay, followed by boulders of reddish-yellow sandstone. Everywhere the red clay appears beneath the shell-limestone, and may be considered as a representative of the red "Werfen Slates" of the Austrian Alps. From Jaworzno to Gistrowice, the way leads from the Carboniferous sandstones, over the variegated sandstones and their red clay, upwards to the shell-limestone, and along a soft northward slope to the dolomite. A boring sunk beyond the dolomite led through about 60 feet of variegated clay, and beneath it through nearly 100 feet of bluish-grey plastic clay with crystals of gypsum. Among the fragments brought to light, silicified *Spongaria* and fragments of *Belemites* were found, so that this clay may be considered as being a continuation of the Belemitic clay, intercalated between the oolites of the "Brown Jura" and the white limestones with *Ammonites biplex*. The "refractory clay," which has become an article of export, is quite as different from the red one as from the Belemitic clay. The strata sunk through in search of this clay are in descending order:—

	feet.
a. White Jurassic limestone	72
b. Clay	30
c. Compact quartzose sandstone	4 $\frac{1}{2}$
d. Clay (not refractory)	12-18
e. White limestone in thin strata	36
f. Compact high-yellow sandstone with coloured boulders of quartz, and occasionally with loose sand	18-24
g. Bluish-grey clay (refractory)	2
h. Loose grey sands	12
i. Grey loam	6
k. Dolomite with <i>Cadmia</i>	—

The organic remains, extracted by these borings, were those of the "Brown Jura," probably from the yellow sandstone (*f*). As far as facts are stated at present, the refractory clay (*g*) and the loose sands (*h*) may be considered as being a rudimentary remainder of the Keuper, lately stated by Prof. Römer to occur in Prussian Silesia.

[COUNT M.]

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

On PLANTS from the KEUPER SANDSTONE, in the ROYAL MUSEUM of STUTTGART. By Prof. KURR.

[Proceed. Imp. Geol. Inst. Vienna, August 8, 1865.]

THE species best represented is *Equisetites arenaceus*. Several specimens distinctly show *Calamites* concealed in their inner portions. Certain bulbous forms decidedly belong to *Equisetites*, of which two species may easily be distinguished; the first is similar to a bottle with a protracted, thin, and broken neck, two inches in length, and with a folded and wrinkled surface. Fragments of stems with tubular processes, broken away and at some distance from the stem, induce the belief that the bottle-like bulbs were connected with these processes. The second bulbous form is oval or spherical, occasionally compressed, of the size of a hen's or goose's egg, and generally with a smooth surface. The best preserved specimens show a mastoid protuberance, with a small funnel-shaped cavity on its apex, and with vestiges of a vagina. This protuberance has generally been supposed to have been the point of insertion of the stems of *Equisetites* into the tubers. The vaginal follicles, however, are directed towards the apex of the protuberance, and not towards the body of the tuber or bulb; the protuberance must be therefore considered as having been the real bud, and in connexion with the bulb, of a young *Equisetites* in the beginning of its growth. Only two of these bulbs exhibit distinct superficial cavities, analogous to those on potatoes, but now filled up with mineral substance.

Another remarkable fossil plant is *Calamites Meriani*, Brongn. One specimen is $1\frac{1}{2}$ foot in length, and has perfectly preserved verticillate leaves, each from 3 to 4 inches long and $\frac{1}{12}$ inch broad; the lower whorls have from eleven to thirteen such leaves; the stem is distinctly striped and ribbed. A series of specimens offers transition forms between *Calamites Meriani* and *C. sulcatus*, Kurr.

There are also fine specimens of *Cheiropteris digitata*, Kurr and Bronn, in the Stuttgart Museum; the most conspicuous one of this species is in the University Museum of Tübingen; its stem is about 1 foot long and 1 inch in diameter, the well-preserved, irregularly digitated leaves are spread on its apex. One of the Stuttgart specimens shows a remarkable trifurcation, descending nearly as far as the stem, the two lower symmetrical lobes having the form of a *Sagenopteris*; and the third or median lobe, incompletely preserved, may be supposed to have been also tripartite in its upper portion, as the

specimen shows indications of imperfectly developed principal nerves, namely, one in each lateral lobe, and three in the median lobe.

Fragments of *Pecopteris quercifolia*, Presl., perfectly correspond with the figure in Count Sternberg's 'Fossil Flora.' One specimen exhibits two pinnulæ cohering at their bases, and the indication of a third^d pinnula. Another showed a considerable number of pinnulæ, whose chief nerves converge nearly all into one point; the mode of adherence to a stem or stalk could not be ascertained. Professor Kurr assigns this form to the genus *Mattonia*, R. Br.

The figures of *Clathropteris meniscoides*, Brongn., with entire margins are incorrect, as the specimens in the Stuttgart Museum show finely dentated margins very distinctly, as in the Liassic species from Fünfkirchen (Hungary), and in the palmate form from the Rushsandstone ("Schilf-Sandsteine"), nor is there any difference in the nervation.

Tæniopteris marantacea is represented by a remarkably fine and complete specimen, 2 feet in length, with well-preserved terminal and lateral lobes. The next two uppermost lateral lobes are almost entirely jointed to the terminal one, and the distance between the lobes increases progressively in the lower leaflets. A second specimen, somewhat smaller and less developed, with narrower lobes, presents no trace of nervation. A third specimen, with still narrower lobes, forms a transition to *Cycadites Rumpfi*, figured by Mr. Schenk ('Flora of the Keuper,' &c., tab. vi. p. 61).

The original specimen of *Pecopteris Stuttgartensis* and many other barren specimens offer not the least trace of nervation. Their primary and secondary petioles, and their pinnulæ, are beset with large and apparently irregular excavations, which Professor Kurr thinks traces of a scaly clothing. No traces of scales appear on the *Pecopteris* from the sandstones of Lunz (Lower Austria), which has a distinct nervation even when not fructifying, and may be identified with *Pecopteris Meriani*, Heer.; *P. rigida*, Kurr, is also clothed with scales.

A complete specimen of *Divonites pennæformis*, Schenk, shows follicles with a narrow base, and traces of the vascular passages of the leaf-scars in two parallel rows. The part of the follicles above the base seems to have been simple. The pinnulæ begin to be apparent only a little farther above, and become more so as they approach the top.

The specimens of *Pterophyllum* are beautiful; *P. Jaegeri* may, according to Professor Kurr's figures, be easily subdivided into the two varieties *brevifolium* and *longifolium*. *P. brevipennæ*, Kurr, is rather frequent. The rarest species, represented by a unique specimen, is *P. macrophyllum*. [COUNT M.]

ATTEMPT at a GENERAL CLASSIFICATION of the UPPER JURASSIC STRATA. By Dr. W. WAAGEN.

[Versuch einer allgemeinen Classification der Schichten des oberen Jura. München, 1865, pp. 31.]

It is well known that certain beds of the Upper Jurassic series con-

tain Coral-reefs; these d'Orbigny included in his 'Étage Corallien,' with the view of preserving in the French language the terms Coral-rag, Coralline Oolite, &c., which had already been used by English authors. The term became speedily adopted, and the same horizon was believed to have been recognized in very various districts; but whether these deposits were really identical with those originally termed Coral-rag by English geologists is a question which, until very recently, has not been fully discussed; and in this pamphlet the author endeavours to contribute to its solution.

Dr. Waagen enumerates the subdivisions adopted in England, from the Purbeck beds to the Kelloway rock inclusive, remarking that he uses this classification on account of its priority, although a division of the beds, much better characterized palæontologically, has since been deduced from observations in most of the Jura-districts of Central Europe. Another reason is that having studied these strata in the vicinity of Weymouth, he is better enabled to give the results of his observations by using our classification.

The author then gives detailed sections of the beds at Ringsted Bay, near Weymouth, with lists of the fossils he collected from them, and makes some observations on the general character of the strata and their parallelism with the continental divisions. The result of his examination he gives in a tabular form as follows:—

	LOCAL HORIZONS.	ENGLISH DIVISIONS.
Kimmeridge Group.	Zone of <i>Trigonia gibbosa</i> . .	{ 1. Portland Stone. 2. Portland Sand.
	Region of <i>Orbicula latissima</i> and <i>Acanthoteuthis speciosa</i> . .	{ 3. Kimmeridge Clay.
	Region of <i>Ammonites mutabilis</i> and <i>Exogyra virgula</i>	
Oxford Group.	Region of <i>Ammonites alternans</i> and <i>Rhynchonella inconstans</i> .	{ 4. Upper Calcareous Grit. 5. Oxford Oolite*.
	Region of <i>Cidaris florigemma</i>	
	Region of <i>Ammonites Martelli</i>	{ 6. Lower Calcareous Grit.
	Region of <i>Ammonites biarmatus</i>	{ 7. Oxford Clay.

* Coral-rag.

Oxford and Kimmeridge Groups in England, France, Switzerland, and South-western Germany.

GENERAL CLASSIFICATION.	ENGLAND.	NORTHERN AND WESTERN FRANCE.	SOUTH-EASTERN FRANCE AND WESTERN SWITZERLAND.	EASTERN SWITZERLAND.	SWABIA.	FRANCONIA.
Portland Limestone and Zone of <i>Trigonia gibbosa</i> .	Portland Stone, with <i>Trigonia gibbosa</i> , and <i>Ammonites gigastus</i> . Portland Sand: <i>A. giganteus</i> .	Portland Limestone of Boulogne: <i>Trigonia gibbosa</i> , <i>T. incurva</i> , <i>Cardium dissimile</i> , &c. Forges-les-Eaux (Seine Inf.), <i>Trigonia gibbosa</i> .	Salins (Dép. Jura) Portland limestone: <i>Trigonia gibbosa</i> (Calc. de Salins, Marcou). CORALLIEN of Cirin. Dolomite of Canton Neuchâtel.	Unknown.	Unknown.	Unknown.
Horizon of the Solenhofen Shales.	Upper part of the Kimmeridge Clay: brown bituminous slate, with <i>Orbicula latissima</i> , <i>Lyngula ovalis</i> , <i>Coccolithus</i> , <i>Acanthothus</i> , sp., <i>Pterodactylus</i> , <i>Ammonites</i> (Planulati).	Upper part of the Kimmeridge Clay of Boulogne. Clays with <i>Ammonites</i> ? Dollfuss, Cap de la Hève.	Calc. de Salins? Marcou (in part). Nerinea - limestone of Neuchâtel. Shales of Cirin, with vertebrate remains.	Uppermost strata of Möschi's Cidaris-beds. <i>Ammonites steraspis</i> .	Lithographic Slate of Nusplingen.	Lithographic Slate of Solenhofen. Kelheim, Eichstädt, &c.: <i>Acanthothus speciosus</i> , <i>Pterodactylus</i> . CORALLIEN of Franconia, with <i>Dicerus arctianum</i> .
Zone of <i>Pterocera Oceani</i> and <i>Ammonites mutabilis</i> .	Middle part of the Kimmeridge Clay of Dorsetshire; Region of <i>Ammonites mutabilis</i> and <i>Exogyra virgula</i> : <i>A. mutabilis</i> , <i>A. Berryi</i> , <i>Exogyra virgula</i> , <i>Panopea talina</i> , <i>Cardium pseudoarctus</i> , &c.	Middle part of the Kimmeridge Clay of Boulogne and Cap de la Hève: <i>Pterocera</i> -Maris, Dollfuss (in part), <i>Pterocera Oceani</i> , <i>Ammonites mutabilis</i> .	Marls of Salins and group Porrentury, of Marcou: <i>Exogyra virgula</i> . Etage virgulen (in part) and Strombien or <i>Pteroceren</i> of Switzerland (Le Banne, near Porrentury): <i>Exogyra virgula</i> , <i>Pterocera Oceani</i> .	Cidaris-beds of Canton Argau: <i>Ammonites mutabilis</i> , <i>A. Eudorus</i> , &c.	Beds with <i>Pterocera Oceani</i> of Söllingen, near Ulm. CORALLIEN of Nattheim.	Dolomite with Corals and <i>Pterocera Oceani</i> . Siliceous Dolomite and Limestone of Engelhardtberg.

<p>Zone of <i>Ammonites tenuilobatus</i>.</p>	<p>Lower part of the Kimmeridge Clay of Dorset; Region of <i>Ammonites alternans</i>, <i>Rhynchonella inconstans</i>, <i>Ostrea deltoidea</i>. Towards the top <i>Ammonites madabilis</i> and <i>Exogyra virgata</i> as isolated specimens.</p>	<p>Lower region of Kimmeridge Clay in N. France; Pteroceras-marls and Triassic-limestones (in part) (Dollé): <i>Ammonites Cyrtoceras</i>, <i>Rhynchonella inconstans</i>, <i>Ceromya orbiculata</i>, &c. CORALLIEN of La Rochelle: <i>A. Altenensis</i>, <i>A. Cymodoce</i>, <i>A. Rupellensis</i>.</p>	<p>Group of Besançon (Gr. sequanien, Marcou): <i>Astarte supracollina</i>, <i>Astartin</i>, <i>Astarte-limestone</i>, of Swiss geologists: <i>Ammonites Rupellensis</i>?, <i>Ceromya excentralina</i>, <i>Astarte supracollina</i>, <i>Rhynchonella humeralis</i>, <i>Rhynchonella semiconstantis</i>.</p>	<p>Baden beds of Canton Aargau: Scyphia-limestone, with <i>Ammonites tenuilobatus</i>, <i>A. alternans</i>, <i>A. Rupellensis</i>. Distinctly stratified grey marls with the same fossils.</p>	<p>Scyphia-limestone, with <i>Ammonites tenuilobatus</i>, <i>A. alternans</i>, <i>A. Rupellensis</i>. Distinctly stratified grey marls with the same fossils.</p>	<p>Scyphia-limestone, with very frequent siliceous nodules or concretions. Well bedded grey marls, with <i>Ammonites tenuilobatus</i>, <i>A. alternans</i>, <i>A. Rupellensis</i>, <i>Terebratula humeralis</i>, <i>Rhynchonella semiconstantis</i>, &c.</p>
<p>Zone of <i>Ammonites bimammatus</i> and <i>Cidaris forjemma</i>.</p>	<p>Upper Calcareous Grit and Oxford Oolite (CORALLIEN): Upper Clay and Pteroceras Iron-sand; below, White Oolite with <i>Cidaris forjemma</i>, <i>Ostrea deltoidea</i>, <i>Lima proboscidea</i>, <i>Myoconcha Semanni</i>.</p>	<p>Limestone and clay rich in fossils. Trigonia-limestone (Dollé, Faune Kim.) in great part: <i>Ostrea deltoidea</i>, <i>Lima proboscidea</i>, <i>Myoconcha Semanni</i>. Yellow marl and white oolite, with <i>Cidaris forjemma</i>.</p>	<p>CORALLIEN of Marcou. CORALLIEN of Swiss geologists: White Oolite, with <i>Nerinea</i> and <i>Cidaris forjemma</i> (Caquereil, Cant. Bern, Zwingen near Lauter, Canton Basle). Grey marl with siliceous nodules: Terrain à chaillies.</p>	<p>Nodule-shales as far as the Geisberg beds of Mösch: well bedded limestone, containing near the base <i>Cidaris forjemma</i>, <i>Hemicidaris arenularis</i>, and <i>Ammonites bimammatus</i>.</p>	<p>Partly well bedded limestone, partly spougy shales, with <i>Ammonites bimammatus</i> (Lochen).</p>	<p>Spongy shales and well bedded limestone, with <i>Ammonites bimammatus</i>, <i>A. microdomus</i>, &c. (Streitberg).</p>
<p>Zone of <i>Ammonites transversarius</i> and <i>A. Martelli</i>.</p>	<p>Lower Calcareous Grit: grey limestone and oolite with <i>Ammonites Martelli</i>.</p>	<p>Grey oolite, weathering reddish, and grey limestone of Trouville and Auberville, with <i>Ammonites Martelli</i>.</p>	<p>Argovien, Marcou; Scyphia-limestone, with <i>Ammonites Aroticus</i>, <i>A. stenorhynchus</i>. CORALLIEN of Thurmann and Etallon (Hypocorallien) in part. Beds with <i>Ammonites Martelli</i>, &c.</p>	<p>Birmensdorf - beds and Ething beds of Canton Aargau: grey marls, containing near the base Scyphia-limestone with <i>Ammonites transversarius</i>, <i>A. Martelli</i>, <i>A. candidulatus</i>, &c.</p>	<p>Impressa-clay of Swabia: grey clay with limestone bands at the base: <i>Ammonites transversarius</i>, <i>A. candidulatus</i>, <i>A. Aroticus</i>, <i>Terebratula impressa</i>.</p>	<p>Grey clay and Glauconitic beds with <i>Ammonites transversarius</i>, &c.</p>
<p>Zone of <i>Ammonites bimammatus</i>.</p>	<p>Upper region of the so-called Oxford Clay of Dorsetshire, with <i>Ammonites Lamberti</i>, <i>A. cordatus</i>, <i>Gryphaea dilatata</i>, &c.</p>	<p>Upper region of Oxford Clay at Vaches Noires, with <i>Ammonites Eugeni</i>, <i>A. Constanti</i>, <i>A. Lamberti</i>, &c.</p>	<p>Oxfordian Marls, Marcou. Oxford Marl of Swiss geologists: <i>Ammonites Lamberti</i>, <i>A. Eugeni</i>, <i>A. Arduennensis</i>, <i>Terebratula impressa</i>.</p>	<p>Iron-ore of the Canton Aargau and Solothurn, with <i>Ammonites Lamberti</i>, <i>A. cordatus</i>, <i>A. perarmatus</i>, &c.</p>	<p>Lamberti-nodule-shales of Quenstedt: dark clay with hard marl-nodules: <i>Ammonites Lamberti</i>, <i>A. Eugeni</i>, <i>A. bimammatus</i>, <i>A. perarmatus</i>.</p>	<p>Very weakly represented by scattered nodules: <i>Ammonites Arduennensis</i>, <i>A. perarmatus</i>.</p>

The continental equivalents are next discussed in the same order, as follows :—(I.) Portland Limestone, or Zone of *Trigonia gibbosa* ; (II.) Lithographic limestone of Solenhofen ; (III.) Zone of *Pterocera Oceani* and *Ammonites mutabilis* ; (IV.) Astarte-limestone and Zone of *Ammonites tenuilobatus* ; (V.) Zone of *Cidaris florigemma* and *Ammonites bimammatus*. Dr. Waagen also says a few words on the continental representative of the Lower Calcareous grit, which he believes to exist in the north of France ; but he remarks that the further one goes southward the nearer do beds apparently of this age approximate to the “Transversarius-zone,” and in the Dep. Côte d’Or there is the first appearance of the Scyphia-limestone on this horizon. But the point to which he especially draws attention is that a “Corallien” formation occurs at all the horizons of which he treats. The preceding detailed Table, translated from Dr. Waagen’s pamphlet, gives his conclusions on this head as fully as possible, so that it is unnecessary to go further into the subject, except to quote his remark that “The ‘Corallien’ extends through the whole Upper Jura ; where it is distinguishable it occurs at the expense of either the Oxford or the Kimmeridge Group, and to preserve these two formations intact I sacrifice the ‘Corallien.’ The boundary between the Oxford and the Kimmeridge Groups falls between the beds with *Cidaris florigemma* (or the zone of *Ammonites bimammatus*) on the one side, and the Astarte-limestone (or the zone of *Ammonites tenuilobatus*) on the other side ; therefore, from the lower boundary of the zone of *Ammonites tenuilobatus* upwards we have, in South-western Germany, not Oxford but Kimmeridge beds.” [J. M. & H. M. J.]

CHEMICO-MINERALOGICAL RESEARCHES on the FELSPARS.

By DR. GUSTAV TSCHERMAK.

[Chemisch-mineralogische Studien. Von Dr. Gustav Tschermak. I. Die Feldspathgruppe. Sitzungsberichte der k.-k. Akad. der Wissensch. zu Wien. Math.-nat. Classe. Band. 1. Erste Abtheilung. Heft V. Jahrg. 1864, pp. 566-613, 2 plates.]

HITHERTO it has been considered that the species of Felspar were very numerous ; but the author of this paper believes that, with the exception of Hyalophane and Danburite (both of rare occurrence), they may all be resolved into mixtures of three true species, or genera (*Gattungen*), as he terms them—namely, those known in the pure state as Adularia, Albite, and Anorthite, those knsh-, Soda-, and Lime-felspars. The Potash-felspars he considers to be the result of regular alternations of Orthoclase with Albite ; and the other Felspars to be isomorphous mixtures of Albite with Anorthite, sometimes with small quantities of Orthoclase. Oligoclase, Andesine, and Labradorite appear to be merely members of a great series, in which many transition-forms occur. The cause of the partial isomorphism of Orthoclase and Albite, of the more complete isomorphism of Albite and Anorthite (as well as Danburite), and finally of Adularia and Hyalophane, lies in their similar atomic constitution, as they possess corresponding atomic formulæ, which are given by the author as follows :—

Anorthite	.....	$\text{Ca}_2 \text{Al}_2 \text{Al}_2 \text{Si}_4 \text{O}_{16}$
Albite	.....	$\text{Na}_2 \text{Al}_2 \text{Si}_2 \text{Si}_4 \text{O}_{16}$
Adularia	.....	$\text{K}_2 \text{Al}_2 \text{Si}_2 \text{Si}_4 \text{O}_{16}$
Hyalophane	.....	$\text{Ba}_2 \text{Al}_2 \text{Al}_2 \text{Si}_4 \text{O}_{16}$
Danburite	.....	$\text{Ca}_2 \text{B}_2 \text{B Si}_2 \text{O}_{16}$

In regard to the genetic relations of the Felspars, they may be classified as follows:—(1) occurring in freely formed crystals (“Drusy” of Tschermak); (2) occurring in rocks of the Basalt and Trachyte families (“Glassy” of Tschermak); and, (3) occurring in other rocks in imperfect crystals or as compact masses (“Compact” of Tschermak.) If, therefore, we place the compact transition-forms between Adularia and Albite with Orthoclase, and the glassy with Sanidine,—and, again, collect the passage-varieties between Albite and Anorthite under the head of Plagioclase, and the glassy under that of Microtine,—we shall have the following scheme, showing the relations of these Felspars:—

<i>Compact</i> :	Orthoclase.	Plagioclase.	
<i>Drusy</i> :	Adularia.	Albite.	Anorthite.
<i>Glassy</i> :	Sanidine.	Microtine.	

The following Table, somewhat abridged from the original, will exhibit more clearly the author’s classification of the Felspars, and his view of the manner in which the different varieties pass into one another:—

A. POTASH-FELSPARS.

1. ADULARIA SERIES. Potash 13 to 16 per cent.
Drusy. Adularia, *Pini*; Valencianite, Paradoxite, *Breit.*; Rhyacolite, *Rose*.
Compact. Orthoclase, *Breit.*, in part; Pegmatolite, *Breit.*, in part; Microcline, *Breit.*, in part, from Arendal; Murchisonite, *Lévy*; Weissigite, *Jentsch*; Chesterlite, *Booth*.
Glassy. Sanidine, *Nose*, in part, from Rockeskyll.
2. AMAZONITE SERIES. Potash 10 to 13 per cent.
Compact. Amazon Stone, *Breit.*; Orthoclase and Pegmatolite, in part.
Glassy. Sanidine, in part (from Drachenfels and Perlenhardt).
3. PERTHITE SERIES. Potash 7 to 10 per cent.
Compact. Perthite, *Thomson*; Orthoclase, Pegmatolite, and Microcline, in part.
Glassy. Sanidine, in part.
4. LOXOCLASE SERIES. Potash 4 to 7 per cent.
Compact. Loxoclase, *Breit.*; Orthoclase, in part.

B. SODA-FELSPARS.

5. ALBITE SERIES. Soda 10 to 12 per cent.
Drusy. Albite, *G. Rose*; Pericline and Tetartine, *Breit*.
Compact. Hyposclerite, *Breit.*; Cleavelandite, *Brooke*; mixed Albite and Oligoclase, in part.
Glassy. Glassy Albite, Pantellarite, *Abich*.
6. OLIGOCLASE SERIES. Soda 8 to 10 per cent.
Compact. Oligoclase, *Breit.*; Sunstone, *Scheerer*; Peristerite, *Thomson*; Potash-oligoclase.
Glassy. Glassy Oligoclase, in part; Hafnefjordite, *Forchhammer*.

C. LIME-FELSPARS.

7. ANDESINE SERIES. Lime 6 to 10 per cent.
Compact. Andesine, in part; Saccharite, *Glocker*; Oligoclase, in part; Labradorite, in part.
Glassy. Andesine, *Abich*; Manilite, *Thomson*.
8. LABRADOR SERIES. Lime 10 to 13 per cent.
Compact. Labradorite, *Werner*; Saussurite, in part; Anorthite of Corsica.
Glassy. Glassy Labradorite, Mornite (?).
9. BYTOWNITE SERIES. Lime 13 to 17 per cent.
Compact. Bytownite, *Thomson*.
10. ANORTHITE GROUP. Lime 17 to 20 per cent.
Drusy. Anorthite, *G. Rose*; Christianite, *Monticelli*.
Compact. Anorthite in Eucrite; in "Protobastitfels," *Streng*.
Glassy. Anorthite in Lava; Thjorsaurite, *Genth*.

D. BARYTA-FELSPAR.

Hyalophane, *Sartorius v. Waltershausen*.

E. BORON-FELSPAR.

Danburite, *Shepard*.

[J. M. & H. M. J.]

On the TRACHYTIC FORMATIONS of SCHEMNITZ.

By BARON ANDRIAN.

[Proceed. Imp. Geol. Instit. Vienna, July 18, 1865.]

THESE metalliferous rocks, the site of the most ancient and extended mining operations in Hungary, consist of greenstone-trachytes, which are rendered conspicuous by their lengthened ridges, which also separate them from the genuine trachytes, whose tops generally assume a pointed shape. Between both runs a zone of greenstone-tuffs, in the form of a low ridge with soft outlines, locally encroaching into both the greenstone and the genuine trachytes, and exhibiting petrographical transitions into both. They are best characterized by their easy decomposition into gravel, and are (at least most probably) connected with breccias, conglomerates, shales, and sandstones, including vegetable remains and patches of fossil fuel. These breccias contain fragments of greenstone and of genuine trachytes in the neighbourhood of those rocks and where they are contiguous to them. They may be supposed to be contemporaneous with the extensive tuffaceous deposits leaning on the masses of genuine trachyte, and to have undergone considerable depression, subsequent to certain extensive volcanic and plutonic eruptions, which are proved to have occurred by the existence of the basaltic cone of Mount Calvary, close to Schemnitz, and of eight distinct veins of Rhyolite. The basaltic veins of Giesshübel run through genuine trachyte, and contain conspicuous fragments of this rock. Lower Triassic deposits have been stated to occur beneath the metalliferous greenstones worked at and around Schemnitz.

[COUNT M.]





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