William Harrison. F.S.A.

THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

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

VOLUME THE TWENTY-SEVENTH.

1871.

PART THE FIRST.
PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

LONDON:

LONGMANS, GREEN, READER, AND DYER.

PARIS: FRIED. KLINCKSIECK, 11 RUE DE LILLE; F. SAVY, 24 RUE HAUTEFEUILLE.
LEIPZIG: T. O. WEIGEL.

SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.

MDCCCLXXI.

List

OF THE

OFFICERS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

Elected February 17, 1871.

President.

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

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Sir P. de M. G. Egerton, Bart., M.P., F.R.S.
Prof. T. H. Huxley, LL.D., F.R.S.
Sir Charles Lyell, Bart., F.R.S.
Prof. John Morris.

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David Forbes, Esq., F.R.S.

Foreign Secretary.

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

Treasurer.

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

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C. J. A. Meyer, Esq.
Prof. John Morris.
Joseph Prestwich, Esq., F.R.S.
Prof. A. C. Ramsay, LL.D., F.R.S.
R. H. Scott, Esq., M.A., F.R.S.
Prof. Tennant, F.C.S.
Rev. Thomas Wiltshire, M.A., F.L.S.
Henry Woodward, Esq., F.Z.S.

Assistant-Secretary, Librarian, and Curator.

W. S. Dallas, Esq., F.L.S.

Clerk.

Mr. W. W. Leighton.

Library Assistant.

Mr. F. H. Waterhouse.

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ERRATA ET CORRIGENDA.

Page 65, line 12 from bottom, *for* Bailey *read* Baily.
,, 98, last line, *for* &c. *read* and *c*.
,, 109, head-line and title of paper, *for* de Orueba *read* d'Orueta.
,, 111 and 113, head-line, *for* de Orueba *read* d'Orueta.
,, 273, line 5 from bottom, for *Nœggarathia* read *Nœggerathia.*
,, 537, descr. of fig. 13, *for* Palæozic *read* Palæozoic.

GEOLOGICAL SOCIETY OF LONDON.

ANNUAL GENERAL MEETING, FEB. 17, 1871.

REPORT OF THE COUNCIL FOR 1870.

The Council of the Geological Society, in presenting their Report for the year 1870, have again to congratulate the Fellows on the increasing prosperity of the Society.

The number of new Fellows elected was 58, of whom, however, only 42 paid their fees before the end of the year, making, with 9 previously elected Fellows who paid their fees in 1870, a total effective increase of 51 Fellows. Against this must be placed the loss of 21 Fellows by death, of 5 by resignation, and of 3 removed from the list on account of non-payment of contributions, making a total of 29, and thus giving a net increase of 22 ordinary Fellows. The number of Contributing Fellows is now 533.

The election of 1 Foreign Member and of 2 Foreign Correspondents took place in 1870, and the death of 1 Foreign Member was announced.

The total number of Fellows and Foreign Members and Correspondents at the end of 1869 was 1222; and at the end of 1870, 1245.

The Council have much gratification in reporting that, notwithstanding a very heavy expenditure in illustrations for the Quarterly Journal of the Society, the Income of the year 1870 exceeded the Expenditure by £156 0*s*. 9*d*.; the total Receipts being £2050, and the total Expenditure £1867 15*s*. 8*d*. Under these circumstances the Council felt justified in investing a further sum of £200 in the purchase of £211 7*s*. 3*d*. of 3 per cent. Consols.

The Council have to announce the completion of Vol. XXVI. of the Quarterly Journal, and the commencement of the publication of Vol. XXVII.

They have also to announce that to provide for the increasing circulation of the Quarterly Journal, and in order to be able to present copies to the Foreign Correspondents, they have decided in future to print 1500 copies of it, and also to give the authors of papers published in the Journal 25 separate copies properly made up, in lieu of the 15 copies which have hitherto been prepared by cutting up twice that number of sheets of the Journal.

The Council have also to announce that Dr. C. F. Fischer of Auckland, New Zealand, presented to the Society the remainder of the copies (in all 291) of a translation made by him of Messrs. Hochstetter and Petermann's 'Geology of New Zealand,' accompanied by an atlas of six maps. The Council decided to sell these books to the Fellows at a low price.

The Council have awarded the Wollaston Medal to Prof. A. C. Ramsay, F.R.S., F.G.S., &c., in recognition of his valuable services to physical and stratigraphical geology, and with especial reference to his numerous and original geological essays relating to Wales and the adjacent counties, and his surveys of that district.

The Balance of the proceeds of the Wollaston Fund has been awarded to Robert Etheridge, Esq., F.G.S., to aid him in prosecuting his work on the Fossils of the British Islands, stratigraphically arranged.

The Council have the gratification of reporting that an Appeal against the Assessment of Parochial Rates was on the 13th of this month decided by the proper Tribunal in favour of the Society, by which their total exemption from such imposts has been established.

Report of the Library and Museum Committee, 1870–71.

Library.

The Standing Library-Committee have continued from time to time to make additions to the Library by the purchase of such books as they thought would prove useful to the Fellows; and amongst those purchased since the last Anniversary Meeting, the following important works may be cited:—

Berendt's 'Geologie des Kurischen Haffes und seiner Umgebung;' Blanford's 'Observations on the Geology and Zoology of Abyssinia;' C. F. Naumann's 'Elemente der Mineralogie;' Landgrebe's 'Mineralogie der Vulcane;' Percy's 'Metallurgy of Lead;' Veith's 'Deutsches Bergwörterbuch;' Issel's 'Malacologia del Mar Rosso;' Zittel's 'Palæontologische Mittheilungen aus dem Museum des Königl. Bayerischen Staates;' Mayr's 'Ameisen des baltischen Bernsteins;' Weiss's 'Fossile Flora der jüngsten Steinkohlenformation und des Rothliegenden im Saar-Rhein-Gebiete;' and continuations of Pictet's 'Matériaux pour la Paléontologie Suisse;' Schimper's 'Paléontologie Végétale;' Milne-Edwards's 'Recherches Anatomiques et Paléontologiques pour servir à l'Histoire des Oiseaux fossiles de la France;' Ooster's 'Protozoë Helvetica;' Quenstedt's 'Petrefactenkunde Deutschlands;' the 'Palæontographica;' the 'Paléontologie Française;' and Reeve's 'Conchologia Iconica.' The cost of books purchased by the Society during the past year was £37 7*s.* 11*d.*, and of binding £33 13*s.* 7*d.*

A great number of valuable books have been presented to the Society's Library during the past year, including, besides periodicals and the publications of learned Societies, many separate works of importance, such as:—

'Gæa Norvegica,' Parts 1–3 (1838–50), from the Royal Norwegian University in Christiania; M. L. Lartet's 'Essai sur la Géologie de la Palestine et des Contrées avoisinantes;' the fourth and fifth parts of M. Laube's 'Fauna der Schichten von St. Cassian;' Prof. Ansted's 'Physical Geography and Geology of Leicestershire;' the continuation of M. Barrande's 'Système Silurien du Centre de la Bohême;' M. Belgrand's 'Le Bassin Parisien aux Ages Antéhistoriques;' Sir John Lubbock's 'Prehistoric Times;' Mr. Seeley's 'Ornithosauria, an elementary study of the Bones of Pterodactyles;' the continuation of M. Stoppani's 'Paléontologie Lombarde;' M. Eugène Eudes-Deslongchamps's 'Notes Paléontologiques;' Prof. Gould's 'Report on the Invertebrata of Massachusetts,' presented by the Editor, W. G. Binney, Esq.; the continuation of Prof. Hall's 'Palæontology of New York;' and Mr. Safford's 'Geology of Tennessee.'

From Mrs. Hamilton, the widow of the late W. J. Hamilton, Esq., the Society received an immense collection of tracts, with permission to select such as might be wanting in the Society's Library. A great number of valuable treatises have been thus added to the Library; and the Society is deeply indebted to Mrs. Hamilton for the liberality thus displayed by her.

Many Maps and Plans have been added to the Society's Collection; they include the Maps of Geological Surveys of Queensland (Cape River Gold-field and Canal-Creek Diggings), Hesse (Sect. Alsfeld), Sweden (5 sheets), Prussia and Thuringia (6 sheets), Austria (2 sheets), and Switzerland (3 sheets and a sheet of sections); also M. Delesse's 'Carte lithologique de l'Embouchure de la Seine;' Mr. Lapham's 'Geological Map of Wisconsin;' a Sketch-map of the Geology of New Zealand, by Dr. James Hector; and a geologically coloured Map of Lundy Island, prepared and presented by N. Whitley, Esq. Prof. von Dechen's 'Geologische Karte von Deutschland' has been purchased for the Library.

Numerous Maps published by the Ordnance Survey, and Maps, Charts, and Plans published by the French Dépôt de la Marine, have also been presented; and 2 Maps of South Africa, by Mr. Henry Hall, have been purchased.

Museum.

The Collections in the Museum remain in good condition, and several portions of them have been consulted by foreign geologists during the past year. Very few additions have been made to the collections, the principal being, numerous specimens of Corals from the South-Australian Tertiaries, in illustration of Dr. Duncan's paper and presented by him; and Fossils and Casts of Fossils from the Newer Tertiaries of Suffolk, presented by E. Ray Lankester, Esq., in illustration of his paper on those deposits.

THOS. WILTSHIRE.
J. GWYN JEFFREYS.
WARINGTON W. SMYTH.
ROBERT A. C. GODWIN-AUSTEN.

Comparative Statement of the Number of the Society at the close of the years 1869 *and* 1870.

	Dec. 31, 1869.		Dec. 31, 1870.
Compounders	210	......	218
Contributing Fellows	511	......	533
Non-Contributing Fellows	420	......	412
	1141		1163
Honorary Members	3	......	3
Foreign Members	39	......	39
Foreign Correspondents	39	......	40
	1222		1245

General Statement explanatory of the Alteration in the Number of Fellows, Honorary Members, &c., at the close of the years 1869 *and* 1870.

Number of Compounders, Contributing and Non-contributing Fellows, December 31, 1869			1141
Add Fellows elected during former year, and paid in 1870			9
Add Fellows elected and paid in 1870			42
			1192
Deduct Compounders deceased		4	
Contributing Fellows deceased		9	
Non-contributing Fellows deceased		8	
Contributing Fellows resigned		5	
Contributing Fellows removed		3	
		—	29
			1163
Number of Honorary Members, Foreign Members, and Foreign Correspondents, December 31, 1869		81	
Add Foreign Member elected		1	
Foreign Correspondents elected		2	
		84	
Deduct Foreign Member deceased	1		
Foreign Correspondent elected Foreign Member	1		
	—	2	
		—	82
			1245

Deceased Fellows.

Compounders (4).

C. Collier, M.D.
The Bishop of Manchester.
Sir F. Pollock, Bart.
A. Rogers, Esq.

Resident and other Contributing Fellows (9).

C. W. V. Bradford, Esq.
E. W. Brayley, Esq.
H. Hakewill, Esq.
R. Hutton, Esq.
E. Jones, Esq.
M. C. Morrison, Esq.
B. B. Orridge, Esq.
S. Perkes, Esq.
C. Sanderson, Esq.

Non-contributing Fellows (8).

C. W. Bigge, Esq.
E. B. Blackburn, Esq.
Rev. C. Erle.
Rev. J. H. Fisher.
Rev. R. Gwatkin.
Capt. L. L. B. Ibbetson.
J. Walker, Esq.
G. Woods, Esq.

Foreign Member (1).

Dr. Gustav Bischof.

Fellows Resigned (5).

Hon. J. Abercromby.
Major Arbuthnot.
F. Hill, Esq.
Capt. Drury Lowe.
H. A. Ward, Esq.

Fellows Removed (3).

Owen Bowen, Esq.
R. Mills, Esq.
Bassett Smith, Esq.

The following Personage was elected a Foreign Member during the year 1870.

Dr. Oswald Heer, of Zurich.

The following Personages were elected Foreign Correspondents during the year 1870.

Prof. Joseph Szabo, of Pesth.
Prof. Otto Torell, of Lund.

The following Persons were elected Fellows during the year 1870.

January 12th.—John Aitken, Esq., Bacup, Manchester; Edward Allen, Esq., 19 St. Saviourgate, York; Clement Cadle, Esq., Gloucester; Arthur Wyatt Edgell, Esq., Lympstone, Exeter; Charles F. Leaf, Esq., Old Change, E.C., and Harrow; and Samuel Joseph Smith, Esq., 29 Park Road, New Wandsworth, S.W.

—— 26th.—Thomas Daniel Bott, Esq., 2 Osborne Villas, Talfourd Road, Peckham, S.E.; Edwin B. Kemp-Welch, Esq., 3 Beaumont Terrace, Bournemouth; James Parkinson, Esq., Sarum House, Church Road, Upper Norwood, S.E.; Henry Sewell, Esq., Villa del Valle, Mexico; and T. F. W. Walker, Esq., M.A., 6 Brock Street, Bath.

February 9th.—Alexander Murray, Esq., Geological Survey of Canada, St. John's, Newfoundland; and Frederick William Rudler, Esq., Museum, Jermyn Street, S.W.

—— 23rd.—Alexander G. H. Harding, King's College, London, W.C.; Thomas Adair Masey, Esq., 6 Crown Office Row, Temple, E.C.; and Samuel Haslett, Esq., Ann Street, Belfast.

March 9th.—John Alleyne Bosworth, Esq., Humberstone, Leicestershire; Robert Erskine Brown, Esq., Wass, Oswaldkirk, Yorkshire; Major E. H. Sladen, Madras Staff Corps, Church Road, Upper Norwood, S.E.; and Henry King Spark, Esq., Green Bank, Darlington.

—— 23rd.—Frederick Antony Potter, Esq., B.Sc., Cromford, Derbyshire.

April 13th.—S. W. North, Esq., Castlegate, York.

—— 27th.—Robert Logan Jack, Esq., Geological Survey of Scotland, India Buildings, Victoria Street, Edinburgh; George Alexander Lebour, Esq., Geological Survey of England, Museum, Jermyn Street, S.W.; Coles Child, Esq., The Palace, Bromley, Kent; and Harry Rivington, Esq., 22 Finsbury Square, E.C.

May 11th.—Sir William Bagge, Bart., M.P., Stradsett Hall, Market Downham, Norfolk; Colonel James Leslie Tait, Montgomery, Alabama, U.S.; and Dr. A. A. Caruana, The University, Malta.

—— 25th.—George Cox Bompas, Esq., 15 Stanley Gardens, Kensington Park, W.; Sir James Anderson, 16 Warrington Crescent, W.; and John Breedon Everard, Esq., 6 Millstone Lane, Leicester.

June 8th.—Henry G. Vennor, Esq., Geological Survey of Canada, Montreal; Alexander Kendall Mackinnon, Esq., Director-General of Public Works, Montevideo, South America; and Arthur Roope Hunt, Esq., Quintella, Torquay.

—— 22nd.—Horace Pearce, Esq., 21 Hogley Road, Stourbridge; and Samuel Spruce, Esq., Tamworth.

November 9th.—Lieut. Reginald Clare Hart, R.E., Brompton Barracks, Chatham; Lieut. James F. Lewis, R.E., Brompton Barracks, Chatham; and M. F. Maury, Jun., Esq., 1300 Main Street, Richmond, Virginia, U.S.

December 7th.—Rev. J. W. Todd, D.D., Tudor House, Sydenham, S.E.; Hon. Henry Ayers, Adelaide, South Australia; R. W. Peregrine Birch, Esq., Palace Chambers, Westminster, S.W.; Alfred Stair, Esq., 4 Surinam Terrace, Stratford, Essex; Harry Rivett Carnac, Esq., Simla, East Indies; Thomas Davies, Esq., British Museum, W.C., and 47 Rutland Road, South Hackney, E.; Rev. J. H. Cooke, Northbourne Rectory, Deal; J. S. Courtney, Esq., Penzance; John Johnson, Esq., Chilton Hall, Ferry Hill, Durham; Rev. R. H. Morris, M.A., Training College, Carmarthen; and Joseph Drew, Esq., Belgrave Terrace, Weymouth.

December 21st.—Valentine D. Colchester, Esq., 4 Buckland Villas, Belsize Park, N.W.; H. J. Heighton, Esq., Gold Street, Kettering; Thomas Hawksley, Esq., 30 Great George Street, S.W.; Frank Rutley, Esq., Geological Survey of England, Museum, Jermyn Street, S.W.; and Isaac Roberts, Esq., 26 Rock Park, Rockferry, Cheshire.

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

Specimens of *Eophyton* and other Cambrian fossils; presented by Professor Otto Torell, F.C.G.S.

Electrotype casts of *Asaphus platycephalus* showing limbs; presented by E. Billings, Esq., F.G.S., and Sir W. E. Logan, F.R.S., F.G.S.

Corals from the South-Australian Tertiaries; presented by Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.

Fossils from the Suffolk Tertiaries; presented by E. Ray Lankester, Esq., B.A.

Rock specimens from Tideswell Dale; presented by the Rev. J. M. Mello, F.G.S.

Models of South-African Diamonds; presented by Prof. Tennant, F.G.S.

Model of the head of a large Labyrinthodont; presented by G. Maw, Esq., F.G.S.

MAPS, CHARTS, ETC. PRESENTED.

Geological Map of Queensland: Cape-River Gold-field (2 sheets) and Canal-Creek Diggings; presented by the Geological Survey of Queensland.

Geological Survey Map of Sweden, Sheets 31–35, with 5 parts of descriptions and Geological Map of Ostradal; presented by the Director of the Swedish Geological Survey, Prof. A. Erdmann.

Geological Survey Map of Prussia and the Thuringian States, Sheets 237–239 and 255–257, with explanations and introductory remarks; presented by the Prussian Minister of Commerce and Public Works.

Geological Survey Map of Austria, Sheets 1 and 2, with explanations; presented by the Director of the Austrian Geological Survey, Franz Ritter von Hauer, F.C.G.S.

Geological Survey Map of Switzerland, Sheets 6, 7, and 22, with a sheet of Sections; presented by the Swiss Geological Commission.

Map of Lundy Island, Geologically coloured and presented by N. Whitley, Esq.
Lithological Map of the Embouchure of the Seine, by M. E. Delesse; presented by the Author.
Sketch-Map of the Geology of New Zealand, by Dr. James Hector, F.R.S., F.G.S.; presented by the Author.
Geological Map of Wisconsin, by F. A. Lapham, Esq.; presented by the Author.

The following Lists contain the Names of Persons and Public Bodies from whom the Society has received Donations to the Library and Museum since the last Anniversary Meeting, February 18, 1870.

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

Bath, Natural-History and Antiquarian Field-Club of.
Belfast. Naturalists' Field-Club.
Berlin. German Geological Society.
——, Society of Naturalists at.
——. Royal Prussian Academy.
Berwick. Berwickshire Naturalists' Field-Club.
Birmingham Free Library, Committee of.
Bordeaux, Linnean Society of.
Boston, Society of Natural History of.
Brussels. Royal Academy of Belgium.

Calcutta. Asiatic Society of Bengal.
Cambridge (Mass.). American Association for the Advancement of Science.
——. American Academy of Arts and Sciences.
Canadian Institute.
Copenhagen. Royal Danish Academy.
Cornwall, Royal Geological Society of.

Darmstadt. Geological Society of the Middle Rhine.
Devonshire Scientific Association.
Dorpat, Natural-History Society of.
Dresden, (Isis) Natural-History Society of.
Dublin. Royal Dublin Society.
——. Royal Geological Society of Ireland.
——. Royal Irish Academy.

East-India Association.
Edinburgh, Geological Society of.
——, Royal Physical Society of.
——, Royal Society of.

Florence. Royal Geological Committee of Italy.
Frankfort. Senckenbergian Natural-History Society.

Glasgow, Geological Society of.
Gloucester. Cotteswold Naturalists' Field-Club.

Haarlem, Society of Sciences of.
Halifax (N. S.). Nova-Scotian Institute of Natural Science.
Halle, Natural-History Soc. of.
Heidelberg, Natural-History and Medical Society of.
Indian Government.

Lausanne. Vaudoise Society of Natural Sciences.
Leeds, Literary and Philosophical Society of.
Liverpool, Geological Society of.
——. Historic Society of Lancashire and Cheshire.
London, Art Union of.
——. British Association.
——. Chemical Society.
——. Geologists' Association.
——. Institution of Civil Engineers.
——. Linnean Society.
——. London Institution.
——. Palæontographical Society.
——. Photographic Society.
——. Quekett Microscopical Club.
——. Royal Agricultural Society of England.
——. Royal Asiatic Society of Great Britain.
——. Royal Astronomical Society.
——. Royal College of Surgeons.
——. Royal Geographical Society.
——. Royal Institution.
——. Royal Society.
——. Society of Arts.
——, Zoological Society of.

Maine, Commissioners of Fisheries of the State of.
Melbourne. Geological Survey of Victoria.
——. Mining Survey of Victoria.
Milan. Italian Society of Natural Sciences.
Minnesota, Government of.
Moscow, Imperial Society of Naturalists of.
Munich, Academy of Sciences of.

Neuchâtel, Society of Natural Sciences of.
Newcastle-on-Tyne. Natural-History Society of Northumberland and Durham.
——. Iron and Steel Institute.
——. North of England Institute of Mining Engineers.
New York, American Museum of Natural History of.
——, Lyceum of Natural History of.
——, Regents of the University of.
——, State Cabinet of.
New Zealand, Geological Survey of.
——, Government of.
—— Institution.

Offenbach, Natural-History Society of.

Paris. Academy of Sciences.
——. Dépôt de la Marine.
——. Geological Society of France.
Philadelphia, Academy of Natural Sciences of.
——. American Philosophical Society.
Plymouth Institution.
Puy. Society of Agriculture, Arts, &c.

Queensland, Geological Survey of.

Salem. Peabody Academy of Sciences.
——. Essex Institute.
St. Petersburg, Academy of Sciences of.
Strasbourg, Society of Natural Sciences of.
Stuttgart. Natural-History Society of Württemberg.
Swiss Geological Commission.
Switzerland, Natural-History Society of.
Sydney. Royal Society of New South Wales.

Teignmouth. Teign Naturalists' Field-Club.
Turin, Royal Academy of Sciences of.

United States Government.
——, Patent Office of.

Vienna, Imperial Academy of Sciences of.
——, Geological Institute of.
Victoria, Government of.

Warwickshire Naturalists' Field-Club.

Wiesbaden. Natural-History Society of Nassau.
Washington. Smithsonian Institution.
Wolverhampton. South Midland Institute of Mining, Civil, and Mechanical Engineers.

York. Yorkshire Philosophical Society.
Yorkshire, Geological and Polytechnic Society of the West Riding of.
—— Naturalists' Club.

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

Abich, Dr. H., F.M.G.S.
Academy, Editors of the.
Achiardi, Sig. A. d'.
Adams, Dr. A. Leith, F.G.S.
Agassiz, Prof. L., F.M.G.S.
Agriculture, United States Commissioners of.
American Journal of Conchology, Editor of the.
American Journal of Science, Editors of the.
Anderson, B., Esq.
Annales des Mines, Editors of the.
Ansted, Prof. D. T., F.G.S.
Archer, W. H., Esq.
Athenæum, Editor of the.

Barrande, M. J., F.M.G.S.
Bauerman, H., Esq., F.G.S.
Beckles, S. H., Esq., F.G.S.
Belgrand, M. E.
Bell, A., Esq.
Billings, E., Esq., F.G.S.
Binney, E. W., Esq., F.G.S.
Binney, W. D., Esq.
Bonney, Rev. T. G., F.G.S.
Bowerbank, Dr. J. S., F.G.S.
Brandt, Dr. F., F.C.G.S.
Brodie, Rev. P. B., F.G.S.
Broome, G., Esq., F.G.S.
Brown, R. E., Esq., F.G.S.

Canadian Journal, Editors of the.
Carpenter, Dr. W. B., F.G.S.
Cartailhac, M.
Caruana, Dr. A. A., F.G.S.
Catlin, G., Esq.
Ceselli, Sig.
Chemical News, Editor of the.
Christy, H., Esq., Executors of the late.
Colliery Guardian, Editor of the.
Cook, Prof. G. H.
Cornalia, Dr. E.
Croll, J., Esq.

Dall, W. H., Esq.
Daubrée, M., F.M.G.S.
Davidson, T., Esq., F.G.S.
Dawson, Prof. J. W., F.G.S.
Desguin, M. P.
Deslongchamps, M. Eugène.
Dewalque, M. G.
Duncan, Prof. P. Martin, F.G.S.

Eichwald, Dr. E. von.
Electric Telegraph and Railway Review, Editor of the.

English Mechanic, Editor of the.
Evans, Caleb, Esq., F.G.S.
Evans, John, Esq., F.G.S.

Favre, M. A., F.C.G.S.
Foetterle, Dr. F.
Fuchs, M. T.

Geinitz, Dr., F.M.G.S.
Geological Magazine, Editors of the.
Gilliéron, M. V.
Gümbel, Dr., F.C.G.S.

Haidinger, Prof. W. von, F.M.G.S.
Hall, Dr. James, F.M.G.S.
Hall, Marshall, Esq., F.G.S.
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Hopkinson, John, Esq., F.G.S.
Hull, H. M., Esq.
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Iron and Coal Trades Review, Editors of the.

Jeffreys, J. Gwyn, Esq., F.G.S.
Jahrbuch für Mineralogie, Geologie, &c., Editors of the.
Jones, Prof. T. Rupert, F.G.S.

Karrer, Dr. F.
Kayser, M. E.
Kawall, M. J. H.
King, Prof. W.

Lankester, E. Ray, Esq.
Lapham, F. A., Esq.
Lea, Isaac, Esq.
Linnarsson, M. J. G. O.
Logan, Sir W. E., F.G.S.
London, Edinburgh, and Dublin Philosophical Magazine, Editors of the.
Longman & Co., Messrs.
Lorenz, M. L.
Lubbock, Sir J., Bart., F.G.S.
Lyell, Sir Charles, Bart., F.G.S.

Mackintosh, D., Esq., F.G.S.
Marcou, M. Jules.
Marsh, Prof. C. O., F.G.S.
Maw, G., Esq., F.G.S.
Maw, H. L., Esq.
Mayer, M. K.
Mello, Rev. J. M., F.G.S.
Mojsisovics, M. E. von.
Montagna, Sig. C.
Monthly Microscopical Journal, Editors of the.
Moore, Charles, Esq., F.G.S.
Morris, Prof. John, F.G.S.
Murchison, Sir R. I., Bart., F.G.S.

Naturalists' Note Book, Editor of the.
Nature, Editor of.
Newberry, Dr. J. S.
Nova Scotia, Chief Commissioner of Mines of.
Nyst, Dr. H., F.C.G.S.

Oustalet, M.

Packard, Dr. A. S., Jun.
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Pessina, Sig. L. J.
Piggot, J., Jun., Esq., F.G.S.
Prestwich, Jos., Esq., F.G.S.

Quarterly Journal of Science, Editors of the.
Quetelet, M. A.

Ramsay, Prof. A. C., F.G.S.
Raynolds, Gen. W. F.
Reuss, Prof. A. E., F.C.G.S.
Revue des Cours Scientifiques, Editors of the.

Richards, Admiral, R.N.
Richthofen, Baron F. von.
Rickard, Major F. J., F.G.S.
Rowney, T. H., Esq.

Safford, J. N., Esq.
Sandberger, Prof. F., F.C.G.S.
Sauvage, M.
Schloenbach, Dr. U.
Scientific Opinion, Editors of.
Seeley, H. G., Esq., F.G.S.
Sorge, Dr. C. T.
Spratt, Capt. T. A. B., F.G.S.
Steen, M. Adolph.
Streeter, G. L., Esq.
Student and Intellectual Observer, Editors of the.
Studer, Prof. B., F.M.G.S.
Suringar, Dr. W. F. R.

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Tennant, Prof. J., F.G.S.
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Trautschold, M. H.
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Ulrich, G. H. F., Esq., F.G.S.
Ungarische Revue, Editor of the.

Walther, Dr. C. F.
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Whittlesey, C. E., Esq.
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Zeuschner, Prof. L.
Zigno, Baron A. de, F.C.G.S.
Zirkel, Prof. F., F.C.G.S.
Zittel, Dr. K. A.

List of PAPERS *read since the last Anniversary Meeting, February* 18*th*, 1870.

1870.

February 23rd.—Additional Observations on the Neocomian Strata in Yorkshire and Lincolnshire, with Notes on their Relations to the Beds of the same age throughout Northern Europe, by J. W. Judd, Esq., F.G.S.

———— On Deep-mining with Relation to the Physical Structure and Mineral-bearing Strata of the South-west of Ireland, by Samuel Hyde, Esq.; communicated by R. Etheridge, Esq., F.G.S.

March 9th.—On the Structure of a Fern-stem from the Lower Eocene of Herne Bay, and on its Allies, Recent and Fossil, by W. Carruthers, Esq., F.L.S., F.G.S.

———— On the Oolites of Northamptonshire, by Samuel Sharp, Esq., F.G.S.

March 23rd.—Notes on a Skull from the Upper Cretaceous of Grünbach, by Dr. Emanuel Bunzel; communicated by Prof. Huxley, F.R.S., F.G.S.

———— On the Discovery of Organic Remains in the Caribbean Series of Trinidad, by R. J. Lechmere Guppy, Esq., F.L.S., F.G.S.

———— On the Palæontology of the Junction Beds of the Lower and Middle Lias in Gloucestershire, by Ralph Tate, Esq., A.L.S., F.G.S.

March 23rd.—Geological Observations on the Waipara River, New Zealand, by T. H. Cockburn Hood, Esq., F.G.S.

——— On the Fall of an Aerolite in Fezzan, by M. Coumbary; communicated by R. H. Scott, Esq., F.G.S.

April 13th.—On Australian Fossil Mammals, by Dr. Gerard Krefft; communicated by H. M. Jenkins, Esq., F.G.S.

——— On Fossil Remains of Mammals found in China, by Prof. Owen, LL.D., F.R.S., F.G.S.

——— Further Discovery of the Fossil Elephants of Malta, by Dr. A. A. Caruana; communicated by Dr. A. Leith Adams, F.G.S.

April 27th.—On the Species of Rhinoceros whose Remains were discovered in a Fissure-cavern at Oreston in 1816, by G. Busk, Esq., F.R.S., F.G.S.

——— On two Gneissoid Series in Nova Scotia and New Brunswick, supposed to be the equivalents of the Huronian (Cambrian) and Laurentian, by H. Youle Hind, Esq., M.A.; communicated by Prof. Ramsay, F.R.S., F.G.S.

May 11th.—Notes on some Specimens of Lower-Silurian Trilobites, by E. Billings, Esq., F.G.S.

——— Note on the Palpus and other Appendages of *Asaphus* from the Trenton Limestone, in the British Museum, by H. Woodward, Esq., F.G.S.

——— On the Structure and Affinities of *Sigillaria*, *Calamites*, and *Calamodendron*, by J. W. Dawson, LL.D., F.R.S., F.G.S.

——— Notes on the Geology of Arisaig, Nova Scotia, by the Rev. D. Honeyman, D.C.L., F.G.S.

May 25th.—Contributions to a Knowledge of the Newer Tertiaries of Suffolk and their Fauna, by E. Ray Lankester, Esq. ,B.A.; communicated by Prof. Huxley, F.R.S., F.G.S.

——— Notes on an Ancient Boulder-clay of Natal, by Dr. Sutherland; communicated by Prof. Ramsay, F.R.S., F.G.S.

——— On the Distribution of Wastdale-Crag Blocks, "Shap-Fell Granite Boulders," in Westmoreland, by Professor Robert Harkness, F.R.S., F.G.S.

June 8th.—On the Superficial Deposits of the South of Hampshire and the Isle of Wight, by Thomas Codrington, Esq., F.G.S.

——— On the Relative Position of the Forest-bed and the Chillesford Clay in Norfolk and Suffolk, and on the Real Position of the Forest-bed, by the Rev. John Gunn, M.A., F.G.S.

——— On a new Labyrinthodont Amphibian from the Magnesian Limestone of Midderidge, Durham, by Albany Hancock, Esq., F.L.S., and Richard Howse, Esq.; communicated by Prof. Huxley, F.R.S., F.G.S.

——— On *Proterosaurus Speneri*, Von Meyer, and a new species, *Proterosaurus Huxleyi*, from the Marl-slate of Midderidge, Durham, by Albany Hancock, Esq., F.L.S., and Richard Howse, Esq.; communicated by Prof. Huxley, F.R.S., F.G.S.

June 22nd.—Notes on the Lower Portion of the Green Slates and Porphyries of the Lake-district between Ulleswater and Keswick, by H. A. Nicholson, M.D., D.Sc., M.A., F.G.S.

——— Observations on some Vegetable Fossils from Victoria, by Dr. Ferd. von Müller, and R. Brough Smyth, Esq., F.G.S.

——— Note on some Plesiosaurian Remains obtained by J. C. Mansel, Esq., F.G.S., in Kimmeridge Bay, Dorset, by J. W. Hulke, Esq., F.R.S., F.G.S.

——— Notes on the Geology of the Lofoten Islands, by the Rev. T. G. Bonney, M.A., F.G.S.

——— On *Dorypterus Hoffmanni*, Germar, from the Marl-slate of Midderidge, Durham, by Albany Hancock, Esq., F.L.S., and Richard Howse, Esq.; communicated by Prof. Huxley, F.R.S., F.G.S.

——— Observations on Ice-marks in Newfoundland, by Staff-Comm. J. H. Kerr, R.N.; communicated by Sir. R. I. Murchison, Bart., F.R.S., F.G.S.

——— On the Glacial Phenomena of Western Lancashire and Cheshire, by C. E. De Rance, Esq., F.G.S.

——— On the Postglacial Deposits of Western Lancashire and Cheshire, by C. E. De Rance, Esq., F.G.S.

——— Observations on Modern Glacial Action in Canada, by the Rev. W. Bleasdell, M.A.; communicated by Principal Dawson, F.R.S., F.G.S.

——— On an Altered Clay-bed and Sections in Tideswell Dale, Derbyshire, by the Rev. J. M. Mello, M.A., F.G.S.

——— On the Physics of Arctic Ice as Explanatory of the Glacial Remains in Scotland, by Dr. Robert Brown, M.A.; communicated by Prof. Ramsay, F.R.S., F.G.S.

November 9th.—On the Carboniferous Flora of Bear Island (lat. 74° 30′ N.), by Prof. Oswald Heer, F.M.G.S.

——— On the Evidence afforded by the Detrital Beds without and within the North-eastern part of the Valley of the Weald as to the Mode and Date of the Denudation of that Valley, by Searles V. Wood, jun., Esq., F.G.S.

November 23rd.—On some Points in South-African Geology, Part I., by G. W. Stow, Esq.; communicated by Prof. T. Rupert Jones, F.G.S.

——— Note on some Reptilian Fossils from Gozo, by J. W. Hulke, Esq., F.R.S., F.G.S.

——— On the Discovery of a "Bone-bed" in the lowest of the "Lynton Grey Beds," North Devon, by F. Royston Fairbank, M.D.; communicated by Prof. Duncan, M.B., F.R.S., Sec. G.S.

December 7th.—On Fossils from Cradock and elsewhere in South Africa, by George Grey, M.D.; communicated by Prof. T. Rupert Jones, F.G.S.

——— On some points in South-African Geology, Part II., by G. W. Stow, Esq.; communicated by Prof. T. Rupert Jones, F.G.S.

——— On the Geology of Natal, in South Africa, by C. L. Griesbach, Esq.; communicated by H. Woodward, Esq., F.G.S.

December 7th.—On the Diamond-districts of the Cape of Good Hope, by G. Gilfillan, Esq.; communicated by Warington W. Smyth, Esq., F.R.S., F.G.S.

December 21st.—On Lower Tertiary Deposits recently exposed at Portsmouth, by C. J. A. Meyer, Esq., F.G.S.

——— Note on some New Crustacea from the Lower Eocene of Portsmouth, collected by C. J. A. Meyer, Esq., F.G.S., by H. Woodward, Esq., F.G.S.

——— On the Chalk of the Cliffs from Seaford to Eastbourne, Sussex, by W. Whitaker, Esq., B.A., F.G.S.

——— On the Chalk of the Southern part of Dorset and Devon, by W. Whitaker, Esq., B.A., F.G.S.

1871.

January 11th.—On the older Metamorphic Rocks and Granite of Banffshire, by T. F. Jamieson, Esq., F.G.S.

——— On the Connexion of Volcanic Action with Changes of Level, by Joseph John Murphy, Esq., F.G.S.

——— On some points in the Geology of the Neighbourhood of Malaga, by Don M. de Orueba; communicated by Sir R. I. Murchison, Bart., F.R.S., F.G.S.

January 25th.—On the Physical Relations of the New Red Marl, Rhætic Beds, and Lower Lias, by Prof. A. C. Ramsay, LL.D., F.R.S., F.G.S.

——— Note on a large Reptilian Skull from Brooke, Isle of Wight, probably Dinosaurian, and referable to the Genus *Iguanodon*, by J. W. Hulke, Esq., F.R.S., F.G.S.

February 8th.—On the Punfield Formation, by J. W. Judd, Esq., F.G.S.

——— Some Remarks on the Denudation of the Oolites of the Bath District, with a Theory on the Denudation of Oolites generally, by W. S. Mitchell, Esq., LL.B., 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,—

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

That the thanks of the Society be given to Professor Duncan, retiring from the office of Secretary.

That the thanks of the Society be given to Harvey B. Holl, M.D., G. Maw, Esq., J. C. Moore, Esq., Warington W. Smyth, Esq., and the Rev. W. S. Symonds, M.A., retiring from the Council.

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

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Date of Election.

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1827. Dr. H. von Dechen, *Bonn.*
1828. M. Léonce Elie de Beaumont, Sec. Perpétuel de l'Instit. France For. Mem. R.S., *Paris.*
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       Mr. W. K. Parker.
1861. Professor A. Daubrée.
1862. Professor Oswald Heer.
1863. Professor Ferdinand Senft.
1864. Professor G. P. Deshayes.
1865. Mr. J. W. Salter.
1866. Mr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Mr. W. Carruthers.
1870. M. Marie Rouault.
1871. Mr. R. Etheridge.

Trust-Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
Balance at Banker's, January 1, 1870, on the Wollaston Donation-fund	31	15	6	Award to M. Rouault	21	5	6
Dividends on the Donation-fund for 1870 on Reduced 3 per Cents.	31	18	2	Cost of striking Gold Medal awarded to Prof. G. P. Deshayes	10	10	0
				Balance at Banker's, Dec. 31, 1870 (Wollaston-fund)	31	18	2
	£63	13	8		£63	13	8

Valuation of the Society's Property; 31*st December*, 1870.

Property.	£	s.	d.	Debts.	£	s.	d.
Due from Longman & Co., on acc. of Journ. Vol. XXVI., &c.	54	8	1	Balance in favour of the Society	6067	0	3
Due from Stanford, on account of Map	13	4	8				
Due from Subscribers to Journal (considered good)	13	0	0				
Due for Authors' Corrections in Journal	20	0	0				
Balance in Banker's hands, Dec. 31, 1870	438	8	2				
Balance in Clerk's hands, Dec. 31, 1870	28	8	10				
Funded Property:— Consols, at 95 (£5542 2s. 2d.)	5265	0	0				
Arrears of Admission-fees (considered good)	75	12	0				
Arrears of Annual Contributions (considered good)	158	18	6				
	£6067	0	3		£6067	0	3

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

J. GWYN JEFFREYS, *Treas.*

Feb. 6, 1871.

ESTIMATES *for*

INCOME EXPECTED.

	£	*s.*	*d.*	£	*s.*	*d.*
Due for Subscriptions for Quarterly Journal (considered good)	13	0	0			
Due for Authors' Corrections	20	0	0			
Due for Arrears (See Valuation-sheet)	234	10	6			
				267	10	6
Estimated Ordinary Income for 1871.						
Annual Contributions:—						
From Resident Fellows, and Non-residents of 1859 to 1861				850	0	0
Admission-fees (supposed)				250	0	0
Compositions (supposed)				250	0	0
Dividends on Consols				163	9	10
Sale of Transactions, Proceedings, Library-catalogues, Ormerod's Index, and Hochstetter's New Zealand	15	0	0			
Sale of Quarterly Journal	150	0	0			
Sale of Geological Map	25	0	0			
				190	0	0
Due from Longman and Co. in June	54	8	1			
Due from Stanford and Co. in June	13	4	8			
				67	12	9
				£2038	13	1

J. GWYN JEFFREYS, TREAS.

Feb. 6, 1871.

the Year 1871.

EXPENDITURE ESTIMATED.

	£	s.	d.	£	s.	d.
General Expenditure:						
Taxes and Insurance	40	0	0			
Furniture	15	0	0			
House-repairs	30	0	0			
Fuel	30	0	0			
Light	30	0	0			
Miscellaneous House-expenses	65	0	0			
Stationery	25	0	0			
Miscellaneous Printing, including Abstracts	75	0	0			
Tea for Meetings	25	0	0			
				335	0	0
Salaries and Wages:						
Assistant Secretary	300	0	0			
Clerk	120	0	0			
Assistant in Library and Museum	65	0	0			
Porter	100	0	0			
Housemaid	40	0	0			
Occasional Attendants	10	0	0			
Collector	20	0	0			
Accountant	5	0	0			
				660	0	0
Library	100	0	0			
Museum	5	0	0			
				105	0	0
Miscellaneous Expenditure				75	0	0
Diagrams at Meetings				15	0	0
Publications: Quarterly Journal	750	0	0			
" Geological Map	50	0	0			
				800	0	0
Balance in favour of the Society				48	13	1
				£2038	13	1

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance at Banker's January 1, 1870	479	15	6			
Balance in Clerk's hands January 1, 1870..	31	0	9			
				510	16	3
Compositions received				252	0	0
Arrears of Admission-fees	56	14	0			
Admission-fees, 1870	264	12	0			
				321	6	0
Arrears of Annual Contributions				205	11	0
Annual Contributions for 1870, viz. :—						
Resident Fellows £783 6 0						
Non-Resident Fellows ... 45 13 6						
				828	19	6
Annual Contributions in advance..................				17	17	0
Dividends on Consols				160	0	10
Journal Subscriptions in advance				1	6	0
Publications:						
Sale of Transactions......................	1	14	3			
Sale of Journal, Vols. 1–25	107	13	9			
„ Vol. 26*	99	13	4			
Sale of Geological Map	39	2	4			
Sale of Library-catalogues	1	12	6			
Sale of Ormerod's Index...................	8	13	0			
Sale of Hochstetter's New Zealand	4	10	6			
				262	19	8
				£2560	16	3

We have compared the Books and Accounts presented to us with this statement, and find them agree.

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

Feb. 6, 1871.

	£	s.	d.
* Due from Messrs. Longman, in addition to the above, on Journal, Vol. 26, &c.	54	8	1
Due from Messrs. Stanford on Geological Map	13	4	8
Due from Fellows for Journal subscriptions, estimated........	13	0	0
	£80	12	9

Year ending December 31st, 1870.

EXPENDITURE.

	£	s.	d.	£	s.	d.
General Expenditure:						
Taxes	41	11	8			
Fire-insurance	6	0	0			
New Furniture	8	6	0			
House-repairs	26	19	9			
Fuel	27	17	0			
Light	25	13	6			
Miscellaneous House-expenses	66	5	1			
Stationery	25	19	10			
Miscellaneous Printing, including Abstracts	53	17	6			
Tea at Meetings	20	7	0			
				302	17	4
Salaries and Wages:						
Assistant-Secretary	210	0	0			
Clerk	100	0	0			
Library and Museum Assistant	59	0	0			
Porter	100	0	0			
Housemaid	40	0	0			
Occasional attendants	8	0	0			
Collector	13	5	3			
Accountant	5	0	0			
				535	5	3
Library				71	1	6
Miscellaneous Expenses				73	16	6
Diagrams at Meetings				10	6	6
Investment in £211 7*s.* 3*d.* Consols				200	0	0
Publications:						
Geological Map	16	17	7			
Journal, Vols. 1–25	9	15	1			
„ Vol. 26	765	14	6			
Ormerod's Index	108	5	0			
				900	12	2
Balance at Banker's, Dec. 31, 1870	438	8	2			
Balance in Clerk's hands, Dec. 31, 1870	28	8	10			
				466	17	0
				£2560	16	3

PROCEEDINGS

AT THE

ANNUAL GENERAL MEETING,

17TH FEBRUARY, 1871.

AWARD OF THE WOLLASTON MEDAL.

THE Reports of the Council and of the Committees and Auditors having been read, the President, JOSEPH PRESTWICH, Esq., F.R.S., handed the Wollaston Gold Medal to Professor RAMSAY, F.R.S., F.G.S., addressing him as follows :—

PROFESSOR RAMSAY,—I have great pleasure in presenting you with the Wollaston Medal, which has this year been awarded to you by the Council of the Society, in recognition of your many researches in practical and in theoretical geology. Distinguished as your services have been in connexion with the Geological Survey since you entered upon it as the Assistant Geologist of Sir Henry De la Beche in 1841, and more particularly since your appointment as Local Director in 1845, during which period you have superintended and carried out the admirably minute style of mapping now general on the survey, and done so much in training its members in the field, you have not less distinguished yourself by your investigations of the higher problems involved in the study of geology. Your first work was on the Isle of Arran; and although then only a beginner, you, instead of taking the rocks to be what they looked, worked out what they were, and gave a new and independent reading of them, which has since in great part proved to be the right one. In 1846 your well-known memoir "On the Denudation of South Wales and the adjacent Counties of England" showed the enormous amount of denudation that the Palæozoic rocks had undergone before the deposition of the New Red Sandstone. At subsequent periods you dwelt on the power that produced "Plains of Marine Denudation," a term introduced, I believe, by yourself, and showed in all cases, by a series of true and beautiful sections, how this had operated in planing across the older strata, and how valleys had been scooped out by subsequent aqueous causes in the great plains so formed.

Whilst unravelling the complicated interior phenomena of the Welsh rocks, you were not unmindful of the very different order of phenomena exhibited on their exterior surfaces. Here you showed the vast extent and power of ice-action, and what a glacier-land Wales once was. Reasoning from the present to the past, you also boldly pushed your ice-batteries far back into geological time, and were the first to bring them to bear on rocks of Permian age. That advanced post you long had to hold alone ; but other geologists have since followed your lead, and we have even lately had evidence in the same direction from Southern Africa, where it is asserted that boulders and glaciated surfaces have been found at the base of the Karoo formation of supposed Triassic age.

You have also held a prominent place among those who, by their public teaching, have done so much during the last twenty years to advance the cause of our science. To myself personally, whose geological career has run nearly parallel in time with your own, it is a source of much pleasure that it has fallen to my lot to hand you this the highest testimonial the Society has to bestow.

Prof. Ramsay made the following reply :—

Mr. President,—I cannot say whether I am more pleased or surprised by the unexpected award to me of the Wollaston Medal by the Council of this Society. Pleased I well may be, not because I ever worked for this or any other honour, but because I feel a sense of satisfaction that the work on which I have been engaged for the last thirty years has been esteemed by my friends and fellows of the Council of the Society so highly that they have deemed me a fit recipient of this honour. It is also a special satisfaction to me that this award has been bestowed by the hand of one of my oldest geological friends, who is so universally esteemed and beloved, and is himself so distinguished a contributor to physical and other branches of our science.

My first endeavour in geology (the construction of a geological map and model of Arran) necessarily drew my attention to the physical part of our science ; and when, consequent upon that work, I was, through the intervention of my old and constant friend Sir Roderick Murchison, appointed by Sir Henry De la Beche to the Geological Survey of Great Britain, my whole subsequent life was thereafter necessarily involved in questions of physical geology ; for no man can work on or conduct the field-work of such a survey who does not, aided by palæontology, necessarily make that his first aim.

If some of my theories, induced by that work, were long in being recognized, the recognition has been all the more welcome when it came. Probably I never should have been able to do what I have done but for the wise example of my old master Sir Henry himself, in his time the best thinker in England on the physical branch of our science, and to whose remarkable work, 'Researches in Theoretical Geology,' all geologists are to this day indebted.

The papers which I have written are mere offshoots from my heavier work on the Geological Survey. Perhaps they are enough for the readers; but I wish they had been more numerous, for I certainly have had many more in my mind. Two of these, on old physical geographies, I have lately given to the Society; and if they should be printed, I shall be well pleased should they soon or late be found worthy. The present physical geography of the world is but the sequel of older physical geographies; and to make out the history of these is one of the ultimate aims of geology. These are the subjects I have striven to master in part. I consider your award a sign that I have had some success; and if, before I cease to work, I have a little more, I may well be content.

Award of the Wollaston Donation-fund.

The President then presented the Balance of the Proceeds of the Wollaston Donation-fund to Robert Etheridge, Esq., F.G.S., in aid of the publication of his great stratigraphical Catalogue of British Fossils, and addressed him as follows:—

Mr. Etheridge,—The Council of the Society has awarded to you the Proceeds of the Wollaston Fund, to aid in prosecuting your valuable work on the fossils of the British Islands, stratigraphically arranged. In this work, on which you have been engaged during the last nine years, and which occupies nine volumes of MS., representing as many geological groups, you give the natural-history lists of each group, and trace the history of each species both in time and space. Of the magnitude of the work few can have any idea; nor would many have an idea of the marvellous extent of past life in our small portion of the globe without a comparison of our recent fauna with those (necessarily incomplete because only partly accessible) which you have enumerated in your most useful lists. This comparison shows:—

	Protozoa, Cœlenterata, Echinodermata.	Crustacea.	Mollusca*.	Pisces.	Reptilia.	Aves.	Mammalia.	Plants.	Total.
Number of Species in the existing fauna and flora of Great Britain	616	278	567	263	15	354	76	1820	3989
Number of Species found fossil in Great Britain	2574	746	7091	815	224	12	172	819	12453

I trust that this work will not be allowed to remain in MS., and that, presuming you will begin with the oldest, we may soon look for an instalment in the fauna of the Palæozoic rocks. I have much pleasure in presenting you with this token of the importance which the Geological Society attaches to your labours.

Mr. Etheridge made the following reply:—

I have great satisfaction in receiving from you, Sir, and the Council of the Geological Society, the award of the Wollaston-fund. It is given for work known to be nearly done, and faith in its completion. The time and labour devoted to my book upon the 'Stratigraphical Arrangement of the British Fossils' has extended over nearly nine years of incessant work, and has been an arduous yet pleasant undertaking, now made lighter by the recognition of those who know and value the researches made for so extensive a catalogue of the British organic remains, now numbering nearly 13,000 species. It is this estimation of my labour by the Council and Society that tends to increase the desire to make my work as perfect as possible, well knowing how difficult, if not impossible, it is to do so. This acknowledgment, Sir, from your hands will stimulate me to complete my researches into the literature of the British species, and trace their history through space and time throughout Europe.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

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

Gentlemen,—I have to congratulate you on the Report of the Council, which announces the flourishing state of your finances, the addition to your number of Members, the extension of your library, and the increasing importance of your Journal.

* Testaceous species only.

It is my duty first to mention those of our fellow-workers whose loss during the past year we have to deplore. Although the number of deceased Members amounts to 23, there are but few whose active cooperation in the special work of the Society has to be recorded.

The name of ROBERT HUTTON is associated with the earliest days of this Society, of which he was elected a Fellow in 1813. He spent the early years of his life in Dublin, which city he represented in Parliament from 1837 to 1841. He was the friend and associate of Greenough, Buckland, and other founders of this Society, in the proceedings of which he ever took the warmest interest. During various excursions through Ireland, he made a considerable collection of minerals and fossils, which, on his leaving Dublin in 1836, he presented to the Geological Society of Dublin, of which he had been a member since its commencement in 1832. In 1836 he was placed on the Council of our Society, in 1837 served as Secretary, and was one of the Vice-Presidents in 1845 and 1846. He took for many years an active part in the Society, but did not contribute any thing from his pen, although always ready to assist others by his advice and countenance. He was also one of the original promoters of the London University (now University College), and was on its Council for 30 years. He was born in 1784, and died in August 1870.

COLONEL SIR PROBY T. CAUTLEY, K.C.B. In 1831 four young men, all of whom subsequently became eminent and distinguished, met, at the commencement of their professional and scientific career, at a remote up-station in India. Sir Proby Cautley, General Sir Henry Durand (whose untimely death the nation has had so recently to deplore), General Sir William Baker, Member of Council of India, then lieutenants in the army, and the lamented Hugh Falconer, had their attention drawn by the first-named and by an Indian Prince to the rich stores of mammalian remains in the Tertiary deposits of the Sewalik Hills. They all entered zealously upon the investigation of this new and unexplored ground; and, as Dr. Murchison observes, "by the joint labours of Cautley, Falconer, Baker, and Durand, a subtropical mammalian fossil fauna was brought to light, unexampled in richness and extent in any other region then known. It included:—the earliest discovered fossil QUADRUMANA; an extraordinary number of PROBOSCIDEA belonging to *Mastodon*, *Stegodon*, *Loxodon*, and *Euelephas*; several extinct species of *Rhinoceros*, *Chalicotherium*; two new subgenera of *Hippopotamus*, viz. *Hexa-*

protodon and *Merycopotamus*; several species of *Sus* and *Hippohyus*, and of *Equus* and *Hippotherium*; the colossal ruminant *Sivatherium*, together with fossil species of Camel, Giraffe, *Cervus*, *Antilope*, *Capra*, and new types of *Bovidæ*; *Carnivora* belonging to the new genera *Hyænarctos* and *Enhydriodon*, and also to *Drepanodon*, *Felis*, *Hyæna*, *Canis*, *Gulo*, *Lutra*, &c.; among the *Aves*, species of Ostrich Cranes, &c.; among the *Reptilia*, Monitors and Crocodiles of living and extinct species, the enormous Tortoise, *Colossochelys Atlas*, with numerous species of *Emys* and *Trionyx*; and among fossil fish, *Cyprinidæ* and *Siluridæ*. The general facies of the extinct fauna exhibited a congregation of forms participating in European, African, and Asiatic types. Of the mammalian remains all belonged to extinct species; but of the Reptilia and freshwater Shells some of the fossil species were identical with species now in existence on the continent of India: and from this fact, more than thirty years ago, Dr. Falconer was led to draw important inferences as to the antiquity of the human race" *.

Joint notices of these remarkable discoveries were sent in from time to time and published in your 'Transactions.' Independently of these, Sir Proby Cautley communicated to the Society separate papers "On the Structure of the Sewalik Hills, and the Organic Remains found in them," and "On the Finding of the Remains of a Quadrumanous Animal in the Sewalik Hills," whilst several others bearing on the same subject were published in the Journal of the Asiatic Society of Bengal, and elsewhere. These researches were continued by Sir Proby and Dr. Falconer during eight years with indefatigable perseverance and at great expense; in 1840 Sir Proby sent this unrivalled collection, which filled 214 cases, each weighing about 4 cwt., to England. This collection was offered to our Society; but for want of room it had to be declined, and it was placed in the British Museum. It was the intention of Messrs. Falconer and Cautley to describe and illustrate the whole of their large collections in a magnificent work entitled 'Fauna Antiqua Sivalensis,' of which 9 parts were published, but which, to the regret of the scientific world, yet remains to be completed.

In 1837 the Wollaston Medal was awarded in duplicate to Sir Proby (then Captain) Cautley and Dr. Falconer "for their geological researches and their discoveries in fossil geology in the sub-Himalayan Mountains." Although an artillery and not an engineer officer, Sir Proby's abilities were so highly valued that he was ap-

* 'Palæontological Memoirs' of Hugh Falconer, vol. i. p. 28.

pointed in 1841 to construct that important work the Ganges Canal. This difficult and great public work, probably the greatest then executed under British rule in India, its main channels being 820 miles in length, was equally to the honour of those who promoted and of him who projected and successfully carried it out. It was completed in 1854. Soon after this, Col. Cautley returned to England, where he was made a K.C.B., and in 1858 he was selected to fill one of the new seats in the Indian Council, which he held till 1868, when he retired into private life after a service of 50 years. Sir Proby Cautley was born in 1802, elected a Fellow of this Society in 1836, and died last month at his residence in Sydenham.

In Lord Chief Baron Sir Frederick Pollock, Bart., we have lost another early and distinguished Fellow. He was elected in 1818. I cannot ascertain that he ever wrote on any geological questions; but the Transactions of the Royal Society are enriched with several memoirs by him on the curious problems connected with mathematical theories of numbers.

Dr. Collier joined the Society in 1838. In early life he saw much of the world as a staff-surgeon in the army, and paid particular attention to the conchology of Ceylon when stationed there. He was also eminent as a Greek scholar. He died last May at the advanced age of 86.

In Mr. Bradford the Society has lost a promising young Member, who took first-class honours in Natural Science at Cambridge, and afterwards during five years taught English Literature and Science at Hooghly College in India. He died at the early age of 32.

The Rev. C. Erle was elected a Fellow of the Society in 1837. For many years he was a very constant attendant at the evening meetings, and he will be remembered by many for the pleasant part he took in some of our discussions. He travelled much in France and Italy, and paid great attention to the volcanic phenomena of those countries. In 1833 he was appointed to the living of Hardwich, near Aylesbury, where he resided till his death last year. Of the Saurian remains of that district he made a large collection. Mr. Erle was also a distinguished classical scholar. He was born in 1790.

Amongst our foreign Members, science has sustained a great loss in Professor Gustav Bischoff, of Bonn, who died last year at the age of 78. At an early period of his life, he devoted himself to Chemistry and Physics; and his attention becoming afterwards directed to Geology, a science then in its infancy, he brought his knowledge of chemistry to bear upon the many difficult and interesting problems of Chemical Geology. In 1826 he published a paper "Sur l'origine des sources Minérales." In 1827 a paper "Sur les efflorescences des Roches Volcaniques." These were followed by various papers on Fossil bones, the inflammable gases of Coal-mines, Volcanic rocks, Glacier action, and others in the 'Neues Jahrbuch.' Many of his papers appeared in the 'Edinburgh New Philosophical Journal;' amongst them are to be found "On the Natural History of Volcanoes and Earthquakes," "On the Terrestrial arrangements connected with the appearance of Man on the Earth," "On the cause of the Temperature of Hot and Thermal Springs, and on the bearings of this subject as connected with the general question regarding the internal temperature of the Earth." He also treated of "The Glaciers in their relation to the elevation of the Alps," and of "The Formation of Quartz and Metallic Veins."

Most of his early papers were afterwards embodied in his great work the 'Lehrbuch der chemischen und physikalischen Geologie,' which appeared between 1847 and 1854. In the latter year a translation of this work by Dr. Paul and Dr. Drummond, made under the supervision of the author, was published by the Cavendish Society. This important work, more condensed than the German edition, is in some respects an independent work. In the first volume, the laws of combination of the mineral kingdom, pseudomorphic minerals, the action of water as a chemical and a transporting agent, the origin of springs, the action of rivers and of the sea, the mechanical and chemical deposits from water, and the character and origin of carbonaceous substances, of various gases, and of the simple salts occurring in the mineral kingdom, are treated of; while in the second the chemical reactions relating to the alteration of minerals, and the characters of and changes in Felspathic and various other minerals, especially those of volcanic and igneous origin, are considered. No geological studies can be complete without a knowledge, at all events, of the elements of Chemical Geology. In 1861, Professor Bischoff was elected a foreign Fellow of this Society; and in 1863 the Wollaston Medal was awarded to him by the Council, in recognition of the eminent services rendered by him to Geological science by his long-continued and laborious chemical investigations on the origin and changes of minerals and rock-substances, and especially by the production of his great work on Physical and Chemical Geology.

Many of the papers read during the past year have been of much interest and well serve to maintain the character of our discussions and publications. Those connected with glacial and drift-action continue to occupy an important place.

Glacial and Tertiary Geology.

The Rev. W. Bleasdell shows how a small island in the St. Lawrence has been removed piecemeal by river-ice floating off detached portions during floods; and Dr. Brown applies the result of his experience in the arctic regions of America to the explanation of the glacial phenomena of Scotland, the sub-azoic Boulder-clay of which country he considers analogous to the deposit under the ice-cap of Greenland, while the associated fossiliferous laminated clays were formed in the fiords and bays skirting the ice-covered land.

Professor Harkness objects to former hypotheses respecting the distribution of the Shapfell Granite boulders over the high hills of Yorkshire, and suggests that their transport could only have been effected by the agency of coast-ice during a depression of the land of 1500 feet.

The superficial drift-deposits of South Hampshire and the Isle of Wight have been carefully investigated by Mr. Codrington, who shows that the unfossiliferous gravels of the higher plains were probably not of river-origin, but were spread out in an inlet of the sea, when the land stood 400 feet lower, whilst the gravels on the lower levels, with mammalian remains and flint implements, were afterwards deposited by river-action.

Mr. De Rance has described the Preglacial and Glacial deposits of Western Lancashire and Cheshire. He considers that at the commencement of the Glacial period the land stood higher than it now does, and that the higher ground was covered with an ice-cap and great glaciers, that the higher Boulder-clay is referable to this land-ice, and that the lower Boulder-clay spread over the lower ground was formed during a period of subsidence when the land-ice was floated off. He infers also that, when the land stood higher, Ireland would have been connected with Wales, so as to render possible the migration of mammals and plants.

Mr. Searles Wood, jun., has reviewed the vexed question of the origin of the Weald Valley, and doubts the sufficiency of the various hypotheses that have been proposed to explain the denudation of that district. From the comparative absence of Lower Cretaceous or Wealden débris in the Thames valley, and the presence of Tertiary pebbles in gravels within the Wealden area, and the manner in which the transverse valleys open out, estuary-shaped, into the Weald, he infers that that was occupied in Postglacial times by an inlet of the sea, into which rivers flowed from the Thames-valley area, and that the denudation was chiefly effected by tidal erosion during a gradual upheaval of the land.

The Rev. John Gunn is now of opinion that the "Forest-bed series," which he has so long and carefully studied, is older than the Norwich Crag and the Chillesford Clays, and that the latter covers both the other deposits transgressively in proceeding from the coast toward the interior of the country.

Mr. Ray Lankester has made further contributions to our knowledge of the Crag-beds of Norfolk and Suffolk. He considers that the Stone-bed at the base of the Norwich Crag is not identical with the Bone-bed at the base of the Suffolk Crag, and shows the marked difference in their mammalian fauna. The Rhinoceros, Tapir, Hipparion, and Hyæna of the Bone-bed are introduced Miocene species; while the Elephants and Deer of the Stone-bed and Forest-bed are of Pliocene species not found in the Bone-bed. He describes from this latter bed a new ziphioid cetacean, and has determined the presence of *Mastodon arvernensis* in a sandstone nodule found in it. Of these nodules Mr. Lankester gave additional particulars, showing, by their organic remains, their derivation from beds of "Diestien" age.

In making excavations for the extension of the dockyard in Portsmouth Harbour, a fine section of the Lower part of the London Clay, with overlying gravel and alluvial beds, has been exposed; and a good account has been given of them by Mr. C. J. A. Meyer. Some of the beds are very fossiliferous, and contain an assemblage of species which have not been found elsewhere in the London Clay: one of the species is a Thanet-sand form, while another is the well-known *Cardita planicosta* of the Bracklesham beds and of the *Calcaire grossier*.

Secondary Formations.

The only communications we have had on the Cretaceous series are as follows. Mr. Whitaker describes the divisions of the Chalk of the south coast. He shows that the Chalk Marl and Lower Chalk thin westwards, while the Upper Chalk with flints passes transgressively over and beyond it, and thus are flints found so far west. Mr. Judd gives the result of his further examination of the Neocomian beds of Yorkshire and Lincolnshire, and shows their relation to those of Hanover, Westphalia, and Brunswick. The Speeton-clay series he considers to be the keystone in the correlation of the beds over the whole area.

In a subsequent paper Mr. Judd gave an interesting account of a series of beds between the Neocomian and Wealden strata of the south coast. The section where they were first noticed some years since by Mr. Godwin-Austen and Prof. E. Forbes is at Punfield, in the Isle of Purbeck, whence Mr. Judd suggests the name of "Punfield Formation" for these beds, which he shows to be of considerable importance, having a wide range through France, and being closely related to the coal-bearing strata of the north of Spain described by M. de Verneuil. The fossils are mixed and of a peculiar type; and there are many species common to the English and Spanish series.

Mr. S. Sharp subdivides the Oolites of the Northampton district, and shows that the line of division between the Great and the Inferior Oolites in the neighbourhood of Northampton is marked by unconformity as well as by organic remains. He states that there are four areas, within a comparatively small space, in which the whole of the beds occurring in each, from the Great Oolite down to the Upper Lias inclusive, are accessible. The Northampton Sands he proposes to class in three divisions—the Upper, Middle, and Lower. Though the beds vary considerably in thickness, according to the different localities, the total thickness of the Northampton Sands may be taken on an average as about 80 feet.

Mr. Mitchell suggests that the valleys of the Oolitic district round Bath are due not so much to denudation as to the circumstance that many of the beds of Great Oolite are old coral-reefs of limited extent, while the argillaceous strata are true sedimentary deposits overlying and wrapping round them, so that the Oolitic beds never in fact extended across the present valleys, though the clay beds did.

Mr. R. Tate continues his researches on the fossils of the different divisions of the Lias in Gloucestershire, and shows the value of the Ammonite-zones over certain areas—also that although the conditions of depth and deposit of the upper part of the Lower Lias are repeated in the lower part of the Middle Lias, there is a total change in the fauna, whence he infers a break in the stratigraphical succession.

Prof. Ramsay states, in an interesting paper "On the physical Relations of the New Red Marl, Rhætic Beds, and Lower Lias," that there is a perfect physical gradation between the first two. He considers that the New Red Sandstone and New Red Marl were formed in inland waters—the latter in a salt lake of great extent. These conditions, and the abundance and peculiar condition of the oxide of iron, would, Prof. Ramsay thinks, be in accordance with those chemical characters of the waters, while he considers that the fossil footprints occurring in these beds are evidences of the absence of tides in the waters. He gives stratigraphical and palæontological reasons in proof of the New Red Marl being more closely related to the Rhætic beds, and even to the Lias than to the Bunter, and traces the sequence of events during the accumulation of these several formations.

Palæozoic and Metamorphic Rocks.

From Dr. Nicholson we have a paper on a part of the "Lower Green-slates and Porphyries" of the Lake district. They were so named by Prof. Sedgwick, and underlie his Skiddaw Slates. Over these are felspathic rocks, succeeded by a series of ash-beds, breccias, and amygdaloids, which are often worked as slates.

Mr. Jamieson divides the older rocks of Banffshire into three groups:—first, a lower arenaceous series more or less altered by metamorphic action into quartz-rock, gneiss, and mica-schist; next, a series of clay slates, with a subordinate bed of limestone; thirdly, an upper group of arenaceous strata. A main object of his communication is to give his reasons for considering that the granites of Banffshire are due to the fusion and recrystallization of the arenaceous beds.

Palæontology.

In the palæontological papers,—

Mr. Busk has pointed out that the Oreston fissure-cavern Rhinoceros is not the *R. tichorhinus,* but *R. leptorhinus.*

Three species of Elephant are now ascertained to have lived in Malta during the Cave-period. Dr. Caruana draws attention to the abundance of their remains in a particular part of the island, including one new locality.

Mr. Hulke has described an *Ichthyosaurus* supposed to have been found in the Isle of Gozo; and if so, it is the first one discovered in beds of Tertiary (Eocene ?) age. He has also described two species of *Plesiosaurus* from the Kimmeridge Clay of Dorsetshire; one of these is a slender-necked species 16 feet in length, and with Pliosaurian-like limbs, which are much larger, compared with the whole length, than those of the typical Liassic forms of this genus.

Professor Huxley communicates a letter from Dr. Bunzel, of Vienna, giving an account of a skull of Cretaceous age, belonging to a new order of reptiles with bird-like heads, for which the author proposed the name of *Ornithocephala.*

Messrs. Hancock and Howse describe a new Labyrinthodont amphibian from the Magnesian Limestone of Durham, and a new *Proterosaurus* (*P. Huxleyi*) from the marl-slate of the same district, associated with the *P. Speneri.* They also announce the discovery in the same rock of specimens of that peculiar fish the *Dorypterus Hofmanni,* showing the ventral fins and heterocercal tail.

A very interesting palæontological discovery has also been made by Mr. Maw of a fine skull of a Labyrinthodont in the middle of the Coalbrook-Dale Coal-measures.

Mr. H. Woodward has drawn attention to some new Crustaceans, including a species of the curious Secondary genus *Palæocorystes,* and also to two new forms referable to the family of Portunidæ, in the lower beds of the London Clay of Portsmouth, of which the section has been described by Mr. Meyer. Mr. Carruthers has described a silicified fern-stem, probably from the sands under the London Clay at Herne Bay. In structure this specimen agrees most closely with the living *Osmunda regalis.* The minutest structure of the original specimen is preserved in a remarkable manner, even showing the starch-grains and the delicate mycelium of a fungus contained in its cells.

Colonial and Foreign Geology.

We have had some excellent papers on Colonial Geology; and we are especially indebted to our correspondents in South Africa.

Dr. Sutherland describes an ancient Boulder-clay in Natal. It is an argillaceous deposit with boulders, reposing upon old sandstones, the surface of which is often deeply grooved and striated. He considers that this deposit may possibly be of Permian age.

Mr. G. W. Stow describes the Jurassic beds (with their *Trigonia*-limestones) and the Saliferous beds of Uitenhage, between the Cape and Natal. These are succeeded by Tertiary deposits, the newer of which follow the coast-line, and run in raised terraces up the river-valleys—the one being characterized by a large *Panopæa,* and the other by a species of *Akera.* The Karoo formation of the Stormberg, which is of Triassic age, with its plant-beds and *Dicynodont* fossils, are described in another memoir. The present surface-conditions of this part of the interior Mr. Stow considers especially due to ice-action; and he points also to the existence of *Roches moutonnées* and moraines in British Kaffraria and adjacent districts.

Mr. C. L. Griesbach has given an excellent account of Natal, and describes the succession of beds, commencing with the granitic and gneissic rocks and mica-schists, overlain by great plateaux of undisturbed sandstone, often capped by basalt. The sandstone is succeeded by the Karoo formation, containing occasionally subordinate beds of coal, and then near the coast by beds of Cretaceous age. Reference is made to various interesting theoretical questions connected with the former distribution of land and water between Africa and India, and to the economical mineral products (graphite, coal, gold, and copper) of Natal.

Some notes on the Diamond districts of the Cape of Good Hope have been given us by Mr. Gilfillan.

We have had only one communication from Australia, by Dr. Krefft, on certain of the later fossil Mammalia, including several species of Wombats and Wombat-Kangaroos of that remarkable continent.

The relations of the two gneissoid series of rocks of Nova Scotia have been discussed by Mr. H. Youle Hind, who believes them to be of Laurentian age, and covered in patches only by the Huronian or Cambrian rocks. The gold is found in Lower Silurian rocks, which formation is there 1200 feet thick, and is destitute of any great beds of limestone.

The Rev. T. G. Bonney describes the general appearance of the Lofoten Islands. Instead of being composed of granite, he thinks that, with few exceptions, the strata consist of highly metamorphosed rocks—quartzites and gneiss.

Foreign Palæontology.

Professor Owen has described some fossil mammals of late Tertiary or Quaternary age found in China. Among them are new species of *Stegodon*, *Hyæna*, *Tapir*, *Rhinoceros*, and *Chalicotherium*.

Principal Dawson has sent us the result of his further examination of the structure of the *Sigillaria*, *Calamites*, and *Calamodendron* of the Nova-Scotia Coal-field. A specimen of *Sigillaria* was described having a transversely laminated pith of the Sternbergia-type, the immediately surrounding tissues much resembling those of Cycads. He agrees with the opinion generally held with regard to *Calamites*, that their affinities were with *Equisetaceæ*, as pointed out by Mr. Carruthers, but more advanced than the modern *Equiseta*, while the *Calamodendra* were similar in general structure, but much more woody plants.

Professor Heer has described the flora of Bear Island, in latitude 74° 30′ N. He considers it to belong to the lower part of the Carboniferous series. There are eighteen species of plants, having a close relation with those of the Yellow Sandstones of county Cork and of the Greywacke of the Black Forest. Taking also the fossil flora of Parry Island and Melville Island, which he considers the equivalent of that of the Bear-Island beds, we have a total of 77 species of plants. Not less remarkable than the occurrence of this rich and luxuriant vegetation in those arctic regions during this Carboniferous period, is the appearance of a flora equally rich and varied, in the same regions, in the comparatively recent Miocene times.

Mr. Billings has made in the Lower Silurian rocks of Canada the interesting discovery of a Trilobite (*Asaphus platycephalus*) with its appendages preserved and the hypostome in position. It shows that the creature had eight pairs of legs; so that probably these Crustacea were walking rather than swimming animals. Mr. Woodward has found in a specimen presented some years since to the British Museum by Dr. Bigsby traces of similar appendages. He considers that the Trilobita should now be placed *next to*, if not actually with, the modern Isopoda.

Dr. Grey has sent us some interesting specimens of Dicynodont fossils, jaws of reptiles, and coal-plants, from the Karoo beds of South Africa.

Mr. Guppy is of opinion that he has detected an *Eozoon*, with a coral and echinoderms, in some Trinidad rocks, the age of which is uncertain, but considered by the author to be pre-Silurian.

The Palæontographical Society continues its valuable publications. The volume for 1870 contains the concluding part of Mr. Davidson's great work on the Brachiopods. It completes the Silurian Brachiopoda, consisting of 28 genera and 210 species, while the whole work, by that author, forms three volumes, with 150 plates, all of which have been drawn and contributed by Mr. Davidson himself. Another paper of importance is the complete monograph of British Mesozoic Mammals by Prof. Owen, containing descriptions and illustrations of 15 genera and 27 species.

Independently of your own Society, the progress of geology is being actively advanced by local societies, the number of which is annually increasing. Many of them publish Proceedings of considerable merit; and others tend, by field-work, to spread a taste for your science.

Deep-sea Life and its Relations to Geology.

Among the collateral subjects which have engaged much attention during the past year, and which must exercise a considerable influence on future geological speculation, is that relating to the nature of the sea-bed, the temperature of the sea at great depths, and the range and distribution of animal life in those depths—investigations which have been so greatly promoted by the recent expeditions of H. M. surveying-steamers 'Lightning' and 'Porcupine.' Subjects of this nature have always been of much importance to the geologist, who has therefore ever followed with the keenest interest the researches of the naturalist and physicist. In studying the marine Invertebrata the early naturalists were long limited in their observations to the shore-line, and to such moderate depths as were within reach of the ordinary fishermen or their own small appliances. Now and then a deep-sea sounding would give a fragmentary insight into other zones of depth; but from their exceptional character they did not attract much notice. Lamarck, O. F. Müller, Montagu, Poli, and Risso furnished some facts relating to depth as well as to geographical distribution; but still, when we look to the short table by Mr. Broderip of the "Situations and Depths at which recent Genera of Marine and Estuary Shells have been observed," appended to Sir Henry de la Beche's 'Theoretical Geology,' it shows how scanty our information was so late as the year 1834. No Mollusca are there given from a depth greater than 420 feet, and no Brachiopoda from one greater than 540 feet.

In the various inquiries which engaged the attention of the eminent men who formed part of the many Arctic expeditions, that of the distribution of life in the sea was not lost sight of, although, from the imperfection of the means, the results were very scanty. The small quantity of mud or stones attached to the sounding-apparatus, or brought up by the deep-sea clam, furnished, in fact, all the glimpses they were able to obtain of the ocean-bottom. Although the specimens were often crushed and broken, still the evidence, so far as it went, was in many cases clear and definite.

Sir John Ross records, in his voyage to Baffin's Bay in 1817–18, three deep-sea soundings. In the first, at a depth of 2700 ft. *,

* I have in all cases expressed the sea-depth in feet instead of in fathoms, in order to conform with the terms applied to elevations on the surface and dimensions of strata.

and two miles off shore, they brought up gravel and two small live crustaceans (*Gammarus*); in the second, in 3900 ft. and eighteen miles off shore, pebbles and brown clay, with *Serpulæ*, corallines, crustaceans, and fragments of shells; in the third, in 6000 ft. and six miles off shore, soft mud, with some worms in it. Again, in a sounding where the depth was 6300 ft., a small starfish was found attached to the line below the point marking 2400 ft.

Mr. Alex. Fisher, in his account of the voyage of the 'Hecla' and 'Griper' in 1819–20, states that, in a sounding taken on approaching Lancaster Sound, they brought up from a depth of 5100 ft. mud, with small stones and pieces of broken shells of very delicate texture.

A curious case is recorded in the voyage of the French frigate 'Venus,' in the Pacific, by M. de Tessan in 1838. When near the Equator, a bottle full of fresh water and well corked was attached to the sounding-line near the lead, and let down to the depth of 7500 feet. The bottle came up with the cork forced in, and containing a small living shell of the genus *Venus*.

Sir James Ross, in his voyage to the Southern and Antarctic Seas, in 1839–43, obtained more definite results. At a depth of 1800 ft. he found "corallines and many animals;" at 1920 ft. "green mud, with a fragment of starfish and coral;" while the result of a haul 2400 ft. deep, subsequently examined by Mr. Charles Stokes and Edward Forbes, showed the presence of small corals, pieces of shells, and two joints of a small fossil (?) *Pentacrinite*, a spine of *Cidaris*, portions of *Echinus*, a small broken *Cerithium*, a fragment of *Cleodora*, and specimens of *Spirorbis* on some stones. With these there were Foraminifera of the genera *Textularia*, *Nodosaria*, and some others, in abundance.

That the specimens brought up on these occasions were generally fragmentary was almost to be expected.

With the application of the dredge to the purposes of deep-sea exploration, materials for a more exact classification of species according to their bathymetrical range rapidly accumulated; and in the year 1839 a Committee of the British Association was appointed to carry out a systematic investigation of the seas of the British coasts. In 1840, Prof. E. Forbes, then about to join the surveying-ship 'Beacon' as naturalist, was requested by the Association to furnish them with a report on the Mollusca and Radiata inhabiting the Ægean Sea. This report * marks an epoch in Natural History and Geology.

* Brit. Assoc. Reports for 1843, p. 173.

Besides giving the lists and range in depth of the Mollusca and Radiata, the Report entered into the question of their distribution considered in its bearing on geology. The observations of Prof. Forbes ranged over a period of eighteen months; and his lists are based on more than 100 fully recorded dredging-operations in various depths from 600 to 780 ft., besides numerous coast-observations. The result of this valuable and special inquiry was to determine more clearly than had hitherto been done the range of species in depth, and the division into zones first proposed by Risso. With regard to much that Prof. Forbes accomplished no question has arisen. Of the eight zones into which he divides the bathymetrical distribution of the Mollusca, the first seven, ranging from the surface to the depth of 630 ft., although possibly too much subdivided, may be applicable to other seas where the conditions are similar; but with respect to his eighth region, which extends from 630 to 1380 ft., Prof. Forbes's generalizations, although correct within certain areas, have been found inapplicable to the two great oceans and applicable only to parts of the Mediterranean. He observes, speaking of this eighth zone, "throughout this great and, I may say, hitherto unknown province, we find an uniform and well-characterized fauna;" but then he goes on to say, "within itself the number of species and of individuals diminishes as we descend, pointing to a zero in the distribution of animal life as yet unvisited." He placed this zero at about 1800 ft.

In a subsequent work *, however, in speaking of the eighth region of depth, E. Forbes remarks, "its confines are yet undetermined, and it is in the exploration of this vast deep-sea region that the finest field for submarine discovery yet remains." "In the Mediterranean, as might be expected, when we consider the peculiar condition under which that great land-locked basin is placed, there are peculiarities in the distribution of both animal and vegetable life which require special consideration;" and in speaking of animal life in the "Arctic province" of the Atlantic, he notices that the Mollusca appear to range much deeper in high latitudes than they do in more favourable climates, and mentions the capital haul made by Mr. Harry Goodsir in Davis's Straits, when a variety of shells, Crustacea, Echinoderms, and Corallines were brought up from a depth of 1800 ft.

In another Report †, on British Marine Zoology, E. Forbes divided the range of the Mollusca into only four zones of depth; and

* Natural History of European Seas, p. 27. † Brit. Assoc. Rep. 1850.

speaking of the fourth or lowest, he observes, "A more difficult task, and which can be hardly hoped for fulfilment without the aid of a steam-vessel and continued calm weather, is the dredging of the deeps off the Hebrides in the open ocean. Much of the deep sea round the Zetlands is sure to reward the explorer.... And lastly, though I fear the consummation, however devoutly to be wished for, is not likely soon to be effected, a series of dredgings between the Zetland and the Faroe Islands, where the greatest depth is under 700 fathoms, would throw more light on the natural history of the North Atlantic and on marine zoology generally, than any investigation that has yet been undertaken."

All who knew Edward Forbes must feel satisfied that, had his valuable life been spared, he would have been in the foremost rank of the investigators of those new fields to which he pointed, and the exploration of which has now been so successfully commenced. His untimely death unfortunately left his investigations with all the weight of his authority, at a point that he doubtless would have considered the first stage in the inquiry, instead of being accepted, as it has occasionally been, as an approximate conclusion.

In 1846, Capt. Spratt, R.N., the friend and companion of Forbes, dredged at a depth of 1860 ft., forty miles east of Malta, eight distinct species of Mollusca, among which was the *Pleurotoma carinata* *, a supposed extinct species of the Coralline Crag; and he observes † that he believed animal life to "exist much lower, although the general character of the Ægean is to limit it to 300 fathoms." In his survey of the Mediterranean, between Malta and Crete ‡, Capt. Spratt afterwards found at the depth of 9720 ft. "numerous dead shells and fragments of shells."

The preliminary observations necessary before laying the different lines of Atlantic telegraphs next came in aid of natural science. In 1855 a United-States steamer made a series of deep-sea soundings across the Atlantic. The fine calcareous mud brought up from depths of from 6000 to 12,000 ft. was examined by Prof. Bailey, who discovered in it numerous shells of *Globigerinæ* and *Orbulinæ*, with Diatoms and sponge-spicules. He doubted whether these Foraminifera could have lived on the sea-bottom, and thought they might rather have fallen upon it from upper sea-zones.

* 'Nature,' vol. i. p. 166, Dec. 1869.

† Brit. Assoc. Reports for 1848, p. 81. The depth given above is corrected on Capt. Spratt's authority.

‡ 'Travels and Researches in Crete,' vol. ii. p. 329.

Ehrenberg, on the other hand, believed that they had lived at those depths.

Similar results were obtained on a line of still deeper soundings, extending to 14,400 ft., made in 1857 by Capt. Dayman; and Prof. Huxley, who reported on them, concluded that in all probability the *Globigerinæ* did live at those depths.

In 1860 Dr. Wallich* carried out an important series of deep-sea researches in connexion with the soundings made on board H.M.S. 'Bulldog,' and obtained some very interesting results. He not only confirmed the prevalence of a *Globigerina*-mud in the great depths of the Atlantic, but also gave much evidence in favour of the *Globigerina* living at those depths. Dr. Wallich also brought up two living Crustacea from a depth of 2670 ft., and living *Serpulæ, Spirorbes*, and Polyzoa from a depth of 4080 ft. His most remarkable discovery, however, was that of living starfishes at a depth of 7560 ft. Dr. Wallich's researches mark another epoch in the history of deep-sea explorations.

The following year further discoveries were made in the Mediterranean, between Sardinia and Algiers †. It having become necessary to raise the French telegraph cable after it had been submerged five years, it was found that at places various Mollusca, Corals, and Bryozoa had grown upon it. Portions of the cable, stated to have been raised from depths of from 6500 to 9000 ft., were submitted to M. Milne-Edwards, who determined the following species, to which I have added their geological range:—

Ostrea cochlear.	Coralline Crag.	Caryophyllia arcuata.
Pecten opercularis.	Coralline and Red Crag.	—— electrica, sp. n.
		Thalassiotrochus telegraphicus, sp. n.
—— Testæ.	Pliocene beds of Italy.	Salicornaria farciminoides.
Monodonta limbata.	Pliocene beds of Italy.	Serpula.
Fusus lamellosus.	Pliocene beds of Italy.	Gorgonia.

The Swedish expedition to Spitzbergen in the same year (1861) also determined the presence, at a depth of 8400 ft., of various Mollusca, Crustacea, and Hydrozoa.

Between 1860 and 1868 a series of most valuable researches was carried on off the coast of Upper Norway by the late Professor Sars and his son, at depths of from 1800 to 2700 feet. At the former depth they found an abundant fauna; at the latter the collections

* 'Notes on the Presence of Animal Life at Vast Depths in the Sea,' 1860, and 'On the North Atlantic Sea-bed,' 1862.

† Ann. des Sciences Nat. 4e sér. vol. xv. p. 3.

were smaller, but still considerable. I annex a list of the number of species dredged at the depth of 2700 feet, for the purpose of showing how these researches already affected questions depending on the relative proportion of recent and extinct species, as to the age of the newer geological deposits :—

	Known species.	New species.	Total.
Mollusca	7	4	11
Crustacea	2	1	3
Echinodermata	3	0	3
Foraminifera	20	4	24
	32	9	41

In 1867 Count Pourtales * dredged, between Florida and Cuba, in depths of about 3000 ft., and found a rich fauna of Mollusca, Crustacea, Corals, and Echinoderms.

Impressed with the value of these observations, and with the importance of a more systematic and yet deeper exploration of the ocean-bed, Dr. Carpenter, at the suggestion of Prof. Wyville Thomson, brought the subject before the Royal Society in June 1868. As the undertaking was beyond the reach of private enterprise, an application was made by the President and Council of the Society to the Government for a vessel for the purpose. The request was readily and liberally responded to; a Government steamer was then, and again in 1869 and 1870, placed at the disposal of the Committee appointed for the purpose; and a most important series of deep-sea dredgings have been carried out by the above-named naturalists and Mr. Gwyn Jeffreys. Only the general results have as yet been laid before the Royal Society. These, however, are quite sufficient to show that the expeditions have proved of the highest service to natural science, whether as regards the existence and distribution of animal life at great depths of the ocean, the temperature at various depths, the direction of the great oceanic currents, or the bearing of such investigations on the past history of our globe.

Almost everywhere the deep bed of the Atlantic was found covered in its greatest depth with a light-coloured calcareous mud, abounding in *Globigerinæ*, rich in siliceous sponges, and often supporting a varied fauna of Mollusca, Crustacea, and Echinoderms. Numerous valuable observations were also made on deep-sea tem-

* 'Bulletin of the Museum of Comp. Zoology,' Cambridge, U. S., 1867, and 'Silliman's Journal' for Nov. 1868.

peratures and currents, with instruments prepared for the occasion. I must refer to the papers by Dr. Carpenter and his colleagues (to whom I am much indebted for the perusal of the last Report, now going through the press), in the 'Proceedings of the Royal Society'*, for the varied information respecting the composition of sea-water at different depths, the gases contained in it, and the speculations on oceanic currents. The points that more particularly interest us are those bearing on geological investigations.

In first drawing the attention of the Royal Society to the importance of undertaking deep oceanic researches, Prof. Wyville Thomson referred to the recent discovery by Prof. Sars of a small crinoid belonging to an order supposed to be extinct, and which flourished from Jurassic to Cretaceous times; he suggested the probability of the continuity of the ancient chalk-sea with the present abyssal depths of the Atlantic, as such depths would be but little affected by any of the later oscillations of the earth's crust in the northern hemisphere, as, since the commencement of the Tertiary epoch, they probably had not much exceeded 1000 ft. The result of the first expedition was more than sufficient to confirm the most sanguine anticipations. Dr. Carpenter, on its return, reported that, of the higher types of marine animals which they had discovered, "many carry us back in a remarkable manner to the Cretaceous epoch;" and, again, it "seems on general grounds highly probable that the deposit of *Globigerina*-mud has been going on from the Cretaceous epoch to the present time (as there is much reason to suppose that it did elsewhere in anterior geological periods), this mud not being merely a chalk formation, but a continuation of the chalk formation." These views have a high significance and interest. Let us see how far we can adopt them.

The Atlantic abyssal mud has been found to contain from 50 to 60 per cent. of carbonate of lime, 20 to 30 of silica, with small variable proportions of alumina, magnesia, and oxide of iron. Its appearance, when dry, is chalk-like; but it is to be observed that our white chalk is a much more homogeneous rock, containing from 95 to 99 per cent. of carbonate of lime, while even our grey chalk contains from 80 to 90 per cent †. The larger proportion of cal-

* Proc. Roy. Soc. vol. xvii. pp. 168–200; vol. xviii. pp. 397–492; and vol. xix. pp. 146–222.

† Since writing the above, Mr. David Forbes has kindly obliged me with the following observations:—"The specimens of Atlantic mud or soundings which I have examined, differ very essentially from chalk in composition; and no single one of them (if consolidated) could be entitled to the appellation of

careous Foraminifera in the chalk, and of siliceous Polycystina and vitreous Sponges in the Atlantic mud, may, however, render this rather a question of proportion than of radical difference. I would point out that the White Chalk (Terrain Sénonien) of Touraine varies in colour from white to light yellow, or greyish yellow, is a much less pure carbonate of lime, and is wonderfully rich in siliceous sponges. In fact there is one portion of it, from 28 to 30 ft. thick, which contains no carbonate of lime at all*. At other places in France, and in Europe, the chemical composition of the chalk differs considerably, and the colour varies from white to dark grey.

Mr. Lonsdale †, many years since, pointed out that white chalk was composed largely of microscopic organic débris, consisting chiefly of minute Foraminifera; and Dr. Mantell ‡ afterwards estimated that more than a million of such remains are contained in a cubic inch of some of our chalk. I would further draw attention to a remark by Dr. Mantell in the same work (p. 315). Speaking of the chalk,

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chalk, as ordinarily understood by geologists or chemists. In order to make a correct comparison of their composition with that of chalk, I was obliged to make analyses of the latter rock, two of which I annex.

	Grey Chalk (base of), Folkstone.	White Chalk, Shoreham (Sussex).
Carbonate of lime	94·09	98·40
Carbonate of magnesia	0·31	0·08
Insoluble rock débris	3·61	1·10
Phosphoric acid	traces	0·42
Alumina and loss in analysis	,,	
Chloride of sodium	1·29	...
Water	0·70	...
	100·00	100·00

On the other hand, the specimens of Atlantic mud received from Mr. Gwyn Jeffreys, Dr. Carpenter, and others (about eight in number), and examined by me, contain at highest not 60 per cent. of carbonate of lime, along with very much siliceous and aluminous matters, oxide of iron, &c.; and if we were even to subtract the amount of water, organic matter, and marine salts found by analysis in them, as these substances would be in greater part removed before such mud could, in the process of ages, be converted into solid rock, the amount of carbonate of lime would be still far less than that present in what would ordinarily be regarded as chalk; in fact the resulting rock would have the exact composition of many of the older marls or impure limestones."

* Mém. Soc. Géol. de France, sér. 1, vol. ii. p. 239.

† Lyell, Anniv. Address Geol. Soc. for 1836, p. 13.

‡ Wonders of Geology, 6th edit. 1848, vol. 1. p. 305.

he says, "The whole forms such an assemblage of sedimentary deposits as would probably be presented to observation if a mass of the bed of the Atlantic, 2000 ft. in thickness, were elevated above the waters, and became dry land; the only essential difference would be in the generic and specific characters of the imbedded animal and vegetable remains." Whether viewed by naturalists or by geologists, the similarity of origin seems to have occurred to both; and I am not aware that the question of depth ever seriously interfered with this view amongst geologists, who, on the contrary, rather considered the mass and fossils of the chalk to be an indication of the possibility of life at great depths. Both deposits were also found to contain numerous peculiar and simple organisms, which were named Coccoliths * and Coccospheres (noticed by Wallich, Huxley †, and Sorby), while the profusion of the particular Foraminifer the *Globigerina*, and the later discovery of siliceous Sponges, are other features in common. Except by Mr. Bailey, the presence of Diatoms has not been noticed ‡.

Prof. Rupert Jones has kindly filled up for me the following Tables, the results being based chiefly on Messrs. Parker and Jones's excellent account of the Foraminifera from the North Atlantic and Arctic oceans §. They determined 110 species as now living in those seas; and of these they recognized 19 as fossil in the Chalk.

* Mr. Carter now considers this to be a calcareous unicellular alga, the frustules of which form the Coccospheres. He proposes for it the name of *Melobesia unicellularis*. It occurs in abundance in the Laminarian zone off the Devonshire coast. Another species, the *M. discus*, he considers peculiar to the deep Atlantic. Ann. & Mag. Nat. Hist. for March 1871.

† Prof. Huxley states that Dr. Gümbel of Vienna has now discovered these bodies in all sedimentary strata.

‡ Count Ab. Castracane, of Rome, however, has since examined some of the mud obtained in the first 'Porcupine' expedition at a depth of 14,610 feet, for Diatoms, and reports that he discovered a rare species of *Asteromphalos*, which he found, for the first time in Europe, in the Adriatic in 1863. He states also that "Specimens of *Hemidiscus* occur in greater number, and perhaps also some allied species like *Euodia*, of which I am not aware that, up to the present time, any examples have before been found in Europe; at least I have not discovered any mention of them in the various authors I possess on the subject. Besides these, the species of Diatoms most abundant in this deposit are the *Coscinodisci*; and of these the *Coscinodiscus lineatus*, Ehr., is the most frequently met with. There are numerous *Melosiræ*, *Bacteriastra*, *Triceratia*, *Bacillariæ*, *Pleurosigmata*, *Synedræ*, *Naviculæ*," &c. Count Castracane is unable to determine whether these lived at the bottom of the ocean or near the surface. (Accademia Pontificia de' Nuovi Lincei, sess. del 3 Aprile 1870.)

§ Transactions of the Royal Society for 1865.

Mr. Jones remarks that the numbers in the following Tables are liable to modification with further research.

	Species† of Foraminifera found in both the Atlantic mud and the Chalk of England and Europe.	Other, older Formations in which they are also found.				
		Upper Jurassic.	Lower Jurassic.	Rhætic and Trias.	Permian.	Carbonife-rous.
Subgenera of the genus *Nodosarina.*	Glandulina lævigata, *D'Orbigny*	*	......	*	......	......
	Nodosaria radicula, *Linn.*	*	*	*	......	......
	—— raphanus, *Linn.*	......	*	*	......	......
	Dentalina communis, *D'Orb.*	*	*	*	*	*
	Cristellaria cultrata, *Mont.*	*	*	*	......	......
	—— rotulata, *Lam.*	*	*	*	......	......
	—— crepidula, *F. & M.*	......	*	......	......	......
	Lagena sulcata, *W. & J.*	......	......	......	......	......
	—— globosa, *Montag.*	......	......	......	......	......
	Polymorphina lactea, *W. & J.*	*	......	......	......	......
	—— communis, *D'Orb.*	......	......	......	......	......
	—— compressa, *D'Orb.*	*	*	*	......	......
	—— Orbignii, *Ehr.*	......	......	......	......	......
	Globigerina bulloïdes, *D'Orb.*	......	......	......	......	......
	Planorbulina lobatula, *W. & J.*	......	......	......	......	......
	Pulvinulina Micheliana, *D'Orb.*	......	......	......	......	......
Subgenera of *Textularia.*	Spiroplecta biformis, *P. & J.*	......	......	......	......	......
	Verneuilina triquetra, *v. M.*	......	......	......	......	......
	—— polystropha, *Rss.*	......	......	......	......	......

Besides the above, *Bulimina* (*Bolivina*) *punctata*, D'Orb., is found in the Atlantic mud and in the Upper Jurassic, and *Nodosarina* (*Dentalina*) *pauperata*, D'Orb., occurs in the Atlantic mud as well as in the Lower Jurassic and the Upper Trias.

Number of Species of Foraminifera common to the Atlantic Mud and to the several undermentioned Geological Formations in England.

Total in the deep Atlantic.	Common to the following Formations.							
	Crag.	London Clay.	Chalk.	Upper Jurassic.	Lower Jurassic.	Rhætic & Upper Trias.	Permian strata.	Carbo-niferous strata.
110	53‡	28§	19	7‖	7‖	7	1	1

† Accepted species and noticeable varieties.

‡ There are 12 other species in more recent beds.

§ The total in the Lower Tertiaries is 36.

‖ Common to both Upper and Lower Jurassic, 9.

With the Foraminifera, however, end the specific identities between the Chalk and the Atlantic mud. Beyond this group we find resemblances or affinities only. Siliceous sponges, of which no less than 20 genera have been dredged, abound, it is true, as they do in the Chalk; but they are either new forms, or are Mediterranean and Azorean species. Professor Thomson * remarks that the Ventriculites of the Chalk are represented by the group of Porifera Vitrea, that the species of *Sympagella*, *Holtenia* (*Sphæroma*), and *Farrea* approach the Siphonias and Ventriculites very nearly, but that they form a distinct subsection of the order. Echinoderms abound, as in the Chalk; and species of the genus *Cidaris* are numerous, while some forms of *Diademidæ* approach the curious *Echinothuria* of the Chalk. The "Saleniæ, Cassidulidæ, and Dysasters approach their Cretaceous antetypes more closely than any known forms; but they are generally dwarfed, and otherwise diverge so far as to require in most cases the establishment of new genera for their accommodation." The *Bourgueticrinus* of the Chalk is represented by the beautiful *Rhizocrinus*, first found by Sars off the coast of Norway, and afterwards by the 'Porcupine' expedition in the North Atlantic; and the Brachiopoda are represented by the smooth forms of *Terebratula* so common in the Chalk; while the *T.* (*Waldheimia*) *cranium* may be considered a Chalk type.

Dr. Carpenter further remarks upon the occurrence of numerous arenaceous forms of Foraminifera analogous to the gigantic forms discovered in the Upper Greensand by Prof. Morris; and there is one that can certainly be identified with a form lately discovered by Mr. Brady in a clay-bed of the Carboniferous Limestone †. The presence of the *Xanthidia*, so frequently preserved in chalk flints, is also observed in the Atlantic mud. Some southern forms of starfishes are found dwarfed from a diameter of 6 inches to one of 2 inches, together with a number of Echinoderms previously known only as Norwegian or Arctic. On the other hand the Foraminifera are large, as in warm climates or in Tertiary beds, or as with the Cristellarian and Milioline groups. Amongst fishes a *Beryx* was found, a genus of which there are 4 species in the English Chalk.

It is also to be noticed that we have in the Chalk the first representatives of the cycloid fishes, which have their maximum development in existing seas, and that, of the 103 genera of testaceous

* 'Nature' for July 1870.

† It was in beds of this age that Prof. Phillips, some time since, indicated the presence of *Globigerina*.

Mollusca found in the Chalk, 80 (of which 19 make their first appearance at that period) are living at the present day. At the same time it is not in the deep Atlantic, but rather on its warmer coasts, that we now find the widest dispersion of this group of cretaceous genera.

These constitute the main points of resemblance. Striking as they are, their limits are confined; and, on the other hand, the divergences are great. The great feature of the Chalk-fauna is the abundance of Cephalopods and its large reptiles, so very few genera of which have descended to present times. The relative distribution of genera of the principal Invertebrata was, according to D'Orbigny*, before the late discoveries, approximately as under:—

	Number of genera.		
	In the White Chalk.	Extinct with the Chalk.	Living.
Cephalopods	13	12	1
Gasteropods	41	9	32
Lamellibranchs	52	11	41
Brachiopods	10	3	7
Echinoderms	34	27	7
	150	62	88

With the Cretaceous series disappear the many genera of Cephalopods allied to *Ammonites* which range through the Triassic and Jurassic formations, together with the Rudistes, so peculiar to the Chalk period.

The MOLLUSCA of the deep Atlantic are still undergoing investigation at the hands of Mr. Gwyn Jeffreys. Enough, however, is already known of the remarkable results to form some opinion of its great value in a geological point of view. The total number now dredged may probably exceed 300 species. Of these, 86 species have been recognized and are noticed in the Reports now published. A very large number are altogether new. With the aid of Mr. Jeffreys, I have drawn up the following lists, which will serve to show the light which may be thrown on the palæontology of our more recent Tertiary strata by these inquiries. Of the 86 determined species, 67 were known before as living, though chiefly as high Northern and Arctic species (while the wider range of some few of the species is very remarkable), and 19 are fossil species

* Paléontologie et Géologie stratigraphiques, vol. iii. § Terrain Sénonien.

previously supposed to be extinct. Of the 67 known living species, there are :—

Species living in the North Atlantic and Arctic seas	51
Species living in the Mediterranean	11
Species living in the Gulf of Mexico	2
Species living in the Japanese seas	3
	67

Among these 67 species, 45 were known as fossil also in the Pliocene beds of Italy and Sicily or in our Crag.

Fossil in Italy and Sicily	25
Fossil in the Crag	20
	45

Of the 19 species which had hitherto been known only in a fossil state, I give, with Mr. Jeffreys's assistance, the list in full, for the purpose of showing their geological range and position.

List of Mollusca known hitherto as Fossil only, and now discovered to be living in the depths of the Atlantic.

Depths dredged *.	Species.	Locality where found fossil.
feet.		
1932 to 2184.	Cancellaria mitræformis.	Italy and Coralline Crag.
1932 to 2184.	—— subangulosa.	Coralline Crag.
5694.	Cylichna ovata.	Sicily and Coralline Crag.
1542 to 4140.	Leda obtusa.	Sicily and Calabria.
4308.	—— pusio.	Calabria.
1752 to 2244.	Limopsis minuta.	Sicily.
4308.	—— pygmæa.	Sicily.
1680 to 1824.	Odostomia plicatula.	Italy.
3600 to 6570.	Omphalius monocingulatus.	Sicily.
1542 to 4140.	Pleurotoma decussata.	Calabria, Sicily, and Coralline Crag.
4140.	Rhynchonella sicula.	Sicily.
1542 to 4140.	Rissoa subsoluta.	Sicily and Calabria.
3600 to 6570.	Scalaria frondosa.	Italy and Coralline Crag.
3600 to 6570.	Siphonodentalium coarctatum.	Italy.
3600 to 6570.	Trachysma delicatum.	Sicily.
1680 to 1824.	Trochus crispulus.	Sicily.
1542 to 4140.	—— reticulatus.	Sicily and Calabria.
2148 to 4302.	—— suturalis.	Sicily and Calabria.
3402.	Turbo filosus.	Calabria.

* Other species of mollusca continued to be dredged down to depths of 14610 feet.

Mr. Jeffreys informs me that, in addition to the above, there are many other species in the same category, though they have not yet been specially recorded. According to him, the total number of species which were, until lately, considered extinct, but which he has now ascertained to be living, is at least thirty.

In the Mediterranean, there is at present little to record. 15 species were dredged from a depth of 8490 feet. They consisted of:—

Northern species	5	Fossil in Italy	9
Lusitanian	9	Fossil in the Crag	4
Oceanic	1	New species	2

Some new species of much interest were discovered in less depths (of from 100 to 1000 feet) in and at the entrance of the Mediterranean. Amongst these there were 31 northern species, also 12 species before known only as fossil in Italy, and 3 species common to our Crag.

Thus, so far from showing any relationship to the Cretaceous fauna, the deep Atlantic mollusca have their nearest allies in Pliocene (and possibly Upper Miocene) forms of Italy and in those of the Crag-beds of this country. Mr. Jeffreys's anticipations, made in 1862 *, that "it is highly probable that all the mollusca which lived during the periods represented by the newer strata still survive in some part or other of those vast tracts of sea-bed which lie between the North Pole and the Pillars of Hercules," and that the deeper recesses of the ocean would be found inhabited, receive therefore great confirmation, though it yet remains to be seen to what extent they may be fully realized. Almost all the species yet found at these great depths are, like so many of our Coralline-crag species, very small.

Prof. Duncan has described † 12 species of corals dredged from depths of from 2000 to 4200 feet; and he informs me that he has under description many others, some of which were obtained from a depth of 6570 feet. Owing to the great range in depth and temperature of the Atlantic sea-bed, the variation in form of some of the corals has been so excessive that Prof. Duncan has absorbed 9 old species in the 12 now established. The range and distribution of these species thus obtained in the first and second expeditions is very remarkable.

* 'British Conchology,' Jeffreys, vol. i. p. xci.

† Proc. Roy. Soc. vol. xviii. p. 289.

Allopora oculina, *Ehren.*—Original locality unknown.	
Caryophyllia cyathus, *Ellis & Sol.* sp.—British Seas, Mediterranean.	Sicilian, Older Pliocene.
Lophohelia prolifera, *Pallas.*—British Seas, Mediterranean, Florida Seas.	
Flabellum laciniatum, *Ed. & H.*—British Seas.	
Ceratocyathus ornatus, *Seg.*—Fossil.	
Amphihelia miocenica, *Seg.*—Fossil.	
—— atlantica, *Dunc.* New.	
—— oculata, *Linn.* sp.—Mediterranean.	
—— ornata, *Dunc.* New.	
—— profunda, *Pourt.* New.—West-Indian Seas, Mediterranean and Norwegian Seas.	
Balanophyllia socialis, *Pourt.* New.	Florida Seas.
Pliobothrus symmetricus, *Pourt.* New.	

Thus out of 12 species there are as many as 5 which were before known as fossil only; or if we take the annulled species, there were 8, all of which had hitherto been confined to the newer Tertiary beds of Sicily or southern Italy. Unlike the Testacea, which show a relationship to northern forms and to those of our Crag, there is not a single species that Prof. Duncan has been able to refer to the Crag, whilst the connexion with the Mediterranean area and with the seas of Florida and the West Indies is most noticeable. Prof. Duncan regards one or two of the new species as allied to Miocene forms; but he does not instance a single case of an approach to Cretaceous forms, except possibly in the case of *Lophohelia* (to the *Synhelia* of the Chalk) and *Diplohelia*, which is really an *Amphihelia*.

Among the Corals, however, now under examination from the second expedition of the 'Porcupine' the *Sphenotrochus* of the Crag is found (locality Tangier Bay), and some *Caryophylliæ* and *Bathycyathi* of Cretaceous types are to be noticed.

Thus while the Foraminifera obtained in these deep-sea explorations show a strong community of genera and a partial identity of species with chalk Foraminifera, the Sponges markedly representative forms, the Echinoderms allied genera, and the Brachiopoda a similarity of groups, on the other hand, as we ascend in the scale, so far from any resemblance being maintained, we find actual identities with the Upper Miocene*, Pliocene, and Quaternary fauna of western Europe. This seems to point to a possible direct descent in the one case of all those lower forms of life, less influenced by temperature and depth, from the epoch of our chalk, and in the other case to a change of physical conditions, resulting from the

* There is nothing which has the facies of the Eocene Molluscan fauna.

different arrangement of our seas and continents, destructive of the higher forms of life, and accompanied by the introduction of northern forms of partly corresponding classes.

Edward Forbes concluded from his researches in the Ægean *that parallels in latitude are equivalent to regions in depth*; and he subsequently showed this hypothesis to hold good by the occurrence at various depths in southern seas of northern species of mollusca. Hence cold-water species of Testacea can have a much wider range in latitude than warm-water species. MM. D'Archiac and De Verneuil had already, on purely palæontological grounds, concluded *that those species which were found at many places, and in districts distant one from the other, are almost always those which have lived through many successive formations* (*systèmes*)*; or, as it was better expressed by Mr. Rogers, "*the species of which the geographical distribution is the widest have also the greatest vertical range.*" Reasoning from these data, M. D'Archiac observed that those geologists who saw "beds of different age everywhere where they found different fossils, were liable to make serious mistakes; for the same bed taken at two distant points and having a natural difference of level, say of 300 feet, might present very distinct groups of species, and might lead to the erroneous conclusion that these two parts of the same bed were not contemporaneous"†. Edward Forbes also observed

* Bull. Soc. Géol. de France, vol. xiii. p. 260, 1842.

† Bull. Soc. Géol. de France, 2nd ser. vol. ii. p. 484, 1845. As the discussion which ensued on this communication bears on the subject of these deep-sea investigations, I give a few extracts from it, which may be new to some present:—

"M. de Verneuil ajoute que, sur les côtes de Suède et de Norvége, là où la mer est assez profonde, M. le Professeur Lovén, de Stockholm, a observé parmi les mollusques une distribution verticale correspondant à leur distribution horizontale, suivant les latitudes. Ainsi, entre Gothenbourg et la Norvége, M. Lovén a trouvé à 80 toises de profondeur, des espèces qui, sur la côte du Finmark, habitent à 20 toises; plusieurs espèces s'élèvent même sur cette dernière côte jusqu'à la région littorale, tandis que dans le sud, elles se tiennent toujours à 12 ou 15 toises au-dessous du niveau de la mer."

"M. Élie de Beaumont fait remarquer . . . . Aujourd'hui la température à la surface de la mer à l'équateur est de 27½° [C.], tandis qu'au fond elle est de 2°. Il n'y a aucune raison de croire à ces différences autrefois." . . . . "La très-grande masse de la mer équatoriale est à une température très-basse et seulement d'un petit nombre de degrés au-dessus de zéro."

M. Pouillet also, in his 'Éléments de Physique,' vol. i. p. 166, 1847, speaking of deep-sea fishes, observes: "On peut juger par là que les régions de la mer ont leurs peuples différents, non seulement suivant les climats, mais encore suivant les profondeurs."

"that all climatal inferences drawn from the number of northern forms in strata containing assemblages of organic remains are fallacious, unless the element of depth be taken into consideration" *.

I mention these observations (made many years since, and which of late have generally been taken into account in all geological inquiries) to show that geologists have still to be guided by the same primary natural-history rules, which have lately received so wide an extension and application in these recent deep-sea dredgings.

The mistake made by Edward Forbes was his assigning the too narrow limit of 1800 feet in vertical depth as the probable zero of animal life in the ocean. Dr. Wallich afterwards extended the probable limits of life to 15000 feet; and now the important researches of Carpenter, Jeffreys, and Thomson show that it must in all probability be carried very much lower, as they have found a highly organized fauna living in abundance at the vast depth of 14,610 feet, and no indication of an approach to the zero of life. It had, in fact, been long felt that the proposition involved in these bathymetrical limits was open to question.

The many interesting problems connected with the temperature and currents of the ocean have often engaged attention since the early part of this century. It was one of the subjects respecting which a large amount of data was collected on the several scientific naval expeditions sent out by the French Government between 1820 and 1840. Humboldt states † that he showed in 1812 that the low temperature of the tropical seas at great depths could only be owing to currents from the poles to the equator.

D'Aubuisson, in 1819, also attributed the low temperature of the sea at great depths at or near the equator to the flow of currents from the poles ‡.

Lenz §, in 1831, gave the results of some experiments he had made at great depths in the ocean, and concluded that between the equator and 45° of lat. the temperature decreases regularly to the depth of 6000 feet, when the decrease becomes insensible. The lowest temperature he recorded was 36° Fahr.

* Edinb. New Phil. Journ., April 1844.

† Fragmens de Géol. et de Climatol. Asiat. 1831.

‡ Traité de Géognosie, p. 450.

§ Edinb. Journ. of Science, vol. vi. p. 341.

Pouillet * briefly discusses ocean temperatures, and concludes that, although all the difficulties of the case are not solved, it seems certain that there is generally an upper current carrying the warm tropical waters towards the polar seas, and an undercurrent carrying the cold waters of the arctic regions from the poles to the equator.

The early evidence on the subject was necessarily contradictory, as the instruments were often imperfect, and the temperature in the early experiments was often taken by means of water or mud brought to the surface. Off the coast of Greenland, Scoresby always found the temperature in descending to increase, in some cases, to 36° or 38° F., while the surface-temperature was only from 28° to 30°. He mentions, however, that in lat. 72° 7′ N., long. 19° 11′ W., where the temperature was 34° F. at the surface, it was 29° at a depth of 700 feet. Sir Edward Parry found the surface-temperature off Spitzbergen to vary from 28° to 31°, and at depths of from 400 to 600 feet to be from 30° to 28°. Sir John Ross found the temperature at a depth of 2520 feet in Melville Bay to be 29½°; in Lancaster Sound, depth 7900 feet, 29°; and in lat. 72° 33′ N. and long. 73° 7′ W. the surface-temperature was found to be 35°, decreasing gradually to 28¾° at a depth of 6000 feet. More lately the carefully made observations of M. Chas. Martins in the Spitzbergen seas led him to the following conclusions:—

1st. In the months of July and August the temperature of the surface, although near freezing-point, is always somewhat above it.

2nd. From the surface to a depth of 240 feet, the temperature here increases, there decreases.

3rd. From 240 feet to the bottom the temperature always decreases.

4th. The mean temperature of the water at the bottom of the sea is 28·84° F. (− 1·75° C.).

The greatest depths of the soundings seem to have been from 2000 to 2800 feet.

These low deep-sea temperatures have not only been found to prevail in high northern latitudes, but to extend, though in somewhat diminished force, to the equator, and thence to the Antarctic regions.

* Élém. de Phys. vol. ii. p. 667, 1847.

The following instances, taken from the many made on different voyages of discovery, will suffice to illustrate this fact:—

Temperatures of the Atlantic.

Latitude.	Longitude (corrected to Greenwich).	Depth.	Temperature. Surface.	Temperature. Bottom.	Observer & Date.	
° ′	° ′	ft.	°	°		
42 0 N.	34 40 W.	4688	62·0	44·0 F.	Chevalier	1837.
29 0 N.	34 50 W.	8399	76·0	43·0	”	”
7 21 N.	20 40 W.	3030	80·0	36·0	Lenz	1832.
4 25 N.	26 6	6037	80·8	37·9	Tessan	1841.
15 3 S.	23 14 W.	7200	77·0	39·5	”	”
25 10 S.	7 59 E.	5315	67·4	37·6	”	”
29 33 S.	10 57 E.	6310	66·4	35·8	”	”
32 20 S.	43 50 E.	6444	71·0	36·5	Lenz	1832.
38 12 S.	54 80 W.	2000?	62·4	37·6	Tessan	1841.

In the Antarctic regions Sir James Ross made a considerable number of observations in 1839–43. Whatever the temperature of the surface, he found the temperature from 2800 to 3600 feet to be from 38° to 39·8°, the higher temperature being at the lower depth. He concluded that below 1800 feet there was very little variation in temperature, and inferred that in lat. 56° 14′ S. there is an ocean belt, the temperature of which from top to bottom is of 39·5°. This conclusion seems to have been based on an erroneous idea of the specific gravity of sea-water, and is possibly in some degree attributable to errors of the instruments used. Captain Willis, however, came to the same conclusion with respect to a belt of uniform temperature. I cannot find that there is any sufficient foundation for this hypothesis, which is in no way confirmed by the observations of others. As the other observations were not generally known, this hypothesis has unfortunately been too often accepted. Later experience has shown that in many instances there is an error in the earlier observations, in consequence (where proper precautions were not used) of the pressure on the thermometer at great depths. Dr. Carpenter has determined this to amount to as much as 2° or 3°, or even more. Consequently a deduction to this extent has often to be made in order to get a true reading of some of the older observations. In many of the French expeditions, however, great care was taken to guard against the influence of pressure.

If we turn to the Pacific, we shall find similar low temperatures prevailing at great depths both in the temperate and torrid zone. I again take merely a few cases in illustration.

Temperatures of the Pacific.

Latitude.	Longitude (corrected to Greenwich).	Depth.	Temperature. Surface.	Temperature. Bottom.	Observer & Date.	
° ′	° ′	ft.	°	°		
51 34 N.	161 41 E.	5741	53·2	36·6	Tessan	1832
28 52 N.	173 9 E.	3600	78·0	41·0	Beechy	1828
18 5 N.	174 10 E.	4261	76·6	40·8		1836
4 32 N.	134 24 W.	12271	81·0	35·2	The 'Bonite'	1837
Equator (near)	179 34 W.	6000	86·0	36·6	Kotzebue	1824
21 14 S.	196 1 W.	5500	81·0	36·0	Lenz	1834
32 57 S.	176 42 E.	4692	61·4	41·8		
43 47 S.	80 6 W.	6400	55·6	36·2	Tessan	1841

These observations tend to show that in the greatest depths, both of the Atlantic and Pacific Oceans, the temperature is not higher than from about 36° to 40°; and allowing for correction of the instruments, the actual temperature will probably be found to be in many cases 2° or 3° or more below this. A more systematic mode of proceeding, however, is needed; for though the general rule may be considered to be established, local variations and exact measurements have to be ascertained. Notwithstanding, less attention has been paid to the subject of late years than formerly. Dr. Carpenter has now taken up the investigation, and has during the last three years carried out a series of observations in the North Atlantic which must prove of high value. Every care has been taken to guard against error; and we shall soon no doubt have tables of temperature at all depths in this part of the ocean, which it is to be hoped will, concomitantly with the dredging-operations, be extended over the whole of the oceanic area.

Time will not allow me to enter upon the question of the course and cause of the cold under-stratum of the great oceans. As before observed it has been generally referred to undercurrents from the poles; and later observations tend to confirm this; but whether in the mid-Atlantic the flow is from the north or the south pole remains to be decided by more accurate inquiries. My own opinion inclines to an undercurrent from the North Pole. The occurrence of boreal and Scandinavian forms of life far south in the Atlantic favours this view. Whatever the cause, the fact of cold undercurrents, which must have a powerful effect in bringing northern and southern forms into close vertical juxtaposition, is indisputable. All seas open to the Arctic and Antarctic oceans are doubtless subject to these conditions of warm surface-currents from the equator and cold undercurrents from the poles. In seas where there is no direct communication with the Polar seas, the case must assume a very different aspect.

Dr. Carpenter in his last cruise made also a number of observations in the Mediterranean, showing that while the surface-temperature in August and September varied from 69·5° to 77°, it fell in all cases to about 56° at a depth of 600 feet, and maintained that temperature through all the depths below that line. This confirms the experiments made in 1840–1845* by M. Aimé, who found that the average temperature of the sea at a distance from land, for the twelve months of the year, was 64·4° Fahr., that of the air being 64·8°; and that the former decreased gradually to 54·6° at a depth of 1148 feet, below which to a depth of 4050 feet it was not found to vary 1° †. He considered that the diurnal variation of temperature ceased at 59 feet, and the annual variation at from 1148 to 1640 feet, although, in fact, his tables show little variation after 656 feet. The mean shore-temperature of January, February, and March, taking together the two stations of Toulon and Algiers, was ascertained to be 54·8°, with which the temperature of this part of the depths of the Mediterranean corresponds almost exactly.

The subject of the currents and temperatures of the Mediterranean engaged also the attention of Captain Spratt for a series of years, and a number of carefully made experiments are recorded by him. He also determined that while the temperature from the surface to a depth of 12 feet ranges generally from 76° to 84° Fahr., gradually decreasing to a depth of 600 feet, there was little variation below that line, and that the temperature of the depths of the eastern basin of that sea is about 59°, and of deep seas off Greece 55½°—that while on the Mediterranean side of the Straits of Gibraltar there is a deep-sea temperature of 59°, there is one of 39½° on the Atlantic side ‡.

* Ann. de Chimie et de Physique, 3rd ser. vol. xv. 1845.

† The following is M. Aimé's summary:—

"Températures moyennes annuelles de la mer à diverses profondeurs.

	Températures.	Maxima des variations entre les moyennes mensuelles.
à la surface	18·2° C.	10·2° C.
à 25 mètres	16·3	6·3
à 50 „	14·4	2·8
à 100 „	13·7	2·0
à 200 „	13·0	1·0
à 350 „	12·6	0·0"

‡ British Assoc. Report (Sections), 1848; and 'Travels in Crete,' vol. ii. p. 345.

The fauna of the Mediterranean naturally presents a considerable difference from that of the Atlantic, especially from that portion which inhabits the greater depths of the latter. There is an absence of the numerous recent arctic forms which follow the cold currents of the Atlantic, although there are many northern forms of Quaternary and Pliocene age, which seem to have been introduced into the Mediterranean area at a period when the communication between the two seas may have been more open—an inference made by several observers both on natural-history and on geological grounds. Newer Tertiary strata extend, in fact, a great part of the way across from the Bay of Biscay to the Mediterranean, and the watershed between the two seas is not higher than about 600 feet above their levels. At one point on this line, and at an elevation of 560 feet above the Mediterranean, M. Virlet d'Aoust many years since discovered, in a fossil state, the *Ostrea hippopus* and *Murex trunculus*, species still living in that sea.

From these considerations the question arises whether the deep sea in which the Chalk, with its more tropical genera, was deposited, may not also have been a sea shut out from direct communication with Arctic seas. The Old and New continents have a north and south extension, with intervening oceans in the same direction; but the distribution of land and water must have been very different during the Cretaceous period. Beds of this age stretch from England through France, Germany, Poland and Southern Russia to Persia and India, and they also traverse the southern portions of the North-American continent. Throughout much of Europe and parts of Asia the Chalk has the common character that it possesses in England, and which has led it to be likened to the Atlantic deep-sea mud. On the other hand, there is no Chalk north of Denmark, in North Russia or Siberia, or in Arctic America. If the direction of the deep Chalk-ocean followed this east and west belt across the present continents, then we must look for dry land on the confines of that ocean; and it is probable that the latter may have been, to the north, in the direction between Greenland and Scotland and Scandinavia, where the present ocean is some hundreds of fathoms shallower than further south. We know that towards the end of the Cretaceous period, a change took place in the fauna, arising apparently from the shallowing of the sea that preceded the deposition of the Maestricht beds, as well as of the *Calcaire pisolitique* of Laversine and Mont Aimé. Many of the great Cephalopods disappeared, and reptiles increased in numbers; at the same time the Lamellibranchiate Mollusca became more predominant. Dry land appeared further south, as evinced by the lignite and freshwater beds intercalated in the Cretaceous series of Southern France. At the close of this period the continent of Europe may have acquired larger dimensions, although it was not until after the great Nummulitic sea of Lower Eocene age (which also stretches through southern Europe to India) had become in part dry land that the "relief" of the continent approximated to that of the present day. On the western edge of the new land formed by the elevation of a portion of the old Chalk ocean more littoral deposits then began to form; and the same thing took place on the sea-belt of the American continent.

The Cretaceous formation of the south-west of England and west of France and north of Ireland passes out under the Atlantic, and reappears on the south-east coast of the North-American continent. As it thus trends in the same direction on both sides of the Atlantic, there would be nothing improbable in supposing that old Cretaceous ocean prolonged further in the same given direction across the present Atlantic.

It is well known that at a distance varying from 50 to 200 miles off the coasts of western Europe, the sea-bed deepens rapidly to 600, then to 1200 feet, and again almost suddenly to depths of from 6000 to 15,000 feet. Does this mark a boundary of the materials drifted out to sea during Postcretaceous times? or is it a line of still older date?

The great and distinctive feature of the Tertiary series is that, with few exceptions, the whole of them were deposited in shallow seas. The London Clay even, which is from 400 to 500 feet thick, does not represent a sea-bed deep in proportion, as there is evidence to show that it was probably deposited during a period of gradual depression of the sea-bed. The total thickness of all the English Tertiaries does not exceed 2000 feet, or that of the Paris-basin Tertiaries 1500 feet*. Therefore, while the deep Atlantic area continued submerged, movements of elevation and depression affecting the continental European area (leaving out the changes during the Glacial period) may have gone on during the Tertiary period to the extent of from 2000 to 5000 feet, leaving abyssal depths of from 10,000 to 12,000 feet unaffected by these movements, even supposing they extended over the oceanic as well as the continental area. It is the same on the American coast of

* Though further south the Tertiary beds attain possibly a thickness of from 3000 to 4000 feet.

the States, which is bordered by Tertiary strata of a like character with their European equivalents.

It is true there have been elevations of the Cretaceous and Tertiary strata during the Tertiary period far greater than the depths first mentioned; but it has been in mountain-chains which have little affected the great plains of continental land. In the same way there may have been partial elevations in the bed of the Postcretaceous Atlantic; but there is nothing to indicate that it has ever been entirely raised. I think, therefore, that the hypothesis with regard to the continuity of that sea-bed from the period of the Chalk to the present period is one of high probability.

If such a northern land barrier as that which I have alluded to existed at the period of the Chalk, and that barrier was submerged during the early part of the Tertiary period, it would (taken in conjunction with the very different conditions of depth under which the Chalk and Lower Tertiaries were formed) go far to account for the great break in the fauna of the two periods. Some years since I had occasion to show on other grounds that the Thanet Sands, which repose on the Chalk in the south-east of England, exhibited a fauna essentially of temperate or cold latitudes, and I inferred the inset of currents from the north. As those remarks bear upon the present question, I will quote some of the passages in the paper to which I refer *.

"In viewing the London Tertiaries as a group, and comparing them directly with the underlying Chalk, it is to be observed that we are not comparing like terms of the two periods. That a great and essential difference existed between these periods must be admitted; but it is a question how far that difference is widened by the comparison being instituted between the deep and shallow sea deposits, instead of between strata deposited under like conditions during those two periods. . . . . The adaptation of this area at the Thanet-Sands period to the existence of the numerous shallow-water burrowing Lamellibranchiates, whatever the duration of the intervening time, would necessarily unfit it for the deeper-sea Cephalopoda, Brachiopoda, and other families which prevail in our Cretaceous series.

"We have therefore, in viewing the Tertiary strata in relation to the underlying Chalk, to take into consideration that the existence of certain classes of fossils in the former of necessity implies the non-existence of other classes found in the latter deposit—and

* Quart. Journ. Geol. Soc. vol. x. p. 443, Nov. 1854.

this, even should the two have been in consecutive and uninterrupted sequence in time.

"The somewhat Cretaceous *facies* which exists, however, in the Lower Landenian [of Belgium] and the Thanet-Sands fossils, is to be recognized in some portion of the fauna of the London Clay itself. Thus among the Echinodermata the *Hemiaster*, a common Cretaceous genus, has three species in the London Clay, and but one in the Barton Clay; whilst the prevalence of Crinoids, amongst which is a species of *Bourgueticrinus*, hitherto considered a Chalk-genus, and three species of *Pentacrinus*, and the new *Cainocrinus* of Forbes, are features more resembling those prevailing in Mesozoic than those usual in Tertiary strata. The two genera of *Asteridæ* (*Astropecten* and *Goniaster*) which occur in the London Clay are common in the Cretaceous strata, the Oolites, and Lias."

"The London Tertiary group seems to have resulted in that order of changes which, commencing with the elevation of a portion of the Chalk area at the end of the Maestricht period, was followed by subsequent depressions which led to the transgressive accumulation of the Lower Tertiaries from north to south. . . . . . I have before shown the probability of the existence of dry land to the south and an open sea to the north during the Thanet-Sands period, and of more insular conditions during the Woolwich and Reading series period; and now with respect to the London Clay the evidence tends in the same direction."

"To have just terms of comparison, we need a Cretaceous series with a similar varied marine, æstuarine, and fluviatile fauna, such as flourished during the successive Tertiary periods. We have already in the Maestricht beds a change in the fauna—a dying-out of many old forms, and the appearance of many genera common in the Tertiary series."

"In considering all these singular vicissitudes, and in contemplating the extent to which certain more northern influences operated in giving to a large portion of the fauna of the London Tertiaries an aspect much more closely resembling that of the present day than is found to exist in many more recent deposits, the question suggests itself of how far that law, enunciated by Prof. E. Forbes, and according to which the distribution of Molluscs in depths of southern seas is equivalent to their appearance at lesser depths or at the surface in parallels of latitude of more northern seas, may by analogy be applied geologically in accounting for any abnormal condition in the vertical succession of organic remains such as here occurs? Can it be that such a group of generic forms, allied to and closely resembling those found in the same zoological province at the present day, had a yet older existence in more northern provinces—that generic forms of temperate regions have travelled from the north, and have been gradually spread further south, giving, when they encroached upon the more southern forms, a more recent aspect to the faunas of such various geological periods than prevailed in those of the same localities when changes in the distribution of land and water brought back for a time the southern forms which had been temporarily displaced?"

That much of the difference between the fauna of the Chalk and the Lower Tertiaries must be due to the elevation of the old Chalk ocean-bed (by which the deep-sea life was exterminated and a shallower-water fauna introduced) is now evident from the recent deep-sea dredgings. Suppose, for instance, a portion of the present bed of the Atlantic were raised to the level of the sea-bed of the present English channel, whereby the depth of water would be reduced from 12,000 or 15,000 to 100 or 600 feet. The deep-sea fauna would be destroyed, and the fauna and sandy beds of the English coast would succeed it; and when these were raised, we should have sand and gravelly beds containing a shallow-water fauna overlying calcareous beds with a deep-sea fauna, and there would be but very few, if any, species common to the two deposits.

As old coast-lines and the oceanic currents changed during the Tertiary periods, we may suppose corresponding changes in the fauna of the littoral and laminarian zones, while the deeper-sea fauna (which was not subject to these changes of conditions) may have had a much longer and more permanent existence. Together with the recurring bathymetrical conditions, the lithological character of the sea-bed further influenced the vitality and persistence of species. The Mollusca of the *Calcaire grossier* of the Paris basin are, according to M. Deshayes, essentially southern in their character and relations. This formation is separated from the Chalk by the London Clay or its equivalents, and the Woolwich series and Thanet Sands, with the fauna of which it has few species in common, whilst, as I have before mentioned, the species of the Lower Eocene beds have a more northern facies. It is not, however, long since MM. Cornet and Briart found under the equivalents of all these English series in Belgium a friable calcareous bed full of fossils, not like those of the overlying Lower Eocene, but resembling, and in many cases identical with, those of the more recent *Calcaire grossier*. Again, in the Barton Clay, many species of the London Clay, which had disappeared during the period of the intervening Bracklesham Sands, reappeared with the reoccurrence of argillaceous strata. One of the most remarkable cases, however, is that of the *Argile de Boom*, which forms the very top of the Eocene series of Belgium,—the Oligocene of German geologists. This deposit is so like the London Clay in lithological character that it would be almost impossible to distinguish them, while the shells (especially the several species of *Fusus*, *Pleurotoma*, and *Natica*) so closely resemble those of the London Clay, from which it is separated by the four or five divisions of the Upper Eocene, that they might easily be mistaken for London-Clay fossils. The exceptional appearances of *Colonies*, whether in the older or newer rocks, are, no doubt, mainly due to the recurrence at certain intervals of similar lithological, thermal, and bathymetrical conditions.

During the Middle Tertiary or Miocene period, it would seem that a different distribution of land and water prevailed. The Miocene beds of Skye and of Greenland, with their remarkable floras, indicate land and fresh-water conditions, while at the same time the Miocene marine beds of France and Germany are rich in subtropical forms of Mollusca. Assuming part of the area which now constitutes the Northern Atlantic area to have been then dry land, the migration southwards of arctic species of Mollusca would have been for a time interrupted.

Approaching nearer to our own times, we have Pliocene beds in Iceland, Quaternary deposits in Spitzbergen and on the western flanks of the Scandinavian peninsula, while in this country Glacial or Preglacial beds range to the height of from 1000 to 1400 feet above the sea-level. There is reason, therefore, to believe that the bed of the North Atlantic may have been from 1500 to 1600 feet or more deeper during the Pliocene and Glacial period than it now is. If northern submarine currents are now checked, as Prof. Wyville Thomson supposes, by the shallower seas between Scotland and Greenland, such an addition to its depth as these emerged portions indicate would materially have affected those conditions, and have allowed of a freer passage of the north-polar waters, and consequently of a freer dispersion of its fauna to the abysses of the mid-Atlantic, where, in fact, so large a number of them are now found to exist. This more open communication gave rise, I conceive, to that great migration of northern Mollusca which are now found fossil in Italy and Sicily, and some of which still survive in the Mediterranean and mid-Atlantic.

It is more difficult to understand the absence of later Quaternary shells, such as those of the Clyde beds, only three of which have been recognized among the late dredgings. Does it arise from the more littoral and shallow forms of that class being stayed by climatal conditions near our shores, while the deeper-sea forms passed on southward free from the influences which affected the others? That a great proportion of the deep-sea forms had migrated during and since that period is probable from their wide diffusion and large numbers. Mr. Jeffreys has enumerated fifty of these more recent northern Mollusca which are not known in a fossil state; and of the Echinoderms and Crustacea mentioned by Dr. Carpenter and Prof. Wyville Thomson a large proportion are Norwegian, Spitzbergen, and other high-northern forms.

From what I have previously said, you will have understood that, lithologically, there is but little resemblance between the Atlantic mud and our typical white chalk, none that could have ever led a geologist into any error of determination. In fact, in no part of the area yet explored is there any thing at all to be identified lithologically with the true white chalk. Even if it were found that the superposition were conformable, the difference of mineral character is too marked. At the same time it is to be observed that the area of the Atlantic is so vast that, variable as the deposit now going on seems to be, it is probably little, if any, more so than that which went on in some parts of the Chalk series in the bed of the Chalk-ocean over the old European area. Of the rate of the present deposit we know nothing. Is it even going on everywhere over the deep Atlantic?

Therefore, although I think it highly probable that some considerable portion of the deep sea-bed of the mid-Atlantic has continued submerged since the period of our Chalk, and although the more adaptable forms of life may have been transmitted in unbroken succession through this channel, the immigrations of other and more recent faunas may have so modified the old population, that the original chalk element is of no more importance than is the original British element in our own English people. As well might it have been said in the last century, that we were living in the period of the early Britons because their descendants and language still lingered in Cornwall, as that we are living in the Cretaceous period because a few Cretaceous forms still linger in the deep Atlantic. Period in geology must not be confounded with "system" or "formation." The one is only relative, the other definite. A formation is deposited or takes place during a certain time; and that time is *the* period of *the* formation; but *a* geological period may include several formations, and is defined by the preponderance of certain orders, families, or genera, according to the extent of the period spoken of; and the passage of some of the forms into the next geological series does not carry the period with them, any more than would any particular historical epoch be delayed until the survivors of the preceding one had died out. Period is an arbitrary time-division. The Chalk or the "London Clay" formations mark definite stratigraphical divisions. We may speak of the period of the London Clay, or we may speak of the Tertiary period. It merely refers to the "time when" either were in course of construction. The occurrence of Triassic forms in the Jurassic series, of Oolitic forms in the Cretaceous series, and of Cretaceous forms in the Eocene, in no way lessens the independence of each series, although it may sometimes render it difficult to say where one series ceases and the other commences. The land and littoral faunas are necessarily more liable to change than a deep-sea fauna, because an island or part of a continent may be submerged and all on it destroyed, while the fauna of the adjacent oceans would survive; and as we cannot suppose the elevation of entire ocean-beds at the same time, the marine fauna of one period must be in part almost necessarily transmitted to the next.

Thus while continental Europe and the sea-bed, as far as from 200 to 300 miles west of the British Islands, was subject to successive changes of level, giving rise to a series of Eocene, Miocene, and Pliocene strata with their diversified and varying faunas, the adjacent depths of the Atlantic may have continued with little variation, except that produced by currents and relatively small differences of depth. Of the nature of that deep-sea fauna we were until lately entirely ignorant. At the same time it may be observed that geologists held to the opinion of deep-sea deposits; and the views of E. Forbes, with regard to the bathymetrical limits of life in the sea, were by no means generally accepted. The Chalk, attaining as it does a thickness of 1000 to 1500 feet, and having a special fauna, was always looked upon by geologists as the deposit of a very deep sea. Even supposing the conclusions of E. Forbes to have been accepted, no geologist could have safely inferred, from a rock being non-fossiliferous, that it had been deposited in a sea the depth of which exceeded the limits he assigned to marine life. In the first place, the sediment of which the rocks are formed may have been of a nature unsuited for the existence of life over the original sea-bed. It is now evident that the absence of life in the depths of the Ægean is due to the fine tenacious mud (which, by the by, E. Forbes likened to chalk), in the same way that those areas of the Mediterranean, discovered by Capt. Spratt, and of the Atlantic at the entrance of the Straits of Gibraltar, discovered in the 'Porcupine' expedition, to be covered by fine mud, apparently in a state of continual slow deposition, were found to be almost entirely barren. On the other hand, where the rocks consist of sandy strata, any fossils composed of carbonate of lime may have been dissolved out, and all traces of them lost by the percolation of rain-water, after their elevation into dry land, as happens in the Bagshot Sands, in which it is only by chance in the few instances where the sand happens to be consolidated by a ferruginous cement that the impressions and casts of shells are preserved. Another well-known cause for the absence of fossils in a sedimentary deposit is the circumstance of the strata having undergone metamorphic action. I should hardly have thought it necessary to mention these various causes to account for non-fossiliferous rocks, but for a recently expressed opinion of a presumed more general acceptance of Forbes's hypothesis amongst geologists than has been at all the case.

As bearing also upon the distribution of life in the same stratum at points in near proximity, Dr. Carpenter notices that there are areas in the North Atlantic in which the temperature varies considerably at the same relative depths; and he infers that there are permanent warm and cold areas, distinguishable not only by differences of from 10° to 15° of temperature, but also by a difference of marine life, such as might present a geological difficulty. He notes the presence of *Globigerinæ* and abundance of vitreous sponges on a fine muddy bottom in the one, and of northern forms of Echinodermata and Crustacea on a bed of sand and stones in the other. Mr. Jeffreys, however, did not find the same difference in the Mollusca. He states that the result of his examination shows that there are forty-four species in the warm area and fifty-five species in the cold area, and these latter included all the forty-four of the former; and he accounts for the absence of *Globigerina* on the ground that "the strength of the submarine current in the cold area is sufficient to sweep away and remove these slight and delicate organisms," which, from later observations by other naturalists and himself, he believes inhabit only the superficial stratum of the sea. The slight difference in temperature seems hardly sufficient to account for the absence of

Globigerina in the cold area, while the extent of the other differences loses much force by the identity of the Mollusca. We know not also whether there is not a passage from one area to the other. We require therefore more evidence before the geological value of the distinction of the two areas can be fully accepted; at the same time the importance and interest of such an influencing cause must be kept in view.

I will now say a few words on one of the most important bearings that these deep-sea researches have on chronological geology. Objections have been taken on various grounds to the percentage test of Sir Charles Lyell, as evidence of relative age. The data of the deep-sea dredgings furnish us with curious and apparently paradoxical results and such as might seem fatal to this test. Suppose an isolated portion of the deep-sea Atlantic bed had been elevated at some late period, and that we were yet ignorant, as we were only twelve years since, of what was to be found in the unexplored depths of the ocean. Suppose further that the Atlantic deposit had taken place on such rocks as the Palæozoic strata of Cornwall or South Ireland. A chalky-looking deposit would then have been found overlying old rocks, with nothing to indicate stratigraphically its geological position, and with fossils to a great extent new. In the absence of a complete knowledge of the deep Atlantic fauna, I will take, as a specimen of what they might have been, the result of one deep dredging in 5964 feet. Mr. Jeffreys obtained in this single dredging 186 species of Mollusca. Of these he found:—

91	species	recent or living.
24	„	formerly known as fossil only, and belonging to the Pliocene strata of Sicily; some of these are undescribed.
71	„	new or undescribed.
186		

The conclusion would have been that 95 out of the 186, or 51 per cent., were of extinct species; and of these, 24 would be referred to Pliocene age. What would have been the inference as to the age of the beds? Certainly, on palæontological evidence alone, there could have been but one conclusion. They must have been classed as Pliocene or older, although these researches have now shown all the species to be recent.

The case, however, is an extreme and exceptional one. It is true that, in future speculations, the possibility of such a case happening must be taken into consideration; but the depths of the Atlantic are so great that, unless in case of a disturbance such as that of the elevation of the Alps or the Andes, we are not likely to find it brought before us in recent geological times *. Apart from such an exceptional case, I consider that, if all disturbing causes be properly taken into account, the percentage test is a good and useful guide for the chronological arrangement of the newer strata; nor, notwithstanding its exceptional character, do I consider that a case like the one just referred to need perplex the geologist, who would seek elsewhere, in superposition or in some points of physical structure, for evidence as to place. Palæontology is an excellent counsellor, but it should always be kept subordinate to stratigraphical geology. It indicates what *may* be the case, but it does not tell us what *must* be the case. The one has rigid, the other flexible lines; and these lines are rarely parallel. The geologist should first determine rigorously the order of superposition, before he speculates on the distribution of the fauna. Stedfast in that mode, there need be no cause for error, however exceptional and varying the fauna may be. It is his business to determine the fact, and then, with the aid of the palæontologist, to discover the cause and amount of variation, and to detect the principle on which the distribution of life in the period under investigation has been regulated. Palæontology must be our guide, but not our master. It is this which gives life and interest to so many of the higher problems of palæontological geology.

In one point of view, the geologist has the advantage over the naturalist. The latter examines the coasts and dredges in the ocean, but he can only skim the surface, whereas the former has the old sea-beds opened out to him. He can see, at any given time, what has been below the surface. The dredge may penetrate a few inches; but the old shoals and shell-banks of the Coralline Crag sea, for example, can be opened out to the depth of 10, 20, 30 feet or more, exposing the range of life both in time and in horizontal distribution at any given epoch. What may be under the surface of the Atlantic mud we know not. Is there a succession of strata extending down to the equivalents in time of our chalk strata? or would the equivalent of the latter prove to be merely one part of a series, the other end of which would convey us back to Oolitic, Jurassic, Triassic, or even to Carboniferous times? Many of the forms of life indicate a sequence in this great chain. Some of our present marine Foraminifera go back

* The absence of any known deposits in our Tertiary series of a character like the present deep Atlantic mud is another proof that none of that part of the old ocean-bed has been raised since the Chalk period.

to these Mesozoic and Palæozoic times; and we know not yet what further resemblances to old forms of life may yet be detected in the vast field just opened to us.

The present explorations, full of interest and valuable as they are, are insignificant compared with the vast area of the ocean; so that when we look at what has been accomplished in these tentative researches, we can only take them as indicative of the rich mine that yet remains to be explored, and look forward to discoveries that will probably modify and throw much new light on the relations between the marine life of the present and the past.

One of the great subjects which these researches may put before us in this new light is, that instead of the imperfect record which geology usually gives us of the life of the old world, with its interrupted succession in local descent, we may have, if the hypothesis of an area continuously submerged from the Cretaceous period should prove true, the lineal descendants of some portion of those creatures which lived in the Chalk seas. If so, naturalists will be able to see the exact amount of changes wrought, and to study in what direction they have been effected. We shall see the effects of continuity in time in conjunction with continuity of conditions, and whether any and what new forms have been evolved, and where no progress has been made. We see already that the Foraminifera, Sponges, and Echinoderms claim relationship with their fossil antetypes, though in an unequal degree. How will the fully ascertained results agree with the theory of Natural Selection? Beautiful, ably handed, and ingenious as this theory is, it seems to me—I will not say to fail, because I am not competent to pronounce on the natural-history bearings; but it fails to satisfy me. Natural Selection is founded primarily on Sexual Selection; and this latter seems to me an implant so strong, and to have an object so definite, viz. that of maintaining the species in full vigour, strength, and health, that, in the absence of any more direct evidence to the contrary, I would believe in the force of this law of life to perpetuate the special type unaltered, rather than in a divergent natural selection, leading, concurrently with changes of condition, to aberrant forms. We have had curious and remarkable evidence of elasticity of structure in certain directions; but does not the rebound, in almost all cases, show the existence of a spring which, while it admits of considerable play, tends to readjustment as soon as the restraint is removed. That there have been gradual changes in structure in all classes of animal life, concurrent with the passage of time, is evident, especially to geologists ; but of the way in which these changes have been carried out, I own to not yet seeing a sufficient explanation. Have terraqueous changes led to variations in the structure of animal life by the law of Natural Selection among the few that best adapted themselves to the changed conditions ? or was it by a gradual modification induced in the many, in consequence of the general change to which they were all subjected ? or was there some law in time, or of a character yet unknown to us, cooperating with the change in conditions, to produce those singular and extraordinary changes and variations of structure of which we have now such full evidence as to fact, but so little as to theory ?

These are some of the problems towards the solution of which I look with great hope in the continuance of these most interesting deep-sea researches, important alike to the naturalist, the physicist, and the geologist.

P.S. The few particulars in this Address relating to deep-sea temperatures were collected some twenty years since for a paper never published. As they form fitting antecedents to the more important recent researches, I have incorporated part of them here, leaving possibly some of the intermediate work rather incomplete.

Note.—Since the greater part of this Address was printed, Mr. Jeffreys informs me that he has now, through the kindness of Prof. Lovén, examined the shells procured in the Swedish expedition of 1869 by dredging on the Josephine Bank and off the Azores, at depths ranging from 110 to 790 fathoms ; and that nearly all these shells belong to the same species as those procured in the 'Porcupine' expeditions at similar depths.

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November 9, 1870.

Lieut. Reginald Clare Hart, R.E., Brompton Barracks, Chatham; Lieut. James Frederick Lewis, R.E., Brompton Barracks, Chatham; and M. F. Maury, Jun., Esq., 1300 Main Street, Richmond, Virginia, U.S., were elected Fellows of the Society.

The following communications were read:—

1. *On the* Carboniferous Flora *of* Bear Island (lat. 74° 30′ N.). By Professor Oswald Heer, F.M.G.S.*

[Abstract.]

The author described the sequence of the strata supposed to belong to the Carboniferous and Devonian series in Bear Island, and indicated that the plant-bearing beds occurred immediately below those which, from their fossil contents, were to be referred to the Mountain Limestone. He enumerated eighteen species of plants, and stated that these indicated a close approximation of the flora to those of Tallowbridge and Kiltorkan in Ireland, the greywacke of the Vosges and the southern Black Forest, and the *Verneuilii*-shales of Aix and St. John's, New Brunswick. These concordant floras he considered to mark a peculiar set of beds, which he proposed to denominate the "Ursa-stage." The author remarked that the flora of Bear Island has nothing to do with any Devonian flora, and that consequently it and the other floras, which he regards as contemporaneous, must be referred to the Lower Carboniferous. Hence he argued that the line of separation between the Carboniferous and

* The publication of this paper is deferred.

Devonian formations must be drawn below the yellow sandstones. The presence of fishes of Old-Red-Sandstone type in the overlying slates he regarded as furnishing no argument to invalidate this conclusion. The sandstones of Parry Island and Melville Island are also regarded by the author as belonging to the "Ursa-stage," which, by these additions, presents us with a flora of seventy-seven species of plants. The author remarked upon the singularity of plants of the same species having lived in regions so widely separated as to give them a range of 26½° of latitude, and indicated the relations of such a luxuriant and abundant vegetation in high northern latitudes to necessary changes in climate and in the distribution of land and water.

Discussion.

Sir Charles Lyell remarked that the Yellow Sandstones of Dura Den in Fife, and of the county of Cork in Ireland, contain *Glyptolepis* and *Asterolepis*, genera of fish exclusively Devonian, or belonging to the middle parts of the Old Red Sandstone—also the genus *Coccosteus*, which is abundantly represented in the Middle Old Red Sandstone, and sparingly, or only by one species, in the Carboniferous formation. The evidence derived from these fishes inclined him to the belief that the Yellow Sandstone, whether in Ireland or Fife, should be referred to the Upper Devonian, and not to the Lower Carboniferous, as Sir Richard Griffiths contended, and as Heer now thinks.

As to the argument founded on the plants, he considered it an important and truly wonderful announcement, that many well-known Carboniferous species are common to Bear Island (in lat. 74° 30′ N.), in the Arctic regions, and to Ireland and other parts of Europe (26° of latitude further south). But fossil plants are supposed to have a wider range in space and time than fossil fish; and we know that the cryptogamic flora of the ancient coal is remarkable for the wide horizontal spread of the same species, extending from North America to Europe, so that we need not be surprised if many species should extend vertically from the Devonian into the Carboniferous strata.

Mr. Carruthers remarked on the bearing of the paper on the Kiltorkan beds, and considered that Dr. Heer had completely established the correlation of the deposits. He differed, however, as to the numerical proportions of the species. He could not recognize *Cyclostigma* as a genus, but considered it founded on insufficient grounds, in which view Prof. Haughton now agreed. It was, in fact, founded on fragments of the bark of *Lepidodendron Griffithsii*, Brongniart, to which species the *Lepidodendron* indicated by Prof. Heer as *L. Veltheimianum* really belonged. Other detached portions of this same plant had been described by various authors under no less than seven different specific names, and referred to nearly an equal number of distinct genera; and Prof. Heer had reckoned these as species in his comparison of the Bear-Island and

Irish floras. Prof. Heer had been led, chiefly by the erroneous determination of the Kiltorkan *Lepidodendron* by the Irish palæontologists, to refer these beds to the Carboniferous rather than to the Devonian formation, the Kiltorkan fossil having been established as a very distinct species by Brongniart and Schimper. Mr. Carruthers considered that both the Irish and Bear-Island deposits belonged to the Devonian.

Mr. Boyd Dawkins pointed out that the proximity of land was exhibited by the presence of terrestrial plants in the deposits, and prevented the correlation of the inshore deposits with those which were being formed in deep water. As the marine fauna changed more rapidly than the terrestrial flora, it was preferable for classificatory purposes. He mentioned forms of vegetable life assigned by Dr. Heer to the miocene which had really been discovered in America in beds of Cretaceous age. He did not believe that corals could have existed in those high latitudes under any thing approaching to the present conditions. Prof. Nordenskjöld had failed to discover any traces of glacial action in these beds; and the question arose whether there had been any change in the position of the Pole or whether the heat radiated by the earth was sufficient to render an Arctic climate equable in Palæozoic times.

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2. *On the* Evidence *afforded by the* Detrital Beds *without and within the* North-eastern part *of the* Valley *of the* Weald *as to the* Mode *and* Date *of the* Denudation *of that* Valley. By S. V. Wood, Jun., F.G.S.

[Plate I.]

The denudation of the Weald valley has long been a subject of interest and of contention among geologists. The theory of a rise of a dome of strata from beneath the sea and the offthrow of the waters on all sides from that dome, their escape through lateral fractures in the upheaved chalk, together with a slow wearing back of the fractured and denuded edges of the chalk in the form of cliffs, long held its ground in our text-books, and it is only of late years that this theory has met with partial dissent.

Sir Roderick Murchison was the first*, I believe, to bring prominently into notice the fact that a large part of the débris contained within the denuded area consisted of angular chalk flints brought from the exterior into the inner part of this area, and so far therefore was at variance with the received hypothesis of a flow of the denuding waters outwards from the exposed subcretaceous strata, over the surface of which these flints were scattered. His view, after an elaborate description of the detrital beds of, more especially, the western part of the great valley, was that the denudation had been accomplished by a powerful aqueous agent directed eastwards from the apex or western extremity of the Weald valley, by which these flints have been thus scattered over the Neocomian strata of that part of the valley.

* Quart. Journ. Geol. Soc. vol. vii. p. 349.

Another elaborate memoir treating of the detrital beds within the Wealden escarpment, and their bearing upon the mode in which the denudation was effected, is that of Messrs. Foster and Topley*. The view of these gentlemen was that after a plane of marine denudation had been effected over the original area, the whole of the denudation by which, not merely the valleys proper of the Wealden rivers, but also the great excavation of the Weald itself (or major valley), with its well-known contour, have been accomplished was effected by these rivers, especially the Medway, flowing in their present direction—a view indorsed, apparently, by Prof. Ramsay †.

Many other notices, special and incidental, upon this question have appeared, and among them notices from Mr. Martin, Mr. Godwin-Austen, Mr. Prestwich, and Mr. Mackie; the first-named of whom has for a long period been a staunch upholder of the marine theory; while Sir Charles Lyell, it is well known, has always adhered, in his 'Elements' and in his 'Manual of Geology,' to the same hypothesis of marine agency.

In 1866‡ a study of the distribution of the gravel of the Thames, of that of East Essex and its continuation in the lower valley of the Medway, and of that of the heights above Canterbury led me to the conclusion that each of these gravel-sheets had partaken of some of the movements by which the Lower Tertiaries upon which they rest had acquired their present position and outcrop, and had thus been contemporaneous with some portion at least of that earlier part of the Wealden denudation to which the removal of the Tertiaries from the North Downs is due.

I then called especial attention to the circumstance that the position of the Thames and East Essex gravels in their troughs precluded the possibility of a connexion between them and the Thames river, either in its present or any prior condition, because that part of the Thames valley which lies east of Gravesend, instead of being coincident with the gravel-troughs, cuts at right angles through them—a feature also possessed by the next river to the north, the Crouch, the valley of that river, as well as the portion of the Thames valley just referred to, being entirely destitute of gravel or brick-earth.

These features, I pointed out, necessitated an admission that the troughs in question had their seaward terminations in the direction of the Weald, because the trough which contained the Thames gravel was absolutely shut in from the north sea by the lofty ridge which separated it from the East-Essex sheet, that ridge not having been opened for the river Thames to reach the North Sea until such

* Quart. Journ. Geol. Soc. vol. xxi. p. 443.

† Physical Geology and Geography of Great Britain: 1863 & 64.

‡ See papers on the Structure of the Thames Valley and its contained Deposits in vol. iii. of Geol. Mag. pp. 57 & 99, and paper on the Structure of the Valleys of the Blackwater and Crouch, and of the East-Essex Gravel, and on the relation of this Gravel to the Denudation of the Weald, *ibid.* pp. 348 & 398; also on the Postglacial Structure of the South-east of England, in Quart. Journ. Geol. Soc. vol. xxiii. p. 394.

a late period as that when the conditions giving rise in these parts to gravels and brick-earths had ceased—the period in fact of the modern alluvium, which alone occurs in the valley, or more properly the wide gorge thus cut through the ridge.

I then pointed out that east of London, where it occupied the more seaward portion of the channel thus opening southwards towards the Weald, the Thames gravel had been greatly broken up, denuded and elevated irregularly, by which action partial terraces had been formed—that under these terraces occurred the gravels and brick-earths of fluviatile origin with *Cyrena fluminalis* which had succeeded to the spreading out of the gravel occupying such terraces—and that these were the deposits of rivers into which the original gravel-inlets had by the elevation of their bottoms become reduced, such rivers, equally with the inlets that had preceded them, opening to a sea in the direction of the Weald. The mouths of these rivers, I considered, had followed the shore-line as this gradually receded southward from the rise of the Wealden area, until the sea, first becoming confined within an estuary of its own eroding, marked by the Wealden escarpments, was eventually expelled from the Wealden area—and that upon this event taking place, the drainage acquired its present reversed direction from the Weald into the Thames estuary, which then came into existence*.

At the time when by a study of the gravels *without* the Weald I was thus led to these views, I had not examined with any detail how far the constitution and position of the gravels lying *within* the chalk escarpments supported or conflicted with them. This I have now done, so far as concerns the north-eastern part of the area, which, from its contiguity to the mouths of the Thames and East Essex gravel inlets, is the part of principal importance in the question; and I propose now to show its bearing upon it.

In doing so it will, I think, be advantageous to consider also a question that I had deferred for the occasion, viz. how far the theories of the denudation of the Weald by agencies which involve the escape of the material removed in the course of denudation outwards from the Weald and into the Thames area, be they atmospheric, fluviatile, or marine, receive support or meet with negation from the composition of the detrital beds lying without the north-eastern part of the Weald.

Taking up this latter inquiry first, we have two sets of detrital beds to consider, viz. the Glacial and the Postglacial. Of the first, we have in this part of England two formations, the Boulder-clay and the gravel underlying it, which I have termed Middle Glacial.

In neither of these deposits can it be said that the débris of the

* In my paper in the Quart. Journ. Geol. Soc. vol. xxiii., at p. 408, I regarded the brick-earth of Erith and Crayford as distinct from that of Grays, and as having preceded the Thames gravel. Finding afterwards, by a clearer section, that it did not pass under that gravel, I, in a letter published at page 534 of the fifth volume of the Geol. Mag., withdrew from that position, and admitted that the Grays and Erith and Crayford Brick-earths are identical, and belong alike to the lower terraces of the Thames-gravel formation.

Wealden denudation is represented. In the gravel (which is composed of chalk-flint, with a considerable percentage of quartzites) there occur fragments of other rocks, among which are some of chert, sandstone, and limestone, that may possibly belong to rocks within the Weald, though I am not aware that such an origin can be with any certainty affixed to them. Again, Mr. Prestwich mentions having found fragments of chert and ragstone that he refers to the Lower Greensand of Kent in the shingle of the cliff near Southwold, belonging to the Glacial formation.

Such occurrences as these, however, afford no ground for concluding more than that prior to the Glacial epoch such a planing off of the Wealden area had begun as to afford exposures of the beds beneath the chalk, from which some fragments might at the commencement of the glacial period have found their way into gravels then in course of formation. The evidence necessary, however, to justify any assumption that the Weald valley existed as a subaerial tract during the whole Glacial period must go very far beyond this. Whether we suppose this valley to have been occupied during the Glacial period with ice which streamed through the lateral valleys of the north-east side into the Thames area—or whether we suppose it to have had a milder climate, so that rivers of water instead of ice followed the same course—in either case great volumes of the wreck of the subcretaceous strata ought to have been brought into the glacial beds which approach so near to the Wealden area as do those of the south of Essex; but these beds, especially the Boulder-clay, are conspicuous by their absence. If we consider through what various beds of stone the Medway and Darent valleys are cut, and what immense quantities of this stone must have been removed to form them, the absence or extreme paucity of such débris in the Glacial beds is significant; but if we couple, as we have been asked to do, the denudation of the great valley of the Weald itself with the erosive action of the Wealden rivers, then this becomes still more significant, and the impossibility of the Weald having been under subaerial conditions during the prevalence of those excessively detrital agencies that we attribute to ice seems to me obvious—and the more especially when we remember the greater extent which the Lower Greensand formation must have occupied in the earlier stages of the Wealden denudation, all of which, with its great beds of stone in fragments, has gone somewhere.

Further, the Boulder-clay of the Essex heights is mainly composed of rolled chalk; but it is not the soft chalk of Kent and Surrey, but the hard chalk of Yorkshire and Lincolnshire, termed "Rock" by the well-borers of those counties. The flank of the Lincolnshire chalk-wold for a long distance is occupied by a vast deposit of glacially degraded chalk, so pure as to be extensively quarried for lime, and so thick that the range of country formed out of it rivals in height the Wold itself. We thus see to what sort of detrital accumulation a range of chalk hills has given rise under the powerful action of glacier ice; and it appears to me but reasonable to expect something of the kind to have occurred over the south-east of England, had that region been under subaerial conditions during the prevalence of this icy envelope; yet, after allowing for the excessive denudation which has, as it seems to me, prevailed in postglacial times over the south-east of England, the complete absence of the smallest vestige of any such accumulation as we find in Lincolnshire is, I think, reconcilable only with the conclusion that during the formation of the Boulder-clay this region was covered by the sea—a conclusion, moreover, to which the position of the Boulder-clay at elevations of 300 feet and upwards on the Essex heights that front the North Downs equally points.

So far, therefore, as the evidence of the detrital beds of Glacial age lying without the north-eastern part of the Weald affords a test, we are, I think, entitled to infer that the Weald was not during the climax of the Glacial period an area undergoing denudation by streams either of water or of ice, and, indeed, that, with the exception of the earlier part of that period, it was not above water at all.

Passing now to the Postglacial beds, the principal formations of this age lying without the Weald are the gravels to which I have already made allusion under the names of the gravels of the Thames, of East Essex, and of the Canterbury heights.

Precisely the same kind of reasoning is applicable to these as to the case of the Glacial beds, so far as concerns the débris of subcretaceous rocks. If the Stour, the Medway, and the Darent, running outwards from the Weald, had effected any thing like the prodigious denudation attributed to them, fragments of the stone-beds of the Lower Greensand ought to make up *at least half the volume* of the Thames, the East-Essex, and the Canterbury-heights gravels where these three streams pass through them.

In the Thames gravel of this part, however, such fragments, though common, form but a small proportion of the gravel mass, the bulk of which is flint with some quartzites intermixed. The East-Essex gravel, both where it lies within the valley of the Medway between the Nore and Rochester, and where it extends along the east coast of Essex, presents similar features; while the gravel of the Canterbury heights, which forms the sides of the valley through which the Stour flows, is even more exclusively flint in its composition, as it requires a search of some time to find half a dozen fragments of any other material, so that in this gravel the proportion of any other material than flint is probably not $\frac{1}{1000}$ of the mass.

If we reflect how small is the elevation of these gravels above the streams which flow beneath them, in comparison with the elevations which the subcretaceous rocks attain within the Weald, can it be contended that gravels so composed could have been deposited from rivers which were effecting the enormous denudation that has placed these rocks as they now are? Can we, even if we reject the hypothesis of this great fluviatile denudation, reconcile the composition of these gravels with their deposition from these rivers when in greater volume than now?

The answer seems to me to be clearly negative, and that under such circumstances the flint in the East-Essex gravel between Rochester and the Nore ought to form but a subordinate proportion of the constituent material, while in the Canterbury-heights gravel nearly as much subcretaceous material as flint ought to occur. The case of the East-Essex gravel, especially of that part of it which extends from the Nore to Rochester, is a very strong one; for the chalk forms but a very small part of the area drained by the Medway, and, while the gravel-producing material, the flint, constitutes only a small percentage of any given amount of chalk strata removed, especially of the Lower Chalk which obtains in this area, the portion of the Lower Greensand formation which is drained by the Medway is largely made up of beds of hard stone. The Hastings-Sand formation, too, abounds with indestructible gravel-forming material, and in as large a ratio at least as does the chalk. Omitting the Weald Clay and the Gault as non-gravel-forming strata, we have, roughly speaking, the following proportions borne by the areas of those gravel-producing formations lying beyond the East-Essex gravel termination at Rochester whose drainage falls into the Medway, viz.:—

Lower London Tertiaries	0·25
Chalk	1·00
Lower Greensand	2·75
Hastings Sand	3·00
Total............	7·00

While the chalk thus figures for only one-seventh in area, it would, in proportion to any given quantity of strata removed, yield no more, indeed less, of flint than the Lower-Greensand beds, or even the Hastings-Sand formation, would of hard gravel-forming material.

If it be objected that the stone beds of the Lower Greensand are mostly limestone, and therefore soluble under the action of acidulated water, such objection does not apply to the Hastings-Sand material, of which, indeed, the broad sheet spreading over the Weald-Clay bottom is mainly, and in some parts exclusively, composed. Neither has it prevented the gravels of the Lower Greensand country from being principally made up of the stone beds of this formation. Moreover, the Kentish Lower-Greensand Limestone, so extensively used in building, is not of a perishable nature, and much of it is in that broken condition most suitable for supplying fragments for gravel-accumulation; while on the other hand so perishable a material as the Kentish Chalk has, according to Messrs. Topley and Foster, found its way, in the form of nodules, into gravels near Maidstone. Allowing, therefore, the fullest weight to this objection, can we resist the admission that if the East-Essex gravel, especially that part of it lying between Rochester and the Nore, resulted from the transport of the Medway, the flint débris in it (exclusive of the Lower Tertiary pebbles) should be largely outbalanced by subcretaceous material, instead, as the case is, of that material forming but a very small proportion of this gravel? This inference will not be appreciably weakened by supposing that the respective escarpments extended southwards in former time, because a careful examination of a map of the drainage-areas and of the elevations will show that the proportions borne by the Chalk, Lower-Greensand, and Hastings-Sand superficies would then remain pretty nearly the same as now—the chief sufferer by such extension being the Weald Clay, owing to the steep upthrow possessed by the Hastings-Sand formation.

The question then naturally arises, how did any fragments having their parentage within the Weald get into these gravels unless there was an outflow from the Weald? The explanation offering itself is that the tidal flow up the inlets in which I regard these gravels as having been deposited would bring such material in moderate quantities from any exposures of the parent rock within the Weald; and I may observe here how little effect geologists seem disposed to attribute, whether in the way of transport or of denudation, to this powerful and uniform force—the tide. It seems to me that the character and contents of the main mass of the gravels of the Thames, East Essex, and Canterbury heights, composed as they are almost wholly of flint in all stages of wear, from the subangular fragment down to the spherical Lower Tertiary pebble*, is far more consistent with a derivation from the wear of a long coast-line of Lower Tertiaries and Chalk than with a derivation from rivers draining, as those of the Weald do, extensive areas of subcretaceous strata abounding in stony beds.

I now propose to consider the case of the detrital beds *within* the portion of the Weald here under consideration.

As before mentioned, Sir Roderick Murchison has shown the great extent and quantity of angular chalk flint which is scattered over the Lower Greensand of the western extremity of the Weald, and that flint and Lower-Greensand débris, with some Tertiary pebble, *is* scattered over the Weald-clay zone drained by the Eden. In the north-eastern part of the Weald, although angular flints are abundant, the gravels which I regard as anterior to those resulting from the present rivers are more or less mixed with pebbles derived from the Lower Tertiaries.

The especially noteworthy feature connected with this intermixture, however, is that the pebbles and the angular flint present no intermediate grades of rolling to connect them; so that it is obvious this admixture of angular flint and tertiary pebble cannot, in finding its way to the positions it occupies, have undergone any considerable or repeated amount of wear by transport†. This feature seems to me repugnant to any presumption that these pebbles have settled

* In this respect the Lower or Fluviatile gravels of the Thames sheet differ greatly from those of the main mass, as their flints are far coarser and more angular, and present less gradation towards the Tertiary pebbles mixed with them.

† Instances occur, moreover, in which chalk fragments have occurred in this intermixture. Considering how impossible it is for chalk to sustain without dissolution any *long-continued* aqueous action, this circumstance is also of much importance. The difficulty is enhanced in the case of one of the gravel patches shown in the map as resting on Weald clay west of Yalding, in which Messrs. Foster and Topley speak of chalk nodules having occurred. Their transport there, however, by drainage, in the reversed condition shown in the map, seems to me simple enough.

down into their present places by successive transport from higher to lower levels during a long-continued fluviatile denudation—because such a successive and long-continued transport could not have failed to grind the smaller pebbles into sand, and to reduce the angular flints into all stages of wear, connecting them with the pebbles themselves.

In the map accompanying this paper, some of the more elevated gravels within the escarpments of the part of the Weald under consideration which are characterized by the presence of an admixture of chalk flints and Tertiary pebble, are shown in a way which distinguishes them from the rest of the gravels there. Of these, such as fall within the area drained by the Medway or its affluents, have been described by Messrs. Foster and Topley*. The rest, lying within the drainage-area of the Stour, I will briefly notice.

About Kennington, near Ashford, these occupy a high position, far above the Stour, and distant about a mile from it. The bulk of the Kennington gravel is composed of subcretaceous material; but there is a considerable proportion of angular flint in it, and some Tertiary pebble.

On the opposite side of the Stour, at Willesboro', is a remarkable patch exposed in the road-cutting west of the village. So far as I could detect, upon a brief examination, this gravel, 5 feet thick, was almost entirely made up of Lower-Tertiary pebbles and fragments of flint. At Smeeth, three miles further west, and midway between Merstham Hatch and Ridgeway, there is a gravel of subcretaceous material, intermingled with flint and Tertiary pebbles and a few pieces of chalk; and over the gault belt near to the chalk escarpment, angular white-coated flints often occur lying on the surface, but apparently no Tertiary pebbles.

The position of these gravels near Ashford, and of those above Maidstone, relatively to the chalk escarpments near each place, and to the rivers Stour and Medway, is indicated by the Sections A and B that accompany the map; and the Sections have their places indicated by lines upon the map. In both cases these gravels lie near what I regard as river-mouths bringing in drainage from the north; while similar gravels, described by Messrs. Foster and Topley, lie within the Medway area on the Weald clay beneath the Lower Greensand escarpment, and occupy a position near what I regard as one of these river-mouths after it had advanced from the Chalk escarpment at Maidstone to the Lower-Greensand one near Yalding.

In the case of some of the gravels near Maidstone, Messrs. Topley and Foster offer, as the explanation of the occurrence of flints, nodules of chalk, and pebbles in them, the action of a rivulet tributary to the Medway, which runs up towards the foot of the Chalk escarpment at Boxley. But though angular flints and chalk might by such a means find their way into the Medway, it is not apparent how Lower-Tertiary pebbles could do so, even at the greatly higher level at which both the tributary and the Medway itself must have flowed to reach the high situation of these gravels at Barming, and above Allington (near Maidstone).

The position of the gravel at Willesboro' is still more antagonistic—

* *Loc. cit.*

because, though composed of angular flint and Tertiary pebbles, the stream that passes Willesboro', a tributary of the Stour, does not reach any way near to the chalk escarpment, while pits in the Lower-Cretaceous stone are close at hand. In striking contrast with this Willesboro' gravel is the gravel skirting the Stour at lowest level at Bucksford, less than three miles west from that at Willesboro'. This low-lying gravel is entirely made up of subcretaceous material, though by long search a solitary fragment of flint may be found in it, derived probably from the flints scattered over the Gault surface, up to which some of the rivulets running into the Stour extend; it is obviously a deposit of the Stour when flowing in greater volume in the same direction as at present. But, looking at the physical and geological features of this part of the Weald, can it be contended that a similar flow at from 50 to 100 feet higher level could have deposited gravel of such opposite character to this as is that hard by at Willesboro' or that, about 15 miles distant, on the heights at Canterbury?

I would, however, prefer to deal with the possibility of these pebbles reaching such positions on broader grounds than the precise position of the rivulets nearest to their place of occurrence; that is, I regard their position as repugnant to any introduction from the Stour or Medway, in their present direction, during the course of a prelonged atmospheric or fluviatile denudation which resulted in the prosent excavation forming the Weald, for the following reasons, viz.:—

1st. The form and character of the great Wealden denudation area (or major valley), as distinguished from the valleys proper of the Wealden rivers (or minor valleys), is diametrically opposite to any that can result from river-action, because, however great we concede the power of that action to be, any excavation resulting from it must be conterminous with the excavating agent itself (the river and its tributaries), since every stream, large or small, can only deepen its own proper valley, and the result cannot be any such excavation as the major valley of the Weald, with its well-known contour and escarpments, but only a series of valleys, or minor excavations, ramifying in the directions in which the stream extends, and in some degree at least coinciding with them; and the longer this action is continued, the deeper and more distinct must these features become.

2nd. If flints and pebbles were derived from the Chalk escarpment, we should look for an increase in their number as the escarpment is approached; but though a few angular flints are in some places scattered over the surface of the Gault, the Lower-Tertiary pebbles seem wholly absent from that part of the area, and from the sources of the streams supposed by some to have brought them.

3rd. The Lower-Tertiary beds yielding pebbles are far away from the escarpments, and rest on the northern extremity of the chalk slope and below the crests of the escarpments; and however high the level be to which we carry our imagination of the flow of the Wealden rivers in past times, even if up to the level of the escarpment-top itself, still the drainage from the Lower-Tertiary strata must at all times have flowed away from the scarp, and not into the Weald. There are, however, some patches of pebble-beds (of date prior to the excavation of the Weald valley, whether of Lower Tertiary age or of some subsequent period) which occur near to, and even on, the chalk escarpment, and are shown in the accompanying map. These, however, clearly could not have supplied the pebbles to the Kennington, Willesboro', and Smeeth gravels, which lie within a separate drainage-area—that of the Stour; and if we suppose those gravels that are shown in the map as lying within the area of the Medway drainage and containing Tertiary pebbles to have been supplied from this source (straining our imagination, and ignoring, in order to do so, various physical features that conflict with such a direction of supply), we ought for consistency to find Tertiary pebbles in increasing proportions in those gravels of the Medway drainage-area, both higher and lower, which lie nearer and nearer to these scarp beds; but such is not the case.

While the introduction of these pebbles, and the nature and form of the area of denudation seem to me alike repugnant to any conceivable river-agency acting in the direction of the present streams, the position and mode of occurrence of all the gravels within this part of the Weald appear to me to be just what might be expected from the sequence of events after the Thames gravel which I have in previous papers put forward; and this sequence I will endeavour here to trace in harmony with the composition and position of such gravels.

I should premise, in order to remove misapprehension, that I have never entertained, and wholly reject, the hypothesis of the escarpments having ever been cliffs, although they appear to me to have formed sea-margins and steep foreshores*. The absence, however, of beds with contemporaneous marine fossils within the Weald, either at the feet of the escarpments or on elevations within the major valley, does not seem to me to be entitled to any weight; for there is proof, from the envelopment of some two or three miles of it in Boulder-clay, that the escarpment of the Yorkshire Wold existed during the glacial period, and must therefore have been a sea-margin, because, in whatever way this Boulder-clay was formed, no one can deny that the Yorkshire Wold passed under the Glacial sea; and if the valley below it was filled with, and the Wold covered by, ice when subsiding, they were clear of this when emerging, and underwent great denudation during that process. The features exhibited by sections of mine, Nos. 7 & 8, at p. 402 of the 23rd volume of the Society's Journal, render it difficult to deny that the same thing occurred with respect to the chalk-escarpment of Herts and the lower grounds below it. Nevertheless we do not in either of these cases meet with beds with marine fossils referable to this period of emer-

* While rejecting the hypothesis of scarps being in any way allied to cliffs, I cannot admit that the absence of beaches at their feet is any argument in the case, because hundreds of steep acclivities in the north of England and in Scotland that could not have been any thing else than cliffs when emerging from the glacial sea, are quite destitute of beaches at their feet. Some of these, such as Gristhorpe cliff in Yorkshire, shown by me and Mr. Rome in section at p. 180 of the 24th volume of the Quarterly Journal, have now become cliffs again, and have the beach at their feet, which they had not when rising out of the glacial sea.

gence and denudation. The Glacial beds of East Anglia have undergone a similar emergence and denudation; and even those who attribute the Wealden denudation to atmospheric and fluviatile agencies admit that the Lower Tertiaries and Chalk over the south of England underwent a previous denudation or planing off by marine agency; but where are the beds with marine fossils in East Anglia or over the south of England representing such emergence and denudation? These questions might be extended to the denudation of the coal-measures and other old rocks; but the phenomena presented by denuded areas appear to me to show, uniformly, that a denudation effected *during upheaval** is *un*represented by beds with contemporaneous marine fossils deposited over the denuded area. Upon any introduction afterwards of the sea, however, we get these beds—as, for instance, the Kelsea gravel in Yorkshire, the fen-gravels of East Anglia, and the brick-earth of the Nar in Norfolk: but there has been no such reintroduction of the sea into the Weald since its denudation, unless it be in the Lewes levels. The beds with marine fossils contemporaneous with the Wealden denudation are to be looked for without the Weald, *i. e.* beyond the region of upheaval and denudation; and thus it is, as well as for the other reasons assigned in the sequel, that I refer the fossiliferous mud-bed of Selsea, lying in the depressed and *un*denuded fold between the two areas of upheaval and denudation, the Isle of Wight and the Weald, to the period of that upheaval and denudation.

In the accompanying map, by means of shading in the escarpment carefully reduced from the ordnance map, the very conspicuous features of mouths opening towards the Weald, presented by the gorges in the chalk escarpment between Guildford and Dover, and by that in the Lower-Greensand escarpment at Yalding, are made apparent †. *The gorges of the South Downs present no such feature.*

Now patches of gravel containing Tertiary pebbles occur near one or other of these mouths: and it is clear that streams flowing from the north through the Tertiary and Chalk area, and debouching through these mouths into a sea occupying the area within these escarpments, would necessarily bring an abundance, both of angular chalk-flint and of Lower-Tertiary pebbles into the Weald, there to intermingle with fragments having their parentage within the Weald itself.

My proposition is that the violent disturbances from east to west at some time subsequent to the older Tertiaries to which, it is universally admitted, the Weald owes its *present* form ‡ took place

* It is the reverse with denudation during depression; for there the advancing sea, as *e. g.* that of the Lower Tertiaries over the Chalk, planes off its floor and then deposits its sediment with contemporaneous marine organisms—preceding this usually, however, with beds of rolled fragments.

† To show better the physical features of the scarp, the strip of Atherfield clay that forms the foot of the Lower-Greensand escarpment has been shaded in with the Weald clay, instead of, as is usual for geological grouping, with the Lower Greensand.

‡ In order not to encumber the case discussed in the body of the paper, I have

subsequently to the accumulation of the Thames gravel, and that their effect was to put an end to that gravel and the coeval gravels of East Essex and of the Canterbury heights, and gradually to raise the sea-bed over Kent and Sussex, and away to the north of France, giving rise thereby to a great submarine denudation—that by this action the inlets in which the Thames and coeval gravels had accu-

avoided reference to any earlier stages of the Wealden denudation. Mr. Prestwich, in his 'Memoirs on the Lower London Tertiaries,' gave reasons for supposing that the first elevatory action over the Wealden dome preceded the Lower Tertiaries. Those also who agree with him as to the age of the Lenham and Paddlesworth beds, must admit that a considerable planing off of the chalk, exposing probably the subcretaceous strata, was renewed prior to those Lenham and Paddlesworth beds being deposited. I would again call attention to the physical fact, plain to any who will take the trouble to extract the contours from the ordnance map, that there are two distinct sets of disturbances traceable in the south-east of England:—one, the sharp rectilinear east and west upthrows, by which the denudation of the Weald *valley* has been induced, and which I consider to have affected the Thames gravel, both east and west of London, and to be connected with the similar upthrows of the Isles of Wight and Purbeck (all, therefore, of a date posterior to the first accumulation of the Thames gravel); and the other, a set of anterior origin, consisting of a series of concentric curves, the exterior of which is formed by the Cotteswold escarpment, and the next to that by the chalk escarpment from Pangbourne to Royston, while the inner ones constitute a series of smaller escarpments, of which the trumpet-mouthed gorges in the North Downs, referred to in the paper as river-mouths, successively form parts, the whole set centring near Canterbury. These curves are connected very distinctly with another, and apparently contemporaneous, set, which centre near the western extremity of the Isle of Wight, and are concentric half circles formed by the Lower-Tertiary outcrop of Hampshire and the chalk escarpments of the south-west. The rectilinear movements to which the denudation of the Weald valley is due, have destroyed this anterior curvilinear contour, *which is perfect up to the points where these rectilinear upcasts occur.* I formerly supposed that these curved groups were, equally with the rectilinear ones, of postglacial origin; but an examination of the glacial beds of Bedfordshire and of Northamptonshire showed these beds in such a position relatively to the chalk and oolite escarpments (which form successive concentric curves of the Canterbury group) as necessitated the inference that the curves were of preglacial origin. These curvilinear movements appear, however, to be clearly synchronous with the first denudation of the Tertiaries from the south of England, and with that planing off of the chalk over the Weald, to which allusion has been made. The two principal rectilinear flexures, by which the direction of the denudation of the Weald *valley* has been induced, are those of Portsdown Hill and the Guildford Hog's-back ridge, running east and west and parallel to each other, and indicated by lines in Map No. II. The upthrow of these I consider to have so acted on the sea expelled from the north of Kent by the synchronous upcast of the country from there over to France, as to have caused it to denude their regular parallelogrammatic trough formed by the chalk escarpments of the Weald. The two inner curves of the concentric series which centres at Canterbury are visible on the accompanying map, No. I., the innermost of the two being formed by the escarpment which skirts the Canterbury-heights gravel on the west, and extends down to the Weald escarpment above Smeeth. The northern extremity of this curve has now disappeared into the north sea. The other, and next outward curve, is formed by the escarpment which skirts the East-Essex gravel on the west, and extends down to the Weald trumpet-mouth above Maidstone. The two trumpet-mouths west of this are successively partial repetitions of these curves; but the next *complete* repetition is made by the chalk escarpment from Pangbourne to Royston; and the next to this, and last, is the Cotteswold escarpment, prolonged by the oolitic escarpment through Warwickshire, and by the oolitic escarpment of Northamptonshire.

mulated shrank into river-channels, through which the drainage of Essex and Middlesex flowed southwards to this disturbed sea. In order to make this intelligible I have placed beside the larger map, which shows the detrital beds and contour surface, two smaller ones illustrating the succession of events thus supposed. The first of these shows the distribution of land and water when the Thames and coeval gravels were accumulating, and the other this distribution when the sea had deserted the chalk country and retired within the chalk escarpments of the Weald.

Now, in addition to the three openings in the North Downs, through which the rivers Stour, Medway, and Darent flow, and which expand trumpet-mouthed towards the Weald, and are regarded by me as the remains, first of old channels, and afterwards of old river-mouths, there is another precisely similar mouth further to the west, through which the Brighton Railway passes. This mouth forms now a dry valley extending from Croydon to Merstham, but so elevated and shallow in comparison with the three others that the railway has to pass out of it into the Weald at Merstham by means of a tunnel. Elevated and destitute of water as is this trumpet mouth, it is identical in form with those through which the rivers Darent and Medway flow, showing undeniably, as it seems to me, that this trumpet-shaped feature is not due to the erosive action of a river flowing outwards from the Weald, for no river at all is there.

The explanation of this dry, shallow, and elevated trumpet mouth seems to me to be this, viz. that it represents another of the channel-, and eventually river-mouths opening into the Weald which became established when the sea was retreating to the chalk escarpments.

As we go eastwards from this point, the chalk and Lower Greensand have an easy dip; but as we go westwards from it the dip becomes much sharper, until between Guildford and Farnham the chalk is all on edge, and at angles varying from 35° to 45°. It seems to me therefore that while this more easy upcast eastwards permitted the fluviatile wearing down combined with tidal erosion to keep pace with the upcast, and so maintain these mouths as points of river discharge, the more abrupt character of the western upcast did not allow of this being done; so that the drainage into the Weald through this trumpet mouth, traversed by the Brighton Railway, was put an end to at an early stage in the retreat of the sea Wealdwards. The gorges through which the Mole and Wey now flow were probably similar mouths, which (although the sharpness of the chalk upcast in their neighbourhood has somewhat destroyed their trumpet-mouthed character, as well as the coast-contour that was synchronous with them) nevertheless were cut through during the disturbances so as to allow the drainage to flow into the Weald.

That part of this easterly drainage which flowed through the Darent gorge seems to have terminated before the Lower-Greensand escarpment became the sea-margin; but that flowing along the lines of the Medway and Stour remained unarrested, the mouth of the

Medway drainage having been worn down step by step as the Lower-Greensand escarpment rose above the waters, until it presented the condition now exhibited by the trumpet-mouthed gorge cutting through that escarpment at Yalding; at which time, or even previously, through the opening in the Lower-Greensand hill to the north of them, the Lower-Tertiary pebbles and angular flints abundantly present in the gravels near that place, shown in the map, were thus brought from the northward through the Lower-Greensand escarpment.

The Lower-Greensand escarpment subsides and disappears near Ashford; so that where the Kennington, Willesboro', and Smeeth gravels containing the flint and pebble admixture occur, there is no such escarpment at all. The mouth by which the drainage through the Stour valley entered the Weald seems therefore not to have much advanced beyond the chalk escarpment; so that the gravels at these places represent both the gravels above Maidstone, accumulated when the Medway mouth was near the chalk escarpment, and the gravels about Yalding, accumulated either about the same time or else later, when that mouth had become established near the Lower-Greensand escarpment. The highest of the Stour area, viz. those at Kennington, seem to be probably coeval with the gravels above Maidstone; while those of Willesboro', which are at a lower level, may be synchronous with the gravels about Yalding.

During the later portion of this change the Hastings-sand country formed, it seems to me, a large island, so that what for convenience' sake I have called sea, was really only an inlet receiving freshwater through these several rivers; and since the width between this island and the chalk escarpment varies only from eight to eleven miles, and between it and the greensand escarpment from five to six miles only at the narrower parts, there would have been a considerable tidal scour exerted under any circumstances, while the far greater volume of the land-drainage of those postglacial times, compared with what now obtains in the east of England, would tend to push the limit of fresh water further out into estuaries than at present. Great freshets too, carrying with them volumes of river-mud with its associated organisms, would be poured into the Weald; and throughout it is to be remembered that the fresh water must follow the salt water as the latter recedes by the extension of the shore-line, and occupy its place. In this way it seems to me that there would be nothing repugnant to the events I have traced, if the gravels in question should hereafter be found to yield the remains of land or fresh-water organisms, such as do occur in some of the gravels and brick-earths shown in the map under a different shading, and which are most of them due to the rivers flowing as they do now.

The views thus sketched assume the Weald, when the sea had retired within the chalk escarpments, to have been the island-studded head of a still longer inlet formed by the British Channel while this channel was closed to the north by an isthmus between Dover and Calais, which had come into existence by means of that elevation of the chalk country which put an end to the Thames gravel and its coeval beds. This assumption I brought forward in 1866*, when first endeavouring to show the process by which I consider the Wealden denudation to have been accomplished, in ignorance that it had been already, as I find, suggested by Mr. Mackie†. The suggestion, however, when fitted into its proper place as to time, *i.e.* posterior to the Thames gravel, appears to me an essential ingredient in the proposition, because the existence of such a barrier between the Channel and the North Sea must have largely augmented the tidal rush and consequent erosive action of the waters within the Weald. On the other hand, the diminution of this tidal scour, produced by the opening of the Dover Straits, supplies an efficient cause why the elevation of the Wealden area should overmaster the denuding agency, and so extricate the Weald altogether from the sea.

It may be further added that this state of things agrees with the features of the marine deposit skirting the sea between Selsey and Worthing, in Sussex, described by Mr. Dixon and by Mr. Godwin-Austen. A numerous fauna has now been obtained from this deposit by Mr. A. Bell, which, while it is quite unlike that of any of the glacial deposits, and also unlike any of the marine postglacial deposits in other parts of England, and in Scotland‡, nevertheless consists *entirely* of species that are still living. Nearly all the shells are denizens of our extreme southern shores; but a few do not reach us, having their northern limit on the Lusitanian coast, so that this deposit indicates that at some Postglacial period the British Channel was subjected to an influx of Lusitanian water, which afterwards ceased and was followed by a change, under the influence of which certain Lusitanian mollusca disappeared from our shores. This order of succession is shown by the deposit in question being overlain§ by a few feet of deposit containing some large angular erratics.

This overlying erratic deposit, I take the opportunity of observing, I regard as quite unconnected with the glacial beds,—its erratics being due to the presence of conditions of climate such as introduced the large angular blocks into beds of the Thames gravel series at Grays, the greywether blocks into the Postglacial gravel of Hampshire, and the boulders into the Postglacial clay of Hessle, in Yorkshire,—such deposits being due to conditions of climate wholly unlike those which gave rise to the Greenlandic conditions of the Glacial period, but similar to what now obtains in the Gulf of St. Lawrence and other parts where ice forms on coasts during the winter. The deposit, however, may perhaps indicate a colder sea-

* Geol. Mag. vol. iii. p. 402.

† Geologist, vol. iii. p. 203.

‡ I group all the Scotch so-called Glacial shell-beds as Postglacial, as they rest on the Boulder-clay, and have a very different fauna from the Glacial beds proper, which include the Boulder-clay on which these Scotch beds rest.

§ Godwin-Austen, Quart. Journ. Geol. Soc. vol. xiii. p. 49. According to Mr. Austen the fossiliferous deposit has large portions of the skeletons of *Elephas primigenius* imbedded with the shells, and is underlain by red gravel. This gravel may probably, therefore, belong to the age of the Thames beds, or nearly so.

water than that underlying it, in which the Selsey fauna lived; and this colder change I associate with the admission of the North Sea through the Dover Strait.

So soon as by these means the elevatory action gained on the tidal erosion, and the Weald was deserted by the sea, the reversal of the drainage of the Stour and Medway into its present direction commenced. Its first result would be that the streams, descending from the northern portion of the Hastings-sand country, and having to seek a new outlet, would form a lacustrine kind of expanse up to the level where a point of outlet along the present line of drainage was found for it. The deposit of that expanse I trace in the wide-spread sheet of gravel which skirts the Medway and its tributaries, the Beult, Eden, and Teise, over the Weald-clay bottom, and which, in the case of the Beult and Teise, is formed almost exclusively of material derived from the Hastings-sand country, locally called "Crowstone gravel," but which in the case of the Eden, as Sir Roderick Murchison has shown*, has a considerable admixture of Lower-Greensand and flint material, and, in the case of the Teise (as I am informed by Mr. Topley), of Tertiary pebbles also, derived, I conceive, from the prior distribution of such material over the area when in the condition shown in sketch map No. III.

A few patches of gravel resting on Weald-clay, but occupying higher ground than this sheet, skirt the Hastings-sand country, such as those at Marden and Wantsuch Green, mentioned by Messrs. Foster and Topley. These are similarly composed of Hastings-sand material; and though these gentlemen speak of flint having been found in them, it must be excessively rare; for I could not detect a trace of it. Their age I regard as similar to that of the gravels with Tertiary pebbles about Yalding and at Willesboro'; but being on the opposite side of the channel formerly occupying the Weald-clay area, they received no Tertiary pebbles like their coeval gravels at Yalding and Willesboro', but were supplied by the material descending from the Hastings-sand hills. The few flint fragments that Messrs. Foster and Topley speak of may have drifted along the island shore from those abundant accumulations of flints described by Sir Roderick Murchison, which are scattered about the more western parts of the Weald. These patches are considerably above the great sheet skirting the Beult, and are divided from it by a slope of bare Weald-clay.

The gravels and brickearths which fringe the valley of the Medway between Maidstone and Chatham, and of the Stour between Ashford and Canterbury, occupying lower levels than the gravels with Tertiary pebbles, already specially discussed, are more difficult to distinguish, as it is obvious that any earlier gravels or brickearths deposited at low levels in these valleys before the drainage was reversed, would, after that event occurred, become undistinguishably mixed up with the deposits from such reversed drainage.

The same remark equally applies to those lowest accumulations of gravel and brickearths which fall within the Thames, the East-

* Quart. Journ. Geol. Soc. vol. vii. p. 381.

Essex *, and the Canterbury-heights drainage-areas, because a similar intermingling must have resulted in these cases. Nevertheless, looking to the fact that there is an absolute absence of gravel or brickearth in the valleys of the Crouch (notwithstanding its tributary rivulets extend up to the heights capped with glacial beds, which would have supplied some gravel material) and of the estuary of the Thames, which, as already described, have been excavated at a late period through the high ridge separating the Thames from the East-Essex gravel-sheet, and through those sheets themselves—and looking to the feebleness of the gravel conditions exhibited by the wide sheet skirting the Medway and Beult, to which allusion has been already made, it is probable that by the period of this reversal the conditions giving rise to the formation of brickearth and to the transport of gravel by such flat-falling streams as the Thames and Medway had ceased in a great degree, and given place to those different conditions to which the river-mud or modern alluvium is due; so that, save to the extent of rearrangement by the action of the river-waters, when more voluminous and at higher levels than now, most of the material of the gravels along the lower levels of the Medway and Stour valleys, except the sheets skirting these rivers and their tributaries within the Weald, was probably transported before the reversal took place. In the case of the Darent, inasmuch as its reversal seems to have preceded the retreat of the sea within the Lower Greensand escarpment, its gravels would be much more due to the rivers while flowing in their present direction than would those of the Stour and Medway, because at this earlier stage the conditions giving rise to gravel and brickearth had not so nearly passed away.

It may be asked where, if it be not represented in the gravels lying without the Weald, has the débris of the subcretaceous rocks removed to form the valley of the Weald gone? The most probable answer seems to me to be that it is distributed over the bottom of the English Channel—not in the modern superficial shingle, but in the form of thick beds far out to the west covered by the modern shingle, and concealed by it and by the waters of the Channel.

To sum up the case as I have endeavoured to put it, we have the following propositions:—

1st. The absence from the Glacial beds of Essex of any débris representing a *considerable* denudation of the Weald during the Glacial period, and grounds, in the position and constitution of the Boulder-clay of the Essex heights, for regarding the Wealden area as beneath the sea during the accumulation of that clay.

2nd. An absence from the principal Postglacial gravel sheets outside the north of the Weald of *any quantity* of Lower-Cretaceous or Hastings-sand material, *adequate to represent* the Postglacial denudation of that valley by any agent that involves a transport of the material removed into the area occupied by these gravels.

* That is to say, the portion only which occupies the Medway valley between Chatham and the Nore; the portion on the north side of the Thames, viz. in East Essex, would, unless the North Sea at this time still remained at some distance from the Thames mouth, be exempt from this later intermixture.

3rd. The difficulty of reconciling the presence of Tertiary pebbles in certain Wealden gravels with an origin by means of rivers flowing in the direction of the present ones, however high we imagine those rivers to have been.

4th. The antagonism between the character and form of the major valley of the Weald and that of any conceivable excavation which could result from the agency of rivers, not merely from rivers coincident with the present ones in direction, but from any rivers at all.

5th. The proof which the position of the gravels of the Thames, of East Essex, and of the Canterbury heights, and especially the position of the lofty ridge dividing the Thames and East-Essex gravels from each other, furnishes that the sea of this gravel-period was to the south of these gravel-sheets.

6th. The circumstance that the old coast-contour, when the sea lay within the Weald, and the channels and river-drainage entered it from the north, remains now stamped, as from a die, on the Chalk and Lower-Greensand escarpments, except in the particular region where that on the chalk was obliterated by the excessive marine denudation consequent upon the acute upthrow of the Guildford Hogsback—especially the dry inlet mouth at Merstham.

7th. The natural manner in which the gravels with Tertiary pebbles, mentioned in proposition no. 3, fall into their places, if they be regarded as having received these pebbles by means of channels and rivers from the north; and the sufficient explanation which a tidal indraught from the south, when the shore-line was chalk, and the principal denudation of the subcretaceous strata not yet accomplished, offers for the small quantity of subcretaceous material and enormous quantity of flint possessed by the Thames, East-Essex, and Canterbury-heights gravels.

8th. The existence of a cause, in the shape of an isthmus at Dover, which was adequate to induce a tidal scour sufficient, with the river-flow from the north, to produce a denudation of the form and character which the major valley and the minor valleys together present; the equally adequate cause for a cessation of this denudation, and for the mastery so attained by the elevatory action over the denudation, which the opening of the Dover Straits (generally admitted to be of a late Postglacial date) furnishes; also the general fitting in of all these propositions with one another, and with the features presented, on the one hand, by the very recent opening of the mouths of the Thames and Crouch through the great ridge, and the absence from the valleys of the Thames mouth and of the Crouch river of either gravel or brickearth; and, on the other hand, by the character of the Selsey deposits.

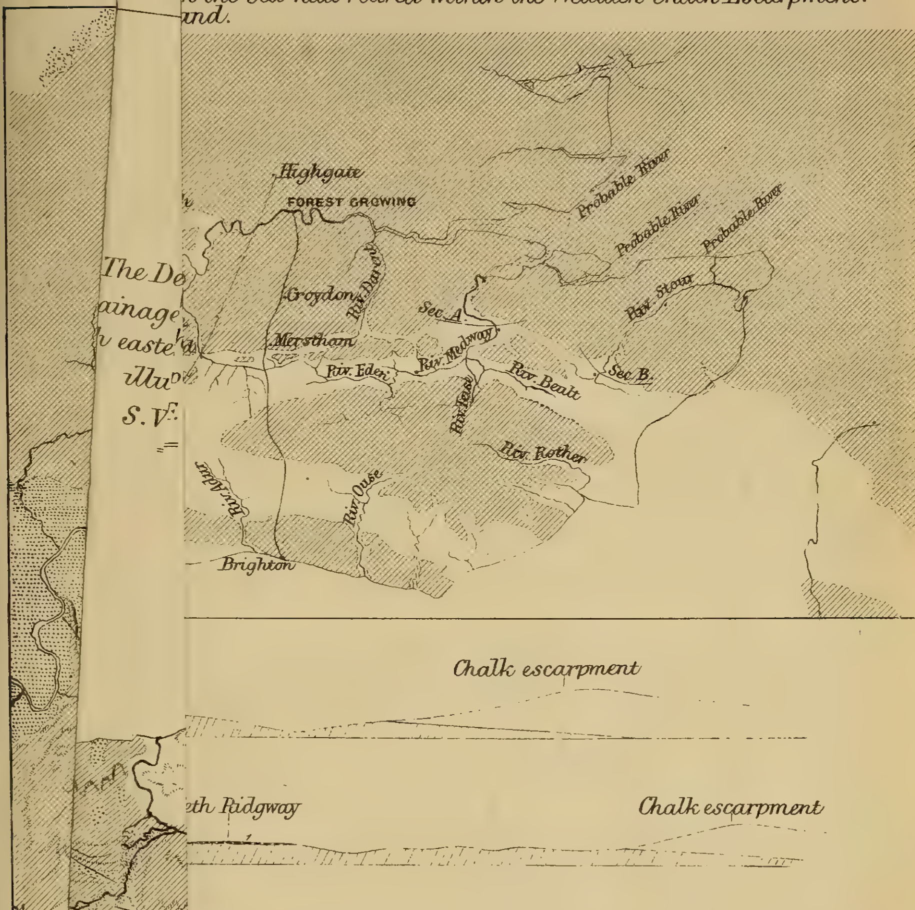
Note explanatory of the Map (Pl. I.).

In order that the physical features may appear, the Atherfield-clay has been shaded in with the Weald-clay, instead of, as usually, with the Lower Greensand.

The lines A and B indicate those of the two sections, A and B, which

No. III.

...n of Land and Water after the termination of the Thames
...n the Sea had retired within the Wealden Chalk Escarpment.
...and.



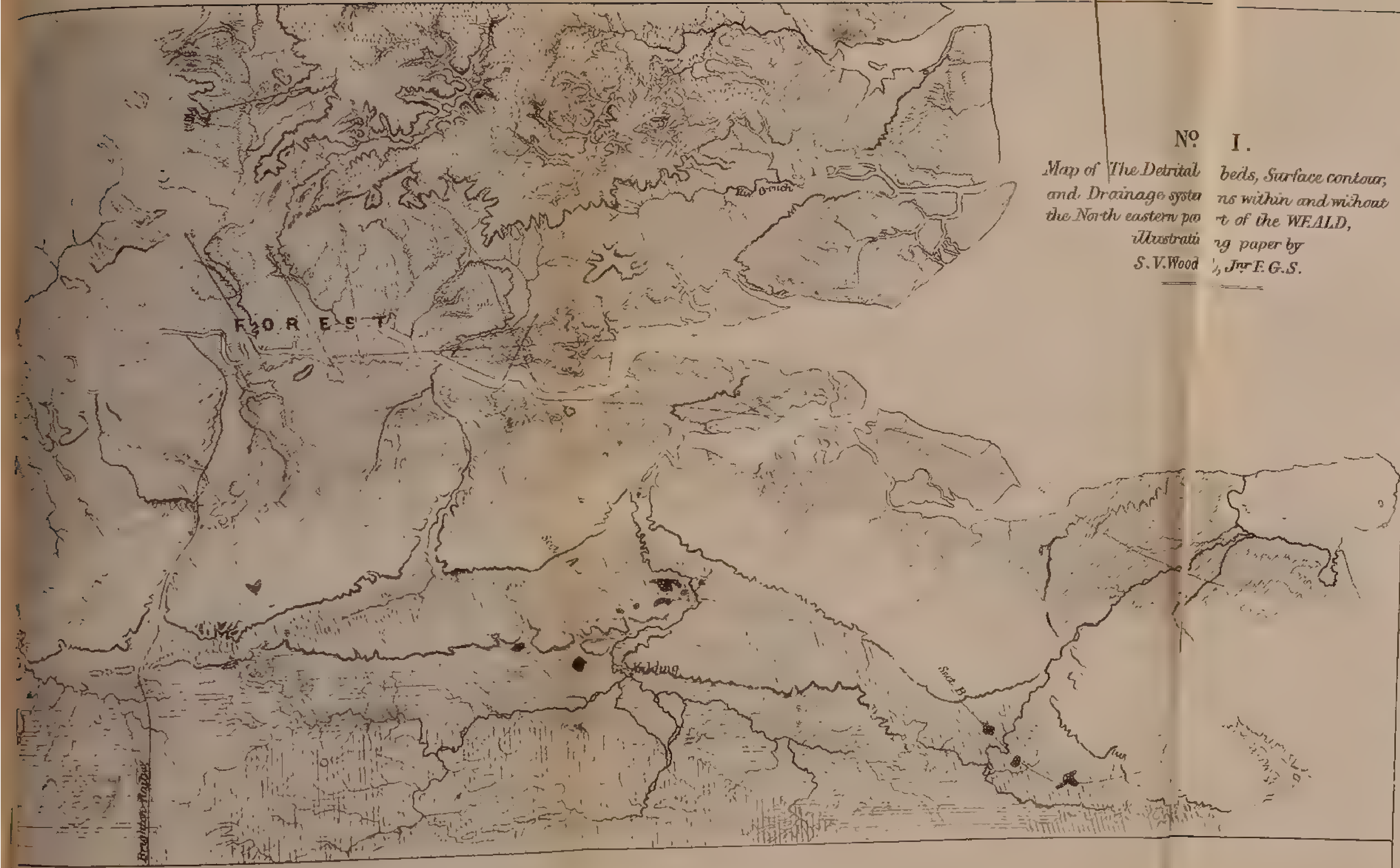
... North into the Weald. 2. Gravels and Brickearths due to or
... No. 1.

I.

...and. Chalk. Older Tertiaries. Pebble beds
Gravels older than the Thames & allied sheets.
...es Gravel formation where distinguishable from the main mass,
...int and Tertiary pebbles, referred to the period when the Drainage
...f these contain flint and Tertiary pebbles.) Gravels, &c.
N.B. Alluvium and Modern Shingle omitted.
The lines numbered 4, 5, 10, 11, 13, 14 and 15 indicate those
...urnal. Escarpments, Ridges and Valley slopes.

S.V.W. Jr. delt.

Ph

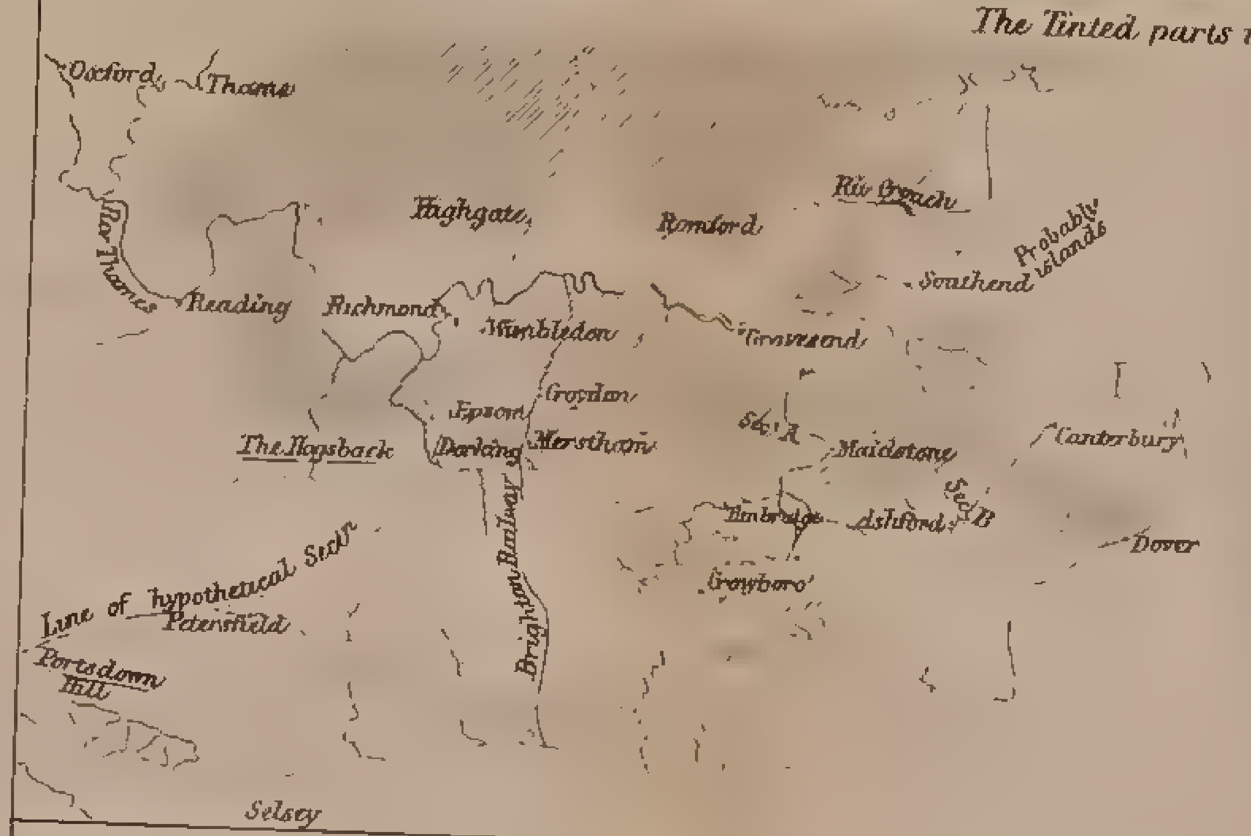


Nº I.

Map of The Detrital beds, Surface contour, and Drainage systems within and without the North eastern part of the WEALD, illustrating paper by S. V. Wood, Jnr F.G.S.

Nº II.

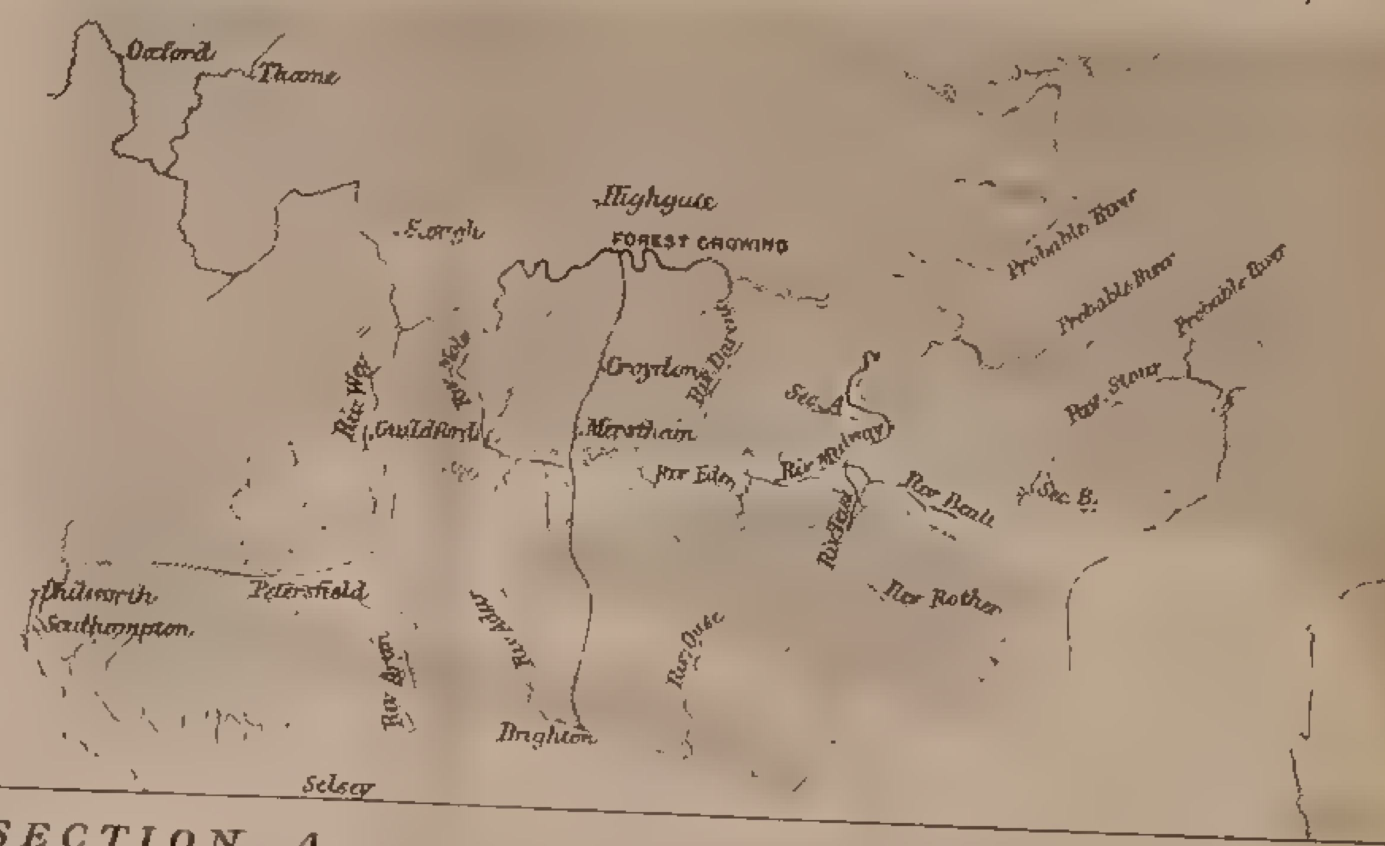
Map of the Distribution of Land and Water at the Commencement of The Thames Gravel Period.



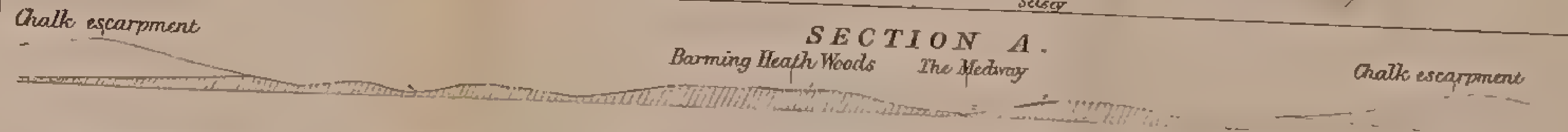
Nº III.

Map of the Distribution of Land and Water after the termination of the Thames Gravel Period and when the Sea had retired within the Wealden Chalk Escarpment.

The Tinted parts in both II and III represent Land.



SECTION A.



SECTION B.

REFERENCE TO SECTIONS A & B. *1. Gravels, referred to the Period when the Drainage was from the North into the Weald. 2. Gravels and Brickearths due to or re-arranged by Drainage in its present direction. The Chalk and Subcretaceous Strata as in Map Nº 1.*

REFERENCE TO MAP Nº 1.

Hastings Sand. Weald and Atherfield Clays. Lower Greensand, Gault and Upr Greensand. Chalk. Older Tertiaries. Pebble beds on or near the Chalk escarpt. The Uppr Glacial Clay. The Middle Glacl. sand & Gravel. Gravels older than the Thames & allied sheets. Gravels &c. of the Thames, East Essex, and of the Canterbury heights. Newer beds of the Thames Gravel formation where distinguishable from the main mass, either by the existence of a terrace, or by the presence of Freshwater shells. Wealden Gravels with flint and Tertiary pebbles, referred to the period when the Drainage was from the North into the Weald. Wealden Gravels of the later part of the same period. (some of these contain flint and Tertiary pebbles.) Gravels, &c both within and without the Weald, which are due to, or re-arranged by drainage in its present direction. N.B. Alluvium and Modern Shingle omitted. The lines with barbed ends, are those of disturbance which have passed through the Thames gravel. The lines numbered 4, 5, 10, 11, 13, 14 and 15 indicate those of sections with corresponding numbers at pages 398, 406, 409, 412 and 415 of the 23rd Vol. of the Journal. = Escarpments, Ridges and Valley slopes.

S.V.W. Jr del.

accompany the Map; but those numbered 4, 5, 10, 11, 13, and 14 indicate the lines of the sections given by me at pp. 394 to 417 of the 23rd volume of the Quarterly Journal of the Society, which have corresponding numbers attached to them there.

The two small maps are intended to make intelligible the changes of the distribution of land and water to which I trace the denudation of the Weald. The first (No. II.) is intended to represent an earlier stage, viz. that when the higher gravels of the Thames, East Essex, and Canterbury heights were being accumulated in inlets filled with salt water, and before the conversion of those inlets into a fluviatile condition had been effected by means of elevation. In this the higher elevations of the North and South Downs and of the Lower-Greensand country are represented as islands, the wear of whose shores and of the Lower-Tertiary and Chalk inlet shores supplied with some Lower-Greensand material the large accumulations of flint and pebble that make up the Thames and East Essex gravels, and supplied the flint to the Canterbury gravel. The highest ridges of the Hastings-sand country are also represented as islands. In the river-beds into which the more northern parts of these inlet channels became converted, accumulated the Brick-earths with *Cyrena fluminalis*, occurring at Clapton, Ilford, Erith, and Grays within the Thames inlet, at Clacton and (according to the President's statement in the discussion) east of Southend in the East-Essex inlet, and at Chislet in the Canterbury area. This shell, unknown from the south or south-west of England, regarded by me as mostly under the sea during this period, ranges north to Yorkshire over the country regarded by me as land. During the transition period preceding the establishment of these *Cyrena*-rivers, those angular blocks (said to be Greywethers) occurring at Grays in a brickearth on the slope above the *Cyrena*-deposit, but a little below the great sheet of Thames gravel covering the plateau, would seem to have been carried in on ice by tidal action*.

The elevation, and the consequent shrinking and partial breaking up of these inlets so as to form river-channels, I regard as a first result of the disturbances under which the sea so retreated as to cause the distribution of land and water to become eventually as represented in Map No. III.† The upthrow of the Guildford Hogsback ridge and of the ridge of Portsdown Hill (shown by lines on Map No. II.),

* These blocks are clearly not derived at second-hand from the Glacial beds of Essex, as supposed by Prof. Morris (Geol. Mag. vol. iv. p. 63); for they are numerous, all alike, generally with sharp fractures, and all collected in one small area; whereas in the Glacial beds of East Anglia large blocks are not common, and what there are consist of divers rocks, and are mostly rounded.

† The commencement of the disturbances of which these rectilinear and highly inclined ridges are the intensified result was, I consider, coincident with the rise of England from the glacial sea, and the cause of the great denudation effected during that rise over both the south-west and the south-east of England. The margin of this complete denudation is distinctly marked by the abrupt termination of the glacial beds, at altitudes exceeding 300 feet, on the Essex heights overlooking the Thames valley. Over the region south of these heights it is obvious that, besides the glacial beds, a considerable mass of the older tertiaries, and probably also much of the chalk and subcretaceous strata, were removed

contemporaneous, as I consider, with the similar rectilinear ridges of the Isles of Wight and of Purbeck, represent, I submit, the elevatory influences under which the chalk area of Hampshire and of Wilts became converted into land, and under which the Wealden upcast acquired that special configuration which gave to the up-channel tide its great scouring power. In No. III. the sea is shown as confined within the chalk escarpments of the Weald, with a barrier of land extending across to France and shutting off the British Channel from the North Sea; while a part of the area now occupied by this sea between East Anglia and the north of France was in the condition of land supplying streams that found their way through the Stour and Medway gorges into the Weald, so much of the drainage as passed through the Thames valley * reaching the Weald through the gorges of the Wey and Mole to the west. The gravel-beds, with remains of an ancient beach, described by Mr. Prestwich and by others near Calais, appear to me to fall into their place between the two stages thus represented, while the Brighton bed seems to belong to the period represented by No. III. and to that following it. It will not be difficult to pursue the change from the stage thus represented in No. III. to that when the shore had become established at the Lower-Green-

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by this preliminary *postglacial* denudation; while to the north of the Essex heights, away to the northernmost extremity of Britain, the parts once covered by the same glacial sea, being remote from the theatre of these disturbances, felt their influence only in the form of a tranquil elevation, and were consequently only partially denuded of their covering of glacial beds. It was during a lull in these disturbances, and when this preliminary denudation and emergence had brought about the conditions represented in Map no. II., that the Thames gravel accumulated; so that more properly it was a renewal, and not the setting-in of these disturbances, which, first completing the sharp inclination of the rectilinear ridges, then lifted them, together with those portions of the chalk and subcretaceous districts which had not yet emerged, above the sea, and, by renewing the causes of denudation, removed this accumulation everywhere except in the places where we now find it (which it seems to me were the parts of least disturbance at the particular epoch), eating also still deeper into the old strata as they underwent elevation from the waters. I have elsewhere (Quart. Journ. Geol. Soc. vol. xxiv. p. 174) endeavoured to connect this renewal of disturbance in the south with the setting-in of that depression in the north of England to which was due the postglacial clay of Hessle, which wraps like a cloth the deeply denuded glacial beds, and is underlain by a gravel containing the characteristic shell of the Thames beds and their allies, the *Cyrena fluminalis*.

* The amount of drainage collected in the Thames valley east of London at this period could have been but small, because the entire bottom of this valley, east of London as far as Erith, which is now occupied by the marsh mud, and which, if the embankment were removed would be all flooded, is covered by an oak, yew, hazel, and fir forest, rooted into the gravel and overspread by the marsh mud. It is clear from this, that subsequent even to the latest part of that gravel, but prior to the general depression of England, which buried so many forests remaining round our coasts, as well as the forest in question, the bottom of this valley, far within limits that, but for the embankments, would now be water, was dry ground. It is this depression of so much of England, at a late period, that I associate with the opening of the mouths of the Thames and Crouch, and the occupation by the present North Sea of the large area to the north of Kent, shown in Map No. III. as land. This general depression seems to have been the recoil from the termination of the Wealden elevation.

sand escarpment, with the Medway and Stour still discharging into the Weald. All that remains, then, is to imagine the land to the north of Kent depressed coincidently with the continued elevation of the Weald, so as to produce an opening through the Straits of Dover* and the introduction of the North Sea, where it now is, with the denudation of the Thames and Crouch mouths taking place synchronously with the desertion of the Weald by the sea, and the condition of things under which the drainage would acquire its present direction is then attained. The terrestrial surface described by Mr. Godwin-Austen as underlying at one place gravel of the Wey seems intermediate between the desertion of the Weald by the sea and the introduction over the spot of the waters of the river Wey, which came into existence by means of that reversal.

In all this, I can but see the most ordinary and gradual changes that must take place wherever land under the influence of active subterranean disturbance is changing its level, pushing back the sea in one place and admitting it in others; and that the elevation of the Weald was accompanied by energy so active as to force the whole thickness of the chalk into the Guildford Hogsback ridge is a matter of universal admission. As this has admittedly occurred since the Eocene period, is it at all incredible that it should have taken place since the Glacial period? considering that beds whose fossils indicate a parallelism with the Crag and earlier Glacial beds, have become elevated in Sicily into mountain tracts. The Oxus has deserted its bed within historical times, and now follows another course to the Caspian.

Postscript.

Since the foregoing paper was sent in, the Journal of the Society, no. 104, containing Mr. Codrington's well-considered paper on the Hampshire and Isle-of-Wight deposits, has appeared (vol. xxvi. p. 528). The carefully prepared sections given by that gentleman, illustrating the position of the gravels which cover so much of the Hampshire Tertiaries, have an important bearing upon the subject of the present paper, and seem to me powerfully to corroborate the mode of origin and conditions of sequence which, in the present and former papers, I have endeavoured to substantiate in the case of the gravels of the London area.

It will be seen that the whole of the great gravel sheet illustrated by Mr. Codrington's sections is, like the Thames, East-Essex, and Canterbury-heights gravels, cut off abruptly by denudation on lofty brows towards the chalk country; while in the opposite direction it descends gradually from these brows towards the sea.

While the gravels of the London area, having been formed in inlets, are necessarily thus cut off on brows towards the chalk

* I think it probable that the land between Kent and Calais was low in the central part, the Wealden elevation having been least in the easterly direction. The wearing back of the cliffs to the point where they cut across the chalk escarpment is a subsequent process still going on.

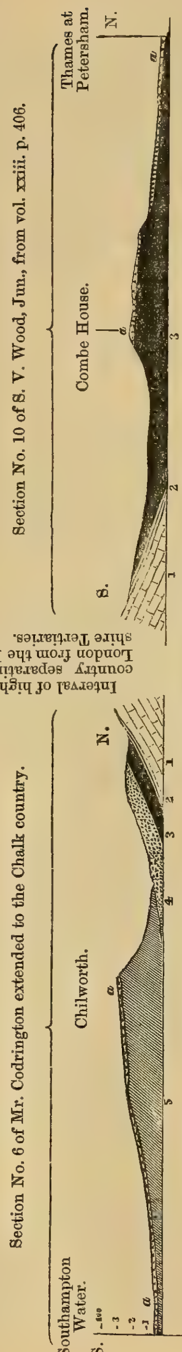
country in those directions only where the inlets opened to the sea (the gravel within the inlets remaining comparatively undisturbed), the Hampshire high-brow gravels are *everywhere* so cut off in the direction of the chalk country—as they would be, supposing them, as I do, to be a remnant of the open sea-bottom of the period. All the numerous sections given by Mr. Codrington present this feature; and though they omit the delineation of the older Tertiaries upon which the gravels rest, an examination of the distribution of these tertiaries as delineated in the Hampshire maps of the Geological Survey will show, by comparison with the sections of Mr. Codrington, that the gravels here have partaken, along with the tertiaries upon which they rest, of that denudation which was consequent upon the upcast of the chalk country. Mr. Codrington regards these gravels as the deposit of an estuary of the sea, some twenty miles wide, that was bounded by the chalk country to the north as land; and so I agree they were, but not at that early stage when the gravel capping the brows of elevation (to altitudes of 400 feet and upwards) rose out of the sea. At *that* time the gravel of the Hampshire high brows stretched, I conceive, across the chalk country into connexion with those gravels of the Thames, East-Essex, and Canterbury sheets which now occupy similar brows of denudation, the conditions of land and water being those represented in Map No. II., save that there may have been many islands of chalk over Hampshire that I have not ventured to represent. The marine denudation, consequent upon the upcast of the chalk country, swept off this continuous gravel sea-bottom from the parts subjected to the principal elevatory movements, and cut back the older tertiary outcrops, with their gravel covering, into the condition of brows just discussed, such brows being lifted above the sea. To the south, towards the Southampton water, the but little disturbed sea-bottom continued to receive and preserve gravel accumulations, which formed a more or less continuous sheet with the gravel which had become land on the brow-tops; while to the north, in the Thames valley, the waters, now converted into the fluviatile condition, continued to deposit gravel and brickearth, which inosculated with those portions of the earlier or marine deposits that had remained undisturbed, but formed terraces beneath the earlier-deposited gravel where this had been elevated*.

I here reproduce a reduction of section 10 of my paper in the 23rd volume of the Society's Journal†, placing beside it one taken from Mr. Codrington's section 6, but extended so as to reach the chalk country, and having the older Tertiaries inserted in it—in order that the identical features which the gravel brows of either area present

* These marked terraces, where they exist in the Thames area, are shown in Map No. I., and the lower terrace deposit indicated by a different set of dots and lines from the main-sheet gravel. Where no such marked terrace exists, the older and newer portions of the Thames gravel are shown necessarily under the same kind of dotting.

† In the original section the denuded shelf separating, along the line of section, the gravel on the brow from that at lower level (with which, however, it inosculates in other directions) was not shown; but it is corrected in the present section.

Fig. 1.—The Aspect presented by the Gravel Brows of the Thames and Hampshire Areas towards the Chalk Country.



1. The Chalk. 2. The Thanet and Woolwich beds. 3. London Clay. 4. Lower Bagshot. 5. The Bracklesham Beds. *a, a.* The respective Gravels of the Thames and of the Hampshire sheets.

in relation to the chalk country that separates them may be more readily apparent.

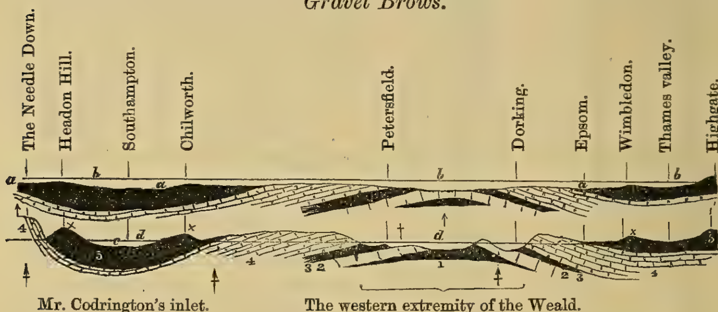
Further, Mr. Codrington shows that these gravels cap, in the form of outliers at an altitude of 400 feet, the chalk ridge stretching from east to west through the Isle of Wight, the elevation of which, like that of the Hog's Back and of Portsdown Hill, followed, as I contend, the Thames gravel, and was coeval in its formation with the upcast of the chalk over the south of England. The double section (page 26) will make more intelligible the views which I hold of the relation of the two gravel-areas to each other, its direction being indicated by a line on Maps II. and III.

The upper representation shows the condition of the Chalk and Tertiaries after the Glacial period, and the removal by denudation of the glacial beds, whose brow of denudation occupies the northern side of the Thames at elevations reaching to upwards of 300 feet. The removal of the Tertiaries and Chalk had been partially effected by this same denudation, but mainly effected by that preglacial denudation associated with the curvilinear configuration to which, in the footnote at pages 21 and 22, allusion has been made.

This upper representation is that of the state of land and water in Map II., while the lower shows the same after the upthrow in which the rectilinear ridges of Portsdown Hill, the Guildford Hog's Back, and of the isles of Purbeck and Wight originated. By this upward movement the chalk country was converted into land, the sea confined within the Weald on the one side, and Mr. Codrington's inlet established on the other; while the part of the tertiaries nearest the surface became elevated with their gravel covering, and cut back by the denudation into the form of scarped brows.

While, however, the high brows of the Hampshire gravel are thus, I contend, coeval, or nearly so, with the high-brow gravel of the Thames, East-Essex, and Canterbury sheets, the lower-terrace beds of the Thames gravel formation are not, I venture to suggest, coeval with the Elephant-gravels of Mr. Codrington, but are con-

Fig. 2.—*Theoretical Section connecting the Thames and Hampshire Gravel Brows.*



1. Weald clay. 2. Lower Greensand. 3. Gault, Malm Rock, and Upper Greensand. 4. Chalk. 5. The Lower Tertiaries. *a.* The sea-bottom on which the high-brow gravel of the Thames and Hampshire sheets accumulated. *b.* The sea-level of *that* period. *c.* The sea-bottom of the inlet wherein the lower Hampshire marine gravels accumulated. *d.* The sea-level of *that* period. The × × × mark the high brows of gravel of the London and Hampshire areas. † The part over which the sharply broken flint accumulations of Sir R. I. Murchison occur. ↑ indicates the foci of preglacial upheaval. ⇞ indicates those of postglacial upheaval. (N.B. The Needle Down should in the upper representation have been drawn free of Tertiaries and near the sea surface.)

siderably anterior to them, and possess a well-known older and somewhat different fauna, both mammalian and molluscan, though of course posterior to the highest-brow gravels of either area. In other words, the great slope of gravel which Mr. Codrington shows as stretching from low levels (where it inosculates with the Elephant-gravels of the valleys) up to brows where it is cut off by denudation at elevations of 400 feet, represents, according to my view, that long postglacial period during which, over Surrey, Sussex, and Kent, those extensive changes of land and water were proceeding which resulted in the denudation of the Weald—the Selsey deposit (which I have correlated with the retirement of the sea within the Wealden escarpment) being covered by the lowest-level portion of the Hampshire sheet.

Discussion.

Mr. Godwin-Austen thought that the author had done his theory injustice in presenting only a portion of the Wealden area for consideration. He remarked that phenomena similar to those of the Weald were to be found in various parts of Western Europe. He was glad to find that Mr. Searles Wood did not regard the escarpments as representing marine cliffs; but he did not attach sufficient weight to the absence of any material of marine origin at their base; so that there was no evidence of the presence of the sea within the Wealden area. He differed wholly from the author as to the age of the gravels; for beneath the gravels were silty beds containing Elephant-remains. These gravels he was inclined to refer to a glacial period, as they contain blocks such as could have been transported only by the agency of ice. The elephants found in the valley of the Wey are of the species (*E. primigenius*) which also occurs in the Selsey beds; and he believed both to be of glacial age. As to the theory of the denudation of the Weald, he professed himself a convert to the views of Messrs. Foster and Topley, and cited what was now going on around Heligoland in illustration of denudation.

Mr. Whitaker observed that the present absence of gravels along parts of the valley of the Thames affords no proof of their not having formerly existed. He pointed out the soft and friable nature of most of the rocks of the Wealden, which would account for their absence in the gravels. The only really hard rock was the Chert of the Lower Greensand, which was abundant in the gravels of East Kent. Angular flints occurred at the base of the chalk escarpment wherever it had been carried back by denudation. The major valley of the Weald had been spoken of; but he denied that any such valley existed; it was merely a series of numerous small valleys. He could not conceive the rivers flowing against the dip of the strata, as supposed by Mr. Wood. He did not agree in the view of the denudation of the Weald being such an enormous affair, but thought that it might be due to comparatively small causes.

The President pointed out that beyond Southend there was a section precisely similar to that of Grays. It was a mistake to suppose that pebbles from the Wealden area did not occur in the Thames gravels. He thought that much of the denudation of the Wealden area might have taken place before the glacial period. The presence of Tertiary pebbles in the Wealden area might readily be accounted for by their presence at the edge of the escarpment.

Mr. Searles V. Wood, Jun., in reply, justified himself for having limited his observations to the northern part of the Weald, as it was there only that it could be brought into juxtaposition with the Glacial beds. He maintained that, under certain circumstances, no beaches or marine beds were formed at the base of sea-cliffs. He pointed out that in Postglacial gravels large blocks of rock were frequently found, and protested against limiting all ice-transport to the glacial period. He could not recognize the Selsey beds, with 150 living species, some of southern character, and none extinct, as glacial. The alleged softness of some of the Wealden rocks, when the great excess both of the Lower-Greensand and Hastings-sand areas over that of the Chalk was considered, did not at all remove the contradiction presented by the enormous preponderance of flint over subcretaceous material in the East-Essex gravel. Like Mr. Austen, he attributed the Wey gravels and the Selsey bed to nearly the same period; but that was a late postglacial, instead of a glacial one.

November 23, 1870.

The following communications were read:—

1. *On* some points *of* South-African Geology.—Part I. By G. W. Stow, Esq.*

(Communicated by Prof. T. Rupert Jones, F.G.S.)

[Abstract.]

In this paper, which was illustrated by numerous sketches, sections, tables, and specimens, observations were made on the stratification of the Jurassic beds of Sunday's and Zwartkop's rivers, resulting from researches made by Mr. Stow, with the view of determining the exact position of the several species of fossils found at the exposures on the cliffs of these rivers, and from this the sequence of the various beds. He indicated the existence of at least nine separate fossiliferous bands, pointing out the relative positions of the several *Trigonia*-beds, Hamite-beds, Ammonite-beds, &c.

He next treated of the so-called Saliferous beds of the district, and gave his reasons for regarding them as later in age than the *Trigonia*-sandstones above alluded to, and therefore not equivalent to that part of the series named "Wood-beds" by Dr. Atherstone.

Other researches of the author related to the Tertiary beds, both inland and on the coast. He distinguished three zones on the coast later in date than the high-level shell limestones (Pliocene ?) of the Grass Ridge and other parts of the interior. One of the coast-zones he named the *Akera*-bed, from the prevalence of a delicate species of that genus. Another zone was described as following the river-valleys in the form of raised terraces, characterized by the presence of a large *Panopæa*. The latest shell-banks have been thought to be kitchen-middens; but the author regarded them as shore-deposits in place. The author concluded by tracing the probable climatal and geographical changes in this region during geological times, and indicated, as far as his material allowed, the probable migrations of the Mollusca, especially of the *Venericardia* characterizing the Pliocene Limestone.

Discussion.

Mr. J. Gwyn Jeffreys remarked that all the shells belonging to the genus *Akera* which he had examined were shallow-water or littoral shells.

Dr. Duncan remarked on one of the corals as being of a well-known Crag form, the *Balanophyllia calyculus*.

Mr. Searles Wood, Jun., remarked on the importance, if the conclusions of the author were sustained, of the older post-tertiary beds denoting a warmer climate than the present, instead of, as in the Northern Hemisphere, a colder.

* The publication of this paper is deferred.

2. *Note on some* Reptilian Fossils *from* Gozo.

By J. W. Hulke, F.R.S., F.G.S.

These fossils were collected by the late Captain Strickland, and forwarded by Mrs. Strickland, for examination and description, to Mr. Busk, who intrusted me with them for this purpose, informing me at the same time that they came from Gozo, the Gauda of Strabo, an island adjoining Malta, reputed miocene.

As one of the fossils indicates, I believe, a new crocodile, and the other, if Gozo be really miocene, if the jaw actually came thence, and if my determination should prove correct, shows the survival of an *Ichthyosaurus* to a much later period than that of the upper white chalk, the most recent formation in which any remains of this genus have yet been found, they seemed to me worthy of being brought under the notice of this Society.

Ichthyosaurus gaudensis.

The fossil which I venture to refer to the genus *Ichthyosaurus* is the symphysial part of a long slender mandible. The front end is wanting; and the rami have also been broken off just behind the symphysis. In its present mutilated state it measures 9 in. long, 1·2 transversely in front, and 2·1 at the posterior limit of the symphysis. Its outer surface is transversely gently convex, smooth, and finely wrinkled longitudinally. The upper surface presents a smooth narrow median tract, in front greatly convex transversely, behind slightly concave in the same direction, mesially divided by the symphysial suture, in which posteriorly the splenial element is discernible. This is bordered externally by a line of shallow tooth-pits, separated by low transverse ridges, the outer ends of which ascend a short distance on a low parapet formed by the slightly higher outer edge of the dentary bone. Most of the pits are empty; and their smooth surface shows the absence of any firmer bond of union than the gum between the teeth and the mandible.

Fig. 1.—Tooth of *Ichthyosaurus gaudensis.*

Natural size.

The teeth are conical, the crown is slightly compressed, its transverse section elliptical; the fang is simple, of a bulbous figure, its exterior is smooth, its base slightly contracted and rounded. The principal tissue is a simple tubular dentine, in the crown covered by a thick enamel, while in the fang it is enveloped by a stout capsule of cementum. A pulp-cavity rises through the fang for some distance into the crown. A minute plug of spar fills its upper end; and its lower end encloses a little mass of osteo-dentine, which is continuous, through the contracted basal end of the cavity, with the external cementum.

Twenty-one teeth occupy a space of 8 inches. The length of a fang slightly exceeds ·3″, the diameter (including the capsule) averages ·3″, and that of the dentinal cylinder minus its investing capsule ·15″. The apices of all the crowns are broken off, so that the entire length of the teeth is not determinable.

In their form and structure these teeth repeat so closely the characters of those of the Kimmeridge *Enthekiodon* as to suggest the great probability of their both belonging to the same genus. My note on *Enthekiodon**, communicated last session, noticed the resemblance of its teeth and of the mode of their attachment to the jaw to those of *Ichthyosaurus*; but my material was too imperfect to justify me in certainly referring it to that genus. I have now, however, indisputable evidence that it is a true *Ichthyosaurus*; and this being so, the similarity of the dental characters of this Gozo mandible to those of *Enthekiodon* affords a strong presumption that it also is Ichthyosaurian.

Crocodilus gaudensis.

The skull is in form elongated and subtriangular. Its sides converge regularly from the posterior and outer angles of the quadrate bones to the 8th tooth, counted from behind. From this they are nearly parallel, to the 14th tooth, in front of which the snout is slightly contracted where the premaxillo-maxillary suture crosses its alveolar border. The end of the snout, including the external nostril, is wanting.

The syncipital area is a nearly flat oblong, measuring transversely along its posterior border 5″·4, along its anterior border (a line connecting the anterior and outer angles of the postfrontal bones) 5″, and from front to back 3″·2. The entire surface of this area is symmetrically pitted. In its frontal part, which is hollow transversely and plane axially, the pits are grouped in lines diverging from the axis of the skull, and there is a large remarkable pit in each posterior angle of the area.

The supratemporal fossæ are very large, and have an angulated pentahedral shape. Their transverse diameter, slightly larger than the others, is 1″·8. The intervening parietal bone has a minimum width under ·1″.

The interorbital space is narrow, hollow transversely, plane axially, and less strongly pitted than the syncipital area.

The orbits are large, their contour is subtriangular, incomplete behind; they look directly upwards; and their long diameter is directed from behind forwards and inwards. The outer, front, and inner part of their margin is raised; and the front part is channelled by two grooves, of which one descends longitudinally on the prefrontal bone, and the other along the junction of the prefrontal and lachrymal bones.

The nasal bones posteriorly reach the level of a line joining the anterior angles of the orbits, and, descending the snout in the form

* Quart. Journ. Geol. Soc. vol. xxvi. p. 172.

of two narrow slips, they meet the præmaxillæ opposite the interspace between the 11th and 12th teeth, counted from behind. For some distance above and below this spot, the widths of the nasals and of the ascending slips of the præmaxillæ are so nearly equal that the junction of the two pairs of bones is inconspicuous and may easily be overlooked.

The prefrontals form rather less than half of the inner border of the orbit, and they are marked by the groove already described. The lachrymals descend along the outer border of the nasals nearly as far again as the prefrontals.

The upper surface of the snout has been flattened by pressure. It is marked with a rather coarse longitudinal wrinkling. The borders of the snout are even behind the 8th tooth, but in front of this the prominence of the alveoli makes them slightly crenated.

The under surface of the skull has the common features of a crocodile's. The mesial borders of the palatine and pterygoid bones meet throughout their length. The posterior nares, wholly included within the posterior border of the connate pterygoid alæ, look backwards. The transverse diameter of their opening slightly exceeds the axial diameter. The pterygo-palatine foramina are long and narrow, their inner border is nearly straight, and their outer border is concave.

The occipital surface of the skull is nearly plane vertically, slightly convex transversely above the foramen magnum, and external to this slightly hollow.

The mandibular symphysis, with about 4″ of both rami behind it, and nearly as much in front of it, remains attached to the under surface of the snout. The symphysis begins opposite the interspace between the 7th and 8th maxillary teeth, counted from behind. The splenial bones are included in it.

The teeth are subequal, conical, sharply pointed; when fully extruded slightly retrocurved, unequally compressed laterally, the outer surface more convex than the inner one, the compression increasing towards the apex of the crown, and forming here a back and front smooth edge. The hinder maxillary teeth are shorter, they taper less, and are more compressed than those in front. The fang is large, and it has a capacious, open pulp-cavity. The crown has a thick coat of enamel, which on the outer side of the tooth is marked by low longitudinal striæ, widely set near the base, and closer and finer near the apex; on the inner side it is extremely finely striated or, rather, wrinkled.

A label affixed to the fossil before it came under my hands, and when it was still nearly hidden in the matrix, showed that it had been referred to *Melitosaurus champsoides*, Owen. I have compared it with the type specimen of this species in the British Museum *, and find that it agrees with this in the long mandibular symphysis, in the narrowness of the ascending processes of the præmaxillæ, and in the

* The terminal 13 inches of the maxillæ and mandible of a large crocodilian.

manner of union of these with the nasal bones; but the teeth differ: those of *Melitosaurus champsoides* (making allowance for the much larger size of the individual) are stouter, much less sharply pointed, and less tapering; their enamel marking has also a different character, being much more finely wrinkled than in this Gozo crocodile.

In its elongated form and its regularly tapering outline (not suddenly contracted in front of the orbits as in the Indian gavial), in the commencement of the nasal bones opposite the front borders of the orbits, in the slenderness of these bones, and in their insensible junction with the ascending processes of the præmaxillæ the skull of the Gozo crocodile resembles that of the existing *Rhynchosuchus Schlegelii*; but it differs from it in several particulars, amongst which are the crenation of the alveolar border of the distal halves of the snout, the more oblong shape of the syncipital area, the larger size and different shape of the supratemporal fossæ, the raised margin of the orbit, and the more hollow interorbital space. I propose for this Gozo crocodile the specific name of *gaudensis*.

Dimensions.

	in.
From the posterior border of the syncipital area to the anterior	3·2
From ditto to the anterior border of the parietal bone	2·1
From ditto to the anterior limit of the frontal bone	6·7
From ditto to the posterior limit of the prefrontal bone	4·0
From ditto to the anterior limit of the prefrontal bone	6·1
From ditto to the anterior limit of the lachrymal bone	7·1
From ditto to the anterior limit of the nasal bones	14·6
From ditto to the posterior limit of ditto	13·5
From ditto to the last maxillary tooth	4·6
Breadth of syncipital area, its posterior border	5·4
Ditto, its anterior border	5·0
Supratemporal foramina, axial diameter	1·7
Ditto, transverse diameter	1·8
Interforaminal parietal septum, minimum width under	0·2
Orbits, distance between their inner borders	1·0
Axial diameter of	2·3
Transverse diameter of	1·5
Breadth of skull at hindermost tooth	5·2
Ditto at 10th tooth from behind	2·6
Ditto in front of 14th tooth	1·6
Length of 6th maxillary tooth	1·6
Antero-posterior diameter of 10th maxillary tooth at the junction of the crown and fang	0·4

Discussion.

Dr. Duncan suggested that the Ichthyosaurian fossil might be derivative from some secondary rock. He mentioned that Dr. Leith Adams had once sent him an *Aspidiscus cristatus* from the Hippurite Limestone, which was stated to have come from Malta. To account for this, he suggested that the Miocene of Malta might have been supported on beds of Cretaceous age, and fossils from that source might have become imbedded in the coral reefs of the later date.

Capt. Spratt expressed a doubt of the fossil having really come from Gozo. He did not recognize the cretaceous-looking matrix as belonging to any of the rocks of that island, with all of which he was acquainted. The nearest approach to that kind of rock was to be found in the lowest of the deposits near Cairo, which were probably Eocene.

Prof. T. Rupert Jones suggested an examination of the Foraminifera in the matrix, with the view of determining its Secondary or Tertiary age. He mentioned the occurrence of rolled nodules of older rocks in beds of later age at Gozo.

Mr. Busk stated that a stone of similar character to the matrix occurred in Malta, if not in Gozo, but probably in both.

Mr. Hulke, in reply, observed that he had in his paper intentionally left the stratigraphical part of the question untouched, and confined himself to the palæontological aspect of the remains.

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3. *On the* Discovery *of a* "Bone Bed" *in the* lowest *of the* "Lynton Grey Beds," North Devon. By F. Royston Fairbank, M.D.

(Communicated by Prof. Duncan, M.B., F.R.S., Sec. G.S.)

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THE

QUARTERLY JOURNAL

OF

THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

December 7, 1870.

The Rev. J. W. Todd, D.D., Tudor House, Sydenham, S.E.; The Hon. Henry Ayers, Adelaide, South Australia; R. W. Peregrine Birch, Esq., C.E., Palace Chambers, Westminster, S.W.; Alfred Stair, Esq., 4 Surinam Terrace, Stratford, Essex; H. Rivett Carnac, Esq., of Simla, E. Indies; Thomas Davies, Esq., 47 Rutland Road, South Hackney, E.; the Rev. S. H. Cooke, Northbourne Rectory, Deal; J. S. Courtney, Esq., Penzance; John Johnson, Esq., C.E., Chilton Hall, Ferry Hill, Durham; the Rev. R. H. Morris, M.A., Principal of the Training College for South Wales and Monmouthshire, Caermarthen; and Joseph Drew, Esq., J.P., Belgrave Terrace, Weymouth, were elected Fellows of the Society.

The following communications were read:—

1. *Remarks on some* Specimens *from* South Africa. By George Grey, M.D., of Cradock, Cape Colony.

(Communicated, with Notes, by Professor T. Rupert Jones, F.G.S.)

[Abstract.]

Specimens.—§ A. From the *Karoo Formation.*—1. Rippled sandstone; 2. Shale with *Estheriæ,* near Cradock; 3. Skulls and bones of two or more species of *Dicynodon*; 4. Water-worn slab of sandstone, containing the skull of a Labyrinthodont (?); 5. Block of coal, from the north-east margin of the Stormberg range; 6. Fossil plants from the same locality, comprising *Lepidodendron* *, *Sigil-*

* [Dr. Rubidge also refers to *Lepidodendron* as a Karoo fossil plant, in Quart. Journ. Geol. Soc. vol. xii. p. 237. Dr. Grey's specimen is in a hard, dark, micaceous shale; and Mr. Carruthers, who has kindly examined this and the associated fossil plants, says that it belongs to *L. crenatum* (Sternberg). On the same slab he observes portions of the stems of *Calamites,* perhaps of three species, such as those that have a very slender periphery.—T. R. J.]

*laria**, *Pecopteris*†, *&c.*; 7. Ferruginous sandstone, with a thick dendrites weathered out on its surface, from the same place; 8. Sandstone, with fucoid (?) markings, from the same place.

§ B. From the *Carboniferous Rocks* of Lower Albany.—1. Black shale (slickensided), with *Stigmaria*; 2. Dark-grey granular quartz rock, with pyrites, from near the shale.

§ C. *Crystalline Rocks.*—1. A variety of brownish steatite, fit for carving, from the Transvaal; 2. Massive prehnite, from Bankberg, Cradock.

§ D. *Crystalline Rocks from the Diamond-bearing Localities of the Orange and Vaal Valley.*—1. Block of calcite, from the Orange-river district; 2. Specular iron-ore; 3. Galena; 4. Block of crystallized quartz and galena; 5. Lydite, with pyrites; 6. Tremolite; 7. Selenite; 8. Amethyst, quartz, agate, and garnet, from the gravel.

Remarks.—With reference to A, No. 1, the direction of the prevalent currents of the Karoo formation might be learned from a study of these rippled surfaces. No. 2. Excavating the shales to examine if they would yield roofing-material, the author found these little bivalves [which are *Estheriæ*, of a new species—T. R. J.]. They were found at one spot only. No. 3. These are water-worn, and furnish evidence, the author thinks, of great aqueous denudation. Their matrix is often, if not generally, permeated by igneous rock. [These and other specimens have the appearance of bones imbedded in *volcanic ash.*—T. R. J.]

Of the country formed of the Karoo strata Dr. Grey observes:—The sweet-grass country, Dutch "Zout-Veldt," yielding the valuable Karoo plant (*Adenachœra parviflora*) accompanies the *Dicynodon-* (Karoo) beds of the great plateau, beginning on the eastern side from about Queenstown, where the pasturage is of a mixed character, locally "Gebrokenveld." From that district it is traceable as in Bain's map, with its margin and watershed on the Zuurberg &c. The author is inclined to think that the bones of the Dicynodons were deposited in the shallow waters of an inland sea—the salts of soda that predominate largely in the salines of the soils of the great Karoo plains, and help to form the "back-grond" of of that region (sandy soil impregnated with common salt and carbonate of soda ‡, and some salts of magnesia and alumina), supporting him, he thinks, in this view §.

* [The cast of a portion of decorticated stem, in hard blue shale.—T. R. J.]

† [In a dark shale. Mr. Carruthers regards this *Pecopteris* as being probably *P. Cistii* (Brongniart). *Alethopteris Lonchitidis*, Stbg., and *Asterophyllites equisetiformis*, Brg. also accompany the foregoing.—T. R. J.]

‡ The ash of some native plant ("Ganna-bush") growing on the plains is used extensively by the Boers in making hard soap, and contains a large percentage of carbonate of soda. The impure carbonate (lixivium), first mixed with sheep's tallow, is deprived of its carbonic acid by a long process of boiling, requiring two or three weeks to be properly effected.

§ [The presence of *Estheria*, which, as a genus, inhabits brackish water, is inimical to the idea of an open sea having formed the Cradock beds, though inland brackish lakes would not be inconsistent. A fragment of an Encrinite (in the Society's Museum) in one of the brecciated limestones of the Rhenosterberg

No. 4. This was forwarded to the author by a friend, who found it on his farm, at the southern margin of the Stormberg, a few miles south of the outcrop of the coal there.

No. 5. This coal is from Mr. H. J. Baillie's best coal at Andries's Nek. Dr. Grey states that some lignite occurs with it, and that some of the coal near by is hard and anthracitic. The specimen was taken not far from the surface; and Dr. Grey observes that this coal does not all burn very satisfactorily; but some of it gives out a moderate amount of heat, flaming for a limited time. Andries's Nek is about twenty-five miles north-east of Queenstown; and its coal is supposed to be the same as that of the Stormberg.

The coal-seams show themselves mainly on the northern slopes of the Stormberg range, where they are thin and shaly, alternating with softish dark-coloured sandstones and purple marls. They are from 400 to 800 feet above the base of the mountains, and are exposed in the hills and ridges [of the flanks?]. The coal is often pyritous; and igneous dykes appear to have rendered much of it anthracitic. Graphite, with black shales, has been found in the north-western range of the Stormberg *.

Mr. Vice's Stormberg coal, got by a shaft, sells at a fair rate at the nearest villages. Considering the small population of the district, the distance of the Stormberg inland, cost of transport, and scarcity of labour, the Stormberg coal cannot be worked largely as yet †.

B, No. 1. [Mr. Carruthers remarks that, although this has somewhat the look of *Cyclostigma*, it is a true *Sigillaria*, with a rootlet, and that its stigmata are smaller and more numerous than in any published forms.—T. R. J.]

The Lower-Albany coalfield is being explored by a Governmental Survey. The reports are rather encouraging; but seams of really good coal do not yet (summer of 1870) appear to have been reached there. [In the micaceous shales of this series, collected by Mr. Neate at Port Alfred, Mr. Bristow, F.R.S., has detected *Sigillaria*, *Stigmaria*, *Lepidostrobus*, *Halonia*, and *Selaginites*, as reported by him to the Colonial Secretary in May 1870.—T. R. J.]

D, No. 2. This in particular was sent to the author from a spot where a large diamond was found. Dr. Grey visited the diamond-yielding districts of the Orange and the Vaal some years ago, and noticed the presence of primary crystalline rocks among the gravel and in the tufa of the alluvium. He now remarks that the conglomeratic alluvium is like that described as occurring in Brazil and other places where diamonds are found. He doubts the diamonds of the Vaal and Orange rivers having been derived from the Draakensberg.

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is almost, if not quite, the only marine fossil known in the Karoo beds (Quart. Journ. Geol. Soc. vol. xxiii. p. 143).—T. R. J.]

* [See also Dr. Rubidge's observations on these changes of the Karoo coal by volcanic heat, Quart. Journ. Geol. Soc. vol. xii. p. 7.—T. R. J.]

† [Notes by Mr. Evans and Dr. Atherstone on the Stormberg Coal were published in the 'Mining Journal' of January 14, 1871.—T. R. J.]

To the Secretary of the Geological Society.

Yorktown, January 28, 1871.

Dear Sir,—Subsequent to the reading of Dr. Grey's "Notes on some Fossils from South Africa," it occurred to me that it is highly probable that the upper or "Stormberg" division only of the "Karoo formation" reaches so far north as the Orange-River Free State, the middle and lower divisions never having been deposited in that region. In this case, the Stormberg strata (of Secondary age) containing the coal with *Palæozamiæ* (Atherstone and Stow) have overlapped the Lower Karoo beds, and have been deposited directly on palæozoic rocks continuous with those of the Transvaal. These old rocks might well be of Carboniferous age, with old coal; for the Devonian rocks appear to the north in the Transvaal; and in Natal the Karoo beds are said by Mr. Griesbach to occur in proximity to the Carboniferous rocks, but unconformably and separated by igneous intrusions. In the Stormberg, therefore, it is possible that the Karoo coal-beds may be resting on the old Carboniferous rocks; and these latter may have yielded the really old coal-plants that have been sent by Dr. Grey from the Stormberg section, and which were also referred to by the late Dr. Rubidge some years ago.

Yours, &c.,
T. Rupert Jones.

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2. *On some* points *in* South-African Geology.—Part II. By G. W. Stow, Esq.

(Communicated by Prof. T. Rupert Jones, F.G.S.)

[Abstract*.]

This paper commenced with a detailed account of the Forest zones, coal, and other strata of the Karoo formation, as seen in sections in the Winterberg and Stormberg. The author particularly pointed out the position of the Fern-beds at Dordrecht, of the Reptilian remains found on the Upper Zwartkei, and of the Coal on the Klaas Smits River. He next referred to the climatal changes of South Africa, as indicated by its geology and fossils, particularly the Karoo beds, the *Enon*-conglomerate, the *Trigonia*-beds, the several post-Tertiary shell-beds, and especially the present surface conditions, which he regarded as due to ice-action, as evidence of which he adduces *roches moutonnées*, moraines, basins, and striæ, both north and south of the Stormberg, in British Kaffraria, and even in Lower Albany. He concluded with remarks on the probable succession of periods, and on the former existence of a great southern continent.

Discussion.

Prof. Ramsay expressed a hope that the author at some future time would discuss the numerous subjects of which he treated at

* The publication of this paper is deferred.

greater length and under separate heads. He was not surprised at the finding of plants of Carboniferous genera in the Dicynodon-beds which appeared to be of Triassic age, inasmuch as the same was the case to some extent in our own later beds of Oolitic date. He agreed in the view of the probability of a vast continent having formerly existed in the southern part of the world, and considered that the denudation of Southern Africa had been so great that it was no wonder the boundaries of the old freshwater lakes were no longer easy to find. It was also by no means surprising to him that a recurrence of glacial phenomena should be found in Southern Africa, as it had been in Europe. He did not, however, think it necessary to call in the action of ice for the excavation of valleys such as some of those described, as rain and running water appeared to him sufficiently powerful for the purpose. At the same time he would not deny the possibility of ice having been the agent in these cases.

Mr. R. Tate had seen evidence of similar effects being produced by aqueous force to those resulting from glacial action, and cited instances of moraine-like deposits having been formed by running streams in Central and Southern America.

Mr. H. Woodward suggested that it would be desirable to wait for further particulars of the sections before assuming the actual association of the *Lepidodendron* and other plants. He added that the *Stigmaria* lately said to have been obtained from the Kimmeridge Clay had really come originally from Newcastle.

Prof. T. Rupert Jones remarked that Mr. Stow, like other South-African geologists, had had ample experience of the effects of violent rain. With regard to the mixture of Palæozoic plants (such as the *Lepidodendron* &c. sent by Dr. Grey) with *Palæozamia* and *Pecopteris*, he thought it somewhat analogous to the mixture of palæozoic and mesozoic fossils in Australia.

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3. *On the* Geology *of* Natal, *in* South Africa. By Charles Ludolf Griesbach, Esq., Corr. Member of the K. K. geologischen Reichsanstalt, and of the K. K. geographischen Gesellschaft, Vienna.

(Communicated by Henry Woodward, Esq., F.G.S.)

[Plates II. & III.]

I. Geography of the country: Watersheds.

The colony of Natal presents the appearance of a series of terraces; the first terrace begins to rise about thirteen to twenty miles from the coast, and forms a hilly country, about 1000 feet above the level of the sea. It forms plateaux in abrupt rising steps until it reaches the height of about 2300 feet, after which the country sinks gradually again to the level of Pietermaritzburg (2080 feet above the sea); but it soon rises again to the high plateaux of the Town Hill and Zwartkop (about 5000 feet high). In a very few steps it forms the long and mighty range of the Draakensberge, which form the great watershed line between the rivers of the Atlantic and the Indian oceans. We find in this range the Mont aux Sources (12000 feet above the level of the sea), a knot of mountains, which sends spurs in five directions, forming the Witteberge and the Quathlamba Mountains. All these great steps and plateaux run parallel to the coast, and consist of more or less broad belts of country. The small belt on the sea-shore shows tropical vegetation. The sugar-cane, the coffee, and now recently the tea shrub, and the greatest variety of tropical fruits find here suitable climate and ought to be sources of immense riches to the country if properly managed. When we ascend the first terrace, the change in the landscape is at once remarkable, and the vegetation has quite a different character. The sugar-cane and exotic creepers disappear, and their place is taken by more European plants; but the coffee-shrub and many a fruit-tree strange to the eye of the newly arrived European still remain. At a still higher point these remains of subtropical vegetation also disappear, and nothing is visible to the eye but vast plains of "*veldt*," stretching for miles, covered with coarse-looking grass, and only interrupted by ant-hills and deep holes made by the ant-bear (the worst foe of those most industrious insects). Nothing more cheerful meets the eye in these vast tracts than small hills and grass—grass everywhere—only occasionally a lonely cattle-farm with the surrounding never missing gum-trees, which give the place a still more lonely and cheerless appearance. This belt is about thirty miles broad, and runs through Kaffirland, Natal and the Zulu country. The succeeding, third district is the most salubrious one, whose climate agrees best with the constitution of Europeans. The soil is covered with a luxuriant grass vegetation, which supports a strong and fine race of cattle. The higher the ground ascends, the more fruitful it becomes; and on the elevated plains, in the district where the yellowwood-tree flourishes, wheat and almost all our European fruits will grow magnificently. Here the winter, although not so severe as in northern Europe, is more like the climate we are accustomed to, and is therefore a real paradise to emigrants, who not only find a country where their labours receive their best reward, but also a more genial climate than the coast-district affords. Natal's rivers flow to the Indian ocean and supply the colony with abundance of water, which makes its soil superior to that of the "old colony," with its vast plains, "karoos," and dreary "veldts."

II. Geology.

The geological structure of the country is shown by the map and section on Plate II., in the preparation of which the author has supplemented the results of his own researches by those of Dr. Sutherland and M. Franz Gröger.

1. *Granite and Gneiss.*—Granite in South Africa does not form the centre of the country or the most prominent of the elevations.

It is only visible at the lowest parts of the river-valleys and near the coast, in fact wherever the river, by its erosive action, has removed the sedimentary rocks. If we draw a straight line from the Umtwalumé river due north, we shall touch all those parts of the country where granite and gneiss reach the surface through the covering of stratified rocks. Granite, as Livingstone correctly observes, forms the bones of the country, which at places are seen through the skin. It only forms hills and the bottoms of river-valleys. The granite is mostly a fine-grained grey variety; sometimes it becomes very coarse and contains large crystals of feldspar; altogether it has the same appearance as the granite at the Cape, which Hochstetter first described as similar to the Karlsbad granite. At some places there is a red variety, in which the quartz and mica nearly disappear, being a mere feldspathic rock, in which decomposition reaches a great depth, when it presents a kaolin-like appearance, similar to that found by me at the Umzinto and at the Jfafa river. Further to the south, at the Umtwalumé, Ehlongeni, and Umkobe rivers in Alfredia, the belt of granite becomes broader, and represents a distinct zone. The greatest elevation is reached by the granite in the counties of Victoria and Umvoti, where the Noodsberg group of mountains and all the surrounding country, and the bottoms of the valleys of the rivers Umvoti and Tugela, in the latter very far up, consist principally of this rock. I have found gneiss at several places, as, for instance at the base of the Sluten-Konga (Mount of Mist), at the head-waters of the Umtwalumé, &c.; but nowhere was it practicable to map it, as the high grass vegetation rendered surveying quite impossible. The granite is traversed in all directions by quartz-veins, which seldom have a thickness of more than from about 1 inch to 2 feet. The quartz itself is a beautiful white variety, almost like glass, which, besides occurring in veins, is very frequently met with in large masses, called "reefs," which usually very soon thin out towards their base. These quartz masses were always a subject of great interest in Natal, as it was thought that they would yield gold in paying quantities. Such is actually the case at almost all places, but not in sufficient quantities to yield a profit for crushing it. At the Umzinto-river valley, after a long time occupied in searching, I succeeded in finding small traces of gold in a variety of grey granite, which also reminds one much of the granitite of Bohemia. The alluvium there also contained gold, but only in traces, and not nearly sufficient to pay any one to work at it.

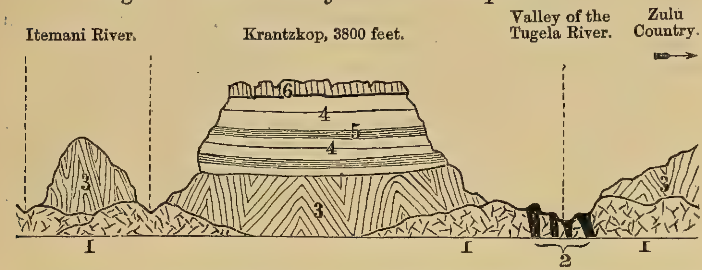
2. *Mica-schists, Clay-, Chlorite-, and Talcose Slate formations.*—All these slate formations are to be met with at places where the granite base is laid bare; and everywhere the slates stand nearly upright, at an angle of 70–75°, with a strike from north to south. The clay- and talcose slates are very well seen at the Umzimculuana (little Umzimculu), in the county of Alfred, and at the Tugela, at the junction of this with the Umziniaty river, and also at the Itemani, a small tributary of the Tugela. At the Umpampinioni river a dark grey clay-slate, dipping at an angle of about 40° and striking from south to north, possesses considerable thickness (about 200 feet or more). It rests on granite, and underlies and is conformable

to the overlying sandstone, to which it belongs, as I think, and not to the older clay-slate formation. It is remarkable that at the Tatin (so-called "goldfields") the slate formations have the same strike and are elevated at the same angle of about 70°. At the mouth of the Umzimculu, about seven or eight miles from it, and north of the young township of Murchison, the river breaks through crystalline limestone of enormous thickness, but whose position relative to the neighbouring strata is not clear. On both sides of the valley the limestone forms precipitous walls of some 1000–2000 feet, which are luxuriantly covered with vegetation. Also the bottom of the river consists there of the same rock, the thickness of which towards the base is not known. On the surface it only covers a space of about four square miles.

3. *Table-Mountain Sandstone.*—The sandstone plateaux, which are so characteristic of the African landscape, lie perfectly horizontally upon the old slate formation, and at some places upon the granitic base. The sandstone, forming precipitous tableland, has never been disturbed; nowhere is a folding of the deposits visible; only fractures run through the zone, in which masses of Aphanitic Diorite are seen, which have burst through the granite and slate formation; but nowhere is the sandstone raised up at an angle, or folded by the greenstone. The high plateaux are covered with a dense grass vegetation; and numerous herds of cattle feed on the level summits of the tableland. The soil is extremely poor, and there is not even a shrub to interrupt the endless uniformity of the landscape. The rivers have made their way through the beds and strata of this sandstone, thus forming precipices, at some points several thousand feet in height. The sandstone shows the same lithological peculiarities as the Table-Mountain Sandstone of the Cape, after which it is named. The tops of many of the "table mountains" of the Colony are crowned by beds of a dark basaltic greenstone (fig. 1) which also possesses the same pillar-like structure as our basalt. It contains fragments of quartz, granite, and gneiss. In a variety of this igneous rock, from the "Great Karoo," I found small traces of gold. I never found any organic remains in the sandstone of the Colony itself, except in a thin soft shale, with much mica in it, which seems at the Krantzkop (fig. 1) to be a bed in the sandstone, from which I got some small bivalves and a finely striated *Patella*, both too indistinct for determination. Such shale is also exposed near the upper drift of the Umkomaz river, near Richmond, and at several other places in the Colony. The Sluten-Konga, Table Mountain near Pietermaritzburg, Inanda, and Noodsberg are examples of the regular-shaped table mountains of South Africa. The same shales and quartz-sandstone form the Krantzkop, which drops nearly vertically down to the Tugela river, about 3800 feet. The high plateau of it is capped with melaphyre-like greenstone. The basis of the Tugela valley is granite, intersected by dykes of an aphanitic diorite. The slate formation, the layers of which stand almost vertical, rests on the granite and is covered with the so-called "Doorns," the celebrated mimosa vegetation of South Africa: the great mass of the mountain is built up of sandstone, and crowned

with basaltic greenstone. In this locality, but on the Itemani side of the Krantzkop, I found the small traces of organic remains in the shaly bed of the sandstone which I mentioned above.

Fig. 1.—*Section through the Krantzkop Mountain.*



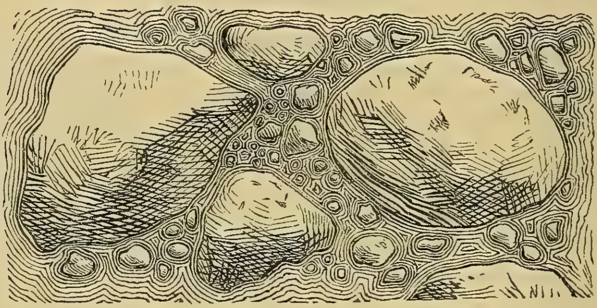
1. Granite. 2. Aphanitic diorite. 3. Mica- and talcose slates. 4. Table-Mountain Sandstone, with, 5, thin layers of a soft shale containing a few traces of fossils. 6. Melaphyre.

4. *The Karoo Formation.*—So called after the Karoos, the immense plains of the interior, as they are principally composed of strata of this formation, which has its greatest height above the sea in the Draakensberg range (see Section, Pl. II.). The lower part of the land on the Natal side of this range rests partly upon the Table-Mountain Sandstone, but not conformably. The Karoo sandstones and shales occupy the largest portion of South Africa, as they compose the whole of the interior, forming the high elevated plains of the Kalahari, the Free States and the Transvaal, as well as the countries to the north as far up as the Limpopo; they are also to be met with at the Zambezi. As Mr. Tate, and Profs. T. R. Jones, Owen, and Huxley have already so ably described this formation with its fossil contents, little remains for me to say. The dark-grey and blue shales of Pietermaritzburg, containing oxide of iron in great quantities, represent the Ecca-beds of the great Karoo. Further up it passes gradually into sandstones of much the same lithological character as the Table-Mountain Sandstone, with intervening layers of shale, which at Ladysmith, Newcastle, in the Tugela valley, &c. contain beds of coal. Numerous remains of reptiles and plants are described, which come from the Natal side of the Draakensberg; and therefore the age of these beds may be determined. Mr. Tate regards them as Triassic, whilst Mr. Wyley thinks that they belong to the Carboniferous period; but as the coal from Tulbagh, in the Cape Colony, is decidedly carboniferous (*Calamites*, *Equisetum*, and *Lepidodendron* in the sandstone), and the succeeding Karoo formation (which is a freshwater deposit) does not lie conformably on the former, Mr. Tate's opinion seems the most acceptable. Also the same formation, with *Dicynodon* and *Glossopteris Browniana*, occurring in India at the base of the cretaceous series, is proved, by a careful examination of its flora, to be a Triassic deposit. There can certainly not be the slightest doubt that the Natal coal belongs to a far younger period

than the Tulbagh coal, which is an equivalent of our Coal-measures.

The "Karoo formation" also occurs in a small belt on the sea-coast of Natal, which belt is never broader than from seven to eight miles, if so much. Beds of the Karoo series are well exposed at the Umgeni mouth and also at the Ifumi river. Any one who has been to Pietermaritzburg must have observed cuttings on the road, about seven or eight miles before he reaches the capital, in a dark shaly rock, with large boulders of older rocks imbedded, of granite, gneiss, slate, and also frequently of greenstone (fig. 2). These boulders are so characteristic of African scenery that they have received general attention. The boulders, often of very large size, are imbedded in a soft grit and shaly clay, containing small particles of mica.

Fig. 2.—*Irregular boulders of Greenstone, sometimes Granite or Gneiss, imbedded in clay and grit.*



The boulders seem to have been formed on the spot, or at least have not travelled very far, as many of them have kept their angular shape, and they seem to have undergone rather a process of decomposition than of rolling. These beds ("boulder-beds") extend often over a very large area, and pass everywhere beneath the dark shale, which represents the base of the Karoo plant-beds. This is proved by a section at Thornville, and also on the sea-coast of Natal at several places, amongst them at the Umgeni valley and the Ifumi river. At the Umgeni and Durban the sections are as in figs. 3 & 4.

Both these sections show that the plant-bearing shales and sandstones rest unconformably on the older Table-Mountain Sandstone, and also that the boulder-bed lies at the base of these plant-beds.

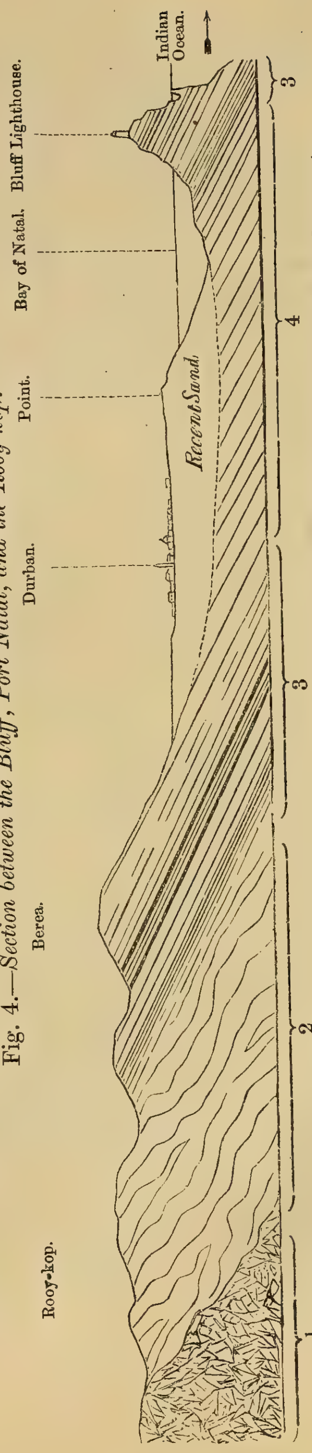
The same is shown at part of the road between Pietermaritzburg and Thornville (see Section, Pl. II.).

The boulder-bed here, in the same way as in the other sections, passes gradually into the shale of Pietermaritzburg, which, as I think, belongs to the lowest bed of the Karoo series. We learn from the Geological Survey of India that almost the same formation of

Fig. 3.—*Section exposed by the Umgeni river, north of Durban.*

1. Granite. 2. Table-Mountain Sandstone. 3. Boulder-bed. 4. Shales with faint plant-impressions and, 5, thin coal-beds.

Fig. 4.—*Section between the Bluff, Port Natal, and the Rooy-kop.*



1. Granite. 2. Boulder-bed. 3. Shales with coal-beds, alternating with, 4, Sandstone-beds belonging to the Karoo series.

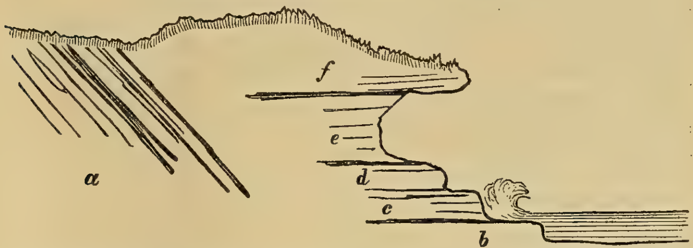
shales, sandstones, and calcareous grit contains the same forms of plants, as well as reptilian remains of *Dicynodon*, and lies conformably on a boulder-bed, which gives the impression that it was formed on the spot, and was not transported by the action of water. It is also remarkable, and an observed fact, that this boulder-bed of Southern India passes gradually into the succeeding shales and sandstones, which have been termed by the Indian geologists "the Ootatoor plant-beds." A lithologically similar boulder-formation I have also seen at the same horizon in the Cape Colony, passing beneath the blue Karoo shales; and I am pretty certain that Mr. Bain and many of our African geologists have taken this boulder-bed, at many localities, for an igneous trappean rock. Mr. Bain (see his map) calls this boulder-bed, which dips under the "Ecca-beds" of the "Pataties Revier," "Claystone Porphyry." There is certainly a basaltic melaphyre, forming beds of considerable extent in this lowest part of the Karoo formation, as, for instance, can be seen near Platte-fontein, in the great Karoo; but this trap does not belong to the extensive beds of boulders at the base of the "Pataties Revier" shale. At first sight the trap and the boulder-bed have many similarities, as the material of the boulders is partly derived from igneous rocks. Dr. Sutherland thinks that the boulder-bed was formed by glacial action, and tries to prove it by the observed fact of grooves and furrows on the plateaux of the Table-Mountain Sandstone. These grooves, quite similar to those in our Alps, occur in great abundance on the sandstone of the Ifumi river, about twenty miles south of Durban.

The greenstone (melaphyre ?) has found its way through this formation at many places, and forms beds between the strata of it. The greenstone contains a great quantity of pebbles of older rocks imbedded, which give it a speckled appearance. But it seems that the greenstone eruption happened at the earliest period of the forming of the Karoo beds, as the "kopjes" of greenstone are only found in the lowest strata of the "Pietermaritzburg shales," and in the succeeding sandstones. The series of greenstone "kopjes," which runs from the Ingeli Range in Kaffirland up through Richmond, York, and Greytown to the Tugela river, is of practical importance, as in it, or in the direction of its strike, the occurrence of copper ores can be traced through the whole of South Africa. Besides this Trappean greenstone, a second igneous formation may be found within the Karoo series, the so-called amygdaloid rock, which caps many of the heights of the upper Karoo beds, and often forms extensive beds between them. From it are derived the various kinds of chalcedony, agates, rock-crystals, and topazes which are so plentiful in the rivers of the Free States and Natal.

5. *The Cretaceous Rocks of South Africa.*—Between the rivers Umtamfuna and Umzambane, about five miles from the southern boundary-line of Natal, on the south-eastern coast of Africa, some deposits are found which at first sight seem to be of the same ma-

terial as the underlying stratum. They consist of sandy marls and hard sandstones of a greyish-brown colour, with a few calcareous concretions. These rocks are partly covered at high water by the sea, which has hollowed out small cavities in them (Fig. 5). They have probably served at some period as a shelter for white people, as the natives of this district call them "Izinhluzabalungu," houses of the white men. These rocks only extend for a short distance, and only form isolated cliffs. They are found, too, at the Impengati river, and at some of the more southern rivulets which run into the sea between the boundary of Natal and the St. John's river (Umzimvooboo). The same are also recognized in the bed of a small stream, running into the St. Lucia bay, in the Zulu country. The strata forming these deposits are perfectly horizontal, and they rest upon a sandstone of much older age, which belongs to the very interesting series of the Karoo formation. It is remarkable that the Izinhluzabalungu rocks do not rest conformably upon the older formation, the plant-bearing sandstones.

Fig. 5.—*Izinhluzabalungu Caves.*



a. Karoo shales and sandstones. *b.* Sandstone with fossil wood &c. *c. Trigonia*-bed. *d.* Ammonite-bed. *e.* Gasteropoda-bed. *f.* Zone of *Ammonites Gardeni.*

I have been enabled to distinguish no fewer than five distinct faunas. The lowest stratum is a hard calcareous sandstone (*b*), very much worn by the sea breaking against it at high water. Large trees and branches are imbedded in it, lying about in all directions. The wood is traversed by large masses of *Teredo*, whose holes are filled with iron pyrites. Resting on this stratum is a bed of softer brown sandstone (*c*), with great abundance of *Trigoniæ*. This bed is more exposed near the Umzambane river, and nearly concealed at the northern end of the deposits. It is overlain by sandstones and grits (*d*), containing Ammonites, resting upon which is a softer sandstone and grit (*e*), containing many fossils, mostly bivalves and Gasteropods. The roof of the caves is formed by a harder limestone stratum (*f*), which has not been so easily worn away by the sea as the underlying sandstone stratum. This limestone contains *Ammonites Gardeni*, Baily.

Fauna of the Izinhluzabalungu deposits.

Species.	Stratum.		Equivalent in Northern Europe.
Ammonites Gardeni, *Baily*............ Fossil bones, wood, &c.	Harder brown limestone (*f*).	Cretaceous period.	White chalk most probably.
Pugnellus uncatus, *Forb*................ Fasciolaria assimilis, *Stol.* .... Fasciolaria rigida, *Baily* .... Tritonidea trichinopolitensis, *Forb.* Scalaria turbinata, *Forb.* .... Solarium Wiebeli, nov. sp. .... Chemnitzia undosa, *Forb.* .... Euchrysalis gigantea, *Stol.* .... Solariella radiatula, *Forb.* .... Avellana ampla, *Stol.* .... Natica multistriata, *Baily* .... Pollia pondicherriensis, *Forb.* .... Lagena nodulosa, *Stol*.................... Cerithium (Fibula ?) detectum, *Stol.* Cerithium kaffrarium, nov. sp. ...... Turritella multistriata, *Rss.* .... Dentalium, spec. .... Ostrea, spec. .... Pecten quinquecostatus, *Sow.* .... Pecten amapondensis, n. sp. .... Arca capensis, n. sp....................... Arca natalensis, *Baily* .... Pectunculus africanus, n. sp. .... Trigonia elegans, *Baily*.................. Cardium denticulatum, *Baily* .... Cardium Hillanum .... Venus arcotensis, *Forb*.................. Astarte, sp................................. Inoceramus expansus, *Baily* .... Hemiaster Forbesii, *Baily* .... Holaster indicus, *Forb.* .... Diadema, spec. .... Ammonites umbolazi, *Baily*	Soft brown sandstone and grit, with numerous fossils (*e*).		Probably Upper Greensand.
Ammonites Soutoni, *Baily* .... Ammonites Stangeri, *Baily* .... Ammonites rembda, *Forb.* .... Ammonites Kayei, *Forb.* .... Anisoceras rugatum, *Forb.*	Sandstone and grit, very much like the above (*d*).		Lower Greensand.
Trigonia Shepstonei, nov. sp.	Hard sandstone (*c*).		
Fossil wood, with *Teredo*...............	Hard sandstone, very much water-worn (*b*).		
Faint plant-remains	Karoo sandstone and shales (*a*).	......	Triassic ?

Description of Species.

Genus AMMONITES.

There are four species described in Mr. Baily's paper, to which I have to add two more, both of which are found in the Cretaceous series in Southern India.

One of the commonest species in this formation is

AMMONITES UMBOLAZI, Baily. Pl. III. fig. 1.

A fine and characteristic form, which is not quite distinctly figured in Mr. Baily's paper. The flexuous ribs on the well-preserved shell are not so strongly marked as in the figure, and do not show the least tendency to form tubercles near the back, but gradually die away in all the specimens I have seen. Number of specimens 26.

Locality. Umtamfuna river, South Africa, from bed *d.*

AMMONITES REMBDA, Forbes. Pl. III. figs. 2, 3.

The whorls are higher than wide; it possesses a remarkably shaped keel. The shell is well preserved. It has distinct furrows, which are about 6 to the whorl, and are slightly bent near the keel, towards the mouth. The suture is easily detected; 6 lobes and 6 saddles can be made out. The dorsal saddle is tripartite, the next two lateral saddles bipartite, and the next three only single saddles. The dorsal saddle is double the height of the dorsal lobe; the lateral lobes are very deep; the lateral saddle is of the same height as the dorsal one; but the succeeding ones decrease very rapidly in size. Forbes's figure of this Ammonite is very indistinct; so also is the fragment which is figured in the 'Memoirs of the Geological Survey of India.' *Ammonites rembda,* from Pondicherry, is in every particular like our African specimen. The shell is perfectly smooth, and shows in some places beautiful colours. There are some small specimens amongst the collection, which seem to me to be only young individuals of *A. rembda.* Number of specimens 3.

Locality. Cliffs on the sea-shore, between the rivers Umtamfuna and Umzambane, in Kaffirland, from bed *d.* Pondicherry, in India.

Age. Probably Cenomanian. India, Valudayur group.

AMMONITES KAYEI, Forbes.

An excellent specimen, with flexuous ribs, and a few furrows parallel to the ribs. The ribs are very fine and narrow, and generally divided into two or three at about the middle of the whorls. There cannot be the slightest doubt about the identity of the African specimen with *Ammonites Kayei,* as it shows all the remarkable peculiarities of Forbes's original specimen in the Collection of the Society.

Locality. Umtamfuna river, from bed *d.* Pondicherry, west of Penangoor, and north of Odium, in the Trichinopoly district.

Range. Cenomanian. In India, the Valudayur and Ootatoor groups.

ANISOCERAS RUGATUM, Forbes. Pl. III. fig. 4.

My specimen shows sharper ribs than the Indian form; and as it is only a fragment, it does not allow a very distinct specification.

Locality. Umtamfuna river. Bed *d.*

In India. The Valudayur group.

Remarks. Altogether there are 15 species of Cephalopods described out of this bed, three of which are also found in the Valudayur group of Southern India. Only two species belong to a higher horizon, one of which occurs in India in the Arrialoor group.

Name.	In India.	Relationship.	Range.
Ammonites Soutoni, *Baily*.	Ootatoor ?	A. implatus.	Ootatoor group.
—— Stangeri, *Baily*.			
—— Gardeni, *Baily*	Arrialoor	A. Gardeni.	Arrialoor group.
—— umbolazi, *Baily*.			
—— rembda, *Forbes*	Pondicherry.	A. rembda.	Valudayur gr.
—— Kayei, *Forbes*	Pondicherry and Trichinopoly distr.	A. Kayei.	Valudayur and Ootatoor group.
Anisoceras rugatum, *Forbes*	Pondicherry.	A. rugatum.	Valudayur gr.

There is only one quite strange form; all the others are found or have their representatives in the Indian Cretaceous series. We see that four out of *seven species* belong to the lowest beds of the Indian Cretaceous formation, to the Ootatoor group and the Valudayur group, and only one, *A. Gardeni*, belongs to a higher horizon, the Arrialoor group, which resembles our white chalk.

Cerithium (Fibula ?) detectum, Stol.

Pal. Ind. fig. 192, pl. xv. vol. i.–iv.

This species is found in the same deposits. Shell perfectly smooth, with scarcely visible lines of growth, and very thick.

Locality. Umtamfuna. Bed *e*.

Cerithium kaffrarium, nov. sp. Pl. III. fig. 5.

Spiral angle 40°. Number of whorls 9.

The shell is very characteristically ornamented—coarse and transverse ribs, which are intersected by thin spiral lines. Each of the whorls is contracted near the suture, forming a deep furrow.

Locality. Umtamfuna river, from bed *e*.

Turritella multistriata, Rss.

—— *Sowerbii*, Forbes.

—— *Bonei*, Baily.

Mr. Baily, in his paper, looks upon this *Turritella* as a new species; but it agrees perfectly with Mr. Forbes's original in the Collection of the Geological Society; his figure is not very clear, which may account for the making of a new species, as the African specimen has nothing in its characteristics which could enable any one to distinguish it from the Indian species.

Locality. Umtamfuna river, bed *e*. Pondicherry, Trichinopoly group.

Scalaria turbinata, Forbes. Transact. Geol. Soc. vii. p. 127, pl. xii. fig. 18.

Scalaria ornata, Baily.

Mr. Baily's specimen not only agrees with the Indian *Scalaria* in the description and figure, but more so even upon a careful examination of the well-preserved original; it seems, therefore, to me not reasonable to create a new species because it is derived from a different locality, but shows again the coincidence of the African and Indian Cretaceous deposits.

Locality. Umtamfuna river, bed *e*. In India: Pondicherry.

Solarium Wiebeli, nov. sp. Pl. III. fig. 6.

Angle 130°. Number of whorls 5.

The surface perfectly smooth, only the lines of growth are faintly visible; but neither transverse striæ nor ribs can be distinguished, as in *Solarium pulchellum*, Baily, from the same stratum; in shape also this species varies much from Baily's *Solarium*, which possesses gradually widening whorls, whilst in the present species each whorl is double the width of the preceding one.

Locality. Umtamfuna river, bed *e*.

Chemnitzia undosa, Sow., spec.
Chemnitzia undosa, Forb.
Scalaria undata, D'Orb.
Turritella (*Chemnitzia*) *Meadii*, Baily.
Chemnitzia Sutherlandii, Baily.

Mr. Baily calls a small *Chemnitzia*, which shows slight spiral lines, *Turritella Meadii*; but it is, I think, only a young individual of his new species *Chemnitzia Sutherlandii*, which can be identified with some varieties of *Chemnitzia undosa*, Forbes. The last whorls do not show the transverse lines so distinctly; and altogether it is impossible to find two specimens which show exactly the same ornamentation of surface. The older whorls are always more distinctly ribbed, but not the later ones. In full-grown specimens, the spiral lines, which even in young ones are very feeble, disappear.

Locality. Umtamfuna river, bed *e*. In India: Garudamungalum, Kulligoody, Alundanapooram, Serdamungalum, Anapaudy, Andoor. Trichinopoly group.

Euchrysalis gigantea, Stol.

This is the species erroneously referred by Bailey to *Turritella Renauxiana*, D'Orb.

Locality. Umtamfuna river, bed *e*. In India: north of Alundanapooram, east of Anapaudy, Comarapolliam. Trich. & Arr. Gr.

Dentalium, spec.

A small fragment of a smooth *Dentalium*, which it is not possible to identify with any already described species.

Bivalves.

Fam. I. Ostreidæ.

Ostrea, *L.*, spec.

Numerous small specimens, imbedded in the sandstone with Ammonites and other shells, beds *d* and *e*.

Pecten quinquecostatus, Sow.

Very numerous in this locality, resembling in every respect the specimen from Pondicherry in Mr. Forbes's Collection in the Geological Society's Museum.

Number of specimens obtained by me, 11.

Locality. Umtamfuna river, bed *e*.

Pecten amapondensis, nov. sp. Pl. III. fig. 7.

The right valve very slightly concave, finely striated concentrically, with broader radial ribs. Towards the end of the valve, two distinct concentric lines, which divide the surface of the valve into two or three areas.

Locality. Umtamfuna river, bed *e*.

Arcadæ.

Arca capensis, nov. sp. Pl. III. fig. 10.

The valves very thick, surface nearly smooth, very slightly cancellated, margins smooth. Hinge-teeth numerous, the lateral ones very strong. The ligamental area with numerous but very narrow grooves; for the cartilage is much smaller than in *Arca natalensis*, and the interior umbones nearly touch each other in closed valves. *Arca trichinopolitensis*, Forbes, is very nearly allied to this species. Mr. Baily's figure of *Arca umzambaniensis* does not suffice to enable me to decide positively whether the present species is distinct from it; but it seems to me that Mr. Baily's figure represents a much flatter specimen than mine.

Number of specimens 9.

Locality. Umtamfuna river, bed *e*.

Pectunculus africanus, nov. sp. Pl. III. fig. 8.

A small bivalve; length about from $\frac{1}{2}$–$\frac{3}{4}$ of an inch. Surface finely radiately striated, showing lines of growth; margins denticulated; hinge semicircular, teeth transverse; ligamental area very small. This species is most nearly related to *P. subauriculatus* from Pondicherry (see Mr. Kaye's Collection); but the latter is more circular in form than *P. africanus*.

Number of specimens collected, 41.

Locality. Umtamfuna river, bed *e*.

Trigoniadæ.

Trigonia Shepstonei, nov. spec. Pl. III. fig. 11.

This species stands between *Trigonia crenulata* and *scabra*, Lamk. The surface shows strong lines of growth, with thick transverse ribs, which run quite straight from the beak to the margin, and form right angles with the ventral margin. The ribs have very prominent tubercles, which become stronger near the ventral margin. The teeth are 2—3, the left divided and striated. The surface is divided near the posterior margin longitudinally by two or three furrows into as many areas, transversely striated and ribbed. The ribs are slightly curved, and in the inner carina they stand perpendicularly to the posterior margins. *T. Shepstonei* shows distinct differences from *Trigonia elegans*, Baily, in its strong and thick tubercles, in the general rough surface of the valves, and also in its shape. Our species is thicker, and the ventral margin is plicated. Very common, forming entire beds in the sandstone. This species seems to have been commoner at the base of the stratum; but the bed is not divisible into different horizons.

Named after the Hon. Theophilus Shepstone, the Secretary of Native Affairs in the Colony of Natal.

Locality. Umtamfuna river.

Cardiadæ.

Cardium denticulatum, Baily. Pl. III. fig. 12.

To Mr. Baily's description I have only to add that the pallial line is simple, and not in the least sinuous. Cardinal teeth 2; lateral ones 1, 1.

A small *Astarte* seems to be not uncommon. A *Teredina* is also found in large masses in fossil wood at the lowest part of the deposit.

Echinodermata.

Hemiaster Forbesii, Baily.

Holaster indicus, Forb.

Diadema, sp. Pl. III. fig. 13.

Table of the Range of the Fossils of the Umtamfuna River.

	Cephalopoda.	Gasteropoda.	Bivalves.	Echinod.
New species, or peculiar to the African locality......	1	4	7 3 of these nearly allied to Ind. sp.	1
In the Arrialoor group ...	1	3	2	2
Trichinopoly group.........	...	11	...	...
Ootatoor and Valudayur groups, India	4	1	...	...
Total of species which also occur in India	5	13	2	2

Gasteropoda of the Umtamfuna River which also occur in India.

Name.	Localities in India, where the species also occur.	Range.
Pugnellus uncatus, *Forb.*	Parchairry, Kulligoody	Trichinopoly gr.
Fasciolaria rigida, *Baily*	Andoor, Coonum, Shutanure	Trich. group.
Fasciolaria assimilis, *Stol.*	Olapaudy	Trich. gr.
Tritonidea trichinopolitensis	Anapaudy	Trich. gr.
Pollia pondicherriensis, *Forb.*	Alundanapooram	Trich. gr.
Lagena nodulosa, *Stol.*	Olapaudy	Arrialoor gr.
Cerithium (Fibula) detectum, *Stol.*	Karapaudy	Arrialoor gr.
Turritella multistriata, *Rss.*	Pondicherry	Trich. gr.
Scalaria turbinata, *Forb.*	Pondicherry	Trich. gr.
Chemnitzia undosa, *Forb.*	Pondicherry	Trich. gr.
Euchrysalis gigantea, *Stol.*	Alundanapooram, Comarapolliam	Trich. & Arr. gr.
Solariella radiatula, *Forb.*	Vylapaudy, Olapaudy, Comarapolliam, Arrialoor	Arrialoor gr.
	Andoor, Kalakonuttom	Trich. gr.
	Puravoy, Moraviatoor, Odium	Ootatoor gr.
Avellana ampla, *Stol.*	N.W. of Veraghoor	Trich. gr.

It is quite clear that most of the species obtained from this African locality ("Izinhluzabalungu") resemble in every respect those of the Trichinopoly series of India. The Trigonia beds with *Ammonites Kayei, A. Rembda*, &c., show the true character of the Ootatoor beds of the Trichinopoly district, whilst we have the Trichinopoly group represented by eighteen species, which also occur in India. The Arrialoor group is proved only by *Ammonites Gardeni*, which was first described from Africa, but has since been found by Stoliczka in the Indian Cretaceous series.

The plant-beds with *Teredo* find their representative in the lower beds of the Ootatoor group of the Trichinopoly district; and from this, and also the fact that the preceding plant-bearing Karoo formation finds its analogue in the Indian Ootatoor plant-beds (not the Ootatoor group), the conclusion is easy to arrive at, that both Africa and India were, after the development of the Table-Mountain Sandstone, one continuous continent, which afterwards was covered by the Cretaceous sea.

Between the deposition of the Table-Mountain Sandstone and that of the plant-bearing blue shales and of their Boulder-bed, which form the base of the extensive *Dicynodon*-sandstones, a long time must have elapsed.

The large area, now covered by the Indian Ocean, must have been the basin for an extensive series of lakes, which would explain the occurrence of the same plants and large reptiles which were then living in India and also in South Africa. It must have been a period of long-enduring tranquillity, and no great disturbance whatever seems to have occurred. These periods of repose, which witnessed so very few changes during the deposition of at least 5000 feet thickness of strata, must have lasted through the Triassic age right up to the Upper Jurassic; as in India the highest of these beds seem to belong to the Jurassic formation. The greater portion of the Indian Ocean must, at this period, have been depressed, together with a large part of India and Southern Africa, which were covered with the shallow Cretaceous sea, having a peculiar fauna of its own. The Cretaceous deposits of Southern India and Africa were all shallow-water and coast-deposits, as is proved by the species of fossils they contain and also by the quantities of wood imbedded in them, which give evidence of a formation on a shallow coast, where the wood was soon covered with sand and mud and in this way preserved. Since that period the coast has been gradually rising, or the sea retiring. The portions of the Cretaceous sea nearest the old coast-line had become dry land; and we see the remains of these deposits in Southern India and Africa. There cannot be the slightest doubt that the upheaval of the country is still going on; for along the whole coast of South Africa, from the Cape to Durban Bluff, and still further north, even as far as Zanzibar, modern raised beaches *, coral-reefs, and oyster-banks may everywhere be seen. At the Izinhluzabalungu Caves is such a point, where the rising of the coast is plainly visible; recent oyster-banks are now 12 feet and more above high-water mark. The same can be observed on the whole line of the Natal coast. Vander Decken has observed the same thing at Zanzibar, and is of the same opinion as myself, viz. that the eastern coast is rising. Early in the present year I had the opportunity of observing at the Bazaruto Islands, about 90 miles to the north of Inhambane, on the east coast of Africa, a series of raised coral-reefs round the island of Marsha, containing many living shells and quite recent oyster-banks. In fact, I believe that the Bazaruto Islands only owe their existence to the circumstance that the coral-reefs have been upheaved, and that their surface was naturally covered with loose sea-sand, which is the only soil of these desolate islands. Everywhere, at about 12–14 feet depth, water is to be obtained at Marsha; wherever the sand is removed the coral-rock is reached.

What with this constant rising of the land and the consequent shallowing of the river, I do not believe that the Port of Durban has much hope for the future, as some day the entrance to the harbour, which is not very deep at present, must be blocked by a bar across it like most of the African ports. The only exception to this rule is the large Port of Delagoa Bay; the port is cleared of sand and mud by nature itself. It was evidently formed by the north and south current of Mozambique, which has gradually hollowed out this fine bay. Between Elephant Island and the *terra firma* the current enters the bay, and, turning round in it, returns to the sea between Elephant and Inyack Islands, in this way always keeping the entrance open by its scouring-out action.

* The writer has seen implements of early man which were obtained by Richard Thornton and others in old raised beaches at Natal, near Inanda, and at the mouth of the Zambesi River.

If we take a vertical section of the Natal formations, we shall find them as follows:—

Brown soft sandstones and grit, with great numbers of fossils.	Cretaceous Series, Lower Greensand up to White Chalk.
Sandstones and shales, with coal-beds, shales, and *Boulder-bed* (greenstone dykes).	Karoo formation: probably Trias, reaching as far up as the Jura.
Quartzose sandstone with shales; containing only traces of fossil remains.	Table-Mountain Sandstone. Coal-period.
Clay- and talcose slates, mica-schists, dykes of diorite.	Primary slate-formation.
Granite and gneiss, dykes of diorite.	Primary rocks.

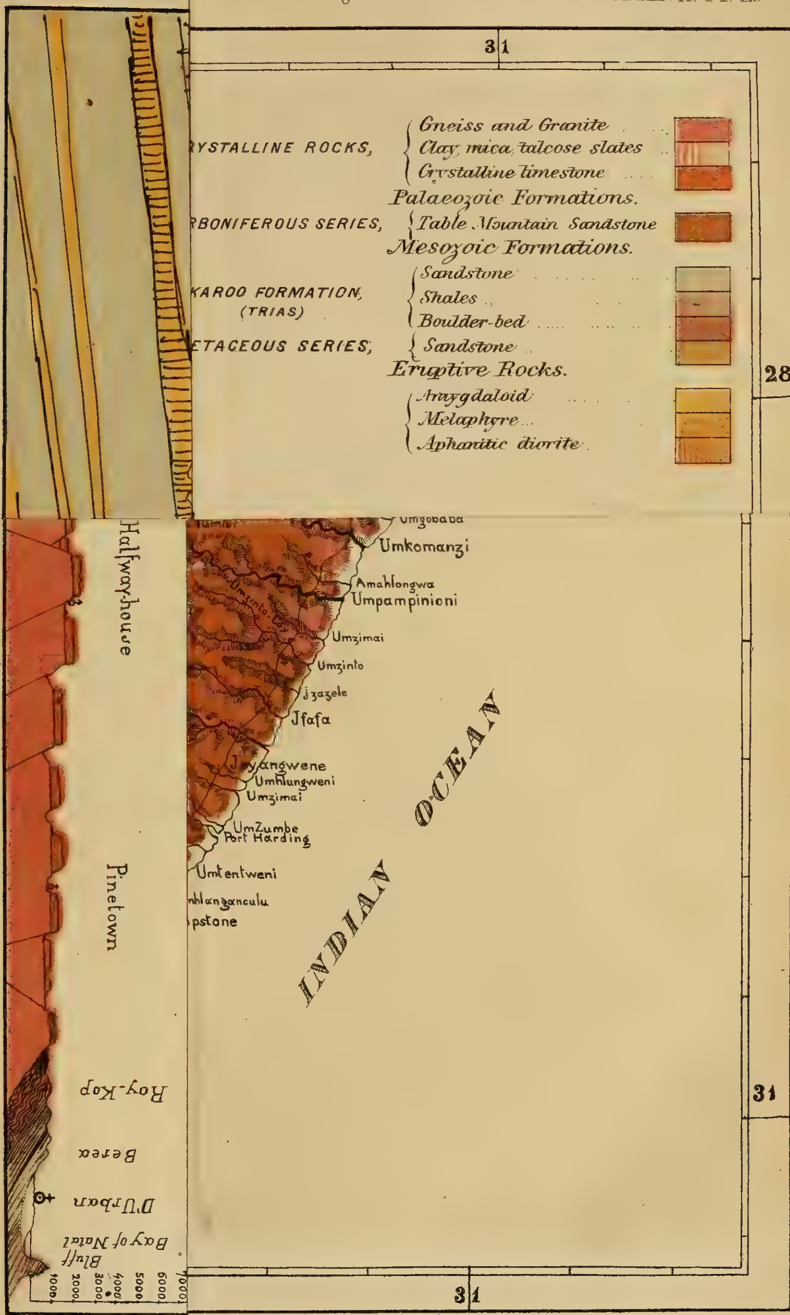
III. Economic Geology.

Industry and the fine arts are still in their childhood in Natal; otherwise the raw materials are there in abundance. Natal possesses good building-material in the quartzose sandstone of the Table Mountains, and an excellent slate which is found at some places (for instance, at the Umpampinioni river). The lower parts of the crystalline limestone would, I have no doubt, afford a good statuary marble.

1. *Graphite.*—A very good quality of pure graphite is found south of Springvale, in Natal—in gneiss, as it seems. As the working of the graphite is not expensive, a ton of pure graphite costing only about £30, it would probably be a lucrative undertaking to ship graphite at Durban. Graphite is not very rare in South Africa; traces of it are found at several points in the "old colony." A considerable amount of this mineral is to be met with, as I have been informed not very far from the Mission-station of Inyatin, about 20° S.

2. *The Coal* of Natal, which belongs to a younger series than the more newly discovered one near Tulbagh, in the Cape Colony, seems to form extensive fields in the sandstone and shales of the plant-bearing Karoo formation. Although it is a good steam-coal, it is still cheaper to import the coal from England or Australia, whence it may be obtained at 27–55 shillings the ton at Durban.

3. *Metals.*—a. *Gold.* Every body remembers the great excitement which was caused by the first "discoveries" of gold in South Africa. Since then companies have been formed, shares sold and bought, diggers have been sent out, and the colonies hoped for better days; but suddenly the gold-fields turned out to be imagination, as it became pretty certain, and indeed an ascertained fact, that gold was not in sufficient quantities to pay the working of the quartz. Not only in the interior, but also near the coast, within the boundary of the colony, gold was sought for. Traces of gold are to be seen in the quartz-veins and quartz masses ("reefs") in the granitic and slate-formation, but not sufficient to pay the expense of crushing. I have visited most of the localities in Africa which were called auriferous; but nowhere did it seem to me likely that it would pay for working, as the quartz-veins (supposing they would yield a paying quantity)



C. L. Griesbach, del. & lith.


GEOLOGICAL MAP
OF THE
COLONY OF NATAL
BY
C. L. GRIESBACH,
1871.
CRYSTALLINE ROCKS,
Gneiss and Granite
Clay, mica talcose slates
Crystalline limestone
Palaeozoic Formations.
CARBONIFEROUS SERIES,
Table Mountain Sandstone
Mesozoic Formations.
KAROO FORMATION, (TRIAS)
Sandstone
Shales
Boulder-bed
CRETACEOUS SERIES,
Sandstone
Eruptive Rocks.
Amygdaloid
Melaphyre
Aphanitic diorite
ORANGE FREE STATE
ZULU COUNTRY
ADAM KOK'S COUNTRY
INDIAN OCEAN
Drakensberg Mountains
Ladysmith
MARITZBURG
DURBAN
PORT NATAL
Newcastle
Tugela
Champagne Castle 9500 ft.
Giant's Castle 9000 ft.
Van Reenen Pass
De Beer Pass
Mt. Malani 7200 ft.
Spioen Kop
Richmond
Verulam
Umkomanzi
Umlamfuna
Jngeli Range
Kok's Lager
SECTION FROM THE BLUFF, PORT NATAL TO THE MONT AUX SOURCES IN THE DRAKENSBERG.
HORIZONTAL SCALE
Mont-aux-Sources
Giants Castle
Spioenkop
Jnhlugani
Zwartkop
Pietermaritzburg
Thornville
Campertown
Halfwayhouse
Pinetown
Roy-Kop
Berea
D'Urban
Bay of Natal
Bluff

CRETACEOUS FOSSILS FROM NATAL.

are everywhere of very limited extent and thickness, and the so-called " reefs " everywhere thin out rapidly towards the base; and, lastly, there is no extensive alluvium anywhere in these districts which yields gold.

It is a well-known fact that gold has actually been exported from the east coast for centuries by the Portuguese in large amounts; and the question may be put, Whence does this gold come? Gold is there; but the question is, Would it pay white labour or not? The Portuguese trader in Quillimane has perhaps one thousand or more slaves, which cost him only a trifle, as they live by their wives' labour; when the dry season sets in, the Quillimane traders send their slaves to their work; they are supplied with old flint-guns, and sent into the interior to hunt elephants. Some are sent to trade, and a great part to the diggings in the rivers which flow into the Zambezi, near Tette, and in those running from the south to the Zambezi, coming from the fabulous country of Manico. There the wives work at fields of rice, which support them sufficiently, whilst the men wash the gold from the rivers in small kalabashes in quite a primitive manner. As the gold itself has no value to them, they bring it faithfully to their masters, who reward them with beads and white Salempore (calico). In this way the master gains a good deal, as all the gold he receives is a clear profit. If he has only 150 slaves engaged in the diggings, and he receives only 1 ounce per head in the season, he makes a profit of £581 5*s.*! Of course white labourers would never find it practicable to undertake gold-washing there under such circumstances.

b. *Copper* is already well known in many districts of South Africa, and is also worked. I found copper at several localities in Natal; but nowhere, I should think, would it be found practicable to work it. Near the Ifumi river, south of Durban, a highly decomposed gneiss occurs which shows traces of copper at the surface. It is situated just along a fissure in the gneiss, and it possibly might lead to a richer point; but this is not probable. In the Insiswa Mountains, in Kaffirland, richer copper-ores have been known for a very long time, but have never been worked out. This locality is situated at the above-mentioned line of greenstone, which strikes from south to north, near the base of the Karoo beds. It is remarkable that along this greenstone line copper is found. Thus, for instance, it occurs near the Tugela valley, in greenstone which intersects the granite.

EXPLANATION OF PLATES II. & III.

Plate II.

Geological Map of the Colony of Natal.
Section from the Bluff, Port Natal, to the Mont aux Sources in the Draakensberg.

Plate III.

Fig. 1. *Ammonites umbolazi*, Baily: *a*, dorsal view; *b*, sutures.
Fig. 2. *Ammonites rembda*, Forbes; *a*, section; *b*, sutures.
Fig. 3. The same, young individual.
Fig. 4. *Anisoceras rugatum*, Forbes.

Fig. 5. *Cerithium kaffrarium*, n. sp.
Figs. 6, 6 *a*. *Solarium Wiebeli*, n. sp., enlarged; 6 *b*, natural size.
Fig. 7. *Pecten amapondensis*, n. sp.
Figs. 8, 8 *a*, 8 *b*. *Pectunculus africanus*, n. sp.
Fig. 9. *Astarte*, sp.
Figs. 10, 10 *a*, 10 *b*. *Arca capensis*, n. sp.
Figs. 11, 11 *a*, 11 *b*, 11 *c*. *Trigonia Shepstonei*, n. sp.
Fig. 12. *Cardium denticulatum*, Baily.
Fig. 13. *Diadema*, sp.

DISCUSSION.

Prof. T. RUPERT JONES commented on the importance of the paper as throwing so complete a light on the geology of Natal, and proving the geological sequence to be similar there to that in other parts of Southern Africa. He remarked that the author had done special service by the great increase of information furnished by him regarding the Cretaceous rocks of Natal, and their equivalence to those of India. He also pointed out that Mr. Griesbach had proved that the Karoo formation was continuous to the other side of the great dividing range, and formed the floor of the Orange and Waal valleys, and remarked that as Mr. Stow had indicated glacial action on the south side of the Orange valley, it was quite possible that the gravels containing the diamonds were of local origin, as Dr. Grey had suggested.

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4. *On the* DIAMOND-DISTRICTS *of the* CAPE OF GOOD HOPE. By G. GILFILLAN, Esq.

(Communicated by Warington W. Smyth, Esq., F.R.S., F.G.S.)

[Abstract.]

IN this paper the author gave an account of a visit paid by him in June last to the diamond-bearing districts of the Cape of Good Hope.

Between Cradock and Hope Town there seemed to be no indications to warrant the expectation of finding diamonds. The geological structure of the country between Cradock and Middelburg is very uniform, showing few traces of upheavals. The rocks are chiefly sandstones of various degrees of fineness, with alternating beds of red or blue marl, in hard nodules of which *Dicynodon*-remains are formed.

On the "Karoo" the author noticed that all the springs in that country rise on the eastern side of dykes which run about N.E. and S.W. Near Hope Town there are immense tracts of sand. This village is surrounded by low bluffs of a peculiar rock, consisting of a calcareous matrix with waterworn pebbles. At Hope Town an active trade in diamonds is carried on.

The author crossed the Orange River at Hope Town, and describes the tract of country between that and the Vaal River, called Albania, as very barren of geological interest, being chiefly a sandy waste, with a few low hills, dykes of greenstone, trap, &c., and occasionally an outcrop of hard blue schist. Where the sandy covering is removed, a deposit of tufaceous nodular limestone is exposed.

Crossing the Vaal River at the Griqua mission-station of Backhouse, the author entered the true diamond-district. At Nicholson's farm, about six miles up the river, he observed the outcrop of a hard conglomerate, sometimes assuming the aspect of a breccia, composed of angular and rounded pebbles and blocks of quartz, jasper, &c. of all sizes to upwards of a foot in diameter. Overlying this was a highly ferruginous soil containing numerous pebbles of quartz, jasper, iron ore, &c., in which, the author was informed, several diamonds had been found.

From Backhouse the author pushed on to Likatlong, about sixty miles further north. On the road along the banks of the Vaal River he occasionally observed schistose rocks, and also a great deal of unstratified limestone, containing quartz and other pebbles, in which diamonds were said to have been found with limestone adhering to them. Beneath this limestone, when denuded away, a ferruginous clay, the same as above described, makes its appearance, and is searched by the natives for diamonds. The author considers that the number of diamonds found at Likatlong had been greatly exaggerated. He states that the diamonds were everywhere obtained from the ferruginous soil, and that the spots which had been searched were always near the river, and, as far as he observed, only on the right bank, where the level of the country for some distance from the river is lower than on the opposite side. He considers that the finding of diamonds on this side only is due to the absence of the great deposit of sand which raises the country on the opposite bank to a much higher level.

Discussion.

Prof. Tennant stated that he had lately seen as many as 500 diamonds from the South-African fields in the possession of one person, some weighing as much as 50 carats. He had seen another fragment of a stone which must have originally been at least as large as the Koh-i-noor.

December 21, 1870.

Valentine D. Colchester, Esq., 4 Buckland Villas, Belsize Park, N.W.; H. J. Heighton, Esq., Gold Street, Kettering; Thomas Hawksley, Esq., 30 Great George Street, Westminster; Frank Rutley, Esq., of the Geological Survey of England, Jermyn Street; Isaac Roberts, Esq., 26 Rock Park, Rockferry, Cheshire; Richard Glascott Symes, Esq., of the Geological Survey of Ireland, of Victoria Terrace, Ballina, County Mayo, and 14 Hume Street, Dublin; and Daniel Pidgeon, Esq., F.R.M.S., Banbury, were elected Fellows of the Society.

The following communications were read:—

1. *On* Lower Tertiary Deposits *recently* exposed *at* Portsmouth. By C. J. A. Meyer, Esq., F.G.S.

The excavations in progress at Portsmouth in furtherance of the works known as the "Dockyard Extension Works," have exposed to view, during the last three or four years, many fine and highly interesting sections in the Lower Tertiaries.

I propose to lay before the Society, by way of record, a brief account of these sections, and of the numerous fossils which have been obtained from them.

The site of the "Extension Works" lies to the east and north-east of the existing Dockyard. A description of the works themselves would be out of place in this paper; I shall therefore confine my mention of them to such points only as may serve to illustrate the geology of the district.

Previously to the commencement of these works, in 1867, the ground intended to be occupied was, for the most part, a vast mud-flat, covered at every tide by the waters of the harbour. The mud, of which I shall have more to say hereafter, was of the soft and sticky character so prevalent in tidal basins, and attained over some parts of the area to the formidable depth of from 35 to 40 feet.

In 1868 the sea was excluded by means of a dam of sheet-piling; and the enclosed area has been since reduced, by pumping and deep drainage, to almost perfect dryness to the depth of 40 feet beneath low water.

Excavations had been already commenced in the higher portion of the ground before the shutting out of the sea-water; and in 1867 I heard from my brother, Mr. C. H. Meyer, that fossils of the London clay were being met with in abundance.

In the spring of 1868, when I first visited the works, a fine section nearly 500 feet in length was exposed to a depth of 60 feet. It consisted of:—

Gravel	10 to 20 feet.
Stiff clay, with Septaria	30 to 40 feet.
A band of rounded black pebbles in clay	8 inches
Sands and shell-rock	10 feet.

The fossils of the clay with Septaria were clearly London-clay species. Those of the sands and shell-rock appeared to represent more nearly an equivalent to the Bognor fauna; but I was puzzled by many of the species, and determined to watch the progress of the excavations.

New sections have been from time to time exposed since 1868, until in August of the present year (1870) the excavations had so far progressed as to have opened out clear and nearly continuous sections of all the strata likely to be seen within the area of the works.

Description of Strata.

The strata exposed in 1870, exclusive of alluvial deposits, amounted to a thickness of 97 feet. To this must be added a thickness of about 30 feet cut through in 1868, but no longer shown in 1870, making a total thickness to be described of about 127 feet (as shown in fig. 1).

These beds have a nearly uniform dip to S.S.W., or more nearly south, of from $2\frac{1}{2}$ to 3 degrees. Their rise, measured horizontally, varies from 1 in 20 to 1 in 25. Their total rise, within the limit of the excavations from south to north rather exceeds 100 feet.

These strata admit of grouping into four more or less marked divisions, characterized partly by mineral structure, and in part also by a change of fauna. They may be described as follows, commencing with the lowest beds:—

	ft.
1. Clays and sandy clays with Pyrites	36
2. Argillaceous sands with *Dentalium*	25
3. Sands with *Lingula*	8
4. Clays with *Cyprina* and sandy clays	55

I propose to give in this place a broad outline of these groups, reserving to an appendix the details of the sections and a full list of fossils.

(1) *Clays and Sandy Clays with Pyrites.*—This group includes:—

	ft.
A. Stiff blue clay	10 to 15
B. Hard sandy clay with Pyrites	15
C. Argillaceous sands with thin layers of blue clay and grains and nodules of Pyrites	10

The blue clay of this group was exposed in a deep cutting in 1868. It contained masses of drifted wood perforated by *Teredo*; and specimens of a large *Ostrea*, referred by Mr. Edwards to *Ostrea gigantica*, Sol. A mass of wood was obtained to which several of these Oysters were attached.

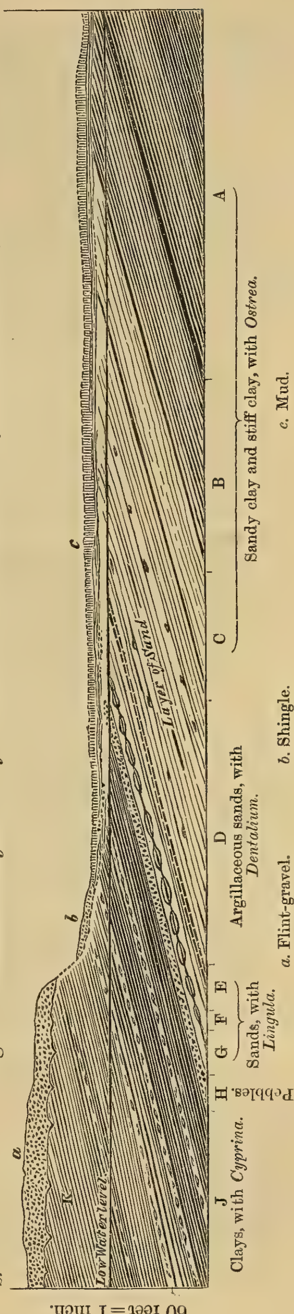


Fig. 1.—*Section through Line of Excavations at Portsmouth.* (Length 2000 feet.)

Teredina personata, Lam., occurs in the wood, and traces of a species of *Cliona* in the shells of the large *Ostrea*. A few specimens of *Pleurotoma* have been observed in the upper portion of this group, but fossils are evidently rare.

(2) *Argillaceous Sands with* Dentalium.—This group (marked D on the Section, fig. 1) consists principally of thinly bedded strata of greenish argillaceous sand more or less mottled and veined with clay. It includes three or four zones of scattered concretional Septaria, and terminates above in a double layer of claystone or tabular Septaria. A layer of fine whitish sand about 5 inches in thickness runs through the centre of the group and forms a marked feature in the cuttings.

The fossils of this group of strata include the following species:—

Ostrea flabellula, *Lam.*
Pinna, sp.
*Cardium Laytoni, *Morris.*
*Cultellus affinis, *Sow.*
*Cytherea suessoniensis, *Desh.*
*Leda substriata, *Morr.*
*Modiola simplex, *Sow.*
Nucula gracilenta, *S. V. Wood.*
——, sp.
—— striatella, *S. V. Wood.*
Panopæa corrugata, *Sow.*
Pholadomya virgulosa, *Sow.*
—— margaritacea, *Sow.*
*Pholas, spec. nov. (allied to *Levesquei*).
*Solen (large species).
*—— sp.
Syndosmya (Tellina) splendens, *Sow.*
*Tellina, spec. nov.
——, sp.
Teredina personata, *Lam.*
Aporrhais Sowerbii, *Mant.*
Fusus, sp.
Leiostoma globatum, *Desh.*
Natica labellata, *Lam.*
—— ——, var.
Pleurotoma, sp.
Rostellaria lucida, *Sow.*
Trophon tuberosum, *Sow.*
*Dentalium, spec. nov.
*—— ——, var.
*Thenops scyllariformis, *Bell.*
*Bryozoon.

These fossils occur dispersed throughout the sands. The specimens of *Panopæa*, *Pholas*, and *Pholadomya* occur in the position in which they lived, and with their valves united. The species marked with a star are restricted to this group; the rest range higher.

(3) *Sands with* Lingula.—This group of sands deserves special notice on account of the number and variety of its fossils. It includes the following beds:—

E.	Greenish sands with thin layers of clay	5 feet.
F.	One or more thin layers of greenish chloritous sand, crowded with fossils, and resting in places on a thin layer of clay	1 to 3 inches.
G.	Greenish sand, finely stratified, with one or more layers of shells	3 feet.

The abundance of green matter in these sands is very conspicuous. Concretions of shell-rock many feet in length occur along the line of sand and shells at F, sometimes including and sometimes resting on, or appearing to be suspended from, the layer of shells. This shell rock, which has very much the appearance of Bognor rock, is so hard as to require blasting.

More than eighty species of fossils, several of which are new to the English Eocene strata, have been obtained from this group of strata. A few of these, such as *Lingula tenuis*, Sow., and *Panopæa* *intermedia*, Sow., occur dispersed more or less abundantly throughout its thickness. The greater number were obtained from near the top of the sands, or from the thin layer of sand at F, where they lie crowded together, at intervals, to a depth of many inches.

Fossils of Sands with Lingula.

Avicula media, *Sow.*
Ostrea flabellula, *Lam.*
Pinna affinis, *Sow.*
——, sp.
Cardita planicosta, *Lam.*, var.
—— Brongniartii, *Mant.*
——, sp.
Cardium (Protocardium) Wateleti, *Desh.*
——, sp. (small species).
Corbula, three species,
Cytherea proxima, *Desh.*
—— orbicularis, *Desh.*
—— portsmeuthiensis, *Edw. MS.*
—— pseudo-orbicularis, *Edw. MS.*
Mactra, sp.
Modiola elegans, *Sow.*
Nucula gracilenta, *S. V. Wood.*
—— striatella, *S. V. Wood.*
Panopæa intermedia, *Sow.*
Pholadomya virgulosa, *Sow.*
Psammobia Edwardsi, *Morris.*
Syndosmya (Tellina) splendens, *Sow.*
Teredina personata, *Lam.*
Lingula tenuis, *Sow.*
Aporrhais Sowerbii, *Mant.*
Bulla constricta, *Sow.* ?
—— sulcatina, *Desh.*
Calyptræa trochiformis, *Sow.*
Cancellaria læviuscula, *Sow.*
——, sp.
Cassidaria diadema, *Desh.*, var.
—— substriata, *Edw. MS.*
Chemnitzia tenuiplica, *Edw. MS.*
Chrysodomus bifaciatus, *Sow.*
Fusus, sp.
——, sp. (small species).
——, sp.
Pisania sublamellosa, *Desh.*
——, sp. nov,
Leiostoma globatum, *Desh.*
Murex coronatus, *Sow.*
Natica labellata, *Lam.*
—— splendida, *Desh.*
Natica portsmeuthiensis, *Edw. MS.*
—— subdepressa, *Morris*, var.
—— microstoma, *Sow.* ?
—— lignitarum, *Desh.*
Pleurotoma helix, *Edw.*
—— stena, *Edw.*
—— (six to ten other species).
Pseudoliva fissurata, *Desh.*, var. ?
—— sulcifera, *Edw. MS.*
Pyrula Smithii, *Sow.*
—— tricostata, *Lam.*
—— Greenwoodii, *Sow.*
Rostellaria lucida, *Sow.*
Scalaria undosa, *Sow.*
—— (small species).
Sigaretus clathratus, *Recl.*
Skenea, sp.
Solarium bistriatum, *Desh.*
—— ——, var.
——, sp.
Triton Morrisii, *Edw. MSS.*
Trophon tuberosum, *Sow.*
Turritella sulcifera, *Desh.*
—— imbricataria, *Lam.*
—— Meyerii, *Edw. MS.*
—— terebellata, *Lam.*
Voluta elevata, *Sow.*
—— depressa, *Lam.*
—— nodosa, *Sow.*
——, sp.
Nautilus centralis, *Sow.*
—— Sowerbii, *Weth.*
—— imperialis, *Sow.*
Flustra.
Bryozoon.
Hemiaster Bowerbankii, *Forb.*
Cliona, spec. nov.
Palæocorystes glabra, *Woodw. MS.*
Xanthopsis Leachii, *Bell.*
Rhachiosoma bispinosa, *Woodw. MS.*
—— echinata, *Woodw. MS.*
Nipadites.
Wood (and fragments of plants ?),

These strata have been exposed in open cuttings from one to two thousand feet in length.

In first looking over the fossils of the "Sands with *Lingula*," one cannot but be struck with the apparent mixture of London-Clay fossils with species which are usually considered characteristic of higher or lower formations. The two species which occur the most abundantly in these strata will serve to illustrate my meaning. These are *Cytherea proxima*, Desh., a species closely allied to *C. suberycinoides*, Desh., and *Natica subdepressa*, Morris. The former of these, although not the Bracklesham *Cytherea suberycinoides*, looks strangely like it. The latter, a Thanet-Sand species, has not, I believe, been hitherto found above the base of the London Clay. The same remarks apply to several other species present less abundantly in these sands—as, for instance, *Cardita planicosta*, *Turritella sulcifera*, *T. imbricataria*, and others, all well-known species of the Middle Eocene, while, on the other hand, *Cardium Laytoni*, Morris, and *Cytherea orbicularis*, if not strictly Thanet-Sand species, range elsewhere only into the lowest of the London-Clay strata.

By taking a Darwinian view of the matter, one may perhaps get over the difficulty of the seeming mixture of species; and this view is probably correct, for on close examination it is evident that the common *Cytherea* of the Portsmouth sands is not quite the *C. suberycinoides* of the Middle Eocene, although probably its predecessor, in the same way as its companion shell, *Natica subdepressa*, var., may be the descendant of the *N. subdepressa* of the Thanet Sands.

The condition in which the fossils occur in the sands with *Lingula* is also worthy of notice. In the lower portion of these sands, as also in the underlying "Sands with *Dentalium*," the shells occur sparingly, mostly with their valves united, and frequently in their natural position. Towards the top of the "Sands with *Lingula*," where the shells lie crowded together in layers or patches, there is clear evidence of drifting. The univalves are often slightly worn. The bivalves appear frequently with their valves disunited, and with the concavity of the valve turned downwards, as is so constantly the case between the tide-marks on a flat sandy shore. Fragments of wood or carbonaceous matter, in minute quantities, are constantly present in and near the layers of shells*. There can be no doubt that the "Sands with *Lingula*" were either accumulated in shallow water, or as a littoral deposit.

(4). *Clays with* Cyprina.—This group includes the following beds:—

H.	Brownish clay, with rounded black flint pebbles	8 inches.
J.	Stiff greyish clay with Septaria	30 feet.
K.	Brown sandy clay, with thin lines of sand	15 to 25 feet.

Fossils are far from abundant in this group. The altered condition, in all probability a deepening of the sea-bed, resulting in the introduction of the layer of pebbles above mentioned, and the abrupt change from sands to stiff clays, is seen to have been accompanied by a marked change of fauna. Of the numerous species of Mollusca occurring in the "Sands with *Lingula*," many of which abound to within an inch of the zone of pebbles, a few species only reappear at a higher level in the series.

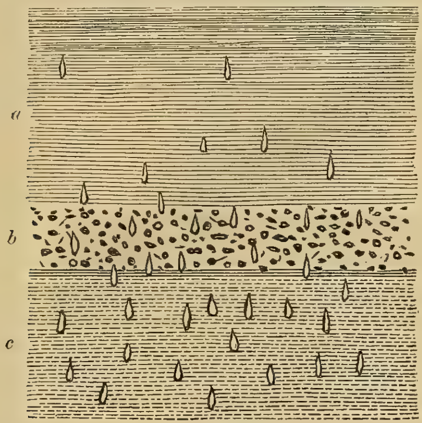
* Some of the blocks of stone, on being split in the line of bedding, are seen to be crowded with carbonaceous markings, as of minute leaflets or seed-vessels.

The "Clay with Pebbles" contains—

Cytherea despecta, *Desh.* A species new to the British Eocene.
Panopæa intermedia, *Sow.*
—— corrugata, *Sow.**
Pholadomya margaritacea, *Sow.*
Teredina personata, *Lam.*
Pinna affinis, *Sow.*
Pecten corneus, *Sow.*
Natica labellata, *Lam.*
—— subdepressa, *More.*
Rostellaria lucida, *Sow.*
And teeth of Lamna and Otodus.

Of these species the *Cytherea* is found only in the zone of pebbles. The *Panopææ* continue their range upwards from the "Sands with *Lingula*" to a few inches (rarely a few feet) above the pebbles, all

Fig. 2.—*Beds with* Panopææ *in position.*



a. Stiff clay (J). *b.* Clay and Pebbles (H). *c.* Sands (G).

species occurring with their valves united, and in their natural position. It is curious that the *Panopææ* should have so long outlived that changed condition of the sea-bed which drove away their comrades in the "Sands with *Lingula*."

Cyprina planata, *Sow.*
Pecten corneus, *Sow.*
Pinna affinis, *Sow.*
Panopæa intermedia, *Sow.*
Pectunculus brevirostris, *Sow.*, var.
Teredina personata, *Lam.*
Pholadomya margaritacea, *Sow.*
Turritella sulcifera, *Desh.*
Natica labellata, *Lam.*
Rostellaria lucida, *Sow.*

and very rarely a *Nautilus* occur in the "Clay with *Cyprina*."

A layer of crushed shells of *Pinna*, an inch or more in thickness, occurs at about two feet above the pebbles. The shells are so much decomposed that it is impossible to say whether they were whole when deposited.

Aporrhais Sowerbii, *Rostellaria lucida*, a *Chrysodomus*, and several species of *Pleurotoma* occur in the sandy clay (K), which forms the highest Eocene stratum exposed on the works.

* *Panopæa corrugata*, Sow., is most plentiful in the pebble-bed. I am not sure that in the sands it can be distinguished from *P. intermedia*, Sow., unless by a difference in size.

Such, then, is a brief account of the strata and fauna of the Lower Eocene deposits as seen in the Portsmouth sections. It remains to determine the position which these beds may be supposed to occupy in relation to the cliff-sections at Alum Bay and Whitecliff. The evidence of the fauna, including as it does many species respectively of a high and low level in the Eocene strata, is too contradictory to be of much value. The stratigraphical evidence which it is my good fortune to be able to lay before the Society, however, is perfectly conclusive.

I propose to show this in two ways:—First, by comparing the ascertained rise per hundred feet of the beds described with their distance from the known outcrop of higher and lower formations; and, secondly, by the more direct evidence of borings and well-sections.

Evidence of Thickness of Beds by Horizontal Measurement.

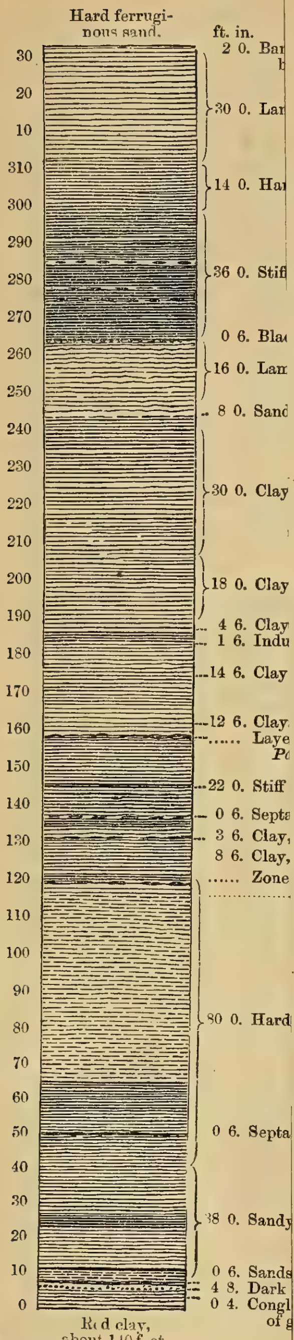
I have shown that the rise of the strata along the line of the section (fig. 1), from south to north, equals a rise of about 1 foot in every 22 feet. Now the distance from the outcrop of the highest beds exposed on the works to the known outcrop of the underlying Red Clay is about 6000 feet, which gives a thickness of about 275 feet to the intermediate beds, or within 25 feet of the thickness of the London Clay and Bognor series of Whitecliff. Then, again, the distance from the line of strike of the higher beds on the works to the nearest known outcrop of the Bracklesham beds is about from 6500 to 7000 feet, giving a thickness to the intermediate strata of from 295 to 315 feet. And this thickness agrees very nearly with that of the Lower-Bagshot strata at Whitecliff. Supposing these measurements to be correct, the strata above described must represent nearly the upper portion of the London Clay of the Whitecliff and Alum-Bay sections.

Evidence by Borings and Well-sections.

The thickness of the strata exposed on the works in open cuttings I have shown to amount to about 127 feet. A boring has been recently sunk from almost the lowest of these beds to a further depth of about 115 feet (fig. 3, *b*). The details of this boring are as follows:—

Details of boring in Extension Works.	ft.	in.
Sandy clay	10	0
„ with more clay	5	0
Stiff clay	5	0
Very stiff clay (="Clay with *Ostrea*" of the Section)	18	0
Claystone		2
Very stiff clay	29	0
Layer of Pyrites and a small shell (*Turritella*)		1
Stiff clay	12	8
Claystone		2
Clay	2	0
Claystone		2
Very stiff clay	10	10
Clay full of rounded black pebbles		9
Hard sand	22	3
Blue clay	39	0
Total	155	1

a. *Whitecli*



c. *Section of Deep Well, Portsmouth Dockyard.*

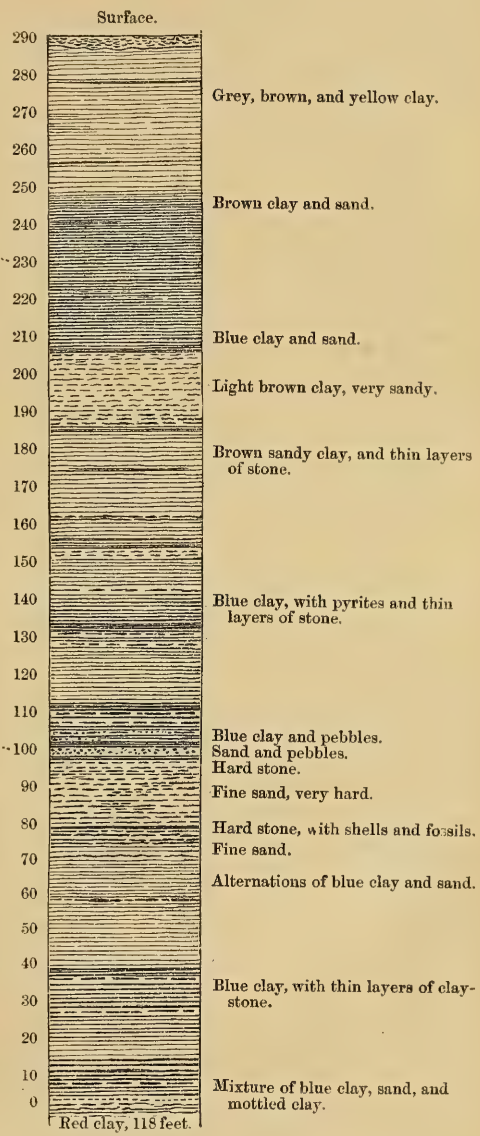
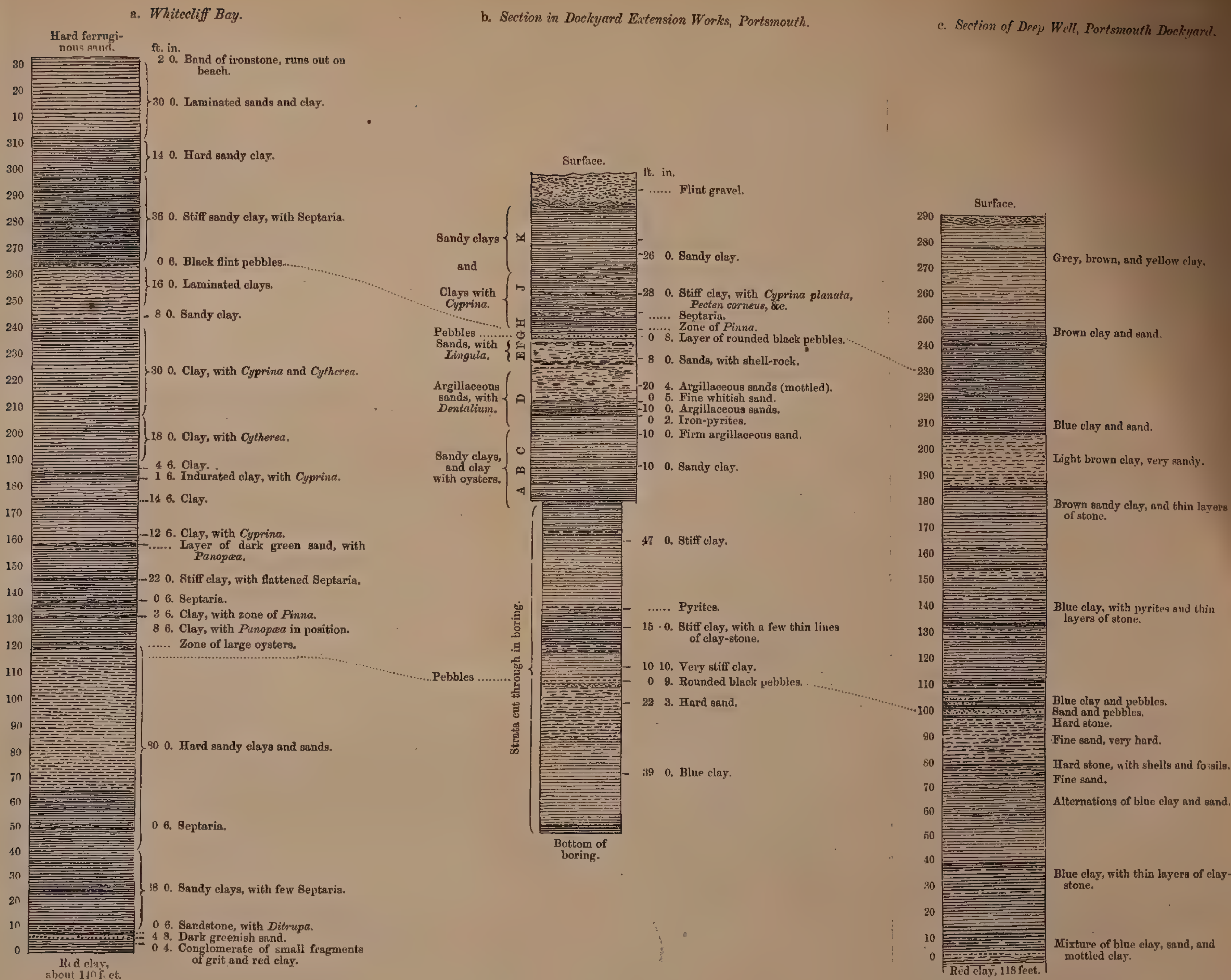


Fig. 3.—*Comparison of Section at Whitecliff Bay with Borings at Portsmouth.*



The point of chief importance in this boring is the occurrence, at 93 feet below the lowest beds exposed in the open cutting, of a band of rounded flint pebbles, similar to that at the base of the "Clays with *Cyprina planata*." The discovery of this second band of pebbles has given a clue to the position, in relation to the underlying Plastic Clay and Chalk, of all the strata seen on the works, as I shall show by comparison with the records of two previous borings in the Dockyard.

For permission to avail myself of the records of these two borings, which probably have not been hitherto published, I am indebted to the kindness of Mr. Wood, the Superintending Civil Engineer at H. M. Dockyard at Portsmouth.

The first of these, known as the Deep-Well boring (fig. 3, *c*), is situated at the distance of 3000 feet from the boring on the Extension Works, or only about 170 feet S.S.W. of the line of strike of the highest strata above described. It was carried down to the depth of 1037 feet. In this boring the chalk is reached at the depth of 408 feet. The thickness of the Red or Plastic Clay amounts to 118 feet. A layer of rounded flint-pebbles is shown at the height of 100 feet above the Plastic Clay, or about 190 feet from the surface. There can, I think, be no doubt whatever that this pebble-bed represents the pebble-bed cut through in boring on the Extension Works. It is curious, however, that the upper pebble-bed is not shown in the Deep-Well section.

The second boring (fig. 3, *b*) in the Dockyard (the first, perhaps, in point of date, as it was made in 1825) is at the distance of nearly 1000 feet S.S.W. of the line of strike of the highest beds on the Extension Works. It has been carried down to a depth of 290 feet. In this boring both the pebble-beds are shown; and the interval between them corresponds exactly to that between the two pebble-beds on the Extension Works. The same beds have been also shown to occur, in the same relative position, in other borings at no great distance from the above, as well as in well-borings through corresponding strata at Southampton*. Two pebble-beds are shown by Mr. Prestwich as occurring in about the same position at Alum Bay†.

It is shown, then, by the evidence of these borings as explained by the open cuttings on the Extension Works, that the strata there exposed range from the height of 163 feet to that of 290 feet above the Red Clay; and by the same evidence the position of the remarkable shell-beds underlying the zone of pebbles and "Clay with *Cyprina*" may be placed at the height of 233 feet above the Red Clay, or within from 60 to 70 feet of the base of the Lower Bagshot.

[*Note.*—The term Red Clay here made use of answers to the Plastic Clay of most authors.]

Taking now a more general view of the London and Bognor strata of the Portsmouth district, we find:—

That their thickness certainly exceeds 290 feet.

* For details of the Southampton well-borings I am indebted to Mr. Bristow, of the Geological Survey.

† Quart. Journ. Geol. Soc. vol. ii. pl. ix.

That this 290 feet is composed of a threefold series of strata, the lowest of which reposes on the Plastic Clay.

That each division of the series commences with a zone of pebbles, and passes upwards from stiff clays to sandy clays and sands*.

Of the lowest series nothing is known with certainty, except its thickness (100 feet) and the mineral composition of its strata, as shown in the Deep-Well boring.

Of the middle series, which includes a thickness of 134 feet, a large portion has been seen in open cuttings on the Works. It includes in its upper part the "Argillaceous sands with *Dentalium*" and the "Sands with *Lingula*," described above. The shell-rock in the "Sands with *Lingula*" at the top of this series *probably* represents the Bognor Rock of Sussex; but of this I cannot speak with certainty, as I have no evidence of the height of the Bognor Rock itself above the Plastic Clay.

The upper series, having a thickness of from 50 to 60 feet of clays and sandy clays, including the "Clays with *Cyprina*," has been sufficiently described above. There can be no doubt whatever that these last beds represent the upper beds of the so-called London Clay of the Alum-Bay and Whitecliff sections. It is evident that the whole of the strata above described are included in group 3 and part of group 4 of Mr. Prestwich's Section of the Whitecliff strata.

The accompanying Sections (fig. 3), which are drawn strictly to measure, exhibit a comparison of the Lower Eocene strata of Portsmouth, with the already well-known Section at Whitecliff Bay, and may, I hope, be ultimately useful for comparison with a much-to-be-desired well-section at Bognor.

I have not thought it necessary to compare the Portsmouth Lower-Eocene strata with those of the London basin, such comparison in effect having been already made by Mr. Prestwich so long since as 1847.

Gravel- and Mud-Deposits resting on the Lower Eocene Strata.

The superficial deposits seen in the excavations at Portsmouth deserve a short description, if only on account of the fine sections exposed.

The first or oldest of these deposits is the gravel-bed shown in the Section (fig. 1) as capping the higher portion of the ground. The base of this gravel-bed stands at from 15 to 20 feet above low-water level, and rests on the unequally eroded surface of the clay. It is a light-coloured subangular flint-gravel, and probably represents the "white gravel" lately described by Mr. Codrington †. The ground on which it rests forms a low escarpment facing to the N. and N.N.E., the direction of the escarpment coinciding with the outcrop and line of strike of the upper beds of the "Clay with *Cyprina*."

A few patches of contorted gravel containing large, partly rounded flints, have been exposed at a slightly lower level near the edge of

* A like sequence in the mineral character of the Lower and Middle Eocene deposits in the Isle of Wight has been noted and commented on by Mr. Fisher (*vide* Quart. Journ. Geol. Soc. vol. xviii. p. 65).

† Quart. Journ. Geol. Soc. vol. xxvi. p. 535.

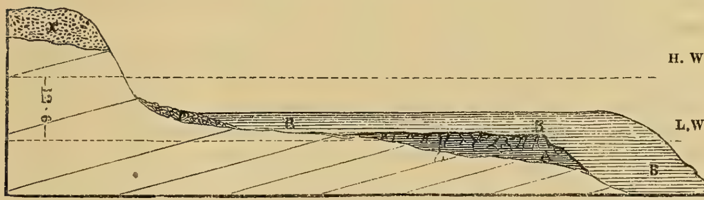
the clay escarpment; but their relation to the principal gravel-bed has not been clearly shown.

Passing from the gravels to the deposits next in age, we come to various beds of silt and silty clay underlying the most recent mud-deposits of the harbour. These beds have been exposed in clear vertical sections many hundred feet in length. In all of these sections the underlying Tertiary deposits are shown to have been cut away to a smooth, if not always to a level surface, the depth to which they have been eroded varying from a few feet above low-water level, as along part of the general Section (fig. 1), to that of from 20 to 30 feet beneath low water in the north-west portion of the area.

The surface of the mud over the whole area stands at from 6 to 7 feet above low-water level of the ordinary spring tide.

The following section (fig. 4) exhibits the principal features seen in these deposits.

Fig. 4.—*Ideal Section showing the Relative Positions of the Gravel- and Mud-deposits.*



x. Gravel.
A. Old mud-deposit, with stumps and roots of trees.
B. Recent mud-deposits.
C. Shingle.

In this section the gravel-bed, marked *x*, and the older and newer mud-deposits, A and B, are shown at their relative levels in relation to the present high and low water. It is not improbable that this section, which represents only a very small portion of the great mud-flat between Portsmouth and the foot of the chalk escarpment of Portsdown, may serve to illustrate the general condition of the surface-deposits of the harbour.

There can be little doubt that the gravel-bed (*x*) was at one time continuous over a great portion, if not the whole, of the surface of the harbour now covered by mud or water. At what time or in what manner it was denuded I shall not stay to consider; it is sufficient to know that the denuding agent, whatever it may have been, has cut down to the underlying sands and clays of the Eocene-beds, which present, in all the sections I have examined, a cleanly swept surface beneath the mud.

The older and newer mud-deposits, A and B, shown in the mud-section (fig. 4), were probably formed under very similar conditions. The bed A is first seen in the sections at about 300 feet from the low gravel-capped escarpment, and spreads out northward and westward until cut off, as it were, by the deep water along the

Fountain Lake. It rests everywhere directly on the Eocene sands and clays; and its lower beds are in a great measure made up of these underlying sands and clays re-deposited. This is so much the case, that it is often difficult, even in the open cuttings, to distinguish between the top of the Eocene and the bottom of the mud.

Change of level, or possibly the silting up of some narrow inlet to the tidal water, must at some time have converted this mud-deposit (A) into a land-surface, as its surface, where not eroded, is seen dotted over with the stumps of trees of small growth—possibly Alder or Willow, their roots often penetrating downwards vertically to the depth of 5 feet. The present surface of this root-bed stands at from 3 feet above to 2 feet beneath the present low-water level of the harbour. It is this root-bed, probably, which has been described by Sir Henry James * as occurring beneath the dockyard at a depth of from 4 to 14 feet beneath low water.

I do not see exactly in what way to account for the difference of level of the root-bed shown in the Mud-section and again beneath the dockyard, except by supposing a subsidence of the underlying Tertiary deposits. It is at least worthy of notice that the dip of the root-bed in this area corresponds in direction with the dip of the Eocene strata on which it rests.

The mud-bed B, or recent mud-bed as it might be called, as compared with the root-bed, commences at the foot of the low escarpment, and, spreading northwards and westwards, rests everywhere directly on the Eocene, or on the mud-bed A where this is present. The surface of the mud (B) stands at from 6 to 7 feet above low-water level, or just midway between ordinary high and low water. One may suppose, indeed, other conditions remaining the same, that this level would be indefinitely maintained, the flow, and consequently the carrying powers of the water on and off the mud being equal. A study of the sections tends to confirm this idea; for there is evidence in these of very slow deposition near the surface of the mud in most places, and of very rapid deposition in a few others—the rapid deposition, as along the edge of Fountain Lake, being clearly the result of *silting up* to a certain level.

The spread or overlap of the mud-bed B so far beyond that of A seems to point to a cutting back of the gravel-capped escarpment, for the same distance, since the submersion of the root-bed.

The gravel-bed x contains no fossils.

The root-bed contains rarely a few specimens of *Littorina*.

The mud-bed A is crowded with recent shells at and near the surface, and usually also near its base. Antlers of the Red and Fallow Deer have also been met with in this bed.

Thin beds of fine subangular shingle are seen in places, either interstratified in the mud or near its base, and in all cases include recent shells.

It has been my good fortune while studying the above sections to enjoy the friendship of several of the gentlemen in command of the works; and to their assistance I am indebted for much valuable

* Quart. Journ. Geol. Soc. vol. iii. p. 249.

information, which would have been otherwise unattainable. My thanks are especially due to Mr. Edw. P. Smith.

To Mr. Edwards, Mr. Etheridge, and Prof. Morris, I am largely indebted for their kind and valuable assistance in the determination of the fossils.

Table of Fossils from the Lower Eocene of Portsmouth.

	4. Clay with *Cyprina.*	× Pebble-bed.	3. Sands with *Lingula.*	2. Sands with *Dentalium.*	1. Clays with *Ostrea.*
LAMELLIBRANCHIATA.					
(*Monomyaria*).					
Avicula media, *Sow.*			r		
Ostrea gigantica, *Sol.*					c
— flabellula, *Lam.*			c	r	
Pecten corneus, *Sow.*	r	r			
Pinna affinis, *Sow.*	c	r	r		
Pinna, sp.			r	r	
(*Dimyaria*).					
Cardita planicosta, *Lam.*, var.			r		
— Brongniartii, *Mant.*			c		
— sp. (small species)			r		
Cardium (Protocardium) Wateleti, *Desh.*			r		
— sp. (small species)			r		
— Laytoni, *Morris*				c	
Corbula Morrisii, *Edw.*, Geol. Journ. x. t. 2. f. 1, low. fig.			r		
—, sp.			r		
— pisum, *Sow.*			r		
Cultellus affinis, *Sow.*				c	
Cytherea proxima, *Desh.* (pl. xxx. figs. 31–34)			c		
— orbicularis, *Desh.* non *Edw.*			c		
— pseudo-orbicularis, *Edw. MS.*			r		
— portsmeuthiensis, *Edw. MS.*			r		
— suessoniensis, *Desh.*				c	
— despecta, *Desh.*		c			
Cyprina planata, *Sow.*	c				
Leda substriata, *Morr*				c	
Mactra, sp.			r		
Modiola simplex, *Sow.*				r	
— elegans, *Sow.*			r		
—, sp.				r	
Nucula gracilenta, *S. V. Wood*			c	c	
— striatella, *S. V. Wood*			r	c	
—, sp.				r	
Panopæa corrugata, *Sow.*		c		r	
— intermedia, *Sow.*	r	r	c		
Pectunculus brevirostris, *Sow.*	c				
— decussatus, *Sow.* ?					?
Pholadomya margaritacea, *Sow.*	c	r		r	
— virgulosa, *Sow.*			r	r	
Pholas, sp. nov				r	
Psammmobia Edwardsi, *Morr.*			r		
Solen, sp. (large species)				r	

	4. Clay with *Cyprina.*	× Pebble-bed.	3. Sands with *Lingula.*	2. Sands with *Dentalium.*	1. Clays with *Ostrea.*
LAMELLIBRANCHIATA (*continued*).					
Solen, sp. (small species)				r	
Syndosmya (Tellina) splendens, *Sow.*			r	r	
Tellina, spec. nov				r	
—, sp.				r	
Teredina personata, *Lam.*	r	r	r	c	r
BRACHIOPODA.					
Lingula tenuis, *Sow.*			c		
GASTEROPODA.					
Aporrhais Sowerbii, *Mant.*	c		r	c	
— —, var.			r		
Bulla constricta, *Sow.*?			r		
— sulcatina, *Desh.*			r		
Calyptræa trochiformis, *Sow.*			r		
Cancellaria læviuscula, *Sow.*			c		
—, sp.			r		
Cassidaria diadema, *Desh.*			r		
— —, var.			r		
— substriata, *Edw. MS.*			r		
Chemnitzia tenuiplica, *Edw. MS.*			c		
Chrysodomus bifasciatus, *Sow*			r		
—, sp.	r				
Fusus, several species			r	r	
Leiostoma globatum, *Desh.*			r	r	
— —, var.			r		
Murex coronatus, *Sow.* non *Born*			r		
Natica labellata, *Lam.*	c	c	c	c	
— —, var.				r	
— splendida, *Desh.*			r		
— lignitarum, *Desh.*			r		
— subdepressa, *Morris*, var.		r	c		
— microstoma, *Sow.*?			r		
— portsmeuthiensis, *Edw. MS.*			r		
Pisania, spec. nov			c		
— sublamellosa, *Desh.*			r		
Pleurotoma helix, *Edw.*			r		
— stena, *Edw.*	r		r		
— terebralis, *Lam.*			r		
— acuminata, *Sow.*			r		
— teretrium, *Edw.*	r		r		
— macilenta, *Edw.*			r		
—, several species	r		r	r	r
Pseudoliva fissurata, *Desh.*, var.			r		
— sulcifera, *Edw. MS.*			r		
Pyrula Smithii, *Sow.*			c		
— tricostata, *Lam.*			r		
— Greenwoodii, *Sow.*			r		
Rostellaria lucida, *Sow.*	c	r	c	c	
— —, var.			r		
Scalaria undosa, *Sow.*			r		

	4. Clay with *Cyprina*.	× Pebble-bed.	3. Sands with *Lingula*.	2. Sands with *Dentalium*.	1. Clays with *Ostrea*.
GASTEROPODA (*continued*).					
Scalaria, small cancellated species	......	......	r		
Sigaretus clathratus, *Recluz* (canaliculatus, *Sow.*)	......	......	r		
Skenea, sp.	......	......	r		
Solarium bistriatum, *Desh.*	......	......	c		
— —, var.	......	......	r		
—, sp.	......	......	r		
Triton Morrisii, *Edw. MS.*	......	......	r		
Trophon tuberosum, *Sow.*	......	......	r	r	
Turritella sulcifera, *Desh.*	r	......	r		
— imbricataria, *Lam.*	......	......	r		
— terebellata, *Lam.*	......	......	r		
— Meyerii, *Edw. MS.*	......	......	r		
Voluta elevata, *Sow.*	......	......	c		
— depressa, *Lam.*	......	......	r		
— nodosa, *Sow.*	......	......	r		
—, sp.	......	......	r		
Dentalium, spec. nov.	......	......	......	c	
— —, var.	......	......	......	r	
CEPHALOPODA.					
Nautilus centralis, *Sow.*	......	......	r		
— imperialis, *Sow.*	r	......	r		
— Sowerbii, *Weth.* ?	r	......	r		
BRYOZOA.					
Bryozoon	......	......	r	r	
Flustra	r	......	r		
ECHINODERMATA.					
Hemiaster Bowerbankii, *Forbes*	......	......	r		
SPONGIA (AMORPHOZOA).					
Cliona, sp. nov.	......	......	r	......	r
CRUSTACEA.					
Palæocorystes glabra, *Woodw. MS.*	......	......	r		
Rhachiosoma echinata, *Woodw. MS.*	......	......	r		
— bispinosa, *Woodw. MS.*	......	......	r		
Thenops scyllariformis, *Bell*	......	......	......	r	
Xanthopsis Leachii, *Bell*	r	......	r		
PISCES.					
Lamna elegans, *Ag.*	......	r			
Otodus obliquus, *Ag.*	......	r			
Sauroid tooth	......	......	r		
Vertebræ (of fishes)	......	......	r		
Myliobates, sp.	......	......	r		
PLANTÆ.					
Nipadites, sp.	......	......	r		
Wood	......	r	r		c

APPENDIX.

Details of General Section of Lower Eocene deposits at Portsmouth (Dockyard Extension Works), commencing with the highest strata exposed.

		feet.	inches.	
Sandy clay.	Brownish sandy clay, with thin partings of sand	25	0	Zone of *Pleurotoma* (several species).
	Sandy clay	5	4	
	Sand, with small nodules of claystone	0	3	
Clays with *Cyprina*.	Brownish sandy clay	4	0	
	Septaria	0	0	
	Brownish clay	5	9	Zone of *Pectunculus*.
	Septaria	0	0	
	Layer of greasy clay	0	2	
	Stiff greyish clay, with thin partings of sand	5	2	Zone of *Aporrhais Sowerbii*.
	Sand, with pyrites	0	0½	
	Stiff greyish-brown clay	2	1	
	Septaria	0	0	
	Stiff greyish-brown clay	5	6	Zone of *Cyprina planata*.
	Sandy clay	0	2	
	Stiff greyish-brown clay	2	10	Zone of *Pholadomya margaritacea*.
	Thin layer of *Pinna*; crushed, and much decomposed. (These shells appear to have been whole when deposited.)	0	2	Zone of *Pinna*.
	Thin seam of greasy clay	0	1	
	Stiff greyish-brown clay	2	1	Zone of *Panopæa*.
Pebble bed.	Brownish clay, with rounded black flint pebbles	0	10	Zone of *Cytherea despecta*.
Sands with *Lingula*.	Greenish sands, finely bedded and interstratified with thin lines of clay and fragments of carbonaceous matter. Fossils numerous	3	0	Zone of *Panopæa intermedia*.
	Layer of greenish chloritous sand, crowded with fossils, and forming the nucleus of a zone of large concretions of shell-rock	0	1	Zone of *Cytherea proxima*, &c. &c.
	Argillaceous sand, slightly mottled	5	0	
Argillaceous Sands with *Dentalium*.	Sand, with double band of tabular Claystone or Septaria, containing thin lines of vegetable matter	1	6	
	Greyish-brown (or greenish-brown) mottled sand, with thin seams of clay	6	0	
	Septaria, at wide intervals	0	0	
	Greenish-grey argillaceous sand, mottled and veined with clay	4	6	Zone of *Pholas* ——.
	Layer of finely laminated sand, nearly white when dry	0	5	
	(This bed is very constant in thickness within the area of the excavations.)			
	Greyish argillaceous sands, slightly mottled	4	6	Zone of *Cardium Laytoni* and *Cytherea suessoniensis*, Desh.
	Septaria	0	0	
	Greyish argillaceous sand, or sandy clay	5	6	

		feet.	inches.	
Clay & Sandy Clays with Pyrites.	Thin line of sand, with pyrites	0	1	
	Thin band of blue clay	0	4	
	Hard sandy clay, with thin lines of stiff clay	10	0	
	Ditto, with more clay	5	0	
	Stiff clay	5	0	
	Very stiff clay, with large Oysters	18	0	Zone of *Ostrea gigantica.*
Strata cut through in boring.	Claystone	0	2	
	Very stiff clay	29	0	
	Layer of pyrites	0	1	
	Stiff clay	12	8	
	Claystone	0	2	
	Clay	2	0	
	Claystone	0	2	
	Very stiff clay	10	10	
	Clay, full of rounded black flint pebbles	0	9	
	Hard sand	22	3	
	Blue clay (to bottom of boring)	39	0	

Discussion.

Prof. Ramsay called attention to the value attaching to such observations as those of the author on the nature of the superficial deposits as distinct from the older rocks on which they repose.

Mr. Etheridge observed that the presence of the *Lingula* determined the position of the Bognor beds in the series, though there appeared great difficulty in fixing it stratigraphically. The commingling of species exhibited in this instance, of shells hitherto supposed to be peculiar to certain horizons, he regarded as very remarkable.

Prof. Morris observed that the section seemed to show, not only the order of the beds, but their manner of deposition, the whole having formed part of a tranquil sea-bottom. He remarked on the difficulty of separating the more recent mud deposits from the beds of more ancient date. He pointed out the method of formation of septaria apparently by segregation, as they sometimes included undisturbed parts of the beds. The number of bivalves bored by carnivorous mollusks was remarkable, as was also the absence of *Pectunculus*.

Mr. Gwyn Jeffreys observed on the habits of *Lingula*, which had been by some regarded as an annelid, and not as a mollusk. It afforded a curious instance of the persistence of species, as there was no distinction that could be established between those of the Crag and of Silurian times. It lived at the present time between high- and low-water mark, and the *Panopœa* at a slightly lower level, and probably had done so in Tertiary times.

Mr. Evans inquired whether the upper gravel, like that on the shore of Southampton Water, contained any flint implements.

Mr. Meyer replied that he had not examined the gravels with that view.

2. NOTES *on some new* CRUSTACEANS *from the* LOWER EOCENE *of* PORTSMOUTH. By HENRY WOODWARD, Esq., F.G.S., F.Z.S., of the British Museum.

[Plate IV.]

HAVING been favoured by Messrs. C. J. A. Meyer and Caleb Evans with the opportunity of examining three new Crustaceans recently obtained by them from the Lower Tertiary Deposits exposed during the excavations for the "Dockyard Extension Works" in Portsmouth Harbour, I beg to submit the following notes thereon.

I. Family CORYSTIDÆ. (Genus *Palæocorystes*, Bell.)

This family, represented at the present day by the genus *Corystes* common on our own coast, and in the Chalk, Greensand, and Gault by the genera *Palæocorystes* and *Eucorystes*, has now been discovered in the Lower Eocene, at Portsmouth, by Mr. Caleb Evans, F.G.S.

The specimen (see Plate IV., figs. 1 *a*, *b*), although far from perfect, is sufficient to indicate at once the genus to which it belongs, namely *Palæocorystes*, and also that it is specifically distinct from those occurring in the Cretaceous rocks, already described by Prof. Bell and others *. The carapace measures one inch in length; but (both its anterior and posterior borders having been injured) it was, originally, probably nearly one-fourth of an inch longer. In breadth it measures 10 lines. Some portion of the anterior (orbital and suborbital) border can still be traced out; but the rostrum is quite destroyed. The surface of the carapace is smooth and devoid of ornamentation, save a few widely scattered and very minute puncta; but where the delicate cortical layer has been removed, the carapace presents a finely granular structure. The two sigmoid markings, observable on the carapaces of all the Corystidæ are also clearly to be seen in this example.

On the underside the branchiostegal pieces (*br*) are traceable, also the basal joint (*m*) of one of the maxillipedes (see Plate IV. fig. 1 *b*).

I propose to name this form *Palæocorystes glabra*. Previously to the discovery of this crab no species of *Palæocorystes* had been met with in any bed younger than the Maestricht Chalk, where a species named *P.* (*Notopocorystes*) *Mülleri* has been noticed by Count von Binkhorst, which much resembles *P. glabra*, save that the sigmoidal markings seen on the latter are absent in the former species. (See Plate IV. fig. 2.)

This is the second family of Crustaceans living at the present day, and met with fossil in the Maestricht Chalk, which I have had the pleasure of recording as occurring also in the Eocene of the south of England †.

* See Prof. Bell's Monograph on the Fossil Crustacea of the Gault and Greensand, Palæontographical Society, 1862, vol. xiv. p. 11, pls. ii. & iii.

† See British Association Reports, Norwich, 1868, on the Occurrence of *Callianassa Batei* in the Upper Marine Series, Hempstead, Isle of Wight, p. 75, pl. 2. fig. 4.

II. Family Portunidæ. (Gen. nov. *Rhachiosoma.*)

Amongst the pelagic Crustaceans we find numerous examples belonging to the Portunidæ, all armed with long spines on the hepatic region, and with the lateral borders of the carapace greatly produced. Thus the genera *Matuta, Orithyia, Podophthalmus, Portunus, Lupea,* and many other forms possess long hepatic spines.

Two Eocene genera have also been described and figured by Dr. Alphonse Milne-Edwards in his 'Histoire des Crustacés Podophthalmaires Fossiles,' namely, *Enoplonotus armatus,* from the Nummulitic beds, Salcedo, and the *Psammocarcinus Hericartii* (Plate IV. fig. 4), from the Sables de Beauchamp (Lower Eocene). We are now, by Mr. Meyer's exertions, made acquainted with two new forms (see Plate IV. figs. 3 and 5) from the Lower Eocene of Portsmouth, which it is proposed to place in a new genus, the characters presented by the carapace in the specimens under consideration not warranting us in referring them with certainty to any genus of fossil Crustacea already established.

Rhachiosoma*, gen. nov.

Carapace produced laterally into two more or less long and pointed spines; latero-anterior border also furnished with spines; surface of carapace tuberculated.

1. Rachiosoma bispinosa, sp. nov. (Plate IV. fig. 3.)

This form is remarkable for the great development of its two lateral spines, which in length exceed half the breadth of the carapace. In section they are nearly round, slightly recurved at their extremities, and taper gradually to a point. The carapace itself measures 1 inch in length and $1\frac{1}{4}$ inch in breadth (exclusive of the hepatic spines, which are each 10 lines in length).

The cardiac region is separated from the branchial regions by two undulating subcentral furrows, and bears a single tubercle upon its centre. The gastric region is ornamented with two small subcentral tubercles. Two prominent equidistant tubercles mark the centre-line of the branchial region, and form, with a third on the mesogastric region, a prominent ridge on either side the mesial line of the carapace, inclined towards the rostrum at an angle of about 80°. A solitary tubercle on the hepatic region, just in front of the base of the great hepatic spine, completes the ornamentation of the surface of the carapace.

The latero-anterior border appears to have been armed with two or more marginal spines; but the intense hardness of the matrix (a fine-grained quartzite) in which the specimen is imbedded has rendered its development unsuccessful. The posterior border of the carapace is half an inch broad.

The surface of the carapace (where preserved) shows it to have been very minutely and delicately punctate.

* From ῥάχις and σῶμα.

The specimen was obtained from a mass of quartzite, and rests enclosed in a portion of the body-chamber of a *Nautilus imperialis*.

2. RHACHIOSOMA ECHINATA, sp. nov. (Plate IV. fig. 5.)

This handsome crustacean, which must have measured 3¼ inches from tip to tip of its lateral spines, and 1½ inch from the anterior to the posterior border of its carapace, is far more robust than the preceding species. The hepatic spines are only ½ an inch in length, and develope a small branch spine midway upon their anterior border, resembling in this character the hepatic spines of *Psammocarcinus Hericartii* (see Plate IV. fig. 4).

The arrangement of the tubercles agrees with that in the foregoing species (*R. bispinosa*), save that around the central tubercle on the cardiac region there are placed three very minute tubercles, whilst two others, equally minute, mark the metacardiac region. The latero-anterior border gives evidence of three marginal spines on either side, all of which, however, have been broken off. The frontal border is quite lost, although most carefully attempted to be worked out by an experienced hand; the extreme hardness of the matrix (a fine-grained and very hard quartzite), as in the former case, defying development. Where the surface of the carapace has been preserved it is finely punctate. The chelate fore-hand is preserved on the right side, exhibiting 3 joints, and measuring about 1¾ inch in length.

EXPLANATION OF PLATE IV.

Fig. 1 *a*. Dorsal aspect of carapace of *Palæocorystes glabra*, H. Woodw. (nat. size), from the Lower Eocene, Portsmouth.

Fig. 1 *b*. The same, seen from the underside: *m*. maxillipede; *br*. branchiostegal piece.

From the Cabinet of Caleb Evans, Esq., F.G.S.

Fig. 2. *Palæocorystes* (*Notopocorystes*) *Mülleri*, Binkh. (two-thirds natural size), from the Uppermost Chalk, Maestricht. (Copied from tab. ix. fig. 1 *b*, Mon. des Gastéropodes et des Céphalopodes de la Craie Supérieure de Limbourg, by J. Van den Binkhorst, 1861; figured for comparison with *P. glabra*.)

Fig. 3. *Rhachiosoma bispinosa*, H. Woodw. (nat. size), from the Lower Eocene, Portsmouth.

From the Cabinet of C. J. A. Meyer, Esq., F.G.S.

Fig. 4. *Psammocarcinus Hericartii*, Desmar., sp. (twice nat. size), from the Sables de Beauchamp (Lower Eocene). (Copied from the Hist. des Crustacés Podophthalmaires Fossiles, by Alph. Milne-Edwards, tome i. pl. 10, fig. 1. Paris, 4to, 1861).

Fig. 5. *Rhachiosoma echinata*, H. Woodw. (nat. size), from the Lower Eocene, Portsmouth.

From the Cabinet of C. J. A. Meyer, Esq., F.G.S.

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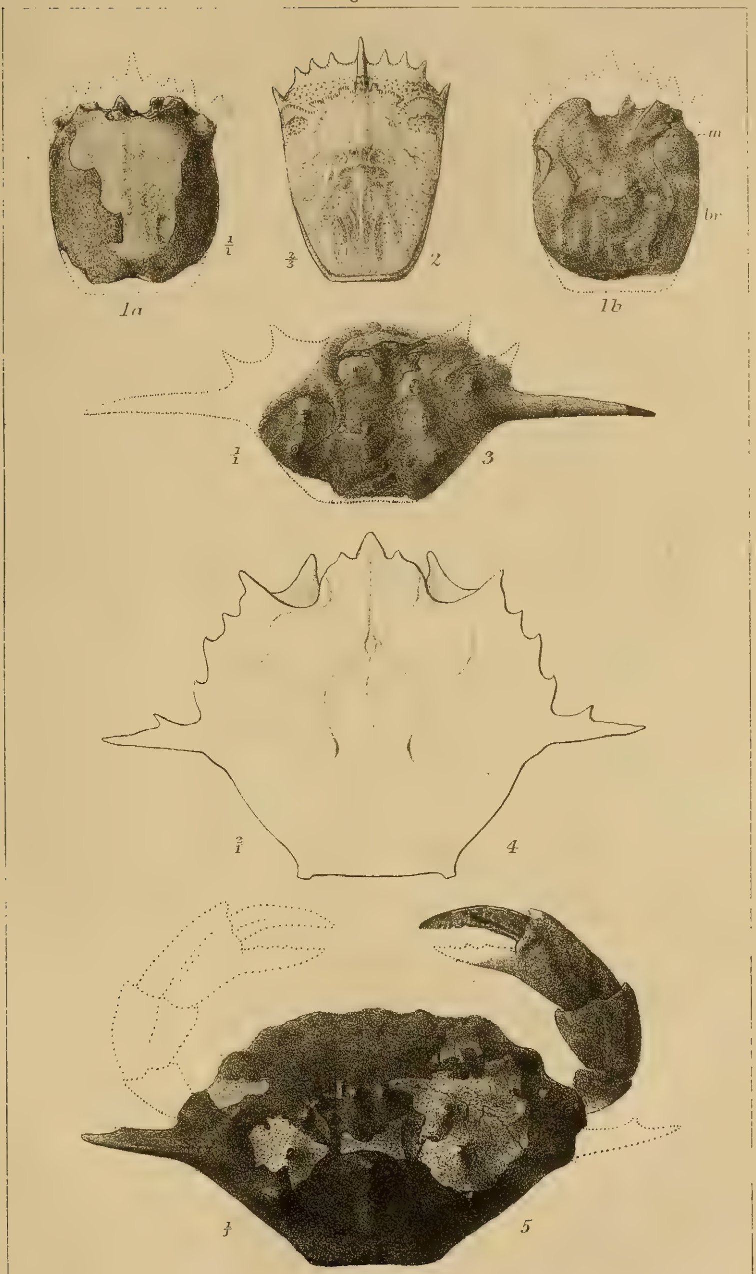
3. *On the* CHALK *of the* CLIFFS *from* SEAFORD *to* EASTBOURNE, SUSSEX. By W. WHITAKER, Esq., B.A. (Lond.), F.G.S.*

* This paper has been withdrawn by the author by consent of the Council.



G.H. Ford.

Mintern Bros. imp.

NEW FORMS OF EOCENE CRUSTACEA.

4.—*On the* Chalk *of the* Southern Part *of* Dorset *and* Devon*. By William Whitaker, Esq., B.A. (Lond.), F.G.S., of the Geological Survey of England.

As my rambles through Dorset and Devon (in 1867–68) were made from east to west, the same course will be followed in transcribing my notes, a course that will also have the advantage of starting from the point nearest to the Isle of Wight, the Chalk of which has been described in a paper of which this may be taken as a continuation†.

At the northern side of Swanage Bay, where the rocks are almost vertical, the Upper Greensand, consisting of green-grey sand with layers of nodular stones, is capped by evenly bedded Chalk Marl, made up of alternations of lighter-coloured thicker and harder beds, with darker thinner and softer, and forming a sort of ridge-and-furrow foreshore, as in the Isle of Wight. The Chalk Marl has a thick grey bed at top, and seems to be about 60 feet thick. It is succeeded by hard bedded Chalk without flints, which again is soon succeeded by a thin layer of the Chalk-rock, hard, with the usual irregular-shaped green-coated nodular lumps (chiefly at the top) and iron-pyrites. Above this is Chalk that weathers to a rough surface, and higher up contains flints. Further east, at the highest part of the cliff, the Chalk is less rough, and not so full of flints as in the Isle of Wight.

I was not able to get at the section between Ballard Hole and the Foreland; but enough has been already written on that part‡. I may remark, however, that two of the isolated pinnacles of Chalk still have a little turf on the top, and so show the former continuation of the land-surface, with its smooth sloping contour, due to subaërial denudation, and greatly differing from the abrupt cliff against which the sea washes. The cliff does not cut through the highest part of the escarpment, but seems here to be along the flank of an old pass or gap.

In Studland Bay the junction of the Reading Beds and the Chalk is piped; but this is hardly enough to prove unconformity between the two formations.

At the gap in the escarpment between Ballard and Nine-Barrow Downs the almost vertical bedding is marked in part by distinct even and parallel lines in the turf, caused by difference of growth on harder and softer beds.

A small pit on the flank of the escarpment about a mile and a half eastward of Corfe Castle shows a northerly dip of about 60° in the following beds:—

* The district referred to is represented in Sheets, 16, 17, & 22 of the Map of the Geological Survey of England.

† Quart. Journ. Geol. Soc. vol. xxi. p. 400.

‡ Rev. W. D. Conybeare, 'Outlines of the Geology of England and Wales,' p. 110 (1822); Rev. W. B. Clarke, Mag. Nat. Hist. vol. x. pp. 414, 461 (1837); Dr. J. Mitchell, *ibid.*, p. 587; T. Webster in Englefield's 'History of the Isle of Wight.'

Chalk, with flints in the top part; at the bottom a thin fissile greenish layer (which also occurs on the coast eastwards).
Chalk-rock; a layer of hard green nodules, the upper surface better marked than the lower.
Chalk without flints.

In a larger pit, at the kiln above Rollington, on the northern side of the range, and therefore in the higher part of the Chalk, there are but few flints.

The step-like outline of the top of the hills from Corfe Castle to Nine-Barrow Down has been noticed elsewhere *. Westward of the former place the range again rises by steps in a like manner, and is partly breached at the western end of Knowl Hill. Here there is a pit in Chalk with few flints, at the northern foot of the hill, whilst further south, and therefore lower down stratigraphically, another pit shows Chalk with layers of flints, and with a sort of slickenside-surfaces at right angles to the bedding. Still further south, the road-cutting up the slope southwards is in Chalk with flints; but at the top of the rather low hill the flints seem to end, and as the road turns down again eastward the hard cream-coloured nodular Chalk-rock is shown, and below it Chalk without flints.

From this slight gap in the escarpment a longitudinal combe runs westward as far as Screech Barrow, making two ridges. Screech Barrow itself is a conical Tertiary hill, close to and rising above the chalk-escarpment.

Signs of the Chalk-rock were again seen on the newly cut road above West Tyneham.

There are many small pits on the flank of the escarpment in the so-called Isle of Purbeck, showing Chalk Marl and Lower Chalk, but not high enough to touch the Chalk-rock. The Chalk is throughout rather hard.

Flower's Barrow, on the top of the ridge where it again meets the sea, is one of those instructive gauges of the loss of land by the sea that are often given us by the old earthworks. Nearly half of the entrenchment has been carried away, and the high cliff now cuts through its middle part. Here the top part of the Upper Greensand stands out, from its hardness. I could not see the Chalk-rock along the top of the cliff, nor could I get near enough to the foot in a boat; but a bluish-grey clayey bed, some feet thick, could be made out at the top part of the Chalk Marl, as in the eastern coast-section.

At the headland on the western side of Worbarrow Bay there is a natural arch at the foot of the cliff, through which small boats can go.

In Mewps Bay the following succession of beds may be seen along the shore:—

Upper Chalk.	Chalk with flints, running out to sea as a ledge, with a hollow and cave cut in the cliff.
	Chalk without flints (?), about 15 feet.

* 'On Subaërial Denudation and on Cliffs and Escarpments in the Chalk and the Lower Tertiary Beds.' Reprinted, with corrections &c., from the Geol. Mag. vol. iv.

Lower Chalk. { Chalk-rock nodules, at a ledge running out into the shingle-beach.
Chalk without flints.

Chalk Marl, more or less hard.

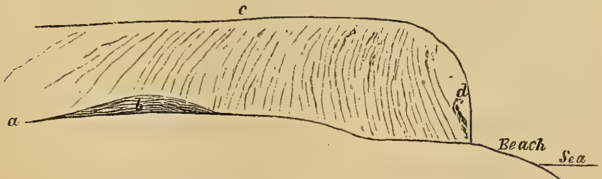
Upper Greensand.—Green-grey and partly hard. Along the top of the cliff the top part of this is calcareous, and passes up into the Chalk Marl.

At Lulworth Cove the fallen state of the cliff hid much of the accessible part of the section ; but the grey soft layer at or near the top of the Chalk Marl was to be seen.

In Man-of-war Cove I could not see the Chalk-rock at the eastern part, where the junction of the Upper and Lower Chalk seems to be much confused. Westward, however, the nodules of the rock are to be seen up to a height of 5 feet above the beach, when they are cut off by Chalk, again with confused bedding, soon succeeded by Chalk with flints, also somewhat confused. Still further west the nodules again occur, and the Upper Chalk is less than 80 feet from the Upper Greensand, the bedding of which latter and of the Chalk Marl is reversed, being at an angle of about 70° S.S.W. instead of northwards. The Chalk Marl seems at one part to be 45 feet thick. It has the usual darker clayey bed at top, whilst the bottom 2 feet or more contains dark grains, small brown nodules, and grains of quartz. The top part of the Upper Greensand is hard from its large irregular-shaped nodules of chert ; and the topmost 2 feet or more is sometimes a buff cherty sandstone.

At the eastern end of Durdle Cove the dip of the Chalk Marl and the Upper Greensand is still reversed southwards, at an angle of 80°. The former, with its grey soft layer near the top, is succeeded by Chalk with a few flints ; and, indeed, there is one layer of flints less than 20 feet from the Upper Greensand, and therefore in the Chalk Marl, which, however, is here not clearly separable from the Chalk above. A little westward the Chalk with flints comes on ; and the bedding is confused at the bottom of the cliff, as in Man-of-war Cove. On turning the corner, into the deeper part of the Cove, a cream-coloured and partly greenish layer of nodules (like those of the Chalk-rock) may be seen. Beyond this the frequent layers of flint show a southerly or reversed dip of about 65°, soon changing to a higher angle, and afterwards to a curved dip in the other direction, 30° at the top, and 60° or more at the bottom of the cliff, as shown in fig. 1.

Fig. 1.—*Section of the Chalk with flints. Eastern side of Durdle Cove.*



a. Beach-line. *b*. Fallen earth.
c. Chalk with Flints. *d*, Nodule-layer.

On the western side of the Cove also the bedding is rather curved.

At White Nore * the lower beds are hidden by an undercliff on the west, where there is but a very slight easterly dip; but the general section is as follows:—

Irregular capping of flints and clay-with-flints all along the high cliff.
Chalk with many layers of flints, and some cream-coloured nodular layers; one near the bottom of the first cliff is 1½ foot thick; another, 2 feet below at one part, joins it in a distance of 20 or 30 yards.
Chalk without flints, or with very few flints, in part weathering roughly (in layers), as certain beds in the Dover and Beachy Head sections.
Chalk Marl, with flint-layers, and with a soft grey layer some 40 or 50 feet from the bottom, which, from its weathering away easily, has given rise to a slight ledge.
Upper Greensand.—The junction the same as at Durdle Cove &c.

I could not well make out the junction of the Upper and Lower Chalk, in the midst of the cliff; it seemed to be faulted and nearly vertical.

From hence westward the Chalk leaves the coast for many miles, though it sometimes comes near the sea.

At a spring-head above Ringstead a small pit shows a vertical junction of Upper Greensand and Chalk Marl. There are a few flints in the latter; and its bottom bed, with dark grains and quartz grains, is thicker than in the coast-sections above noticed. The same junction is again laid open by a road-section, about half a mile N.W. of Sutton Pointz.

From Upway westward to Portisham the Chalk is bounded by a fault, according to the Geological Survey Map, and consequently its bottom part does not crop out to the surface.

The next junction with the Upper Greensand that I saw is at a farm called "Higher Combe," about five miles east of Bridport, where the very bottom of the Chalk Marl is in the form of hard lumps, with some hard nodules (greenish outside), and fossils in plenty.

At Eggardon Hill †, N.E. of Bridport, the Upper Greensand forms rocky ledges at the base of the Chalk, the highest being of a more or less calcareous grit, and the next of irregularly weathered (? calcareous) sandstone, with dark grains and full of fossils. Between these is green-grey sand, full of stony nodules in the higher part, and, indeed passing up into the stone above. The grey rocks, clad with lichen, small ferns, and ivy, are very pretty. On turning from the side of the hill facing Powerstock, round the sharp ridge formed by the Upper Greensand, to the side facing seaward, the upper rock-bed is seen to crop out evenly along the flank, and to dip slightly southward; whilst above it is the bottom Chalk Marl, with dark grains and quartz-grains; 2 feet up the grains get fewer, and they are lost at about 4 feet.

Westward from Bridport the Chalk does not occur near the coast,

* So spelt on the Ordnance Map. Should it not be "White Nose"? a fit name for a chalk headland.

† Just in Sheet 18 of the Geological-Survey Map.

until we pass the border of Dorsetshire, just beyond Lyme Regis, and enter Devonshire, where the high cliffs are broken by the great range of landslips that add so much to their beauty. The sections here have been described by Sir H. De la Beche *; and from his account of the Chalk seen near Lyme it appears that the lower, or flintless, division is thin, having a thickness indeed of not more than 40 feet, whilst the lowermost 50 feet of the Upper Chalk contains fewer flints than the overlying part, in which they are frequent. I cannot understand, though, how so great a thickness as 20 feet is given by him to the Chalk with quartz-grains, unless, as seems likely, the whole of the Chalk Marl is therein included.

In the Chalk with flints at Pinhay † &c. there are brown hard nodular layers, weathering to a rough surface, as at White Nore, east of Weymouth. In the undercliff fallen masses show the junction of the Chalk and the Greensand, the bottom of the former consisting of a hard buff nodular bed, with dark grains and quartz-grains, from 2 to 3 feet thick, above which, for from 2 to 4 feet, the Chalk has irregular masses of the same brown nodular character, and also the distinctive grains. Here, indeed, it is often hard to mark the junction; the Chalk gets nodular, darker, and harder, until it seems almost one mass with the Greensand.

Near the cliff-top just east of Charton, the junction may be seen in place, the same two beds occurring, and the upper of them passing up into white chalk with hard brownish nodular lumps, which (8 or 10 feet above the greensand) form a projecting bed about 1½ foot thick. Some of the quartz-grains here are larger than those in the country to the east.

At the western end of the Dowland's landslip the bottom six feet of the chalk are hard, quartz-grains occur therein, and the lower part is slightly darker and compact.

At the mouth of the Axe the bed with quartz-grains is about three feet thick and contains fossils.

The section near Beer has also been described by Sir H. De La Beche; but something may be added to his account. The chalk-with-flints of White Cliff contains hard buff nodular layers (as elsewhere), and its bottom part has fewer flints than the rest. The chalk without flints also contains hard nodular layers, and is of comparatively small thickness, perhaps thirty feet; the lowermost three feet or so are the same as to the east.

Westward of Beer Head the bold cliffs, here separated from the sea by a fine undercliff, give a most interesting section, part of which shows a thinning-out of the Lower Chalk, and consequently the direct superposition of Upper Chalk on Upper Greensand—an occurrence which I believe has not been before noticed in this country. This junction is inaccessible, and can be seen only from below, and then, from the roughness of the cliff, not with the greatest ease. In fig. 2 it has been thrown into the form of a diagram, as it would

* Trans. Geol. Soc. ser. 2, vol. ii. p. 110, and "Report on the Geology of Cornwall, Devon, and West Somerset," p. 237.

† Pinney on the Ordnance Map.

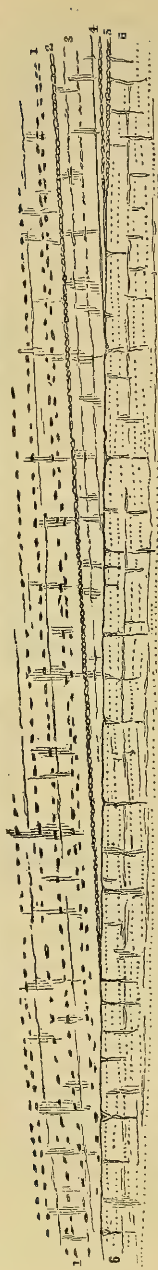


Fig. 2.—*Diagram of a portion of the upper part of the Cliff west of Beer Head.*

Chalk. { 1. Chalk with flints. 2. Nodular bed (Chalk rock ?). 3. Chalk without flints.

Chalk Marl? { 4. Calcareous bed, with green grains, quartz-grains, and nodular lumps. 5. Calcareous bed, of lighter colour and with fewer grains.

6. Upper Greensand: hard calcareous grit and sandstone.

be difficult to draw the actual cliff with its succession of irregular projections.

The junction of the Chalk without flints and the Greensand may be seen amongst the fallen masses west of the landslip (of 1790). In the cliff the nodular Lower Chalk is underlain by, and passes into, a calcareous bed (4 of fig. 2) full of green grains and quartz-grains, with lighter-coloured harder nodular lumps and small hard brown nodules, about five feet thick; below this is a hard brown and greenish nodular layer, also with quartz-grains, forming the top of the succeeding bed (5 of fig. 2), which is like that above (but whiter and with fewer grains), and five feet thick; it is underlain by another nodular layer that forms the top of a calcareous grit (Greensand). The two beds, 4 and 5, seem to thin out westward as in the figure, the higher one going the further.

The opening of the gallery of an old quarry in the high cliff above the western end of the great landslip is in what I take to be the "Beer stone." As the beds worked are just above the Chalk Marl, it follows that they are simply Lower Chalk; and this conclusion as to the position of the Beer stone is strengthened by an examination of the great quarry inland, where the stone is still worked.

This quarry is about three quarters of a mile westward of the village of Beer; and at the time of my visit the part on the northern side of the road gave the section below, with a dip of 4° E.

Chalk with flints	....	30 or 40 feet.
Chalk without Flints.	*a.* Thickly bedded, massive, with a rough layer on top (mostly forming a hard even cap)...	15 or more.
	b. Massive, more crystalline bed ("freestone") ....about	10
	c. More splintering, and with dividing lines of a darker tint ....about	8
? Chalk Marl. Bottom part with a few quartz-grains and black grains.		

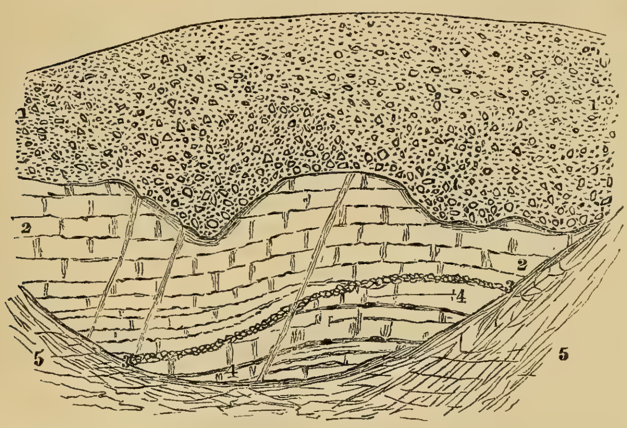
a, *b*, *&c.* are all parts of one mass, without marked divisions; and the Beer stone must take its place therefore simply as Lower Chalk.

To return to the cliffs. Near Branscombe there is white hard Lower Chalk over the cream-coloured sandstone of the Greensand; but sometimes a flint-layer occurs little more than a foot above the latter. At the highest part of the cliff the section is:—

Irregular pipy deposit of flints.
Chalk with flints.
Chalk without flints, but with hard cream-coloured nodules, 30 or 40 feet.
Sandstone (Greensand).

A little westward there is a layer of flints a few feet above the Greensand, to which also the Chalk with flints is nearer. Still further westward, where the cliff again rises, a thick continuous deposit of flints caps the Chalk, and there are signs of the bed with quartz-grains at the bottom of the latter. Then a part of the section (fig. 3) shows flint-layers, some of which end abruptly—and some nodular layers not parallel with the former, but cutting through them.

Fig. 3.—*Section of part of the top of the Cliff west of Branscombe Mouth.*



1. Flint-gravel.
2. Chalk with many layers of flint.
3. Nodular layers.
4. Chalk with a few layers of flint and of marl, and a layer of nodules.
5. Talus.

At the small outlier on the hill west of Weston Mouth, the most westerly patch of chalk shown on the Geological Survey Map, hardly any thing can be seen, from the great surface-deposit of flints; but at the next cliff beyond, just east of Salcombe Mouth, there is again a little chalk, which I believe to be the most westerly mass of that rock now existing in England.

The above notes must be taken as merely a record of a few facts observed in a summer ramble, from which, however, the following general conclusions may be rawn.

(1) That along the South Coast of England the Chalk Marl thins westward from the Isle of Wight, where it is in good force, and its bottom part becomes marked, in that direction, by the presence of quartz-grains, mostly very small, but sometimes as large as a pea, showing perhaps signs of a less deep-sea character than usual in the deposit. This bottom bed is the most constant part westward, where, indeed, it seems sometimes to be all that represents the Chalk Marl.

(2) That along the South Coast the Lower Chalk, of no very great thickness in the Isle of Wight (about 200 feet perhaps), thins westward until in Devonshire it is but 30 feet thick, and occasionally less.

(3) The consequent nearness of the Upper Chalk (with flints) to the Greensand helps to explain the occurrence of the great deposits of flints on the hills of the latter in Devonshire.

Discussion.

Mr. Etheridge pointed out the resemblance between the series described by the author and that of the Chalk of Antrim. He thought it probable that the Cretaceous beds had originally extended over the whole of Western England. He called attention to the Blackdown beds, which had been regarded as Upper Greensand, but certainly were not so, though probably Cretaceous, as well worthy of examination.

Mr. Hull hoped that some Fellows of the Geological Society would extend their examination of the Chalk into Ireland, and visit the Antrim district. It was the case there that the Chalk with flints rested immediately on the Upper Greensand, though there was an intermediate band known as the Mulatto-bed, which might possibly represent the Chalk-rock.

Prof. Morris thought the paper afforded evidence in favour of the Chalk having been deposited in a sinking area, and during the process various alterations in the conditions took place.

Mr. D. Forbes inquired as to the character of the nodules mentioned, and whether they were siliceous or not.

Mr. Meyer mentioned that near Branscombe there occurred a band within 8 feet of the Red Marl, containing fossils apparently the same as those of Blackdown.

Mr. Whitaker had purposely avoided characterizing the greater part of the Greensand-beds as either Upper or Lower. He thought the cherty beds of the west were stratigraphically higher than those of the Isle of Wight. The nodules inquired about were not siliceous, though probably containing some silica, but were rather phosphatic.

JANUARY 11, 1871.

William Salter, Esq., of Maldon, Victoria, Australia, was elected a Fellow of the Society.

The following communications were read:—

1. *On the* OLDER METAMORPHIC ROCKS *and* GRANITE *of* BANFFSHIRE.

By T. F. JAMIESON, Esq., F.G.S.

CONTENTS.

INTRODUCTORY.

THE information we have regarding the geology of Banffshire is chiefly to be found in Dr. MacCulloch's map of Scotland, a memoir by R. J. Cunningham in the Transactions of the Highland Society, 2nd ser. vol. viii. p. 447, and a paper by Professor Harkness in the Quart. Journ. of the Geol. Soc. for 1862, vol. xviii. p. 331.

Mr. Cunningham's memoir deals with the structure of the whole county, and is accompanied by a map and some sections, while the paper of Professor Harkness describes the section of the rocks exposed along the coast. I have carefully examined the whole of the section described by Professor Harkness, and also the coast eastward as far as Fraserburgh; but being unable to satisfy myself as to the true succession of all the various beds which are there exposed, I betook myself to the interior of the country; and from an examination of the district lying between the Spey and the Deveron, I was enabled to arrive at clearer views regarding the relation of the various strata to one another, and have constructed a section (fig. 1) extending from near the village of Rothes, on the river Spey, in a south-easterly direction by Mortlach, and the Old Castle of Auchendown, for a distance of about twelve miles, which shows the succession of the beds very distinctly.

THE THREE DIVISIONS OF THE STRATA.

At the bottom we have a great thickness of arenaceous beds, which rise up at the western end of the section, beside the river Spey, and are more or less altered by metamorphic action into quartz-rock, gneiss, and mica-schist (fig. 1, *a*). The base of this series is not exposed, and it seems to extend across the Spey for some distance into Morayshire. In tracing the section eastward, we find these lowermost beds disappearing underneath a series of fine-grained argillaceous beds or clay slate (fig. 1, *b*), varying in colour from green to a very dark, almost

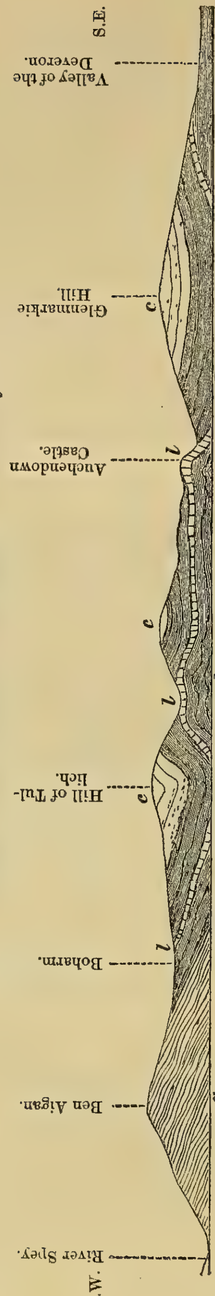


Fig. 1.—*Section from the Spey to the Deveron, a distance of 12 miles.*

a. The lower gneiss and quartz-rock. *b.* The middle division, or slates. *c.* The upper quartz-rock. *l.* Limestone.

blackish hue. In the midst of this mass of clay-slate there is a bed of limestone (fig. 1 *l*); and both the limestone and the slate beside it often contain a large proportion of magnesia, and the varying metamorphism of these beds has in some localities given rise to masses of serpentine and talcose slate. This slaty series is covered by a second or upper group of arenaceous strata (fig. 1 *c*), often assuming the character of quartz-rock of a very pure white colour, forming the top of many of the hills of this district. Although in many places this upper quartz-rock is much worn away, yet in some of the mountains in the higher parts of the county it attains a great thickness, and forms the uppermost bed of the old metamorphic rocks exposed in this region.

We see therefore that the arrangement and succession of the metamorphic strata here are very similar to what we find in Bute and Argyleshire (see Quart. Journ. of Geol. Soc. 1860, vol. xvii. p. 133), namely a mass of clay-slate enclosed like a sandwich between two great masses of arenaceous beds. The rocks of Banffshire, in fact, seem to belong to the same formation as those of Bute. That is to say, they form the north-eastern extension of those beds which range through the central Highlands of Scotland, from the Moray Firth to the Firth of Clyde. In mineral quality and state of metamorphism the resemblance is very close.

1. *The Lower Division, or Gneiss and Quartz-rock.*—The passage from the lower quartz-rock upwards into the slates may be clearly seen along the course of a small stream, locally known as the Burn of Mulben, on the east side of the Spey, which is traversed by the line of railway from Keith to Elgin. Near the mouth of the stream, where it falls into the Spey, the mineral quality of the rock is, when freshly broken, white and

quartzose, almost a pure quartz-rock, with ferruginous stains along the joints and planes of division. In Mac Culloch's map it is by some mistake coloured as part of the Old Red Sandstone, its arenaceous character having probably in some measure led to the error. As we proceed up the course of the stream the rock is seen to lie in gentle undulations dipping south-east at a low angle, the quality still much the same, but rather more micaceous—being a fine-grained micaceous quartz-rock, or quartzose mica-slate. Near its junction with the slate the rock becomes more micaceous—a ferruginous-stained micaceous grit, alternating with seams of mica-slate, often thin-bedded and well laminated lying in regular order and dipping south-east, at an angle of 30° or 35°. The colour now becomes greener and the lamination more distinct; and the passage upwards into the base of the overlying mass of slate is thus accomplished, there being thin seams of grit interbedded with the slate where it commences. The slate is here of a dull greenish colour, and is well exposed along the railway on to Mulben station, dipping south-east at from 30° to 40°. The mineral character of the group of rocks lying beneath the slate series may also be well studied along the western flank of Ben Aigan, where there are some deep gullies cutting far into the hill. The whole of this side of the mountain from top to bottom consists of these rocks, indicating a thickness of about 1200 or 1400 feet; and as they seem to extend across the Spey for some distance westward, the depth is probably very great. In such a mass of sedimentary strata there must of course be a considerable variety in the quality; and although the general character is quartzose, yet seams and beds of a softer and more slaty nature may here and there be met with. At one place I found the strata so rotten that considerable masses were reduced to the consistency of mud. The crushing, squeezing, and twisting to which the beds have been exposed have probably had something to do with this; and the occurrence of such rotten beds here and there in a mountain must greatly facilitate the operation of those forces which carve out valleys and have removed such immense quantities of rock from the surface in many places. The rapidity with which the waste occasionally goes on may be seen in a deep gully or trench in the west flank of Ben Aigan, which seems to have been excavated by the action of a petty stream of water, so insignificant that at some seasons of the year it is almost quite dry.

Similar masses of rotten rock, approaching the consistency of soft sandy mud, occur near the top of the Glenmarkie ridge to the east of Auchendown Castle, in the upper quartz, although part of the strata in the immediate neighbourhood is a hard-grained white quartz-rock, or metamorphic grit. It is interesting to examine this mouldering bank of rusty brown sand and mud, containing some seams of disintegrated slate, where we see the rock reduced to something like what we may suppose to have been the original condition of the bed when it lay at the bottom of the ancient sea.

In some places the lower quartz-rock is much impregnated with oxide of iron; and at Arndilly, on the west base of Ben Aigan, an attempt was made to work a small vein of ironstone which occurs there. On the top of the hill the rock is of purer quality; and along the eastern slope it is covered by the clay-slate, which, however, seems to have its stratification more disturbed than at Mulben, and the junction is not so well exposed.

If the quartzose gneiss on the west side of the Spey comes out beneath the basement beds of Ben Aigan, as seems probable from the disposition of the strata, it would show that the thickness of the group of rocks lying beneath the slate is very considerable. The quartz-rock of Cullen lies on the line of strike of the Ben Aigan quartz, and is probably the northern extension of the same strata.

2. *The Middle Division, or Slates.*—With regard to the slate, the lower portion, as I have already mentioned, is well exposed to view along the line of railway at Mulben, and on the coast between Gamrie Head and Macduff there is a fine section. The limestone is exposed in a great many places along the river Dullan at Mortlach, the Loch of Drummuir, Auchendown Castle, &c. Its thickness varies a good deal in different places; and in the coast-section between Gamrie and Macduff no limestone occurs, so that it would seem occasionally to thin out altogether.

The thickness of the slate lying between it and the upper quartz-rock I estimated as about 500 feet in some places; and probably there is as much beneath it, which would make a total of 1000 feet for the mass of slates. But the thickness of the slate itself seems to vary a good deal, and to increase towards the coast. It probably consists of the finer sediment accumulated in deep still water, and would be thickest in the troughs of the old sea-bottom. We should therefore expect to find it thickening in certain directions. So far as I can judge, the thickness of the slate in this region seems to increase towards the trough of the Moray Firth. The arenaceous beds, which we may suppose to have been deposited in water that was shallower or more traversed by currents, seem to thicken, or bear a greater proportion to the slates, as we go towards the interior of the country, as, for example, in the region of Braemar and Glentilt, where the quartz-rock is much developed and of great purity.

3. *The Upper Division, or Upper Quartz-rock.*—The meeting of the slate with the upper quartz-rock may be seen in some of the gullies that rut the side of the hill which forms the eastern bank of the river Dullan, in the neighbourhood of a place known as the Giant's Chair, a little way above the village of Mortlach. This Giant's Chair is an old pot-hole worn by the former action of the stream in the limestone which here forms the bed of the river. The top of the ridge which divides the Dullan from the Fiddich consists of the upper quartz, and so likewise does the top of that which separates the Fiddich from the Deveron. In the latter ridge, to the east of the old castle of Auchendown, the slate may be seen forming the base of the Glenmarkie Hill, and has been quarried for roofing purposes here and there along its western slope; but the top of the ridge is of quartz. The slate may also be seen passing underneath the upper quartz-rock, on the eastern bank of the river Fiddich, opposite Bal-

venie Castle, close by the edge of the stream. Here the slate troughs the quartz in a synclinal fold, which is much more abrupt at one side than it is at the other; for as we walk along the river from north-west to south-east, we find the slate disappearing under the quartz at an angle of from 20° to 25°, and emerging again to the south-eastward almost vertically. The quartz-rock is here much crushed and disintegrated, as if by the nip it had got in the sharp curve of the synclinal fold.

The Granite—its Origin.

The granite of this region, I am inclined to think, has resulted from the fusion and recrystallization of the arenaceous beds. It is evident that the granite has originated after the deposition of these old sedimentary strata, because they are everywhere penetrated by its veins and injected masses, as may be well seen in the district around Lower Craigellachie. The granite, however, does not derange the strike of the beds to the degree that such a mass of foreign material should have done had it been erupted in an igneous condition, or forced up in any other conceivable way. I would rather suppose that the heat from the interior of the earth gradually approached the base of these sedimentary beds and, by heating, caused them to expand and thereby become wrinkled into huge folds, as a necessary consequence of a great mass of swollen matter having to find room in the space occupied by the same matter when in a cold and contracted state. The portions most liable to be fused would be softened and dissolved *in situ*, and be injected with enormous force, in consequence of the pressure, into all the openings and crevices around them. Crystallization would then take place as the whole very slowly cooled. In some such way, I imagine, the granite of this region has been formed out of the lower arenaceous and silty beds, and the greenstone of the Portsoy district out of the more argillaceous strata. The heat, as well as the watery vapour under such immense pressure, would probably penetrate further into the arenaceous beds than into the closer-grained clays. These views are confirmed by finding the granite occupying the room of what should have been gneiss or quartz-rock and the greenstone replacing the argillaceous beds. The serpentine of this region, as I have before mentioned, seems to have resulted from the metamorphism of beds containing much magnesia. In some places around Lower Craigellachie and the southern base of Ben Aigan, the gneiss is plentifully streaked with granite, as if partial fusion had just begun. These portions are found along the circumference of the great mass of granite, and seem to me to represent the gradual passage of arenaceous or silty strata by way of gneiss into granite. And here I may mention that the gneiss and quartz-rock of this region, even where most siliceous, always contains a proportion of felspar. The softening and fusion, as it progressed, would advance more rapidly along certain lines where the mineral matter was of such a nature as to yield most readily to the influence of the forces acting upon it.

As examples that may be easily examined, I may cite a section on the Dufftown Railway, at the Popine meal- and saw-mill, near Lower Craigellachie, also the rock at Craigellachie Bridge, and along the side of the Fiddich from Craigellachie Station to near Kininvie Castle. The rock of the hill called Upper Craigellachie near Aviemore, is also of a similar nature, so that in many places I should be at a loss to say whether the granite or the gneiss prevails. Along the Fiddich, from Craigellachie Station to near Kininvie Castle, the rock exposed in the railway-cuttings is a hard quartz, so full of veins that one is occasionally in doubt whether to pronounce it a stratified rock or a granite. In many places, where the aggregation of the mineral particles is granitic (rather small-grained and reddish), traces of the undulating bedding may be observed; in short, the rock seems to me to consist of the beds of lower quartz-rock merging into granite—that is to say, incipient granite, a stratified rock far gone on its way to granite.

In some places, near Craigellachie, there is a good deal of greenish matter in the rock, as if it had consisted of alternations of talcose schist or grit and quartz-rock, such as occur near the base of the slate on the Mulben stream, and also near the Giant's Chair, where the upper beds of slate meet the overlying quartz-rock. I observed that the small granite veins occasionally form alternating laminæ in the rock, and reddish streaks parallel to the bedding, the greenish matter segregating into irregular branching plates.

The hill called Little Conval, near Dufftown, is of granite, which at its south-eastern base I found to be large-grained and composed of red felspar and whitish quartz, with little or no mica; but higher up the rock becomes finer-grained, and at the top consists of a small-grained mixture of red felspar and quartz, much resembling some varieties of quartzose gneiss, such as that at Red Hythe Point, as if the metamorphism decreased in intensity as it passed upwards. The felspar, however, is redder than is usual in gneiss, and seems to bear a larger proportion to the quartz. There are the remains of an old stone rampart or enclosure round the crest of this hill.

Theory of the Derivation of the Sedimentary Strata and of their Present Strike.

The general texture of the materials of which the gneiss, quartz-rock, and clay-slate are composed is fine-grained, and I observed no beds of conglomerate or large pebbles. The nearest approach to these which I saw was in the coast-section between Gamrie Head and Melrose, near a place called the Grey Mare's Point, where the anticlinal fold occurs that is shown in Prof. Harkness's section. Here I observed a seam composed of water-worn pebbles of white quartz, some of which were two inches in length. This is near the base of the slate, and is the nearest approach to a conglomerate that I have observed. But in general there is nothing larger-grained than what, in its original condition, would have been a coarse sand. It is a curious circumstance that such a thick mass of sediment should have been accumulated showing so little variety in character, and without the occurrence of any large boulders or beds of conglomerate. Perhaps it may be explained by supposing it to have been accumulated in the depths of the sea, off the mouth of a great river like the Amazon, which may have been continually pouring in sediment, but with a current not sufficient to carry large pebbles. The slate, or fine argillaceous sediment, between the two great masses of arenaceous strata may be accounted for by a subsidence of the area of deposit into deeper and stiller water, where little except the finer sediment would be floated.

The Red (Cambrian) Sandstone and Conglomerate of the North-west Highlands, which stretches for a hundred miles from S.W. to N.E., with a comparatively narrow breadth in the opposite direction, looks as if it had been accumulated along a shore-line which was probably the coast of an ancient continent of the Laurentian gneiss. This Cambrian Sandstone is overlapped on its eastern border by the Lower Silurian schists and quartz-rocks of the Highlands, which we may therefore suppose to have been accumulated at a somewhat later period, but which, in all likelihood, consist of the sediment poured into the sea by the rivers draining the same Laurentian region to the north-west. After a great thickness of sediment had been accumulated, a glow of heat from beneath seems to have approached it, and by the expansion thereby occasioned wrinkled the mass into huge folds running from S.W. to N.E. The reason why the wrinkles run in that direction, I imagine, must be that expansion in the transverse direction was more difficult, owing perhaps to the opposing mass of the Cambrian and Laurentian land preventing extension towards the north-west side.

Discussion.

Prof. Ramsay observed that the general section wonderfully corresponded with that given many years ago by Sir Roderick Murchison of the Silurian and Laurentian rocks at Cape Wrath, and it seemed to him that the large views originally propounded by Sir Roderick were confirmed by the author. He was glad that the metamorphic origin of granite was supported by Mr. Jamieson, as he had held that view for many years; and he was pleased to find that opinions which had formerly met with so many opponents were constantly gaining acceptance. The fusion of these sedimentary rocks by metamorphic action was not identical with the fusion of lava; but their fluidity might be the same; and if that were the case, there could be no difficulty in accepting the possibility of the injection of such fused rocks into crevices and fissures. The crumpling of the beds, however, was due to more extensive causes than those contemplated by the author. The proportion of igneous rock injected into contorted rocks, like those of North Wales, was comparatively small, and the crumpling could hardly be due to mere local causes.

Prof. Ansted referred to what he had observed in the north-west part of Corsica, where about 40 feet of granite was distinctly interstratified between perfectly unmetamorphosed beds of sandstone and limestone, without any alteration at the points of contact, such as would be produced by an igneous rock. He also cited the crumpled strata in the Maritime Alps, in which the granites were parallel with the other beds, and seemed to form part of them.

Mr. Carruthers mentioned that the late Prof. Fleming, twenty years ago, had taught the same doctrine as to the nature of granite as that held by the last speakers. He also stated that similar views would be found expressed in Headrick's 'Mineralogy of Arran.'

Mr. David Forbes agreed that the crumpling of the strata was not due to the intrusion of any eruptive rock. He completely disagreed with Prof. Ramsay and the author as to the origin of granite, and maintained that, in the sedimentary rocks traversed by the granite, the requisite ingredients for the formation of granite did not exist. The proportion of felspar in quartzose rocks was infinitesimally small, as compared with that entering into the composition of granite. He could not accept the notion of the heat from the interior approaching gradually to some portion of the surface.

Prof. Ramsay, in reply to Mr. Forbes, maintained that some of the slaty rocks of Wales, by extreme metamorphism, would pass into some kinds of granite. As to the conditions of metamorphism of the rocks, this process must have gone on at a time when these older rocks were overlain by a great thickness of more recent beds which have since been removed by denudation.

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2. *On the* Connexion *of* Volcanic Action *with* Changes *of* Level. By Joseph John Murphy, Esq., F.G.S.

[Abstract.]

The purpose of this paper was to show that "volcanic action is not the cause, but the effect, of secular changes of level; and secular changes of level are due to the subsidence of the surface of the interior, as the interior contracts in cooling." Change of level is a differential action, and consequently cannot be due to the cooling of a sphere by radiation into space. Volcanic action cannot be due to a spontaneous outburst of the expansive force of the earth's internal heat; for this could not burst through a crust once formed by cooling. Changes of level and volcanic action were explained as follows:—The interior of the earth is constantly cooling, and as it cools must contract; but the cold surface-strata cannot contract with it; and as their weight keeps them in contact with the core, they are compelled to form ridges like those on the skin of an apple which shrinks in drying. When such a ridge rises into an arch, the hot matter below rises and fills the arch, forming the igneous core of a mountain-chain. Volcanoes are formed when in these foldings the surface is broken through, so as to liberate the expansive force of the internal heat. Darwin has shown, in his work on Volcanic Islands, that volcanoes are formed only in regions which are

rising or have recently risen. The reason of this is, that an upward bend in a stratum is resisted only by the weight of the stratum itself, while a downward bend is resisted by the pressure on the strata below; so that an upward bend is more likely than a downward one to become great enough to produce fracture.

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3. *On* Some Points *in the* Geology *of the* Neighbourhood *of* Malaga. By Don M. de Orueba.

(Communicated by Sir. R. I. Murchison, Bart. F.R.S., F.G.S.)

[Plate V.]

Much remains to be done in the investigation of the geological structure of Spain. The Spanish geologists have principally described in a general manner the mineral character of the soil in various districts, but they have not paid sufficient attention to the order of superposition and the character of the fossils, and few foreign men of science have made this country the subject of their investigations. For this reason, what we know at present about the formations of the province of Malaga is principally owing to the able memoir and excellent map of M. Verneuil. However, as I believe this gentleman did not travel in the northern part of this district, he has not given any particular description of many geological formations which, by their order of superposition, mineral composition, and the character of their fossils, might be of great help in ascertaining the place in the geological scale of the analogous strata which exist in other localities of the province, but which do not present so many interesting data and facilities for study. Although I am only acquainted by reference with the opinions of this gentleman (possessing only the map he published in conjunction with M. E. Collomb), I believe that he dwelt principally on the Tertiary formations in this vicinity, and, above all, on those on which the city of Malaga is built. I think that he was the first person that ever described them, publishing also a list of several shells, which he collected at the "Tejares" (clay-pits in the suburbs of this city). Professor Ansted also wrote a very valuable article on the Geology of Malaga, which appeared in the 'Quarterly Journal of the Geological Society' for 1859*. He also paid a deserved attention to the "Tejares" clays, which are no doubt of the greatest interest, and described several formations in this neighbourhood, particularly those lying on the eastern side of the town; but I feel rather surprised to see that, while treating on the metamorphic rocks, he does not mention the plutonic, which are also found about here, mentioning only the serpentine of the Sierra de Meijas, and not saying one word about the greenstone (diorite), which is very abundant in several parts of the province, especially in this locality, and which may have been the cause of

* Vol. xv. p. 585.

the upheaval and the mammillated shape of the mountainous region situated on the north-eastern side of this town. Neither was he acquainted with the modern volcanic district of Riogordo; this, however, is not suprising, as the place is out of the common track, being situated in the centre of a mountainous region, and it has not been brought into notice until very lately, by my friend the distinguished archæologist Dr. Berlanger.

But what struck me more particularly in Prof. Ansted's memoir was his assertion that fossils are exceedingly rare in the Secondary limestones of the south of Andalusia, and that, although the few specimens that different geologists had been able to collect had enabled them to agree as to the Jurassic character of the rocks, they could not determine whether they belonged to the upper or lower division of that period. My limited personal experience corroborated this view; but having lately become acquainted with a Secondary formation rich in fossils, and bearing a character similar in its composition to those which exist in several parts of the south of Spain, I shall make its description the subject of this communication.

A couple of miles to the south of the city of Antequera, and about thirty miles from Malaga, there exists a mountain-chain, running from E. to W. for about thirty miles. It is very rough and steep, and in some places attains the height of 7000 feet above the level of the sea. Near Antequera it divides into two branches: the one nearer to the city, in the northern direction, called Sierra de la Chimenea, is the culminating point of the whole chain; and the other, which is about 1000 feet lower, extends to the south-west, sloping in that direction, while at other points it presents nearly vertical precipices. This branch of the Sierra is popularly called the "Torcal," on account of the huge blocks of stone of which it is composed. I had long heard much about its wonderful structure; but, owing to its difficult access, few persons have climbed it, and therefore all the information I could collect was of a very vague character. At the end of last year I determined to visit it, accompanied by some friends.

Fancy yourself in a great city of marble, with immense squares and numerous streets, covered with castles, arches, and pyramids, and other buildings of the most fantastic shape and colossal size. Such was the spectacle which developed itself before us, without much strain upon the imagination. The rocks sometimes assume the form of huge monsters; and in other places we thought they looked human, and as if great giants were frowning upon us. Natural bridges were seen in every direction; but what surprised us more was the wonderful state of equilibrium in which many of the rocks were piled together; we repeatedly saw, for example, an enormous rock on the top of a slender pyramid, which, although it looks likely to fall at the slightest breeze, has stood firm in this position for successive ages. I assure you that I do not exaggerate in the slightest degree the extraordinary magnificence of this natural wonder. I should recommend all travellers who love to contemplate the beautiful and capricious forms of nature in her strangest mood to visit the Torcal, and hope that soon some abler pen may do full justice to its merits.

As soon as our first impression had subsided, we began to speculate upon the causes which had made the rocks assume such a fantastic shape. We all agreed that it must have been an effect of denudation; in what particular way, however, we could not determine, although we were inclined to ascribe it to an ancient glacier: this opinion appeared to acquire some support when we found, on our descent, some rocks detached and separated a long way from the general mass, which we considered to be erratic blocks carried down by the action of ice. However, not being satisfied with this conclusion, and desiring to study the phenomena of the place with more attention, some of us returned there; and by starting before daybreak from Antequera we were able to remain several hours on the Torcal, and had more time for observing the form and composition of the rocks.

In order to convey to you the best idea that I can of these formations, I shall begin with the plain of Antequera, which, in our rapid excursions through it, we considered to belong to the Tertiary period. The soil of the southern part of the city consists of a dark blue and compact limestone, in a semicrystalline state, which is overlapped on the northern side by a coarse and fragile rock, also calcareous, with a certain mixture of sand, seeming to me to be analogous to the "Calcaire grossier" of the Paris basin. This stratum dips to the south; its thickness is rather considerable—I believe, reaching twenty or thirty yards. It contains many fossils, principally the casts of an *Arca*, which are very abundant. In the same valley, in a place called Castillon, about three miles west of Antequera, at the site of an ancient Roman town named Singilia, I have found many fragments of a beautiful marble, entirely composed of shells of *Foraminifera*—I believe, of the same kind as that which Sir Charles Lyell describes in page 301 of the sixth edition of his 'Elements,' under the name of Miliolite limestone. I had no opportunity of ascertaining the position of the blocks from which these fragments were detached; they were wrought remains of ancient buildings; but, considering their abundance, I came to the conclusion that their quarry could not be far off. We have also in this neighbourhood the same Miliolite limestone, in concretion with another calcareous stratum, containing many Nummulites (said also to be found near Antequera, although I have not met with them myself); and it is probable that both may belong to the same period, and that this may be either the Middle or the Lower Eocene. I see this is also the opinion of M. de Verneuil; for in his map he classifies the plain of Antequera as "Tertiaire inférieure," although he does not seem to have found any Nummulites; for that portion of his map does not contain the sign which indicates their presence. Between Antequera and the Torcal there is another calcareous formation, containing many forms of *Gryphæa*; it is above the blue limestone, and of very limited extent.

The Torcal rises abruptly from the plain of Antequera, its northern side being very precipitous. Its formation is also calcareous. It consists of a very compact limestone, generally of a red colour, owing to the great proportion of peroxide of iron which it contains. It makes a very good building-material, and has been largely employed in the construction of Antequera. On the eastern side it reposes in conformable stratification on a fine-grained and white oolitic marble, which attains a considerable thickness, the extent of which I was not able to determine with any degree of precision, although it appeared to me that it could not be less than 1000 feet. In the divisional line between the two formations there were many Ammonites, lying in a position perfectly parallel to the plane of stratification, and in the same place in which they were originally deposited, without having suffered the slightest disturbance. It is the red marble that presents the fantastic forms alluded to before.

At the top of the ridge there are large platforms surrounded by vertical rocks, which are scooped out horizontally in a continuous direction, being principally grooved at their base—so much so that in some places the top greatly projects, making the rock assume the form of a great table, while in other places the grooving is reduced to three or four yards above the level of the plateau, whilst the rest of the cliff remains vertical, having the appearance of long continuous caves. The platforms are generally perfectly plane and horizontal, although full of crevices and faults, which are sometimes of considerable depth. Large angular masses of detached rocks are found in all parts of these basins; these, however, are more rounded; that is, their angles are not so sharp as those of the cliffs. We received the impression that these platforms had been the beds of ancient lakes, the water of which had subsided at certain intervals, but not in a gradual and uniform manner, causing certain levels to remain longer stationary than others, the lower ones enduring the longest. In support of this view, we found that the basins have generally an outlet through which they have been drained, so that we could easily trace to a considerable distance the direction of the current as it escaped from the lake. In many of these lakes (if I may so call them) there exist vertical caverns of great depth. The strata dip to the south-west at a very slight angle; and the declivities of the mountain in that direction are those which present the grandest points of scenery. They contain an immense labyrinth of small valleys and ravines, in the mazes of which we should have lost ourselves had we not been accompanied by a local guide. It is in this locality that the rocks assume their wildest and most fantastic appearance. I calculate that these windings extend for a distance of three or four miles at the least; and the whole length of the Torcal will be about two leagues. In its upper part, there exist veins of laminated peroxide of iron; and on the slopes we found a great many crystals of carbonate of lime, some of the common rhombohedral type (calcite), while a great majority had a very fibrous structure.

This mountain-chain must have risen from the valley of Antequera; but its upheaval must have been exceedingly gradual and gentle, as its planes of stratification run perfectly parallel throughout, and we

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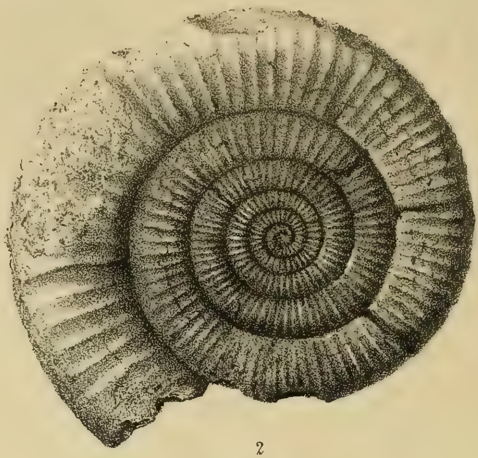

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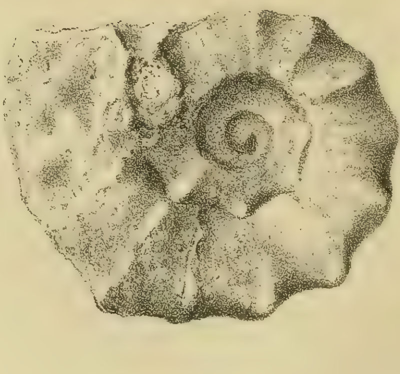


De Wilde lith.

M & N. Hanhart imp.

AMMONITES FROM MALAGA.

could not anywhere perceive the slightest distortion. We concurred in opinion that it had been denuded after attaining its high level.

The mountain-chain of which the Torcal forms a part extends in a western direction for about thirty miles. After leaving the plain of Antequera it takes the name of "Sierra del Valle de Abdalagis," ending a little to the west of the place crossed by the Malaga and Cordova Railway, named the "Tajos del Gaitan." In this spot the river Guadalhorce has not only excavated a very deep and narrow ravine, but it has actually pierced through an enormous mass of rock at least 800 feet high, giving a further proof of the highly disintegrable character of the rock. The scenery here is also very wild and grand; and no traveller who passes through this defile can be wholly free from a feeling of awe and admiration. The colour of the compact limestone in these parts of the chain is white, having little or no admixture of iron. However, this rock is everywhere to be seen superposed upon the Oolite. The Jurassic strata which constitute the mountainous districts to the south and west of Ronda may belong to the same period, as well as those which exist in this neighbourhood, about two miles west of the town, constituting the quarries of St. Telmo, mentioned in Professor Ansted's memoir; these rocks, though devoid of fossils, have a marked similarity to those which constitute the Tajos del Gaitan. The corroboration of these views, however, must be the result of a careful and conscientious study, which I have not undertaken.

Note.—This paper was accompanied by photographs of Ammonites obtained from the compact limestone of the Sierra del Valle de Abdalagis, and of one from the Sierra de la Chimenea. These Ammonites are all of Jurassic age, and probably from the middle and higher members of that group of rocks. Some of the specimens represented are far too imperfect for identification; but Mr. Etheridge, to whom they have been submitted, refers four of them to *Amm. Achilles*, D'Orb. (Pl. V. fig. 1), and two others to *Amm. perarmatus*, Sow., one of which closely resembles the var. *catena*, D'Orb. (fig. 3). The remainder cannot safely be identified. Of the species represented in fig. 2, there are photographs of two ages.

EXPLANATION OF PLATE V.

(Figures about half the natural size.)

Fig. 1. *Ammonites Achilles*, D'Orb.
2. *Ammonites*, sp.
3. *Ammonites perarmatus*, Sow., var. *catena*, D'Orb.

Discussion.

Prof. Ansted remarked that the condition of the Torcal was similar to that prevailing in many other limestone districts, and was probably due to subaerial denudation.

Mr. W. W. Smyth mentioned that he had lately had an opportunity of examining, at Cadiz, a collection of fossils formed by Mr. Macpherson in that district, which also contained specimens of Ammonites. It appeared that there were large tracts in which the rocks seemed to be almost destitute of fossils, which rendered their classification extremely difficult; and great credit was due to the author for his exertions in a country where unfortunately so little interest is taken in geology. He mentioned that some of these unfossiliferous rocks had been classified as Silurian by some French geologists; but for this there was not the slightest evidence. It appeared far more probable that they were of Jurassic age. Some red beds, which had been called Triassic, were also in all probability Tertiary.

Mr. Gwyn Jeffreys, who had examined several collections in Spain and Portugal, stated that he had been much struck with the absence of newer Tertiary fossils, the latest being of Miocene age. These latter presented a tropical aspect, and differed from the mollusca now inhabiting the neighbouring seas.

Mr. Blake was not satisfied with the determination of the Ammonites, which appeared to him to be Cretaceous rather than Jurassic forms.

Mr. Tate observed that the French geologists had determined the existence in Spain of the whole Jurassic series, from the Middle Lias to the Portlandian beds; and, judging from the photographs, he should consider the Ammonites to be Middle Jurassic.

Mr. Boyd Dawkins cited the remains of *Rhinoceros etruscus*, procured by the late Dr. Falconer at Malaga, as affording evidence of the presence of beds of Pliocene age in that district.

Prof. Duncan mentioned that corals of the genus *Flabellum*, such as were found in the Tejares clays, had been obtained in recent deep-sea dredgings in the Atlantic, and also occurred among specimens brought from Japan.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPERS.

1. *On the* Structure *of the* Crag-beds *of* Suffolk *and* Norfolk, *with some* Observations *on their* Organic Remains. By Joseph Prestwich, Esq., F.R.S., F.G.S. Part I.—The Coralline Crag of Suffolk.

(Read March 11, 1868.)

[Plate VI.]

Previously to 1835, although some observers, and Mr. Searles Wood in particular, had noted the peculiarity of the fossils from the beds now known as the "Coralline Crag," no stratigraphical divisions of the Crag-beds of Norfolk, Suffolk, and Essex had been established. In that year Mr. Charlesworth*, in a paper communicated to this Society, showed that in Suffolk the Crag could be divided into an Upper (the Red) and a Lower (the Coralline) Crag; and he afterwards formed a third and higher zone of the Mammaliferous Crag of Norfolk. With respect to the two lower divisions several cases of direct superposition were given, which established beyond doubt the relative position of the Red and Coralline Crags. On the other hand, the difference between the Red and Mammaliferous Crag was founded entirely on palæontological evidence, as no instance of superposition was known; and although more than thirty years have now elapsed, the question in that respect remains in the same condition. The observations of Mr. Charlesworth were followed by those of Sir C. Lyell† and, more lately, of Mr. Searles Wood, Jun.‡, and several other geologists; but the Red Crag has received more attention than the Coralline Crag.

The object of this communication is to describe the physical structure of the several Crags, and to determine, if possible, the exact relation the Suffolk Crags bear to the Crag of Norfolk. With this object in view, I have examined on several occasions the coast-section from Aldborough to Weybourne, and the various inland pit- and railway-cuttings, of all of which latter I took notes during the construction of the Great Eastern Railway. The greater part of my observations date, in fact, so far back as from 1845 to 1855, which will explain the variation in some of the coast sections, and account for the disappearance of some inland sections. The difficulty of obtaining direct evidence showing the relation of the Mammaliferous Crag of Norfolk to the Red Crag of Suffolk, and of correlating the beds beneath the Boulder-clay with the other beds of the same age through the south of England, led me to delay bringing this

* Proc. Geol. Soc. vol. ii. p. 195.

† Proc. Geol. Soc. vol. iii. pp. 126 & 437, and Mag. Nat. Hist. 1839, p. 313.

‡ Ann. & Mag. Nat. Hist. for March 1864.

paper forward until I was in possession of facts which might afford sufficient grounds for the conclusions I now venture to submit to the Society. The whole question is intimately connected; yet, as the geological series is divisible into distinct stages, I will take each of these separately, commencing with the lowest.

Coralline Crag.—The area of the Coralline Crag has not been extended since Mr. Charlesworth first drew attention to it, giving the neighbourhood of Orford as its centre, with outliers at Aldborough, Sutton, Ramsholt, and Tattingstone. The boundaries only are better known. The extent of superficial area exposed is about eight square miles. Originally the Coralline Crag may have extended uninterruptedly from Aldborough to Tattingstone; but, with the exception of the low range of hills extending from Gedgrave northward to Orford, Sudbourne, and Iken, and the small outlying masses of Aldborough, Sutton, and Tattingstone, it has everywhere been removed by denudation. Not only did this denudation remove the Coralline Crag, but it has also removed a portion of the underlying London Clay; so that the base of the Red Crag is in places lower than that of the older Coralline Crag, round and over which it wraps and passes transgressively.

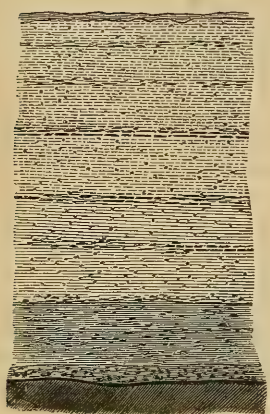
The surface of the London Clay under the Coralline Crag is also uneven. In the Bullock-yard pit, on Mr. Colchester's farm at Sutton, it is found under 4 feet of Red and 2 of Coralline Crag, and 20 feet above high tide of the river Deben; but an eighth of a mile to the west the London Clay is 12 feet lower, and a lower zone of the Coralline Crag comes in. This and other circumstances lead me to believe that at the noted old pit at Ramsholt the Coralline Crag, which there lies on the London Clay, does not belong to the lowest zone, but to one some 10 to 15 feet higher.

The well-known outlier of Sutton supplies us with a typical exhibition of the Coralline Crag, the several pits which have from time to time been opened there giving us the best clue to its structure and dimensions, whilst at the same time the extent of denudation by the Red Crag, and the varying levels of the sea during the deposition of these latter beds, are well shown (see Plan and Sections, Pl. VI.).

It is generally known that the Coralline Crag consists of two divisions—an upper one, formed chiefly of the remains of Bryozoa, and a lower one of light-coloured sands, with a profusion of shells. The more exact dimensions and subdivisions of these beds at Sutton, Orford, Sudbourne, and Gedgrave I now purpose to give.

The discovery of the so-called Coprolites in the Red Crag by the late Professor Henslow, in 1848, led to a great extension of crag-pits. With one exception they were all in the Red Crag. The only one in the Coralline Crag was opened by Mr. Colchester, on the south side of Sutton-farm Hill (H, Pl. VI.). Unfortunately the pit did not prove remunerative, and a year or two later it was filled up, and the ground levelled; so that it was only seen by myself and Mr. Ray Lankester, as mentioned by him in a paper read before this Society. The section was of much interest, as it exposed beds which belong, I believe, to the lowest zone of the Coralline Crag, and showed a basement bed with fossils and boulders of an unexpected and remarkable character (fig. 1).

Fig. 1.—*Section of old pit on Mr. Colchester's farm, Sutton.*



(Unless mentioned to the contrary, all the pit-sections in this paper are on the same scale, viz. 12 feet to the inch vertical.)

The surface of the London Clay is here 8 feet above high-water level of the adjacent river Deben. Immediately on the London Clay we find a bed, from 1 to $1\frac{1}{4}$ foot thick, of phosphatic nodules, not to be distinguished in general appearance from those of the Red Crag. Among them I found, as in the Red Crag, a great many fossil Crustacea, much worn, derived from the London Clay, and consisting of the following species:—

Archæocarabus Bowerbankii.	Scyllaridia Kœnigii.
Dromolites Bucklandii.	Thenops scyllariformis.
Hoploparia Bellii.	Xanthopsis Leachii.
—— gammaroides.	Xantholithes Bowerbankii.

With these I found one fragment of the horn of a Deer much mineralized, a small Cetacean vertebra retaining the ordinary bone-structure, together with numerous teeth of sharks. In the same bed were worn blocks of Septaria from the London Clay, drilled by boring mollusca, and flat, worn, highly mineralized Cetacean bones, superficially punctured, as those in the Red Crag, together with fragments of Bryozoa, *Terebratula grandis*, and *Cyprina*, much worn, and the latter full of the cavities made by minute boring sponges. With these organic remains there were a small number of the nodules or balls of coarse dark-brown sandstone, often containing the cast of a shell, so common in places in the Red Crag; there were also small pebbles of quartz and of flints, and some large pebbles of light-coloured, hard, siliceous sandstone: but the most remarkable specimen I there found was a rounded boulder of dark-red porphyry of considerable size, and weighing about a quarter of a ton. None of the specimens were angular or striated.

On mentioning these circumstances to Mr. Colchester, I found that he and his son had made a valuable collection from this pit, which he at once kindly placed in my hands.

The following is a list of the principal and more important specimens thus obtained.

One tooth of Mastodon (*M. arvernensis*)*.
Two teeth of Rhinoceros (*R. Schleiermacheri?*); both milk-teeth.
Two teeth of Deer (*Cervus dicranoceros*).
Four teeth of Cetaceans.
One vertebra of Whale, large.
Two ear-bones of Whale; one mineralized, the other not.
Four skulls of *Belemnoziphius*.
Many teeth of *Carcharodon* and *Lamna*.
One vertebra of a Saurian (an extraneous fossil of Jurassic age).

These are fossils identical with the species from the Red Crag; and, like them, they present a highly mineralized condition, and are, with the exception of some of the Cetacean and a few of the other Mammalian remains, all more or less rolled, worn, and polished.

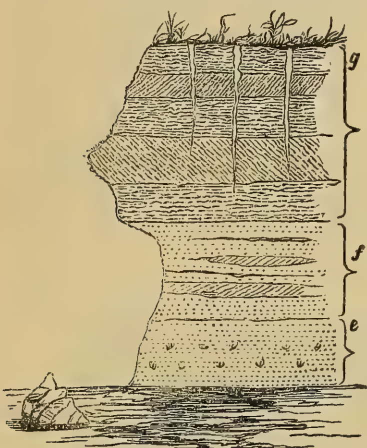
Over this nodule-bed are about 4 feet of finely comminuted shells, with a few single valves of *Pecten*, *Cyprina*, *Mactra*, together with *Turritella* and *Terebra*, and then 17 feet of light-coloured marly Crag, abounding in large shells and with few Bryozoa. In the lower part of this bed were some specimens of the *Mya truncata*, in the position in which they lived; the *Cyprina islandica*, var., sometimes double, was common in certain layers; and in the upper part of the bed *Anomia*, *Astarte*, *Diplodonta*, and *Venus* abounded, together with a variety of Foraminifera, whilst univalves were comparatively scarce. They had ceased working this pit when I visited it in 1861 and 1862; and on my returning at a later period, hoping to make a more complete collection of the shells, I found it levelled down. It is probable that part of bed *c* of this section is synchronous with the crag of the small Ramsholt pit, which yielded so large a number of rare and beautiful fossils to the researches of Mr. Charlesworth, Sir Charles Lyell, and Mr. Colchester. Many species were more abundant at Ramsholt than in any other locality, and were generally in a very fine state of preservation—the bivalves often with both valves. Among the commoner species were *Cardita senilis*, *Cyprina islandica*, *Pecten maximus*, *P. opercularis*, *Panopæa Faujasii*, *Astarte Burtini*, *A. gracilis*, *Trochus zizyphinus*, *T. conulus*, and the large *Balanus concavus*. The latter occurred in hundreds. This bed is also characterized by *Cytherea chione*, *Hinnites Cortesyi*, *Lima hians*, *Tapes perovalis*, *Natica proxima*, *N. varians*, *N. cirriformis*, *Pyrula reticulata*, *Balanus bisulcatus*, *Pyrgoma anglica*, *Spatangus purpureus*, *Brissus scillæ*, *Flabellum Woodii*, and several species of *Echinus* and *Temnechinus*.

The upper part of the section at this pit (fig. 1) seems to be on the level of that part of the Coralline Crag which is under the Red Crag in the Bullock-yard (D, Pl. VI.). It may be seen by digging through the 2 to 4 feet of Red Crag forming the floor of the pit. It was full of *Cardita*, *Pecten*, *Astarte*, and various characteristic shells of the

* Mr. Lankester says, however, "a *Mastodon* tooth which I have seen from that situation is not *M. arvernensis*, but belongs to the Trilophodont species."—Quart. Journ. Geol. Soc. vol. xxvi. p. 497.

Coralline Crag. It is on the side of this old yard, and therefore immediately above the bed with *Cardita* &c., that the Coralline Crag rises in an old cliff well described by Sir Charles Lyell *, and to which I shall have occasion to refer again. The lower part of this cliff consists of light-coloured sands (*e*), with a few Bryozoa and a good many small shells ; while the upper part (part of *f*) is composed in great part of comminuted shells. No higher bed is seen here ; but on the other side of the hill, and at a distance of 400 feet west of this pit, is an old quarry, which, when I first visited it in 1836, had recently been extensively worked for rubble to form the river-wall. In the lower part of this pit (fig. 2) the bed of sand *e*, just referred to in the Bullock-

Fig. 2.—*Section in old Quarry, Sutton. Top of hill overlooking the Deben.* (See F, Map and Sections, Pl. VI.)



yard pit, is well exposed. It is 12 feet thick, and consists of a light yellow sand, with a few shells, mostly small or young individuals, with a number of Bryozoa in a fine state of preservation and mostly in the position in which they lived. In some places these Bryozoa are very numerous, and arranged in regular but not continuous bands, like flints in the Chalk. The prevailing species are *Cellepora coronoporus*, *Eschara porosa*, and other species of *Cellepora* and *Eschara*, a species of *Ceriopora*, and another large branching species. Many of these are in the most beautiful state of preservation and perfectly uninjured. They are now, however, best seen in a small section between the large pit or quarry and the cottages at the entrance to the Bullock-yard.

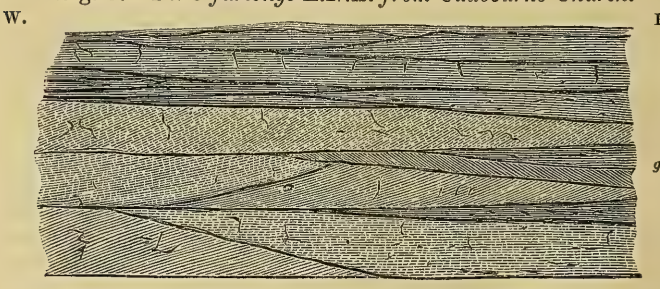
Overlying these sands with undisturbed Bryozoa is a bed, *f*, from 5 to 8 feet thick, consisting of comminuted shells with seams of oblique lamination, containing a few Bryozoa, and with a considerable number of shells, also mostly small or young individuals, in a good state of preservation. Intercalated in this bed are several finely laminated indurated irregular seams of yellow marl or limestone, containing small shells, Foraminifera, and some rare species

* *Op. cit.*

of Bryozoa, including the *Salicornaria sinuosa*, which I found here in greater abundance and more perfect preservation than at any other spot. It also contains dark green grains of silicate of iron, dispersed and in seams. The globose *Fascicularia* and *Alveolaria* are common in both *e* and *f*.

In strong contrast with this lower bed is the overlying ferruginous soft rock, which forms the upper part of this quarry. It consists essentially of comminuted shells and of fragments of Bryozoa, and often shows oblique lamination. This mass, which here is about 11 feet thick, is cemented together, partly by carbonate of lime, and at this spot partly by the oxide of iron, and forms a soft and very porous dark brown rock. Detached valves of Pectens and other shells, and a considerable number of *Fasciculariæ* and *Alveolariæ* are found entire, together with remains of Crustacea and Echinodermata. This bed at Sutton is but 11 feet thick, forming only the lower part of the upper division of the Coralline Crag. It is more largely developed in the neighbourhood of Sudbourne, where it attains a thickness of 20 feet. At Low Gedgrave there is a pit where it is nearly 30 feet thick. This division of the Crag often presents numerous curious instances of oblique lamination, and exhibits, in fact, a very instructive illustration of the frequent reconstruction of old shell-banks. Altogether the series of beds at and around Sutton and Sudbourne, especially some in the near vicinity of Sudbourne church (as in fig. 3), are of the greatest interest.

Fig. 3.—*Pit 5 furlongs E.N.E. from Sudbourne Church.*



Beds of comminuted shells and of Bryozoa forming a soft building-stone.

This division is generally very uniform in its composition. There is a pit, however, at the corner of the two cross-roads, 6 furlongs N.N.E. from Sudbourne Church, where the upper 6 feet consists of finely comminuted shells, with a few Bryozoa.

This completes the series of beds forming the two divisions of the Coralline Crag. I have denoted them by letters, for the convenience of correlation with the same beds in other parts of the district.

The thickness of the lower division of the Coralline Crag, as proved at Sutton, is about 47 feet, and that of the upper division, as it exists in the neighbourhood of Sudbourne and Gedgrave, about 36, making a total of 83 feet.

Taking the whole together, the general section of the Coralline Crag is as follows (fig. 4):—

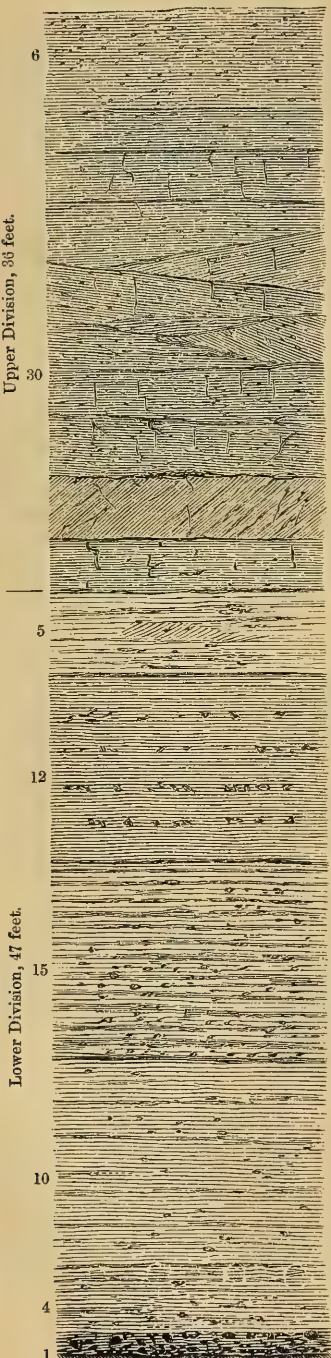


Fig. 4.—*General Section of the Coralline Crag.*

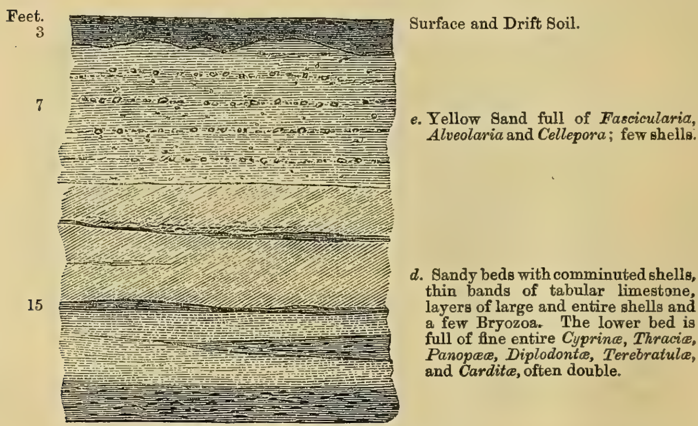
h.	Sand and comminuted shells.	Sudbourne. Gedgrave.
g.	A series of beds consisting almost entirely of comminuted shells and remains of Bryozoa, forming a soft building-stone. False stratification and oblique bedding are its constant characters.	Sutton. Sudbourne. Gedgrave. Iken. Aldbro'.
f.	Sand with numerous entire small shells and seams of comminuted shells.	Sutton. Iken. Sudbourne. Gomer.
e.	Sands with numerous Bryozoa, often in the original position of growth, and some small shells and Echini.	Sutton. Broom Hill.
d.	Comminuted shells, large entire or double shells, and bands of limestone in the upper part.	Sutton. Broom Hill. Sudbourne. Iken. Tattingstone.
c.	Marly beds with numerous well-preserved and double shells, often in the position in which they lived.	Sutton. Ramsholt.
b.	Comminuted shells, Cetacean remains, Bryozoa.	Sutton.
a.	Phosphatic nodules and mammalian remains.	Sutton.

Near Aldborough the upper division of the Coralline Crag, but with more shells than at Sutton, is alone exposed. It contains casts of *Voluta Lamberti*, of *Cyprina islandica*, with specimens of Echini and Crustacea. Of the latter, a beautiful specimen referable, according to Mr. H. Woodward, to the genus *Gonoplax*, and probably to *G. angulata*, Leach, was found by my young friend Mr. Norman Evans.

At Iken brick-yard and some adjoining pits the same upper division with Bryozoan remains is found; while in the lower ground, between the brick-pit and the church, and again between the Brick-pit and Webber's-Whin Farm, the upper bed *f* of the lower division (which is here more developed than at Sutton, and contains some thin seams of hard shelly indurated limestone) crops out. In the numerous pits in the neighbourhood of Sudbourne Church the upper division *g* is alone exposed; but it is now rarely quarried.

In Sudbourne Park there is a pit on the higher ground which shows a good section of the Bryozoa-beds of the upper division; while a small shallow pit in the low ground close by the Hall has been long noted for the beauty and variety of its fossil shells. *Cyprina*, *Astarte*, *Cardita*, and *Terebratula*, &c. abound in this pit, which belongs, I think, to part of bed *d* (see general section, fig. 4).

Fig. 5.—*Pit on Broom Hill, near Keeper's Lodge,* 1 *mile* W. *from Orford Church.*



The well-known pit by the keeper's lodge at Broom Hill, Gedgrave (fig. 5), shows 7 or 8 feet of yellow sands, full of detached Bryozoa, chiefly *Fascicularia* and *Alveolaria*, belonging to the zone *e*; beneath this are 15 feet of comminuted shells, intercalated in which are seams of large shells in a fine state of preservation. In the lower part of this pit, some of the semiindurated seams, when broken open in the plane of bedding, are found studded with magnificent specimens of *Cyprina islandica*, *Mya truncata*, *Panopæa Faujasii*, various species of *Astarte*, *Cardita*, *Venus*, and other shells. These beds belong to the zone *d* *.

At Low Gedgrave, there is a shallow pit near the farm-buildings, showing a section composed of layers of comminuted shells with irregular seams of shelly limestone and sand, in which a number of

* As showing the importance of keeping each stratum separate, I give two special lists of specimens collected by my friend the late Dr. Woodward during a residence of some weeks in the district. In the one case (Broom Hill) the fossils of zone *d* (including parts of *e*), and in the other (Gomer) those of zone *f*, thus appear as distinct groups.

CORALLINE CRAG.

Keeper's-Lodge pit, Broom Hill (near Orford).

(Bivalves abundant; univalves comparatively scarce. Authority, S. P. Woodward, from specimens collected in 1863.)

Cypræa europæa.
Buccinum undatum.
Turritella incrassata.
Scalaria subulata.
—— clathratula.
Rissoa crassistriata.
Cæcum mamillatum.
Trochus zizyphinus.
—— formosus.
Margarita trochoidea.
Adeorbis striata.
Natica proxima.
Calyptræa chinensis.
Emarginula fissura.
Fissurella græca.

Anomia ephippium.
—— striata.
Ostrea edulis.
Pecten maximus.
—— Gerardii.
—— tigrinus.
—— pusio.
—— opercularis (very abundant).
Lima Loscombii.
Pinna pectinata.
Mytilus hesperianus.
Crenella sericea.
Pectunculus glycimeris (abundant).
Limopsis aurita.
Nucula nucleus.
Leda semistriata.
Lucina crenulata.
—— borealis (abundant).
Diplodonta rotundata.
Lucinopsis Lajonkairii.
Verticordia cardiiformis.
Cardium strigilliferum.
—— decorticatum.
Cardita senilis (abundant).
—— scalaris (abundant).
Cardita orbicularis.
—— corbis.
—— ——, var.
Astarte Basterotii.
—— mutabilis.
—— Omalii (very abundant).
—— gracilis.
—— Burtinii.
Cyprina islandica (very abundant).
—— rustica.
Cytherea chione.
—— rudis.
Venus imbricata.
—— casina (abundant).
—— ovata.
Psammobia ferroënsis.
Tellina obliqua.
—— donacina.
Mactra arcuata.
Solen ensis.
Thracia inflata.
—— ventricosa.
Corbula nucleus.
Mya truncata.
Panopæa Faujasii (abundant).
Glycimeris angusta.
Lingula Dumortieri.
Terebratula grandis (abundant).

Spirorbis.
Balanus crenatus.
Blumenbachium globosum.
Fascicularia, sp.
—— tubipora.
Cladocora cariosa.
Turbinolia Milletiana.

Echinus Woodwardi.
Spatangus.
Discoporella.
Heteropora pustulosa.

rare small fossils have been found: this bed either belongs to part of zone *d*, or may possibly be an expansion of zone *f*. The same

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Lunulites conica.
Hornera reteporacea (infundibulata).
—— striata.
Eschara monilifera.
Cupularia canariensis.

Gomer (a small temporary pit in a field between Low Gedgrave and Broom Hill, but on slightly higher ground than the latter).

(Very rich in species, univalves and bivalves. Authority, S. P. Woodward, from specimens collected in 1863.)

Ovulum (Leathesii) spelta?
Cypræa retusa.
—— europæa.
Erato lævis.
—— Maugeriæ.
Voluta Lamberti.
Mitra ebenus (Mr. Evans?).
Aporrhais pes-pelicani.
Terebra inversa.
—— canalis.
Cassidaria bicatenata.
Nassa labiosa.
—— granulata.
—— consociata.
—— prismatica.
Buccinum Dalei.
—— undatum, var.
Murex corallinus.
Triton heptagonum.
Fusus gracilis, var. propinquus.
—— alveolatus.
—— consocialis.
Trophon muricatus.
Pleurotoma porrecta.
—— semicolon?
—— ——, var.
Mangelia castanea.
—— perpulchra.
—— costata.
—— mitrula.
—— cancellata.
Bela concinnata.
Cancellaria mitræformis.
—— scalarioides.
Cerithium trilineatum.
—— tuberculare, var.
—— adversum.
—— granosum.
Turritella incrassata.
Pyramidella læviuscula.
Chemnitzia, n. sp.
—— elegantissima.
Odostomia plicata.
—— truncatula?
Scalaria varicosa.
—— frondicula.
—— foliacea.
—— subulata.
—— clathratula.
Scalaria? cancellata.
Eulima subulata.
Rissoa confinis.
—— obsoleta.
Cæcum mamillatum.
—— glabrum.
Lacuna reticulata.
Trochus zizyphinus.
—— ——, var. monstrosus.
—— granulatus (papillosus).
—— millegranus.
—— villicus?
—— Adansoni.
—— Kicksii.
—— tricariniferus.
—— obconicus.
Margarita? maculata.
—— trochoidea.
Adeorbis striatus.
—— supra-nitidus.
—— pulchralis.
Natica proxima.
—— varians.
—— cirriformis.
—— multipunctata.
Pileopsis ungaricus.
Calyptræa chinensis.
Emarginula fissura.
—— crassa.
Bulla lignaria.
—— conuloidea.
Cylichna cylindracea.
Dentalium costatum.
—— bifissum.
Anomia ephippium.
—— striata.
Ostrea edulis.
Pecten maximus.
—— Gerardii.
—— similis.
—— tigrinus.
—— pusio, var. striata.
—— opercularis.
—— ——, var.
Lima exilis.
—— subauriculata.
Pinna pectinata.
Modiola phaseolina.
—— marmorata.

sand and flaggy limestone is worked in a pit a few yards to the south-east of the barn at the extreme south-west point of Gedgrave Hill. The shelly beds, with flags of shelly limestone at Tattingstone (see section in Part II.), may possibly be referred also to zone *d*.

With regard to the bed of phosphatic nodules, it is no longer exposed at Sutton, and it has not been reached in any of the pits in the neighbourhood of Orford; but there is a shallow pit now worked between Butley Abbey and Butley River, which may probably belong to the base of the Coralline Crag; the crag-beds themselves have been removed, with the exception of a foot or two, which is so disturbed as to render its identification doubtful. Still, from the abundance of *Cardita senilis*, *Astarte Omalii*, and *Cyprina islandica*, the occurrence, although rare, of *Mytilus hesperianus*, *Pecten maximus*, and *Isocardia cor*, and the absence of the ordinary shells of the Red Crag, with the exception of a few specimens of *Trophon antiquus*, near the surface, I should feel disposed to consider this a disturbed portion of the Coralline Crag, and to refer the 2-foot coprolite-bed below it to this formation.

Organic Remains.

The Mollusca of the Coralline Crag have been worked out by Mr. Searles Wood with so much skill and perseverance that there is little

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Pectunculus glycymeris.
Limopsis aurita (rare).
—— pygmæa.
Nucinella miliaris.
Arca pectunculoides.
Nucula lævigata, var.
—— tenuis?
—— nucleus.
Leda pygmæa.
Kellia ambigua.
—— ——, large var.
Montacuta bidentata.
—— truncata.
—— substriata.
—— ferruginosa.
Cryptodon sinuosum.
Lucina borealis.
Diplodonta rotundata.
—— dilatata.
Cardium nodosum.
—— strigilliferum.
—— decorticatum.
Cardita senilis.
—— scalaris.
—— orbicularis.
—— corbis.
—— ——, var.
Erycinella ovalis.
Astarte triangularis.
—— parvula.
—— Basterotii.
—— mutabilis.
—— Omalii.
—— gracilis.
Astarte Burtinii.
—— ? digitaria.
—— parva.
Cyprina islandica.
—— rustica.
Circe minima.
Cytherea rudis.
Venus imbricata.
—— casina.
—— ovata.
Gastrana laminosa.
Donax politus.
Tellina obliqua.
—— donacina.
Syndosmya prismatica.
Mactra obtruncata.
—— triangulata.
Lutraria elliptica.
Solen ensis.
Thracia phaseolina.
—— inflata.
Pholadomya hesterna (?).
Corbula nucleus.
Saxicava? carinata.
Glycimeris angusta.
Terebratula grandis.

Ditrupa subulata.
Balanus concavus (retaining colour).
—— bisulcatus (common on Lucina and Pecten Gerardii).
Cellepora edax.
Hornera infundibulata.
Cupularia porosa.

chance of any observer adding to his list without being able to devote very much more time to the subject than I have had at my disposal. There is certainly no formation in England, and probably none abroad, the fossils of which have been the object of researches more assiduous and more conscientiously made than those of Mr. Searles Wood. Not only has Mr. Wood formed collections rarely equalled in their completeness and extent, but he has also ably described and illustrated them in the early volumes of the Palæontographical Society*. The other organic remains of the Crag have also been described in the same work by most competent authorities in the different natural-history sections in the following order:—

Mollusca, by Mr. Searles Wood (Palæontographical Society's Monographs†)	1848, 1850, 1856
Corals, by MM. Milne-Edwards and J. Haime	1850
Cirripedia, by Mr. Darwin	1851, 1854
Brachiopoda, by Mr. Davidson	1852
Echinodermata, by Mr. Edward Forbes	1852
Entomostraca, by Mr. Rupert Jones	1856
Polyzoa (Bryozoa), by Mr. Busk	1859
Foraminifera, by Messrs. Jones and Parker	1866

We are thus, with the exception of the Mammalia, which are only of recent discovery in the Coralline Crag, furnished with a very complete exposition of the fauna of this formation; but there is still work to be done in defining more exactly, by careful collections on the spot, the fossils of each particular zone. In zones *d* and *f* this has been partly done. Zone *c* is typified at Ramsholt, and may be characterized by its Echinoderms and various large Testacea (see list), as zone *e* is by its profusion of Bryozoa.

Mollusca.—So large a proportion of the shells of the Crag are of recent species that we are furnished with unusually good data for investigating the conditions under which this deposit was formed, by the study of the geographical range and distribution of those living species, and of the zones and depths through which they range. The tendency of natural history at present is rather to extend and remove the barriers of special zoological provinces. Mr. Gwyn Jeffreys remarks‡:—"It seems to me, after a long and careful study of the question, that no more than two groups (which are apparently distinct from each other) can be recognized in a geographical point of view; and for these I would suggest the general but not inappropriate names of 'Northern' or 'North-European,' and 'Southern' or 'South-European.'" And he adds that "it is extremely difficult to fix the limits of even those comparative areas of distribution; but the 'facies' of each group is manifest to some extent in the littoral or shallow-water species." To these groups, or divisions, Mr. Jeffreys adds a third, viz.

* I am happy to hear from Mr. Wood that he is engaged upon a supplement to his original work.

† Last year (1870) the first part of Prof. Owen's 'Fossil Cetacea of the Red Crag' was added to this series.

‡ British Conchology, i. introd. p. lxxxvi.

"Oceanic, or occasional visitants." "The first of these divisions corresponds with the 'Arctic' and 'Boreal' types of Forbes and Hanley; and the second to their 'Atlantic' and 'Lusitanian' types. Their 'South-British,' 'European,' 'Celtic,' and 'British' types indicate mixed or neutral ground, and partake both of northern and southern characters." The high authority of Mr. Gwyn Jeffreys would induce me to adopt this broad division; but for geological purposes, such as tracing the old land-margins, the old sea-areas, and other questions connected with the physical geography of former periods, I think it desirable to look at the subject more in relation to existing continents and sea-margins. I have therefore retained the term "Arctic" for the species living on the Spitzbergen or Greenland coasts, "Scandinavian" for the species frequenting the coasts of Norway, Sweden, and Denmark, "British" for those of the seas immediately surrounding Great Britain, "West European" for the species frequenting the coast of Europe from France to the Straits of Gibraltar. Although Mr. Jeffreys has shown that the Mediterranean molluscan fauna cannot be considered distinct from that of the East Atlantic, I have retained the Mediterranean area as a separate province, in consequence, not so much of its existing fauna, as of the relation of that fauna with the fauna of the later or recent Tertiaries of Italy, France, and England—a relation of the most marked character. For the species which have a more southern range and are found on the shores of Madeira, the Canary Isles, and the Azores I use the term "Mid-Atlantic." To this another region is now added, embracing the great depths of the Atlantic generally—depths from 1200 to 15,000 feet.

Mr. Searles Wood described 322 species of Coralline-Crag Mollusca, which, with the 5 species of Brachiopoda described by Mr. Davidson, gives a total of 327 species. The late Dr. Woodward, basing his calculations on these lists, was of opinion that the number of extinct species was 159, and of recent species 168, which gave a percentage of 51 of recent species. Of the latter he considered that 139 were still to be found in British seas, whilst 27 were now confined to southern and 2 to northern seas *. The great extension of the field of research by means of deep-sea dredging, however, has brought to light facts which render a review of the relation of the fossils of the Crag to living species desirable. Several species which were then supposed to be extinct have since been found living; and other links have been found which tend to show that some of the species supposed to be distinct may be considered merely varieties of others; and I am glad to have

* Sir Charles Lyell's 'Antiquity of Man,' 1863, p. 209. In his 'Student's Elements of Geology,' p. 178, just published (1871), Sir Charles Lyell has revised these lists as under:—

	Total number.	Not known as living.	Percentage of shells not known as living.
Bivalves	161	47	31·5.
Univalves	184	60	
Brachiopods	5	3	

the opportunity of recording the opinion of another distinguished naturalist, Mr. Gwyn Jeffreys, who has made European conchology his especial study, and has particularly worked out the deep-sea fauna with a view to a comparison with fossil species upon this question. We have visited the Crag district together; and he has examined all the more important Crag collections, while with the same object in view he has also extended his researches to the Pliocene collections of the Continent. The special results of his elaborate inquiry will be found in the tabular list, pp. 137–146. The list of Coralline-Crag Mollusca so revised gives a total of 316 species, of which Mr. Jeffreys considers 264 to be living and 52 extinct, thus giving a percentage of 84 recent, and apparently only of 16 extinct species *.

Of these 265 living species of Mollusca, Mr. Jeffreys has determined 185 to be still living in the British seas, and 80 to be species living now only in extra-British seas. Of the latter, 14 species live in northern seas only, 65 in southern only, and 1 lives in both northern and southern seas. Dividing the living species into zoological provinces, I find their distribution is as under:—

	Bivalves.	Univalves.	Total.	Peculiar.
Arctic	19	15	34	2
Scandinavian	75	60	135	0
British	101	84	185	2
West European	90	81	171	1
Mediterranean	103	97	200	17
Mid-Atlantic	49	50	99	4
Deep Atlantic	41	51	92	10

Special localities.—North America, 2; Africa, 4; West Indies, 2; Gulf of Mexico, 1; Japan, 3.

Of the 5 species of Brachiopods in the Coralline Crag, 1 only is extinct. Two are British species with an extensive range. Mr. Gwyn Jeffreys has dredged the *Argiope cistellula* in from 20 to 80 fathoms water; and the *Terebratulina caput-serpentis* ranges from the shore to 632 fathoms. The *Discina atlantica* has been dredged in the deep Atlantic (7560–13,500 feet). The *Lingula Dumortieri* has been dredged in the seas of Japan. As a rule, Brachiopoda may be considered to indicate deep water.

Bryozoa.—According to Mr. Busk, there are not less than 95 species of Bryozoa found in the Coralline Crag; 30 of these species are now living, and 65 are extinct. Of the former, 26 still inhabit the British seas; and of the other four, 3 are found on the west coast of Africa and at Madeira, and 1 is probably living in the Australian seas. Of the 26 British species, 9 have a southern range, some as far as Patagonia and the Falkland Islands. There is one remarkable exception to this southern character; the *Retepora Beaniana* has been found on the coast of Norway by Mr. M'Andrew, and in the Arctic sea by Sir Edward Belcher. Mr. Busk considers it to be a wholly northern

* Whether or not the greater number of shells will prove to be living, remains for future research; but certainly the conclusions of Mr. Jeffreys are in harmony with the inquiries of Sir Charles Lyell, which have shown a smaller percentage of extinct species in the Coralline Crag of late than formerly.

species*. Alcide D'Orbigny† states that he has dredged Bryozoa at a depth of 160 mètres off Cape Horn, and he considered the sea-bed there to be formed of dead and living Bryozoa. In many places the banks of Newfoundland are, in his opinion, covered entirely with similar débris, *Cellepora*‡ being especially abundant. The conditions most essential to the growth of Bryozoa, according to the same experienced observer, are:—first, considerable depth of water; secondly, clear and limpid water; thirdly, water constantly agitated by waves and deep currents. 13 out of the 26 British species found in the Coralline Crag belong to the genus *Lepralia*. According to Dr. Johnston§, the greater number of these species are found in deep water; and Mr. Busk mentions that the *Lepralia ciliata* has been dredged at 45, the *L. Peachii* at from 110 to 147, the *L. hyalina* at from 4 to 40, and the *L. Malusii* at 48 fathoms.

Amongst other common genera of the Crag are *Idmonea* and *Retepora*, which may be considered essentially characteristic of rather deep seas. The *Escharæ*, again, live in deep water and among strong currents. One extinct species of this genus, the *E. monilifera*, is the abundant and characteristic species of the Coralline Crag. Another common species is the *Biflustra delicatula*, now to be found only in the seas of Australia and Manilla. The curious globose genera *Alveolaria* and *Fascicularia* are extinct, and peculiar

* Mr. Busk, however, has recently informed me that, from an examination of the Bryozoa collected in the Mediterranean in the late voyage of the 'Porcupine,' he believes that *R. Beaniana* occurs in that sea. He has also furnished me with the following lists of Crag species now living in the Mediterranean and Adriatic, or fossil in the Italian Pliocene beds:—

Crag species living in the Mediterranean.	*Crag species occurring in the Italian Pliocene.*
Salicornaria sinuosa.	Lepralia ansata.
Lepralia annulata.	,, Bowerbankiana.
,, ansata.	,, Brongniartii.
,, Brongniartii.	,, ciliata.
,, ciliata.	,, innominata.
,, innominata.	,, Malusii.
,, Malusii.	,, mamillata.
,, Morrisiana?	,, Morrisiana?
,, Pallasiana.	,, Pallasiana.
,, unicornis.	,, unicornis (tetragona, *Reuss*).
,, violacea.	,, violacea.
Retepora cellulosa.	Retepora cellulosa.
Cupularia canariensis.	Cupularia canariensis.
Patinella patina.	Membranipora andegavensis.
	,, oceani.
	,, Lacroixii.
	Biflustra delicatula.
	Cellepora coronopus.
	,, ramulosa.
	,, scruposa.
	,, tubigera.

† Annales des Sciences Naturelles, 1851, p. 295.

‡ The curious *Cellepora edax* is often found covering, as a mantle, several species of univalve shells.

§ History of British Zoophytes. London, 1847.

to the Coralline Crag. Of the species and genera of Bryozoa inhabiting shallow water, there is a marked absence.

The Bryozoa make their appearance in the lowest bed of the Coralline Crag. I found species of *Cellepora* and *Eschara* amongst phosphatic nodules at the base of this deposit. At Ramsholt the *Cupularia denticulata*, *C. canariensis*, and other species were met with. In ascending order they become gradually more numerous, and in zone "*e*" they attain a large development and, further, occur in the position and place of growth. The species seem somewhat gregarious. At Sutton we find chiefly species of *Cellepora* and *Eschara* in this bed, whilst at Broom Hill little else is found but the various species of *Fascicularia* and *Alveolaria* and some *Cellepora*. In the highest bed, "*f*," of this division, where extremely fine sedimentary seams are intercalated with a mass of comminuted shells, the delicate *Salicornaria sinuosa* seems to have flourished.

The upper division of the Coralline Crag, as is well known, is composed to a great extent of fragments of Bryozoa and comminuted shells, with a certain number of entire *Alveolariæ* and *Fascicularice* and shells. As the structure of these beds shows them to have been subjected to the action of shifting currents and frequent reconstruction, it is probable that these banks of Bryozoan remains and dead shells were formed in great part by the scour of deep-sea currents out of the upper beds of the lower division of the Coralline Crag. At the same time, the perfect state of the *Alveolariæ* and *Fasciculariæ* and the known habits of most of the Bryozoa render it perfectly possible that many of the individuals may have lived among these shifting currents and shell-banks.

Crustacea.—Besides the specimen referred to *Gonoplax angulata*, Mr. Woodward has ascertained the existence in the Coralline Crag of the following species:—*Cancer pagurus*, *Carcinus mænas*, *Maia squinado*, and *Portunus puber* and *depurator*.

Entomostraca.—Mr. Rupert Jones describes 18 species of Entomostraca from the Coralline Crag*, 3 only of which are known for certain as living forms (*Cythere punctata*, *C. ceratopora*, and *Loxoconcha tamarindus*), all in the Atlantic—though *Cythere laqueata*, *C. sublacunosa*, *C. trachypora*, and *C. retifastigata* have almost undistinguishable allies in the Norwegian sea; and the subdeltoidal *Bairdia* of the Crag has its closest analogue (*B. fusca*, Brady) in the Australian seas. The last-mentioned seems to be of deep-water habits; but the others are mostly littoral.

As we do not know the exact distribution of the Entomostraca in the Coralline Crag, we cannot speak of them in relation to the different zones.

Cirripedes.—Mr. Darwin has described 10 species in the Coralline Crag, 4 of which are from Ramsholt and 6 from Sutton. The proportion of recent to extinct species is 6 to 4. Of these six, four are species still living in the British seas, one ranging to the Scandinavian coast and one to the Arctic seas. Both these species, how-

* These conclusions are drawn from Prof. Rupert Jones's revision of these Tertiary Entomostraca in 1870 (Geol. Mag. vol. vii. pp. 155–159).

ever, have an equally wide range in a southern direction, and the other 4 are entirely southern in their range. Owing to the way in which so many Cirripedes attach themselves to floating seaweed, wood, shells, Crustacea, and Bryozoa, their range is generally wide, and they have less definite value in a geological point of view. Mr. Darwin states that *Pyrgoma anglica* is found from 12 to 45 fathoms, and the *Verruca Strömia* at all depths from low water to 90 fathoms.

Corals.—M. Milne-Edwards could only recognize 3 species of Corals in the Coralline Crag, and considered them all to be extinct species,—one, the *Cryptangia Woodii* of the lower Crag zones, belonging to an extinct genus. Professor Duncan, however, informs me that in the last expedition of H.M. ship 'Porcupine,' specimens of a Coral were found alive in Tangier Bay, which could only be regarded as a variety of the *Sphenotrochus intermedius* described by Von Münster. The habitat of that species is between 60 and 300 feet. Professor Duncan also says that the deep-sea dredgings off the south-west coast of Spain in the same expedition of the 'Porcupine' have yielded a *Flabellum* which, although not very closely allied to the Crag form (*F. Woodii*), is found in the Miocene deposits of the south of Spain. This species exists on the sea-bed at a depth of from 1824 to 5964 feet, and therefore it is reasonable to assert that *Flabellum Woodii* was a deep-sea form. It is more closely allied to Indian species than to those of more northern seas, viz. *Flabellum laciniatum*, Ed. & H., and *Flabellum MacAndrewi*, Ed. & H. Prof. Duncan further remarks that these genera are such as chiefly inhabit deep water, and that neither they nor their congeners have ever formed part of the assemblage which produces reefs.

Echinodermata.—16 species have been found in the Coralline Crag, of which only 3 are recent species—2 British and Scandinavian, and 1 Mediterranean. If we were to judge by genera alone, several of the Crag genera are such as are now found only in warm and tropical seas. Their range of depth is variable. The *Comatulæ* generally inhabit deepish water. Different species of Echini seem to mark the different zones of the Crag.

Foraminifera.—One hundred and five species (including notable varieties) have been recorded* by Messrs. Rupert Jones, W. K. Parker, and H. B. Brady. Of these, 5 possibly are derived from other strata; 53 are living species, and 47 are extinct. Of the recent species, 37 are stated by the authors to be living in the North Atlantic and 37 in the Arctic seas. The species of the Foraminifera from one bed of Crag at Sutton, they observe, "are remarkable, for the most part, for size and abundance. The leading forms are *Miliola*, *Lagena*, *Nodosarina*, *Polymorphina*, *Textularia*, *Planorbulina*, *Pulvinulina*, and *Nonionina*. As a fauna, they are best represented (in our collections) by dredgings from the Atlantic, south of the Scilly Isles, at from 50 to 70 fathoms, and from the Mediterranean north of Sicily at 21 fathoms. From all

* "Monogr. Foram. Crag" (Pal. Soc.), part 1, 1866; and "Monogr. Polymorphina" (Linn. Soc.), 1870.

other parts of the Lowest or White Crag of Suffolk, as far as our collections serve, we have got a somewhat similar fauna, not only greatly reduced in number of individuals and variety of form, but composed of dwarfs in contrast with those of Sutton, except in the case of some of those that inhabit shallow water, as *Rotalia Beccarii* and *Polystomella crispa*, and even these are but feeble. Hence we may suppose that the Foraminiferal deposit at Sutton was formed either in deeper or in warmer water than other portions of the Crag were. Some of our sources of these less luxuriant growths are specimens of Crag full of *Cyprina* and *Cardita*; and as the former shells live in the British seas at from 5 to 80 fathoms, a depth similar to that affected by the Atlantic and Mediterranean groups of Foraminifera above alluded to, we must suppose that some deteriorating influence, either cold currents, floating ice, or cold climate, was at work locally, at least, in the Crag, excepting possibly the Sutton area."

Fish-remains.—A sea like that of the Coralline Crag doubtless contained its due proportion of fishes. Their remains nevertheless are scarce. This can in part be accounted for by the fact that a proportion of them were probably cartilaginous fishes. Small vertebræ of fishes and otoliths are not so scarce. The subject, however, has received little attention, and requires further investigation. Mr. Higgins states that all the Crag otoliths which have passed through his hands belong to Gadoid fishes. The species which he has been able to recognize are:—

(*Morrhua.*)	Common Cod.	probably identical.
"	Green Cod.	
"	Power Cod.	
(*Merlangus.*)	Pollack.	nearly allied, but not identical.
"	Whiting.	
"	Whiting-pout.	

Large teeth of the extraneous *Carcharodon megalodon* with those of *Otodus*, and remains of *Platax Woodwardi*, of *Raia antiqua*, and *Zygobatis Woodwardi* are common in this as they are in the Red Crag.

Mammalian Remains.—The term "Mammaliferous Crag" was especially applied to the Norwich Crag by Mr. Charlesworth, to indicate the common occurrence of mammalian remains in that Crag, in contradistinction to their scarcity in the Crags of Suffolk. The extensive workings of the Red Crag have since shown that it also is rich in such remains; but they present this difference from the fossils of the Norwich Crag, that whilst the latter are in greater part or in whole those of animals living at the time of the Norwich Crag, those found in the Red Crag are, on the contrary, in great part, if not altogether, those of animals which lived at previous times and are derived from older strata. Of this we shall have to speak more fully when on the subject of the Red Crag. Whilst, however, these two Crags were known to contain mammalian remains, no land Mammalia were known in the Coralline Crag. A few remains of Cetaceans had been found, but nothing else. But here again, as with the Red Crag, the cause of their non-discovery appears to have been that they are confined almost entirely to the basement-bed of both deposits, and this bed, in the Coralline Crag, as well as in the Red Crag, proves to consist chiefly of water-worn fragments and pebbles derived from older deposits. It was only at one small pit, and there for a short time, that the bed of phosphatic nodules at the base of the Coralline Crag was worked; and yet there were there found as many, or more, specimens than are usually found in Red-Crag workings of the same extent. The following species have been found:—*Mastodon arvernensis*, *Rhinoceros* (*Schleiermacheri*?), *Cervus*, *Belemnoziphius*, *Balæna*.

The large teeth of *Carcharodon*, the skull-bones of *Belemnoziphius* and the flat Cetacean bones are all drilled superficially by some boring animal. This must, in all probability, have been done before the bones were fossilized; and as the holes present mere segments of their original forms, either they may have been rolled and worn so as to reduce the thickness of the bone and so remove a portion of the drilled surface, as has been suggested, or else the bones may have been originally imbedded in some clays or marls through which boring shells may have drilled until, coming into contact with the harder bone, they merely impinged on its surface, which they failed to penetrate. Neither explanation, however, is satisfactory. In the one case, the bones have generally lost little or nothing of their substance, while the difficulty on the latter supposition is that many of these bones are drilled on all sides; one of the skulls of the *Belemnoziphius*, for example, shows traces of these holes on all its four surfaces, whereas, if the bone had been imbedded in clay or marl, we should have looked for perforations in one surface only.

The condition, in fact, of the bones at the base of this Crag is precisely of the same character as that of those at the base of the Red Crag. In both they are worn and mineralized. At the same time I think it not improbable that the Mastodon and the Rhinoceros may have lived at the Coralline-Crag period—though the general absence of all bones other than teeth, and the circumstance that the materials of the bed in which they occurred is so largely derivative, throw doubt on the whole collection generally. The Whale certainly lived at that period. The condition of many of the vertebræ, their distribution at various levels, and the occurrence, in one case, of seven vertebræ in connexion, show that this animal lived in the Coralline-Crag sea, as did probably some of the other Cetaceans.

From the preceding particulars of the fauna of the Coralline Crag, it would seem that the differences in the proportions of recent to extinct species in the different classes is so great that I do not see how the results are at present to be reconciled. As with the Mollusca, however, I think it extremely probable that the other groups will, after we know more of their distribution in the greater depths of the Atlantic, be found to require considerable revision. In the annexed table I recapitulate this relation of the fauna of the Coralline Crag.

		Extinct.	Living.	Total.
Mollusca.	Brachiopoda	1	4	5
	Conchifera	23	126	149
	Solenoconchia	...	2	2
	Gastropoda	28	132	160
	Pteropoda	...	1	1
		52	265	317
	Bryozoa	65	30	95
	Entomostraca	15	3	18
	Foraminifera	47	53	100
	Corals	2	1	3
	Cirripedes	4	6	10
	Echinodermata	13	3	16
		146	96	242

General Considerations.

Between the period of the London Clay and that of the Coralline Crag the area now forming the Eastern Counties seems to have been dry land. Parts, however, of France and Belgium, together with parts of the south of England, had continued longer submerged, though successive elevations had brought much land to the surface during the later Eocene and early Miocene periods. The sea, however, still occupied the western area of Belgium and Holland. This sea gradually encroached in a westerly direction, and at the Pliocene period had spread over part of the eastern counties. As it spread in one direction the land rose in another; and at the time of the formation of the Coralline Crag a portion of the Miocene and older Pliocene area of Belgium and the north-west of France (as, for example, the top of the chalk hills round the basin of Boulogne), and probably of Kent (Lenham and other parts of the North Chalk Downs), had been raised and exposed to the denuding action of the sea, in which the newer beds were in process of formation.

As the sea extended northward, and the land rose to the south, the climate became colder, and we have evidence of ice-action even at the earliest period of the Coralline Crag; for I do not see how otherwise than by transport by ice to account for the large block of porphyry before mentioned in the basement-bed at Sutton. It is still a question whence this block may have been derived. I know of nothing analogous to it in the rock-specimens from the north of England and Scotland; whether it came from Scandinavia or the Ardennes remains to be determined. The Oolitic remains were probably derived from strata in Central England*. The abundance of London-clay fossils shows a great local denudation, and possibly also

* Mr. Boyd Dawkins refers the Pliosaurian vertebra to the Oxford or the Kimmeridge Clay.

a transport from adjacent Eocene land, while the occurrence of flints shows the proximity of some Chalk shore.

We have therefore in this basement-bed evidence of the sea gaining on the land, and of the drifting of ice-carried boulders. As the land subsided the coarser materials of the basement-bed were covered up by a bed of comminuted shells. This subsidence continuing, beds "*c*" and "*d*" were deposited in comparatively deep and tranquil water. These beds are succeeded by the sands "*e*," abounding in Bryozoa, with small Echini, and a number of small bivalves, indicating apparently the greatest depth of sea (possibly of from 500 to 1000 feet) attained during the Coralline-Crag period. A change then took place, and a bed of comminuted shells, with occasional oblique lamination, was spread over this deep-sea bed, indicating possibly a shallowing of the sea by a reverse movement of elevation, and the setting in of stronger currents with intervals of quiet deposition. Further elevation, exposing the sea-bed to the action of tides and currents, led to considerable wear and denudation of the lower beds and to the heaping up of the remains of Bryozoa and of Mollusca of beds "*f*" and "*e*" in banks over portions of the sea-bed. Under such conditions the upper division, "*g*," of the Coralline Crag seems to have been generally formed; at a few places only do some of the beds seem to have been formed tranquilly. I know of no more illustrative geological instance of the wearing action of sea-currents than the reconstruction of the banks of comminuted Mollusca and Bryozoa which constitute this upper division of the Coralline Crag.

Bed "*h*" shows, in the finer state of comminution of the shells and Bryozoa, that the water probably continued to get shallower; and finally a continuance of the same movement of elevation gradually raised the Coralline Crag above the sea, and exposed it to the denuding action which has removed so large a portion of it. Then, or during the Red-Crag period immediately following, the Coralline Crag was broken up into detached islands and reefs, amongst which the Red Crag was deposited during a period of slow and small subsidence, as I hope to show in the next part of this paper.

The more southern forms of Mollusca which had migrated thus far north during the Falunian period and that of the "Sables Noirs" of Belgium are replaced in the Coralline Crag by an assemblage of forms partly of southern range with others of a northern type. Either a general lowering of the temperature, or else the setting in over this area of fresh currents from the north (more probably the latter, as the Coralline-Crag fauna is not a littoral one), owing to the continued subsidence of land in that direction, led to the introduction of northern forms of life and the gradual extinction of more southern forms. Amongst the Mollusca we thus see several northern forms, as *Astarte undata*, *Glycimeris siliqua*, *Neæra jugosa*, *Tellina calcaria*, *Buccinopsis Dalei*, *Cerithium granosum*, *Emarginula crassa*, *Piliscus commodus*, *Puncturella Noachina*, *Tectura fulva*, and *Trichotropis borealis*, amongst the Bryozoa the *Retepora Beaniana*, and amongst the Foraminifera the *Lagena globosa* and *L. ornata*—all forms which are now confined chiefly to the Scandinavian or Arctic provinces. These appear from the commencement of the Crag period. Of the exact ratio in which these forms may have increased during that period we are yet ignorant.

The relation which the Coralline Crag bears to the Crags of Antwerp has been the subject of much inquiry. It was first treated in a systematic manner by Sir Charles Lyell, and his conclusions still generally hold good. The corrected lists and more exact divisions of the several members of the Antwerp Crag, recently given by Prof. G. Dewalque, have, however, rendered some modification necessary.

Taking the Belgian beds in descending order, the relation which their molluscan remains show to those of the Coralline Crag is as under:—

		No. of species of Mollusca in the Antwerp beds.	No. common to the Antwerp beds and the Coralline Crag.	Proportion of Coralline-Crag species.
Scaldisien	Sables jaunes...	197	135	69 per cent.
	Sables gris ...	187	133	71 „
Diestien	Sables noirs ...	228	98	43 „

This question will be treated more fully in the next part of this paper, in connexion with the Red Crag.

With the Pliocene beds of Monte Mario the Coralline Crag has 147 species in common.

P.S. Owing to the great additions made to the number of known species, and the recognition amongst them of so many Crag species in the recent deep-sea dredgings, the Council of the Society have kindly allowed me to bring the lists of fossils up to the present date (April 1871).

List of the Mollusca found in the Coralline Crag.

This List (alphabetically arranged) is compiled from the Monograph of Mr. Searles Wood, with the addition of Mr. Davidson's Brachiopods, whose references and names of species are given in columns I. and II. Mr. Jeffreys has, with the assistance of Mr. Bell, made some additions to the list of species; these have the letter J prefixed to them in column I. The names to which a † is prefixed denote species which Mr. Jeffreys identifies with those now living, in addition to all the species which had been already recognized by Mr. Wood to be living*. Every form regarded by Mr. Jeffreys as a variety ranges through all the columns in italics.

Column III. comprises the names adopted by Mr. Jeffreys, except those to which a ¶ is prefixed, which he regards as synonyms, or names of later date, but desirable to notice. In this column also are added other names adopted by M. Nyst for the Belgian Crags; the last are within brackets.

Columns IV. and V. indicate the zones of depth or bathymetrical range, and the geographical distribution, both of which have been furnished by Mr. Jeffreys.

* A very few species, to the names of which a † is prefixed, are not the species to which Mr. Wood referred the Crag fossils, although the latter are living. These are *Bulla Lajonkaireana*, *Eulima subulata*, *Odostomia truncatula*, *Rissoa costulata*, and *Trophon gracile*.—J. G. J.

The list of Coralline-Crag localities in column VI. has been enlarged by the author. The recent work of M. Dewalque (Description Géologique de la Belgique, 1868), which gives the latest lists of fossils by M. Nyst, has served the author more fully to correlate the Coralline Crag with the Crags of Antwerp: see column VII.

In column VIII., the correlation of the Coralline-Crag Mollusca with those which occur in the typical Pliocene deposit of Monte Mario, near Rome, is given on the authority of Mr. Jeffreys.

Note. Abbreviations:—Lt, Littoral; L, Laminarian; C, Coralline; D, Deep-sea; **D**, depths exceeding 1200 feet. B, British; S, Scandinavian; A, Arctic; M, Mediterranean; W, West European; At, Mid-Atlantic; Am. North America; A, Aldborough; I, Iken; Sd, Sudbourne; G, Gedgrave; S, Sutton; R, Ramsholt; Go, Gomer; B, Broomhill.

I. Brachiopoda.

I. Page of Monograph.	II. Names of Species.	III. Critical remarks and synonyms.	IV. Zones of depth.	V. Geographical distribution.	VI. Localities in the Coralline Crag.	VII. Belgian Crags*. Sables gris.	Sables jaunes.	VIII. Itay. — Monte Mario.
10.	Argiope cistellula ...	Orthis lunifera, *Philippi*?	C	B S M	S			
5.	†Lingula Dumortieri	¶ L. jaspidea, *A. Adams*.	C	Japan	S B	*	*	
7.	†Orbicula lamellosa?	Discina atlantica, *King*.	**D**	At	S			
16.	Terebratula grandis	¶ T. ampulla, *Brocchi*	......	....	S Sd B Go	*	*	*
12.	Terebratulina caput-serpentis.	Genus Terebratula ..	L–**D**	B S A M W At	S			

II. Conchifera.

I.	II.	III.	IV.	V.	VI.	VII. Sables gris.	Sables jaunes.	VIII.
237.	Abra alba	Genus Scrobicularia.	Lt–**D**	B S M W At	S	o *	*	*
239.	—— prismatica	„ „	L–**D**	B S M W	S Go	o *	*	*
9.	*Anomia aculeata* ...	*A. ephippium, var.*...	......	....	*s r*	......	......	
8.	—— ephippium ...	....	Lt–**D**	B S M W	passim	o *	*	*
10.	—— patelliformis ...	....	L–C	B S A M W	Sd S	......	......	*
11.	—— *striata*	*A. patelliformis, var.*	......	....	*passim*	*	*	
77.	Arca lactea	....	L–C	B M W At	S	o	......	*
79.	—— pectunculoïdes	(A. pusilla)	C–**D**	B S A M	S Go	o	......	*
76.	—— tetragona	....	Lt–D	B S M W At	Sd S R	......	......	*
215.	Artemis lentiformis	Venus exoleta, *Linné*, var. (Dosinia exoleta).	Lt–C	B S M W	G?	*	*	*
215.	—— lincta	G. Venus (D. lincta)	Lt–**D**	B S M W	S R	*	*	*
177.	Astarte Basterotii ...	A. sulcata, *Da Costa*, var.	L–**D**	B S A M W At	passim	*	*	*
188.	—— Burtinii	....	......	....	passim	*	*	
190.	—— digitaria	G. Woodia	C–**D**	B M W	S Go	*	*	
191.	—— excurrens	....	......	....	S	......	......	

* I have further shown by the mark o in the column with the "Sables gris" those shells which are found in the "Sables noirs" of Antwerp and Edeghem.

Conchifera (*continued*).

I. Page of Monograph.	II. Names of Species.	III. Critical remarks and synonyms.	IV. Zones of depth.	V. Geographical distribution.	VI. Localities in the Coralline Crag.	VII. Belgian Crags. Sables gris.	VII. Belgian Crags. Sables jaunes.	VIII. Italy. — Monte Mario.
185.	Astarte gracilis	A. compressa, *Montagu*.	C	B S A W	passim	*	*	
186.	—— *incerta*	*A. compressa, var.* ...	......	....	*g s*	*	*	
178.	—— *incrassata*	*A. sulcata, var.*	......	....	*sd s*	......	*	
179.	—— mutabilis	Italian Pliocene ...	......	....	passim	o *	*	
180.	†—— Omalii	¶A. undata, *Gould*	C	Am	SGRBGo	*	*	
192.	†—— parva............	A. pusilla, *Forbes* ...	C–D	M W	S Go	o	......	
175.	—— *parvula*	*A. triangularis, var.*	*C*	*At*	*s go*	......	......	
187.	—— pygmæa	(A. Waelii)	......	....	S	......	......	
173.	—— triangularis ...	....	L–D	B M W At	S Go	o	......	
51.	Avicula tarentina ...	A. hirundo, *L.*	L–C	B M W At	G	......	......	
167.	*Cardita chamæformis*	*C. scalaris, var.*	......	....	*sd s*	*	*	
168.	—— corbis	....	C	M W	S B Go	o	......	*
167.	—— orbicularis......	....	......	....	Sd S B Go	o *	*	
166.	—— scalaris	....	......	....	Sd G S B Go	*	*	
165.	†—— senilis	C. sulcata, *Bruguière*	C	M W	passim	......	......	*
159.	†Cardium decorticatum.	C. lævigatum, *Poli*...	C	M W	passim	......	......	*
155.	—— edule, var. rusticum.	....	Lt–L	B S M W	R	*	*	*
153.	—— nodosum	C. fasciatum, *Mont.*	L–D	B S M W At	S Go	o	......	
J	†—— norvegicum, *Spengler*.	....	L–D	B S M W At	......	*	*	*
154.	†—— strigilliferum	C. elegantulum, *Möller*.	C	A	S B Go	......	......	
162.	Chama gryphoides...	....	Lt–C	M W	S	......	......	*
198.	Circe minima.........	....	L–D	B S M W At	S Go	*	*	*
264.	†Cochlodesma prætenerum.	Thracia prætenuis, *Pulteney*.	Lt–D	B S M W	S	......	......	*
200.	Coralliophaga cyprinoides.	....	......	....	S R	......	*	
274.	Corbula striata	C. gibba, *Olivi*	Lt–D	B S M W At	passim	o *	*	*
135.	Cryptodon ferruginosum.	G. Axinus	C–D	B S A M W	S	......	......	*
134.	—— sinuosum	A. flexuosus (Lucina sinuosa).	L–D	B S A M W At	S Go	o *	......	*
258.	Cultellus tenuis	....	......	....	S	......	*	*
132.	Cyamium? eximium	....	......	....	S	......	......	
196.	Cyprina islandica ...	....	Lt–D	B S W	passim	o *	*	*
197.	—— rustica	....	......	....	Sd G R B Go	o *	*	
207.	Cytherea chione......	G. Venus (C. cyprinoides).	L–C	B M W At	R B	o *	*	*
208.	—— rudis	G. Venus (V. cycladiformis).	C	M W	passim	* o	*	*
146.	†Diplodonta? astartea.	D. trigonula, *Bronn*	C–D	M At	S	*	*	
145.	—— *dilatata*	*D. rotundata, var.* (*D. Woodi*).	......	....	*s go*	*	......	
144.	—— rotundata	....	L–C	B M W At	passim	......	......	*

CONCHIFERA (*continued*).

I. Page of Monograph.	II. Names of Species.	III. Critical remarks and synonyms.	IV. Zones of depth.	V. Geographical distribution.	VI. Localities in the Coralline Crag.	VII. Belgian. Crags. Sables gris.	Sables jaunes.	VIII. Italy. — Monte Mario.
220.	Donax politus	(D. vinacea)	Lt–C	B M W	G S Go	......	*	
171.	Erycinella ovalis‡ ?	....	......	....	G S Go	o	......	
217.	†Gastrana laminosa	(Fragilia laminosa)	......	South Africa	G S R Go	*	*	
292.	Gastrochæna dubia	....	L–D	B M W At	S	*	......	*
291.	Glycimeris angusta	Gl. siliqua, *Chemnitz*	L–C	A	Sd G R B Go	*	*	
19.	†Hinnites Cortesyi ..	H. giganteus, *P. Carpenter.*	......	Am	R	......	......	*
150.	†Hippagus verticordius.	H. acuticostatus, *Ph.*; G. Pecchiolia, *Meneghini.*	C–D	W At Japan	S	......	......	*
193.	Isocardia cor	....	L–D	B S M W	G S R	*	*	*
120.	†Kellia ambigua ...	Erycina pusilla, *Ph.*	C	B M	S Go	o *	*	*
123.	†— coarctata	Galeomma compressum, *Ph.*	C	M	S	o *	*	
122.	†— cycladia.........	G. Axinus; not Scacchia ovata, *Ph.*	C–D	B M	S	*	*	
121.	— elliptica.........	G. Scacchia	C–D	M At	S	o *	......	
120.	— *orbicularis*......	*A. cycladius, var.* ...	......	....	*s*	*	......	
124.	†— pumila	....	D	B At	S	o *	......	*
125.	— rubra	G. Lasæa	Lt–C	B S M W At	S	......	......	*
118.	— suborbicularis	....	Lt–D	B S M W At	S	o	......	*
95.	Leda pygmæa	....	C–D	B S A M W At	G S R Go	o	......	
91.	— semistriata ...	....	......	....	S R B	*	*	
115.	†Lepton deltoïdeum	Erycina Geoffroyi, *Payraudeau.*	C	M	S R	o *	*	*
116.	†— depressum ...	L. nitidum, *Turton*	C	B M W	S	*	*	
116.	— *nitidum*.........	*L. squamosum, jun.* .	......	....	*s*	......	......	
110.	— squamosum ...	....	L–C	B S W	S	......	......	*
J	†Lima elliptica, *Jeffr.*	....	C–D	B S M	S	......	......	
43.	†— exilis	L. inflata, *Lamarck*	C	M	R Go	*	......	
44.	— hians	var. tenera	Lt–C	B S M W At	R	......	......	*
45.	— Loscombii......	....	L–D	B S M W	S R B	*	......	*
48.	— ovata	Ostrea nivea, *Brc.* ...	......	....	S	......	......	*
46.	†— plicatula	L. squamosa, *Lam...*	C	M	S	......	......	
47.	— subauriculata	Certainly Montagu's species.	C–D	B S A M W At	S R Go	o *	*	*
70.	† Limopsis aurita ...	(L. sublævigata) ...	D–D	B A M W At	G B Go	o *	......	*
71.	†— pygmæa	(L. anomala)	C–D	M W	S Go	......	......	*
139.	Lucina borealis	....	Lt–D	B S M W At	passim	o *	*	*
140.	— crenulata	....	......	....	S B	......	......	
141.	— decorata	....	......	....	S	......	......	
148.	Lucinopsis Lajonkairii.	....	C	M	S R Go	......	*	
251.	Lutraria elliptica ...	....	Lt–L	B S M W	Sd R Go	*	*	*
J	†— oblonga, *Ch.*...	....	Lt–L	B M W	......	......	......	*
252.	Macha strigillata ...	G. Solecurtus.........	C	M W	S	o	*	*
243.	Mactra arcuata	M. glauca, var.	Lt–L	B M W	G S B	*	*	*
244.	— *artopta*	*M. glauca, var.*	......	....	*sd*	......	......	
248.	— *obtruncata*......	*M. subtruncata, var.*	......	....	*s go*	......	......	*

‡ Miocene, North America (*Conrad*).

Conchifera (*continued*).

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246.	Mactra ovalis........	M. solida, *L.*, var. elliptica.	Lt–D	B S M W	? S	*	*	
241.	—— stultorum	....	Lt–C	B S M W At	S	......	......	*
325.	†—— triangulata ...	M. subtruncata, *Da C.*	Lt–D	B S M W	S Go	*	......	*
60.	Modiola costulata ...	G. Modiolaria	Lt	B M W At	S	o	......	*
62.	—— marmorata ...	,, ,, ...	L–D	B S M W At	S Go	o	......	*
57.	—— modiolus	G. Mytilus	Lt–D	B S W	R ?	o *	*	*
59.	—— phaseolina......	,, ,, ...	Lt–D	B S M	S R Go	*	......	*
64.	—— rhombea	G. Crenella (C. Prideauxana).	Lt–C	B M At	S	......	......	
61.	—— sericea	(C. sericea)............	......	....	S R ? Go	o *	......	*
J	†Modiolaria discors, *L.*	....	Lt–L	B S A M	S	......	......	
126.	Montacuta bidentata	....	L–D	B S M W	G S Go	*	*	*
131.	†—— ? donacina......	....	C	B	S	......	*	
129.	—— ferruginosa ...	....	L–D	B S M W	S Go	o *	......	*
128.	—— substriata	....	L–D	B S M W	S Go	o	*	*
127.	—— *truncata*	*M. bidentata, var.* ...	......	....	*s go*	......	......	
277.	Mya truncata.........	....	Lt–D	B S A W	G R B	*	*	
55.	Mytilus hesperianus	M. edulis, *L.*, var. ungulata.	Lt–L	B S A M W	Sd B	*	*	*
273.	Neæra cuspidata ...	....	L–D	B S A M W At	S	o *	......	*
272.	—— jugosa	¶N. lamellosa, *Sars.*	C–D	B S At	S	......	......	
73.	Nucinella miliaris...	(N. ovalis)	......	....	S R Go	o *	......	
81.	Nucula lævigata ...	....	......	....	S Go	o *	*	
85.	—— nucleus	....	L–D	B S M W	passim	*	*	
84.	—— tenuis	....	C–D	B S A M At	G ? Go	*	*	*
86.	†—— trigonula	N. proxima, *Say* (N. Waeli).	C–D	Am	S	o	*	*
J	†Ostrea cochlear, *Poli*	....	C–D	B M At	......	......	......	*
J	†—— cristata, *Born* ..	....	C	M	S	......	......	
13.	—— edulis............	....	Lt–D	B S M W	passim	o *	*	*
17.	—— princeps	....	......	....	Sd S R	*	*	
270.	Pandora inæquivalvis.	var. pinna	Lt–D	B S A M W At	S	......	......	*
283.	Panopea Faujasii ...	....	......	....	Sd G R B	*	*	*
29.	*Pecten Bruei*	*P. dubius, jun.*; *not Bruei.*	......	....	*s*	......	......	
38.	—— dubius	....	......	....	Sd G R	*	*	*
24.	†—— Gerardii	P. grœnlandicus, *Ch.*	C–D	A At	passim	*	*	
22.	—— maximus	....	L–D	B S M W At	passim	o *	*	*
35.	—— opercularis ...	....	L–D	B S M W At	passim	*	*	*
31.	†—— princeps	P. islandicus, *Ch.* ...	L–C	A Am	R	*	*	
23.	—— pusio	....	Lt–D	B S M W At	passim	o *	*	*
25.	—— similis	....	L–D	B S M W	S Go	*	......	*
27.	—— tigrinus.........	....	L–D	B S W	passim	o *	*	
66.	Pectunculus glycymeris.	....	L–D	B S M W At	passim	......	*	*
298.	Pholadidea papyracea.	....	Lt–D	B W	S	o	......	

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266.	Pholadomya hesterna	......	......	......	Sd R Go?	......	......	*
296.	Pholas crispata	A fragment only ...	Lt	B S W	S	......	......	
295.	—— cylindrica	......	......	......	S	......	......	
50.	Pinna pectinata (?)	P. rudis, *L.*	Lt–D	B M W At	passim	o *	*	
268.	Poromya granulata	......	C–D	B S M W At	G S R	o *	......	
J	†Psammobia costulata.	......	Lt–D	B S M W At	......	......	......	*
222.	—— Ferröensis......	......	L–D	B S M W At	G S R B	*	*	*
223.	—— tellinella	......	L–D	B S W	S	......	......	
222.	—— vespertina	......	Lt–C	B S M W At	Sd R	......	*	*
287.	*Saxicava arctica* ...	*S. rugosa, var.*	......	......	*s*	o *	*	*
289.	—— *? carinata*	*Panopea plicata, Mont., var.*	......	......	*s go*	......	......	*
288.	†—— ? fragilis	P. plicata	L–D	B S W	S	o	*	
285.	—— rugosa	......	Lt–D	B S A M W At	S	o *	......	*
J	†Solecurtus antiquatus, *Pult.*	......	L–C	B S M W At	......	......	*	*
256.	Solen ensis	......	L–C	B S M W	passim	o *	*	*
276.	Sphenia Binghami?	G. Mya	L–C	B M W	S	......	......	
203.	*Tapes perovalis*	*T. virgineus, L., var.*	......	......	*r*	......	*	
201.	—— virginea......	" "	Lt–D	B S M W	S	......	*	*
227.	Tellina balaustina ...	......	L–D	B M W At	S	*	*	*
226.	—— crassa......	......	Lt–D	B S M W	S	*	*	*
234.	†—— donacilla	T. compressa, *Brc.*...	C	M W	S	*	......	
233.	—— donacina	......	L–C	B M W At	Sd S B Go	*	*	*
228.	—— obliqua	T. calcaria, *Ch.*, var.	L–D	B ? S A At	Sd R B Go	*	*	
300.	Teredo norvegica ...	......	Lt	B S M W	S R	*	*	
J	†Thracia distorta, *Mont.*	......	Lt–C	B S M W	Sd	*	*	
261.	†—— inflata	T. corbuloïdes, *Deshayes*, var.	C	M	Sd B Go	......	*	
260.	—— phaseolina......	T. papyracea, *Poli*...	Lt–D	B S M W At	S Go	*	*	
259.	—— pubescens	......	C–D	B M W At	G S	......	*	*
262.	†—— ventricosa	T. convexa, *W. Wood*	L–D	B S M W	G R B	......	*	*
210.	Venus casina	......	L–D	B S M W At	passim	*	*	
212.	—— imbricata	V. fasciata, *Da C.*, var.	Lt–D	B S M W Japan	G R B Go	......	......	*
213.	—— ovata......	......	L–D	B S M W At	passim	*	*	*

III. Solenoconchia.

190	†Dentalium bifissum	Dischides Olivi, *Scacchi.*	C–D	M W	S Go	......	......	*
188.	—— costatum	D. dentalis, *L.*	C–D	M W	S Go	o *	......	*

IV. Gastropoda.

J	†Aclis ascaris, *Turt.*	......	C–D	B S M W	S	......	......	
J	†—— Gulsonæ, *Clark*	......	C	B W	S	......	......	
J	†—— Walleri, *Jeffr.*	......	D–D	B S A M W At	S	......	......	
171.	Actæon levidensis ...	(Tornatella elongata)	......	......	S	o *	......	
170.	—— tornatilis	......	Lt–D	B S M W	S	o *	......	*

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139.	Adeorbis pulchralis	....	......	....	S Go	......	......	
137.	†—— striatus	Trochus Duminyi, *Requien.*	C	B M	G S B Go	......	......	*
139.	—— subcarinatus ...	....	Lt–L	B M W	S	*	*	
137.	†—— supranitidus ...	....	C	At	S Go	o *	......	
138.	—— *tricarinatus* ...	*A. supranitidus, var.*	......	....	*s*	......	......	
99.	Alvania ascaris	Aclis supranitida, *S. Wood*; not A. ascaris, *Turt.*	L–C	B S M W	S	......	......	*
25.	Aporrhaïs pes pelecani.	....	L–D	B S M W	G R Go	o	*	*
34.	Buccinum Dalei......	G. Buccinopsis	C–D	B S	SdGRGo	*	*	
35.	—— undatum	....	Lt–D	B S W	R B Go	*	*	
174.	Bulla acuminata ...	G. Volvula............	L–D	B S M W	S	o	......	*
176.	—— concinna	G. Cylichna	......	....	S	......	......	
173.	—— conulus	Not B. conulus, *Lam.* C. umbilicata, *Mont.*, var.	C–D	B S M W At	S Go	......	......	*
175.	—— cylindracea ...	G. Cylichna	L–D	B S M W At	S Go	o *	*	*
178.	†—— Lajonkaireana	Utriculus obtusus, *Mont.*, var.	Lt–D	B S A W	S	o	......	
173.	—— lignaria.........	G. Scaphander	Lt–D	B S M W	S Go	o *	*	*
178.	†—— nana	G. Utriculus	C	M	S	......	......	
176.	—— truncata	U. truncatulus, *Brg.*	L–D	B S M W At	S	......	......	*
179.	Bullæa quadrata ...	G. Philine	Lt–D	B S A W	S	......	......	
181.	—— scabra	,, ,, ...	Lt–D	B S A M W At	S	o	......	*
180.	—— sculpta	P. catena, *Mont.*......	Lt–D	B M W	S	o	......	
182.	†—— ventrosa	G. Philine	D	W	S	......	......	
117.	Cæcum glabrum ...	....	L–C	B S M W At	S Go	......	......	
117.	—— *incurvatum* ...	*C. glabrum*, jun.	......	....	*s*	......	......	
116.	†—— mammillatum	....	C	Japan	S B Go	......	......	*
115.	—— *trachea*	*C. mamillatum, var.*; not C. trachea, *Mont*	......	....	*s*	......	......	
159.	Calyptræa chinensis	....	Lt–D	B M W At	passim	o *	*	*
66.	Cancellaria costellifera	Admete viridula, *Fabricius.*	C–D	B S A At	S Sd	*	*	
65.	†—— mitræformis (?)	....	C–D	W	G Go	o	......	
316.	—— scalaroïdes......	C. varicosa, *Brc.*	......	....	S Go	*	*	
66.	†—— subangulosa ...	....	C–D	W	S	......	......	
157.	†Capulus fallax	Piliscus commodus, *Middendorff*	C–D	A W Japan	S	......	......	
156.	—— *militaris*	*C. ungaricus, jun.*...	......	....	*s*	*	*	
155.	—— ungaricus	C. ungaricus, *L.* ...	Lt–D	B S M W	G S R Go	*	*	*
27.	†?Cassidaria bicatenata	C. tyrrhena, *Ch.*, var. ?	C	M ?	G R Go	*	*	
72.	Cerithium adversum	G. Triforis; T. perversa, *L.*	Lt–D	B S M W At	S Go	......	*	*
71.	†—— cribrarium ...	....	D	W	S	......	......	
73.	†—— granosum	¶C. Macandrei, *H. Adams* (not C. sinistrorsum, *N.*).	C–D	B S	S Go	......	......	
71.	†—— metaxa (?)......	Cerithiopsis metaxa	L–D	B M At	S	......	......	

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72.	Cerithium perpulchrum.	....	......	....	G	......	......	
70.	—— trilineatum ...	....	C	M	S Go	......	......	
70.	—— tuberculare ...	G. Cerithiopsis	Lt–D	B S M W At	S Go	......	......	*
80.	†Chemnitzia costaria	G. Odostomia	C	M	S	......	......	
79.	†—— curvicostata ...	O. indistincta, *Mont.*	Lt–D	B S M W At	S	......	......	*
82.	—— *densecostata* ...	*O. rufa, Ph., var.* ...	......	....	*s*	......	......	*
81.	—— elegantissima	O. lactea, *L.*	Lt–C	B S M W At	S Go	......	......	*
82.	—— filosa	G. Odostomia	......	....	S	......	*	
81.	†—— internodula ...	¶C. Corbis, *Conti* ...	C–D	M W	S	......	*	*
80.	†—— nitidissima (?).	Not O. nitidissima, *Mont.*, but allied to O. acicula.	D	M	S	......	......	
79.	—— rufa	A doubtful identification.	L–D	B S M W At	S	......	......	*
84.	—— *similis*	*O. filosa, var.*..........	......	....	*s*	o *	......	
83.	—— unica (?)	Not Cioniscus unicus, *Mont.*	......	....	S	o	......	
84.	†—— varicula.........	G. Cerithium.........	D	W	S	......	......	
185.	Chiton fascicularis (?)	....	Lt–D	B S M W At	S	......	......	
186.	—— Rissoi (?)	C. cinereus, *L.*	Lt–D	B S A M W	S	......	......	
186.	†—— strigillatus ...	C. Hanleyi, *Bean* ...	C–D	B S M	S	......	......	
60.	*Clavatula brachystoma.*	*Pleurotoma concinnata, var.*	......	....	*s*	......	*	*
61.	—— cancellata	Defrancia reticulata, *Renier*, var. formosa	L–D	B S M W	S Go	......	......	*
57.	—— *castanea* (?) ...	*D. linearis, var.*.......	......	....	*s go*	......	......	
61.	†—— concinnata ...	P. decussata, *Ph.* ...	C–D	M W	G S Go	......	......	
58.	—— costata (?)	G. Pleurotoma	Lt–D	B S M W	S Go	......	*	*
62.	—— lævigata (?) ...	,, ,, ...	Lt–C	B M W At	S ?	......	......	
56.	—— linearis	G. Defrancia	L–D	B S M W At	S	......	......	*
59.	—— *mitrula*	*P. costata, var.* (*not P. mitrula*).	......	....	*s go*	......	......	
58.	—— *perpulchra*......	*D. linearis, var. æqualis.*	......	....	*s go*	......	......	
57.	—— Philberti	Defrancia purpurea, *Mont.*, var.	Lt–D	B S M W At	S	......	......	
23.	Columbella sulcata ..	....	......	....	S	......	*	
16.	*Cypræa affinis*	*C. avellana, var.*.......	......	....	*s*	......	......	
15.	—— avellana.........	....	......	....	S	......	......	
17.	—— europæa	....	Lt–D	B S M W	S B Go	o *	*	*
16.	—— retusa	....	......	....	S Go	......	......	
J	†Defrancia hystrix, *Bellardi.*	....	C–D	M	S	*	......	
165.	Emarginula crassa...	....	Lt–D	B S W	S R Go	*	*	
J	†—— elongata, *Costa*	....	C	M	S	......	......	
164.	—— fissura	....	Lt–D	B S M W At	S B Go	o *	*	
J	†—— rosea	....	L–D	B M W	S	......	......	*
18.	Erato lævis	G. Marginella	L–D	B M W	S Go	o	......	*
19.	—— Maugeriæ......	,, ,, ...	C	West Indies	S Go	......	......	
98.	†Eulima glabella ...	¶E. Stalioi, *Brusina*	C–D	M W	S	......	......	
96.	—— polita	....	L–D	B S M W	S	......	......	*

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97.	†Eulima subulata ...	Not E. subulata, *Donovan.*	**D**	W	S R Go	o *	*	*
J	†Fissurella costaria, *Basterot.*	¶F. neglecta, *Desh*...	C	M	S	......	......	*
168.	—— græca	....	Lt–**D**	B M W At	S R B	*	*	*
121. 317.	} Fossarus sulcatus .	¶F. clathratus, *Ph*...	C	M	S	......	......	
319.	*Jeffreysia ? patula* ...	*Velutina virgata; fry*	......	....	*s*	......	......	
122.	Lacuna reticulata ...	G. Fossarus	......	....	S Go	......	......	
88.	Litiopa papillosa ...	Qu. G. Litiopa ? ...	......	....	S	......	......	
135.	Margarita (?) maculata.	(Solarium turbinoïdes.)	......	....	S Go	o *	*	
136.	—— trochoidea......	....	......	....	S B Go	......	......	
151.	Marsenia tentaculata.	Lamellaria perspicua, *L.*	Lt-D	B M W At	S	......	......	
J	†Murex aciculatus, *Lam.*	¶M. corallinus, *Sc.*	Lt–C	B M W At	G	......	......	
40.	†—— tortuosus	M. erinaceus, *L.*, var.	Lt–C	B S M W At	S	......	*	
310.	Mitra ebenus	....	Lt–D	B S M W At	S Go	......	......	*
21.	—— *plicifera*.........	*M. ebenus, var.*	......	....	*g*	......	......	
31.	Nassa consociata ...	N. elegans, var.......	C–D	W At	G S Go	......	*	
29.	—— granulata	....	C	W	S Go	......	*	
29.	—— incrassata	....	Lt–D	B S M W At	S	o *	*	*
28.	†—— labiosa	N. semistriata, *Brc.*	C–D	M W	G Go	o *	*	*
32.	—— prismatica ...	N. limata, *Ch.*	L–C	M W	G Go	o *	*	*
315.	—— *pygmæa*	*N. incrassata, var. simulans.*	......	....	*s*	......	*	
145.	Natica cirriformis ...	N. sordida, *Swains.*	L–**D**	B M W At	R Go	*	*	*
J	†—— heros, *Say*	¶N. catenoides, *S. Wood.*	Lt	Am	S	......	......	
148.	—— multipunctata	N. millepunctata, *Lam.*, var.	C	M	G R Go	*	*	*
143.	—— *proxima*	*N. cirriformis, var*...	......	....	*r b go*	......	*	
143.	—— *varians*	*N. cirriformis, var.?*	......	....	*s go*	......	......	
J	†Odostomia acuta, *Jeffr.*	....	L–C	B S M W At	S	......	......	
J	†—— insculpta, *Mont.*	....	L–D	B S W	......	......	......	
J	†—— obliqua, *Alder*	....	C	B M	S	......	......	
86.	—— pellucida	O. decussata, *Mont.*, var.	C–D	B W	S	o	......	*
85.	—— plicata	O. conoïdea, *Brc.*; not O. plicata, *Mont.*	L–**D**	B S M W At	G S R Go	o	*	*
86.	†—— pupa	O. interstincta, *Mont.*, var.	Lt–C	B S M W At	S	......	......	*
87.	—— simillima (?)...	Not Turbo simillimus, *Mont.*	......	....	S	......	......	
318.	†—— truncatula......	O. plicata, *Mont.* ...	L–C	B M W	S Go	......	......	
14.	Ovula Leathesii......	Bulla spelta, *L.*......	C	M	S Go	......	*	*
109.	Paludestrina ulvæ...	G. Hydrobia	Lt–C	B S M W	G	......	......	
54.	†Pleurotoma carinata.	(P. modiola)	D–**D**	B S M W At	G	......	......	

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J	Pleurotoma nebula, *Mont.*	....	L–C	B M W	S	......	......	
55.	†—— porrecta	P. nivalis, *Lovén* ?...	D–D	B S At	G Go	o	......	
54.	†—— semicolon	P. galerita, *Ph.*	C–D	B M At	G Go	......	......	*
J	†—— striolata, *Sc.* ...	....	C–D	B S M W At	S	......	......	
J	†—— Renieri, *Ph.* ...	....	D	M	G	......	......	
J	†Puncturella noachina, *L.*	....	C–D	B S A W	S	......	......	
77.	†Pyramidella lævi-uscula.	P. uniplicata, *Dujardin* (P. plicosa).	D–D	M W	S Go	o	......	*
42. 311.	Pyrula acclinis	P. subintermedia, *Bronn* (P. reticulata).	......	....	R	o *	*	
22.	Ringicula buccinea	R. auriculata, *Menard*	C–D	M W At	S	o *	*	*
22.	†—— ventricosa	....	D–D	M W At	S	......	......	*
104.	Rissoa confinis	....	......	....	S Go	......	......	
106.	†—— costulata	R. Stefanisi, *Jeffr.*; not R. costulata, *Alder.*	D–D	M W	S	......	......	
106.	—— crassistriata ...	....	......	....	S B	......	......	
105.	—— obsoleta.........	....	......	....	S Go	......	......	
J	†—— proxima, *Ald.* .	....	C–D	B M At	S	......	......	
103.	†—— punctura (?)...	R. concinna, *Wood*; not R. punctura, *Mont.*	......	....	S	o	......	
103.	—— reticulata (?)...	R. calathus, *Forbes & Hanley*; not R. reticulata, *Mont.*	L–C	B S M W At	S	......	......	
318.	—— soluta	....	C–D	B S M W At	S	......	......	
100.	—— striata	....	Lt–D	B S A M W At	S	......	......	
107.	—— *supra-costata*...	*R. confinis, var.*.......	......	....	*s*	......	......	
102.	—— vitrea.............	(Not R. vitrea, *N.*)...	C–D	B S M W At	S	......	*	*
101.	—— zetlandica	....	L–D	B S M W At	S	......	......	
95.	†Scalaria cancellata	Not S. cancellata, *Brc.*	C–D	M At	S Go	......	......	
94.	—— clathratula ...	....	L–D	B S M W	S B Go	......	*	*
91.	—— fimbriosa	S. lamellosa, *Brc.*, var.	......	....	S R	o *	......	
93.	—— *foliacea*	*S. frondosa, var.* (*S. frondosa*).	......	....	*s go*	......	*	*
92.	—— frondicula......	....	......	....	G S Go	o *	*	*
92.	†—— frondosa	¶S. soluta, *Tiberi* ...	D–D	M W	S	......	......	
91.	—— *hamulifera* ...	*S. fimbriosa, var.* ...	......	....	*s*	......	......	*
95.	†—— obtusicostata...	....	D–D	At	S	......	......	
93.	—— *subulata*.........	*S. foliacea, var.*	......	....	*s b go*	*	......	
90.	—— *varicosa*.........	*S. fimbriosa, var.* ...	......	....	*sd s go*	......	......	
163.	Scissurella crispata	....	L–D	B S A M W At	S	......	......	
149.	†Sigaretus excavatus	....	D	W	S	......	......	
161.	Tectura fulva.........	....	C–D	B S A W	S	......	......	
26.	Terebra inversa......	G. Columbella	......	....	G Go	*	*?	
26.	—— *canalis*	*C. inversa, var. dextrorsa.*	......	....	......	......	......	
67.	Trichotropis borealis	....	L–D	B S A	S	......	......	
41.	†Triton heptagonum	Not Murex heptagonus, *Brc.*, but T. cutaceus.	Lt–C	B M W At	G Go	......	.....	

Gastropoda (*continued*).

I. Page of Monograph.	II. Names of Species.	III. Critical remarks and synonyms.	IV. Zones of depth.	V. Geographical distribution.	VI. Localities in the Coralline Crag.	VII. Belgian Crags. Sables gris.	VII. Belgian Crags. Sables jaunes.	VIII. Italy. Monte Mario.
129.	Trochus Adansoni...	A doubtful identification.	Lt	M	S Go	*	*	
J.	—— bullatus, *Ph.*...	Italian Pliocene ...	......	....	G	......	......	
125.	—— *conulus*	*T. zizyphinus, L.* ...	......	....	*r*	*		
133.	†—— ditropis	T. biangulatus, *Eichwald, fide* Hörnes	C	M	S	......	......	
125.	—— formosus	T. occidentalis, *Mighels*, var.	C–D	B S	S B	......	*	
130.	—— *Kicksii*	*T. Adansoni, S. W., var.*	......	....	*s go*	*	......	
127.	—— millegranus ...	....	C–D	B S M W	Go	o	......	
129.	—— Montacuti......	A doubtful identification.	L–D	B M W At	S	......	......	*
133.	—— obconicus	....	......	....	S Go	......	......	
132.	—— tricariniferus...	....	......	....	S	......	......	
128.	—— *villicus* (?)	*T. Adansoni, S. W., var.*	......	....	*s go*	......	......	
124.	—— zizyphinus......	....	Lt–D	B S M W At	S R B Go	*	......	*
49.	Trophon alveolatum	T. alveolatus	......	....	G Go	*	*	
49.	—— *consociale*	*T. alveolatus, var.* ...	......	....	*g r go*	......	......	
48.	†—— costiferum ...	T. costifer	D	W	G	......	......	
46. 313.	†—— gracile ...	Not Fusus gracilis, *Da C.*; F. curtus, *J.*	C	Am	G Go	......	......	
51.	†—— gracilius	G. Pleurotoma	D	W	S	......	......	
50.	—— imperspicuum	....	......	....	Sd	......	......	
50.	—— muricatum ...	T. muricatus	L–D	B M W	S Go	*	*	
51.	†—— paululum	Defranciateres, *Forb.*, jun.	C–D	B S M W At	S	......	......	*
122.	†Turbo sphæroidea .	Cyclostrema sphæroïdeum	C–D	At	S	......	......	
75.	Turritella incrassata	T. triplicata, *Brc.* ...	C–D	M W	G R B Go	o *	*	*
76.	†—— planispira	T. subangulata, *Brc.*	C–D	M	S	......	......	
153.	†Velutina virgata (?)	V. undata, *Smith* ...	D	A	S	......	......	
113.	†Vermetus intortus .	V. subcancellatus, *Biv.*	Lt-C	M	S R	......	......	*
20.	†?Voluta Lamberti .	V. Junonia, *Ch.* ? ...	D	G Mexico ?	A R Go	*	*	

V. Pteropoda.

191.	†Cleodora infundibulum.	Clio caudata, *L.*	Pelagic	B At	S	......	......	

Number of species in the Coralline Crag according to the original lists of Mr. Searles Wood... 331
Species regarded by Mr. Jeffreys as varieties 42
Species added by Mr. Jeffreys 27
Resulting total number of species.. 316
Species for the first time identified as recent, and marked † 106

EXPLANATION OF PLATE VI.

Plan of the Coralline-Crag Hill at Sutton, Suffolk.

Section through this hill from the river Deben to Shottisham Hall, with branch section through the principal pits.

M HALL.

F. Dangerfield lith. Bedford S.t Covent Garden

PLAN OF CORALLINE CRAG HILL, AT SUTTON, SUFFOLK.

Horizontal Scale.

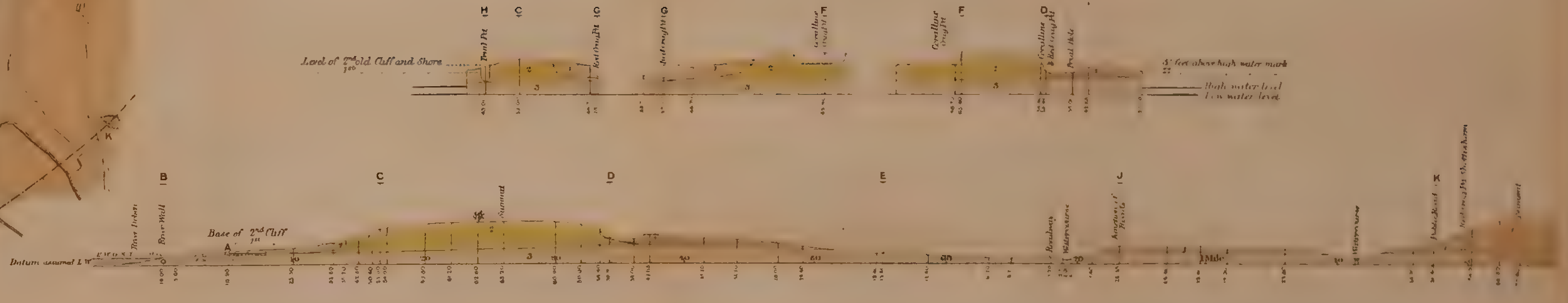
Planned and Levelled by Mr. Miller, by the direction of Mr. P. Bruff, C.E. Ipswich.

D Bullock Yard Pit.
F Old Quarry.
G. Red Crag Pit with Coralline Crag Boulders.
J K Red Crag Pits.

1 Red Crag.
2 Coralline Crag.
3 London Clay.

SECTION FROM RIVER DEBEN AT SUTTON TO SHOTTISHAM HALL.

FEBRUARY 1868.



Horizontal Scale.

Vertical Scale.

J. Dangerfield lith. Bedford St. Covent Garden

2. *On the* Structure *and* Affinities *of* Sigillaria, Calamites *and* Calamodendron.

By J. W. Dawson, LL.D., F.R.S., F.G.S., Principal of McGill University.

(Read May 11, 1870*.)

[Plates VII.–X.]

1. Sigillaria.

The difficulty of arriving at a correct knowledge of the structure of these curious trees is caused principally by the unequal durability of the different parts of the stem. It arises from this that some portions have usually perished, while others were in process of mineralization, and the portions which remain have in a great degree lost their original form and arrangement. The outer bark, while extremely durable, was too impenetrable to be preserved in any other way than as compact coal. The fibres of the bark and of the woody axis are often mineralized or imperfectly preserved as mineral charcoal. The cellular portions of the bark and of the axis have usually entirely disappeared. Still, imperfectly preserved stems can be obtained in great abundance in any coal-field by those who are content to work on such unpromising material.

Probably the finest specimen of a *Sigillaria* hitherto described is that of *S. elegans*, so admirably figured by Brongniart, and which has long served to give to the student of palæobotany his ideas of the structure of the genus. Unfortunately, however, Brongniart's specimen represents a small or young stem belonging to the somewhat aberrant subgenus *Favularia*; so that it fails to give an adequate idea of the structure of the typical fossil *Sigillariæ*, which are much more common and important, at least in the coal-fields of Nova Scotia. The structure of these last, as observed in specimens obtained at the South Joggins, was, I believe, first described by me in my paper on the Vegetable Structures in Coal, published in the 'Journal' of this Society in 1859. The specimens subsequently figured in the 'Journal' of this Society, and in the 'Transactions' of the Royal Society, by Mr. Binney, under the name of *S. vascularis*, belong, in part at least, to types of structure quite distinct from that of the true *Sigillariæ*†.

My own results as to the typical *Sigillariæ* are thus shortly summed up in my paper on the "Conditions of Deposition of Coal"‡:—"In the restricted genus *Sigillaria* the ribs are strongly developed, except at the base of the stem; they are usually much

* For the discussion on this paper see Quart. Journ. Geol. Soc. vol. xxvi. p. 490.

† It would seem that the specimens figured by Mr. Binney as *Sigillaria vascularis* (Philos. Trans. vol. clv.) belong in part to the *axis* of a remarkable Sigillarioid tree, of which specimens have been kindly shown to me by Prof. Williamson, and in part (especially pl. xxxv. figs. 5 & 6) to the *whole stem* of a *Lepidodendron*. The latter plant has been described by Mr. Carruthers as *Lepidodendron selaginoides*.

‡ Quart. Journ. Geol. Soc. vol. xxii. p. 129.

broader than the oval or elliptical tripunctate areoles, and are striated longitudinally. The woody axis has both discigerous and scalariform tissues, arranged in wedges, with medullary rays as in exogens; the pith is transversely partitioned in the manner of *Sternbergia*; and the inner bark contains great quantities of long and apparently very durable fibres, which I have, in my descriptions of the structures in the coal, named 'bast-tissue.' The outer bark was usually thick, of dense and almost indestructible cellular tissue. The trunk, when old, lost its regular ribs and scars, owing to expansion, and became furrowed like that of an old exogenous tree."

It will be understood that this statement refers to the main stems of the ribbed *Sigillariæ* of the type of *S. reniformis* and *S. Brownii*, so abundant in the coal-formation of Nova Scotia, and that it is made with especial reference to the conditions of the accumulation of coal in that province. The evidence on which it is based may be stated under the following heads:—

Erect Trunks.—The numerous erect stumps of *Sigillariæ* occurring at the South Joggins, and at Sydney, Cape Breton, are usually preserved as casts in sandstone, the only part of their organic substance remaining being the outer bark, which exists in the state of compact coal. Still the interior structures have not altogether perished, but may be recognized as a layer of mineral charcoal in the bottom of the stony column, under the sand and other foreign matters subsequently introduced. Occasionally the bark of the tree has collapsed before it could be filled with sediment, and the only remains of the trunk consist of the little mound of carbonaceous matter derived from the tree itself. Cases of this kind are mentioned in my paper on the South Joggins*. In addition to the coaly matter showing structure, we can also occasionally find in the interior of such erect trees a transversely striated sandstone cast (*Sternbergia*) representing the medullary cylinder. In one instance only have I found the medullary cylinder calcified in such a manner as to show its structure, and surrounded by the woody cylinder also in a calcified state. This specimen was that described, but not adequately figured, in my paper on the Structures in Coal, and I now propose to figure it more in detail (Plate X.). Ordinarily the coaly mass consists of confused fragments of mineral charcoal derived from the wood and the fibrous tissues of the bark; but these often retain their structure very perfectly.

After collecting and examining the woody matter thus remaining in twenty or more of these erect trees, I have found that, with one exception, it consists of tissues of a uniform character, presenting only such differences as might be expected in trees generically allied. The tissues observed are discigerous or porous wood-cells with from one to four rows of pores, pseudo-scalariform tissue, and elongated structureless cells of the bark (the "bast-tissue" of my former papers). These structures indicate that the woody parts of these trees were identical in character with those of the calcified axis above-mentioned.

* Quart. Journ. Geol. Soc. vol. x. p. 1.

The exception above referred to is, that in one tree, which from its markings I supposed to be a *Sigillaria*, the woody tissue was composed of large cells, with many rows of pores ("multiporous tissue" of my former papers) of the type of that to which Prof. Williamson has given the name of *Dictyoxylon**. Since, however, as Prof. Williamson has well shown, such tissue may be regarded as a modification of the discigerous variety, and since Corda long ago found it in the axis of a species of *Stigmaria*†, there is nothing improbable in the supposition that we have here merely an indication of a specific or subgeneric difference coming within the limits of the genus *Sigillaria*, as at present understood.

It is to be observed that most of the erect trunks in the coal-formation have not preserved their external markings with sufficient distinctness to allow the species to be determined by the leaf-scars; but they show in most cases the characteristic ribs and rows of punctures or areoles, modified in the manner which is usual in the case of old trunks of these plants near their bases‡.

In Plate VIII. figs. 12, 14, 15, 16, I have represented some of the more usual forms of tissue in the erect *Sigillariæ*.

In Plate X. I have represented the best-preserved axis in my possession. Fig. 23 shows the structures in the entire stem, except the portions of cellular bark lost by decay. In the centre is a *Sternbergia*-pith (*a*). This is surrounded by a woody cylinder (*b*), the inner part of which (fig. 24, *b* 1) consists of scalariform tissue passing towards the outer surface into pseudo-scalariform (*b* 2), reticulated with pores (*b* 3), and discigerous (*b* 4). This woody axis has medullary rays (figs. 25, 26, 27), and is traversed by bundles of scalariform tissue proceeding from the inner part of the cylinder. The outer portion of the inner bark, not seen in this specimen, but in similar prostrate stems, is composed of elongated thin-walled bast-cells, with somewhat obtuse ends, and of larger diameter than the woody fibres of the axis (fig. 29). The tissues of the woody axis are all arranged in radial series (fig. 28).

Prostrate Trunks.—In the coarse shaly coals, and in the roof-shales of the ordinary seams, there are often flattened stems of *Sigillaria*, having the tissues partially infiltrated with carbonate of lime or carbonate and sulphate of iron. The tissues usually preserved in these flattened trunks are those of the bark, and more especially its large bundles of elongated or prosenchymatous cells ("bast-tissue"). Of this I have been enabled to obtain very perfect specimens from these flattened trunks. In a few instances only the woody structure of the axis remains, showing the same descriptions of wood-cells already referred to as characteristic of the erect trees. Plate VIII. fig. 11 is an example of the structures in one of these prostrate stems.

* Trans. Royal Micro. Soc., Aug. 1869.

† Beiträge zur Flora &c. 1845, pl. xiii. Corda regards this as the structure of *S. ficoides*, and the more ordinary variety as that of *S. anabathra*.

‡ The species which I have described as *S. Brownii*, Acad. Geol. 2nd edition, may be regarded as a representative of these trees.

Sternbergiæ.—The fine specimen of the axis of an erect *Sigillaria* already referred to shows that the pith of these trees was of that transversely laminated character which gives rise to the fossils known as *Sternbergiæ*. Hence we may suppose that some at least of the numerous casts of *Sternbergiæ* found in the Coal-formation have been derived from *Sigillariæ*; but this can be ascertained only by a careful microscopic examination of the remains of woody matter clinging to the casts. The results of the study of a considerable number of specimens may be stated as follows:—

(*a*) As Prof. Williamson and the writer have shown, some of these *Sternbergia*-piths belong to coniferous trees of the genus *Dadoxylon*. Plate VII. fig. 1 represents a beautifully preserved cylinder of this kind enclosed in the wood of *Dadoxylon materiarum*.

(*b*) A few specimens present multiporous tissue, of the type of *Dictyoxylon*, which, according to Williamson, has a *Sternbergia*-pith. Plate VII. fig. 4 affords an instance of this.

(*c*) Other examples show a true scalariform tissue, comparable with that of *Lepidophloios* or *Lepidodendron*, but of finer texture. Corda has shown that plants of the type of the former genus (his *Lomatophloios*) had *Sternbergia*-piths. Some plants of this group are by external characters loosely reckoned by botanists as ribless *Sigillariæ* (*Clathraria*); but I believe that they are not related even ordinally to that genus. Plate VII. fig. 5 represents a *Sternbergia*, with tissue partly reticulated and partly scalariform. Plate VIII. fig. 7 represents a specimen with true scalariform tissue. Plate VII. fig. 6 is a scalariform vessel of *Lepidophloios* drawn to the same scale for comparison. It will be seen that it is of much coarser texture.

(*d*). The majority of carboniferous *Sternbergiæ* show structures identical with those described above as occurring in erect *Sigillariæ*. Such *Sternbergiæ* and their structures are represented in Plate VII. figs. 2 and 3, and Plate VIII. figs. 8, 9, 13. Fig. 8 is a reduced section of a large flattened tree, apparently a *Sigillaria* with *Sternbergia*-pith (fig. 9), of great beauty, and not dissimilar from those sometimes found in the erect *Sigillariæ*. The tissue enclosing it was unfortunately imperfectly preserved, but had three rows of pores (fig. 9 *a*).

Structures in Coal.—The constant association of *Sigillaria* with the beds of coal, in the underclays, in the roof-shales, and in the coal itself, is too well known to require any detailed reference; and the inevitable conclusion that the *Sigillariæ* were the principal plants concerned in the accumulation of the mineral fuel of the true coal-measures is generally accepted by geologists. It would naturally follow from this that tissues of *Sigillaria* should be more abundant in the coal than those of other plants. Accordingly, as I have shown in my paper on the "Structures in Coal," and on the "Conditions of Coal-deposition," tissues similar to those above described are those which actually occur most abundantly in the mineral charcoal of the coal-seams. That of the liber or fibrous bark is perhaps the most abundant of all, and that of the woody axis the next in frequency of occurrence.

It has been held to be an objection to the identification of the discigerous tissues above mentioned with those of *Sigillaria*, that the *Stigmariæ*, when their structure happens to be preserved, show merely scalariform tissue. To this it may be answered :—(1.) That, as Corda has shown*, some *Stigmariæ* have reticulated or multiporous tissues. (2.) The tissue of *Stigmaria* is not essentially different from the pseudo-scalariform fibres of the stem, and is arranged in a similar manner, showing that it is homologous rather with woody than with vascular tissue. (3.) Many *Stigmariæ* probably belong to *Favularia* and similar forms, or possibly even to Lepidodendroid plants†. In either case the structure would be unlike that of the stems of *Sigillaria* proper. (4.) Inasmuch as the proportions of pseudo-vascular and discigerous tissue may differ greatly in the stems of *Sigillariæ*, it would not be unreasonable to suppose that the tissue, which is more particularly important for the strengthening of the stem, should be absent, or in a feeble state of development, in the root. Something of this kind occurs in the roots of Cycads, and perhaps, if detailed examinations were made, might be found to be more general than is commonly supposed. (5.) The outer part of the axis, being left exposed by the decay of the loose cellular matter of the inner bark, may, in most cases, have perished. In my specimen of the axis of *Sigillaria*, above described, it is in parts much disorganized, and has disappeared, or been converted into coal, on one side.

The evidence included under the above heads is sufficient to show that the ordinary ribbed *Sigillariæ* referred to in my previous papers, possessed in their main trunks the following kinds of tissue, in proceeding from the circumference to the centre :—

(*a*) A dense cellular outer bark, usually in the state of compact coal—but when its structure is preserved, showing a tissue of thickened parenchymatous cells.

(*b*) A very thick inner bark, which has usually in great part perished, or been converted into coal, but which, in old trunks, contained a large quantity of prosenchymatous tissue, very tough and of great durability. This "bast-tissue" is comparable with that of the inner bark of modern Conifers, and constitutes much of the mineral charcoal of the coal-seams.

(*c*) An outer ligneous cylinder, composed of wood-cells, either with a single row of large bordered pores‡, in the manner of Pines

* Beiträge zur Flora der Vorwelt.

† Brown, in 1847, described, in the 'Proceedings' of this Society, Stigmaria-roots of *Lepidodendron*. Baily seems to have shown that such roots belong to the singular Lepidodendroid *Cyclostigma* of the Devonian of Ireland; and Schimper asserts a connexion of Stigmaria roots with trees which he refers to *Knorria*.

‡ These are the same with the wood-cells elsewhere called discigerous tissue, and to which I have applied the terms uniporous and multiporous. The markings on the walls are caused by an unlined portion of the cell-wall placed in a disk or depression, and this often surrounded by an hexagonal rim of thickened wall; but in all cases these structures are less pronounced than in *Dadoxylon*, and less regular in the walls of the same cell, as well as in different layers of the tissues of the axis.

and Cycads, or with two, three, or four rows of such pores sometimes inscribed in hexagonal areoles in the manner of *Dadoxylon*. This woody cylinder is traversed by medullary rays, which are short, and composed of few rows of cells superimposed. It is also traversed by oblique radiating bundles of pseudo-scalariform tissue proceeding to the leaves. In some *Sigillariæ* this outer cylinder was itself in part composed of pseudo-scalariform tissue, as in Brongniart's specimen of *S. elegans*; and in others its place may have been taken by multiporous tissue, as in a case above referred to; but I have no reason to believe that either of these variations occurred in the typical ribbed species now in question. The woody fibres of the outer cylinder may be distinguished most readily from those of Conifers, as already mentioned, by the thinness of their walls, and the more irregular distribution of the pores. Additional characters are furnished by the medullary rays and the radiating bundles of scalariform tissue when these can be observed.

(*d*) An inner cylinder of pseudo-scalariform tissue. I have adopted the term pseudo-scalariform for this tissue, from the conviction that it is not homologous with the scalariform ducts of Ferns and other Acrogens, but that is merely a modification of the discigerous wood-cells, with pores elongated transversely, and sometimes separated by thickened bars, corresponding to the hexagonal areolation of the ordinary wood-cells. A similar tissue exists in Cycads, and is a substitute for the spiral vessels existing in ordinary Exogens.

(*e*) A large medulla, or pith, consisting of a hollow cylinder of cellular tissue, from which proceed numerous thin diaphragms toward the centre of the stem.

The structures above referred to may undoubtedly exist in different proportions in different species, and also in the same species in different parts, and at different stages of growth. In the woody axis more particularly, there is evidence that in such forms as *S.* (*Favularia*) *elegans*, the scalariform, or pseudo-scalariform, tissues were predominant. In young stems also, and in roots, this would probably be the case; and in the latter the texture was much coarser than in the stem; and, further, Prof. Williamson has shown me specimens from the Lancashire coal-field, which I have no doubt are Sigillarioid trees of the type of *S. vascularis* of Binney, and which, instead of a *Sternbergia* pith, have scalariform cells and vessels in the centre, and in which the bundles of scalariform vessels traversing the wood are included in considerable masses of cellular tissue, elongated vertically, like medullary rays. This plant presents external markings of the *Clathraria*-type. Mr. Carruthers has also shown me a specimen ribbed externally, and apparently a *Sigillaria* or *Syringodendron*, which shows only a cylinder of large scalariform fibres similar to those of *Stigmaria*. These facts show how wide differences may exist in the structures of stems referred by their superficial markings to *Sigillaria*.

In the case of specimens showing structure merely, it will undoubtedly require much further investigation to enable us always to distinguish the structures characteristic of the subgenera of *Sigillaria*, or absolutely to separate these from those of certain peculiar conifers on the one hand and from those of the higher acrogens on the other. Young and succulent stems of *Dadoxylon* may have much resembled *Sigillaria* in their structure. Young stems of *Sigillaria* proper may have approached closely to those of *Favularia*; and since I have shown* that the branches of *Favularia* resemble *Clathraria* in their scars, this last may have presented a still feebler type of internal organization. Further, there is, as I have already stated, reason to believe that some of the species referred by palæobotanists to the *Clathraria*-division are really forms of *Lepidophloios*. These difficulties, in connexion with the defective state of preservation of specimens, may excuse many differences of opinion, though I think the facts already stated in this paper are sufficient to put all students of the subject on the right track in regard to at least one leading type of these plants, and to remove some of the more fruitful sources of error.

We may now proceed to inquire what light the structures of *Sigillaria* throw on its affinities. On this question, taken in its most general aspect, there have, I believe, in modern times been only two opinions, the views as to alliance with *Euphorbiæ* and *Cacti* held by some older botanists having been given up. Some botanists, conspicuous among whom is Brongniart, hold that *Sigillariæ* were gymnospermous plants, allied to Cycadaceæ. Others are disposed to regard them as acrogens, and as closely related to Lycopodiaceæ.

In favour of the latter view may be urged the apparent association with *Sigillaria* of certain strobiles resembling those of *Lepidophloios*, the points of resemblance between the tissues of *Favularia elegans* and those of *Lepidodendron*, and the resemblance of certain *Sigillariæ*, or supposed *Sigillariæ*, of the *Clathraria*-type to *Lepidophloios*.

In favour of the former view, we may adduce the exogenous structure of the stem of *Sigillaria*, and the obvious affinity of its tissues to those of Conifers and Cycads, as well as the constant association with trees of this genus of the evidently phanerogamous fruits known as *Trigonocarpum* and *Cardiocarpum*. On the other hand, the resemblance to *Lepidodendron* may be shown to depend merely on comparisons of a part of the tissues of *Sigillaria* with those of that genus. Grave doubts may also be entertained as to whether strobiles of *Lepidophloios*, and even stems of that genus have not been improperly mixed up with *Sigillaria*.

It is probable that all botanists who have studied these plants, might agree that, if not Gymnosperms, they at least present points of affinity with them, and might be regarded as in some sense a link connecting them with Acrogens. Supposing this much to be admitted, important questions remain as to their possible relations to the modern Conifers and Cycads. The higher *Sigillariæ* unquestion-

* "Conditions of Deposition of Coal," Quart. Journ. Geol. Soc. vol. xxii. p. 130.

ably resemble Cycads in the structure of their stems. Their long rigid narrow leaves may be compared to single pinnæ of the leaves of Cycads. Their cord-like rootlets, as I have ascertained by actual comparison, are similar to those of Cycads. If their fruit was of the nature of *Cardiocarpum* or *Trigonocarpum*, this also would correspond. They differed principally in the division of the stem below into those remarkable underground branches, the *Stigmariæ*, and in the great upward extension and, in some instances at least, ramification of the stem. The former may be regarded as a special modification connected with their peculiar habitat. The latter may be interpreted as a modification either tending backward to the Lycopodiaceæ or forward to the Coniferæ. Since, so far as we at present know, the ramification prevails chiefly in the lower forms, the former may be the more correct view. It is even possible that the *Sigillariæ* may include forms bridging over the space between the higher Acrogens and the Gymnosperms. Viewed in this way, the typical ribbed *Sigillariæ* point downwards through *Calamodendron* and *Calamites* to the Equisetaceæ, and the *Favularia*- and *Clathraria*-types point through *Lepidophloios* and *Lepidodendron* to Lycopodiaceæ. In the upward direction their affinities point both towards Conifers and Cycads. As our knowledge of the structure of individual species of *Sigillaria* increases, we may hope more certainly to trace the links of these affinities. It is, however, to be observed here, by way of caution, (1) that, of the plants reckoned among the several genera or subgenera of *Sigillariæ*, some may eventually prove to be gymnospermous and some cryptogamous, and (2) that, as we shall find in the next group to have been actually the case, some of these plants may, with a cryptogamous fructification, have presented a structure of stem more complex than that found in modern plants of similar grade.

2. Calamodendron and Calamites.

Calamites are among the most abundant fossils of the Carboniferous period, and occur also in the Devonian; and from their peculiar habitat and mode of growth, they are not only preserved as flattened stems, but also occur in immense numbers standing on the beds on which they grew.

They have naturally been regarded from the first as allied to Equisetaceæ; and this opinion is ably and, indeed, conclusively maintained by Schimper in his recent work*, and has been illustrated by the recent description of the fruit by Mr. Carruthers. Difficulties have, however, arisen from the fact that some stems regarded as Calamites have been found to be surrounded by a thick woody cylinder composed of discigerous and pseudo-scalariform tissue, similar to that of the type of *Sigillaria* above described. Some botanists have regarded these last as distinct from the true *Calamites*, and have placed them in the genus *Calamitea*, Cotta, or *Calamodendron*, Brongniart; and Williamson has recently proposed

* Paléontologie Végétale.

the name *Calamopitus** for a group believed to be intermediate between *Calamodendron* and true *Calamites*. On still other grounds, *Bornia* and other genera or subgenera have been separated from *Calamites* proper. Latterly Schimper has endeavoured to combine the view of the Equisetaceous affinities and annual growth of the stems of *Calamites* with what, at first sight, seems the totally irreconcilable woody character of the stem of *Calamodendron* as described by Cotta, Dawes, and Binney.

In all my own publications on this subject, from the date of my first paper on *Calamites* published in the Journal of this Society†, I have held that Calamites proper are Equisetaceous plants, having the external characters of their stems preserved, and that in the last respect they differ from the internal casts which belong to *Calamodendron*. All my subsequent observations have served to confirm these conclusions, which I would now illustrate by the following considerations.

1. The true *Calamites* (e. g. *C. Suckovii, C. cannæformis, C. Cistii*, &c.), when well preserved, present, externally, somewhat flat smooth striated ribs, with distinct nodes, and having, at the upper end of each rib, a rounded areole with a central dot or scar, marking the disarticulation of a leaf, branchlet, or root, or, in some cases, the extremity of one of those radial prolongations of the pith which have been described by Williamson. In one specimen in my possession there is a double set of marks—smaller ones on the node, apparently belonging to the appendages, and larger marks below the node, which may represent the radial prolongations of the pith (Pl. X. fig. 22). The cortical investment is very thin and dense, and presents externally the characters of an epidermis, not showing, as in the case of *Sternbergia* or *Calamodendron*, a coating of woody fibres externally, and therefore cannot be regarded as a mere medullary sheath or, as Schimper supposes, the membrane lining the hollow interior of the stem. I may remark here, that erect Calamites are sometimes surrounded by a calcareous or ferruginous concretionary coating which must not be confounded with the true surface of the stem.

2. The ordinary Calamites are seen to stand erect, rooted *in situ*, and attached together at the bases, or arising from rhizomata. The stems can be seen to bud from each other; and the roots can be traced proceeding from their bases and lower nodes. Figures of erect specimens were given in my paper on Erect Calamites, and also in that on the South Joggins‡. Abundant specimens may be obtained in the magnificent petrified Calamite brakes at the last-mentioned locality, and, I venture to say, cannot be studied by any geologist without producing the conviction that the erect cylindrical casts imbedded in groups in the sandstone must represent the true external form of the plant. I have also shown, in the paper above cited, that these erect stems are crushed by lateral pressure, and broken down

* Preoccupied by Unger for certain Devonian plants.

† On the Occurrence of Upright Calamites near Pictou, Nova Scotia, Quart. Journ. Geol. Soc. vol. vii. p. 194.

‡ Quart. Journ. Geol. Soc. vol. vii. p. 194, and vol. x. p. 1.

and flattened at the top, exactly as somewhat strong fistulous stems would be. It is obviously impossible that casts of medullary cavities could be preserved in this manner. Neither *Sternbergiæ* nor casts of the pith of *Calamodendra* ever occur under such circumstances.

3. The stems of *Calamites* may be seen to have produced leaves and branchlets in such a manner as to prove that they are complete stems preserving their external surface. In my paper on the South Joggins, I figured and described the leaves of *C. Cistii* as seen attached to the erect stems. I have since, in 'Acadian Geology,' figured those of *C. Suckovii*, found under similar circumstances; and I have specimens which appear to me to verify the figure given by Lindley and Hutton of the leaves of *C. nodosus*. I have also obtained beautifully preserved specimens of the leaves of *C. transitionis*, a species common to the Devonian and Lower Carboniferous. It has been supposed that the scars on the nodes of *Calamites* are merely the marks of bundles of vessels passing from the interior towards the surface; but it is obvious that, in the case of stems actually producing leaves and branchlets, this cannot be the true explanation, though after seeing the very instructive slices of Prof. Williamson's *Calamopitus*, kindly shown to me by him, I am prepared to admit that in some specimens, at least, they may represent the "medullary radii," which, as already stated, sometimes appear *in addition to* the true vascular scars.

4. The leaves of *Calamites* were not, as is often stated, identical with those of *Asterophyllites*; and the genus *Calamocladus*, in which Schimper has placed many plants of the latter genus, is therefore altogether unnecessary. A careful microscopic examination of the leaves which I have found attached to Calamites convinces me that they have distinct characters, and affords an additional link of connexion with Equisetaceæ. The leaves of *Asterophyllites* proper are flat, expanded in the middle, and with a distict midrib. Those of *Calamites* are strictly linear, thick, and angled, and are besides marked with transverse lines or striæ. Similar transverse lines occur on the branchlets of some modern *Equiseta*, and are produced by lines of minute stomata. Well-preserved specimens of Calamite-leaves have precisely the same appearance, so that they may be compared to branchlets of *Equiseta* deprived of their sheath. Flattened leaves of *Calamites*, it is true, sometimes present the appearance of a midrib; but this arises either from the prominence of the upper angle, or the appearance of an internal axis through the substance of the leaf. Unless very badly preserved, they can always be distinguished from *Asterophyllites* or *Annularia*. The connexion supposed, by Ettingshausen and others, to obtain between *Calamites* and *Asterophyllites* has arisen either from accidental association, or from failure to distinguish leaves and stems of *Calamites* from the corresponding parts of *Asterophyllites**. The conjecture of Brongniart that some, at least, of the *Asterophyllites* may be leaves, not of

* The species *Asterophyllites comosus*, L. v. H., appears to consist of, or to include, leaves of *Calamites*; and there is reason to doubt whether the proper *Asterophyllites* should be separated from *Annularia*.

Calamites, but of *Calamodendron*, rests on different grounds, and is supported by the fact that some of the larger stems which may be supposed to represent the external surface of *Calamodendron*, have tumid nodes similar to those of the branches of *Asterophyllites*. Stems of this kind are sometimes found in an erect position in the Coal-measures of Nova Scotia, and are manifestly distinct from those of ordinary Calamites.

5. The microscopic structure of *Calamites* is not precisely identical with that of *Calamodendron*, though the latter may be regarded as a more advanced type of the former. The Calamites have a thin outer coat with lacunæ, or air-cells, like those of modern *Equiseta*; and the tissue intervening between these contains large vasiform tubes marked on the surface with numerous rows of small pores ("multiporous tissue" of my papers on the Structures in Coal, &c.), and which bear some resemblance to the fibres of *Dictyoxylon* as described by Williamson (Pl. IX. fig. 19). This structure has been illustrated by Goeppert, Unger, Schimper, and others; and I have verified it by the microscopic examination of numerous flattened Calamite-stems in the shales and coarse coals. Facts of this kind kind were mentioned in my paper on the 'Structures in Coal.'

The *Calamodendra*, on the other hand, are casts of the medullary cavities of stems having a thick woody envelope disposed in wedges separated by intervening tracts of cellular tissue, which, according to Williamson, are of the nature of large medullary rays, while smaller medullary rays occur in the intervening wedges, and presenting the same discigerous and pseudo-scalariform tissues observed in *Sigillaria*. I have represented in Plate IX. two forms of *Calamodendron* with the tissues found attached to them. These stems, no doubt, have lacunæ like those of Calamites, and resemble them in general arrangement of parts, but differ in the much greater development of the woody tissue, and, in some species at least, in the character of this tissue.

6. The fructification of Calamites I have not found in connexion with the stems. I have no doubt, however, that some of the spikes of fructification described by authors as the fruit of *Calamites*, really belong to these plants. There has, however, been some confusion between the fruit of *Calamites* and *Asterophyllites*, which demands attention from those who have access to the specimens.

It results from the facts above stated that the true equisetaceous Calamites are well known to us by their external forms, habit of growth, and foliage, as well as by their internal structure; and on all these grounds no reasonable doubt can be entertained as to their affinities. Whether, as Schimper supposes, they were merely annual stems like those of modern *Equiseta*, admits of more doubt. In the equable climate of the Coal-period such stems may have continued growing from year to year. Nor do I think that their rhizomata were relatively so important as those of *Equiseta*. In some of the species, at least, the erect stem itself, fortified by adventitious roots, and partly buried by increasing deposits of sediment, seems to have served the purpose of a rhizoma*. The best example that I have seen of the rhizoma of a Calamite is that figured in Plate IX, (fig. 21), from a specimen presented by me to the Geological Society many years ago.

With regard to *Calamodendron* the difficulties are greater, and have been well stated by Prof. Williamson in a recent paper in the 'Memoirs of the Literary and Philosphical Society of Manchester'†, in which he describes under the generic name *Calamopitus* a peculiar stem, which, while he identifies it in its general characters with *Calamites*, he justly regards as being in internal structure distinct from the *Calamodendra* described by Cotta and Binney.

The characters of *Calamodendron* as distinguished from ordinary *Calamites* may be summed up as follows:—

(*a*) The part usually preserved is the internal axis, corresponding to a *Sternbergia*. It presents ribs similar to those of *Calamites*, but more angular, and almost always having traces of woody fibres capable of showing the structure on some part of their surface. I have not seen on these casts any distinct traces of scars or areoles. These casts of the pith of *Calamodendron* constitute the greater part, if not the whole of the specimens referred to *C. approximatus*.

(*b*) More complete specimens are invested with woody matter, arranged in wedges, and consisting of elongated cells and porous, discigerous, or pseudo-scalariform tissue. My specimens do not show distinctly the arrangement of these; but this has been well described by other observers. Williamson describes medullary rays in the woody bundles in addition to the large cellular tracts intervening between them.

(*c*) The actual external surface of *Calamodendron* is not certainly known; but I have been disposed to regard as of this kind those ribbed stems, found in the coal-formation, which have swollen nodes as if caused by the emission of whorls of small branches. I have specimens of these in my collection, which I have hesitated to name or describe until they could be better understood. Prof. Williamson's description of *Calamopitus* now inclines me to suppose that they belong to that genus or to allied forms.

With regard to the affinities of the *Calamodendra*, the structure of the stem raises them above the Calamites and modern *Equiseta*, and justifies the conjecture of Brongniart that they may have been gymnosperms. Williamson, Carruthers, and Binney, however, attribute to them a cryptogamous fructification. In this case they may, as the former suggests, be a connecting link between Acrogens and Gymnosperms. Should subsequent investigations confirm this view, it will throw an interesting light on the possible affinities of *Sigillaria*. *Calamites*, on the one hand, and *Lepidodendron* on the other, are distinctly cryptogamous and are related to, or included in, the modern families of Equisetaceæ and Lycopodiaceæ. But *Calamodendron* seems to form a connecting link between *Calamites* and the ribbed *Sigillariæ*; and in like manner *Lepidophloios* seems to connect the

* See my description in Quart. Journ. Geol. Soc. vol. x.

† Vol. iv. 3rd Series.

Lepidodendra with the *Sigillariæ* of the *Favularia*-type. On the other hand, as already stated under *Sigillaria*, the ribbed *Sigillariæ* may be related through *Ormoxylon* and *Dadoxylon* to the modern Conifers, and the *Favulariæ* may be related to the Cycads. This relationship may be expressed as follows:—

Cycadaceæ.	*Coniferæ.*
	Dadoxylon.
Favularia ?	Palæoxylon.
	Ormoxylon †.
	Dictyoxylon.
SIGILLARIA.	
Rhytidolepis.	Calamodendron.
Favularia ?	Calamopitus.
Clathraria.	Bornia.
Syringodendron.	Calamites.
Lepidophloios.	*Equisetaceæ.*
Lepidodendron*.	
Lycopodiaceæ.	

I do not give this Table with any view to theories of derivation, but merely as an expression of probable affinities among these very curious and ancient types of vegetation.

I may add here a few words with reference to *Sphenophyllum*, a genus which some authors unite with *Calamites*. The verticillate, cuneate, veiny leaves of this plant, and its spikes of fructification have long been known; and in 1865 I was enabled by a specimen in the collection of Sir W. E. Logan to determine the structure of its stem, which contains a slender axis of reticulato-scalariform vessels of the type of those in *Tmesipteris*‡. These plants obviously had no connexion with *Calamites* or *Calamodendron*, but constitute a peculiar synthetic type, presenting points of resemblance to Ferns and Marsiliaceæ.

In conclusion, and with reference to my former papers on the "Structures in Coal," I would repeat the statement made in those papers, that the tissues of *Sigillaria*, as defined in this paper, and of *Calamodendron* enter more largely than any others into the composition of the mineral charcoal, and other parts retaining structure, of the coal of Nova Scotia; and I have reason to believe that similar tissues are at least very abundant in the coal of this country.

Supplementary Note.—Owing to the delay in the publication of the above paper, it is necessary to add the following statements:—

(1) Prof. Williamson has described another type of Calamitean stem, which he regards as intermediate between his *Calamopitus* and *Calamodendron* §, but which has the *reticulated* or *multiporous* vessels of the former. To Prof. Williamson is due the credit of recognizing this structure for the first time in English specimens, though, as above

* Including *Sagenaria*. † Dawson, MS.
‡ Quart. Journ. Geol. Society, May 1866.
§ Manchester Lit. and Phil. Soc. Proceedings, 1870.

stated, it had previously been well known elsewhere. I regard these plants, so well described by Williamson, as true *Calamites*, in the sense in which that word is used above.

(2) The same palæobotanist has independently expressed the belief above stated, that the leaves of *Calamites* are distinct from those of *Asterophyllites*, and has also stated a distinction between those so-called *Volkmanniæ* which may be regarded as fruits of *Calamites* and those which belonged to *Asterophyllites* *. He has also described a specimen of *Stigmaria* showing the medullary rays, and otherwise approaching to the structures which should be found in the roots of the typical *Sigillariæ* above described.

(3) Schimper, in his 'Paléontologie Végétale,' vol. xi., has treated the *Sigillariæ* very slightly. He adds no new facts of importance to their history, does not separate them from the plants of the genus *Lepidophloios*, usually mixed with them, refers the whole to one genus, and places them with the Lycopodiaceæ.

(4) Binney, in the Palæontographical Society's Publications, vol. xxiv., has described, under the name of *Bowmanites cambrensis*, a very interesting plant, which I regard as a typical member of the group *Asterophylliteæ*, as distinguished from *Calamiteæ*.

(5) Attention having been directed by Prof. Huxley to the presence of *spore-cases* in Coal, I have endeavoured to show, in a paper in the 'American Journal of Science' for April, that these bodies are not a large constituent of ordinary Coal, and that any importance which they possess in this respect is due to their identity in chemical composition with those *cortical* and *epidermal* tissues which, like the *suberin* of cork, are more nearly allied in composition to Coal than any other recent vegetable matters, and better fitted, by their chemical and mechanical properties, for its production.

EXPLANATION OF THE PLATES.

Plate VII.

Fig. 1. *Sternbergia*, pith of *Dadoxylon*; 1 *a*, section of one side, showing diaphragms; 1 *b*, section of a diaphragm and three wood-cells, magnified; 1 *c*, two wood-cells, highly magnified, showing reticulated walls.

2. *Sternbergia*, pith of *Sigillaria*, natural size; 2 *a*, 2 *b*, discigerous tissue investing the same.

3. *Sternbergia*, pith of *Sigillaria*, natural size; 3 *a*, discigerous and scalariform tissue.

4. *Sternbergia*, natural size; 4 *a*, reticulato-scalariform tissue.

5. *Sternbergia*, natural size; 5 *a*, 5 *b*, scalariform and reticulato-scalariform tissue.

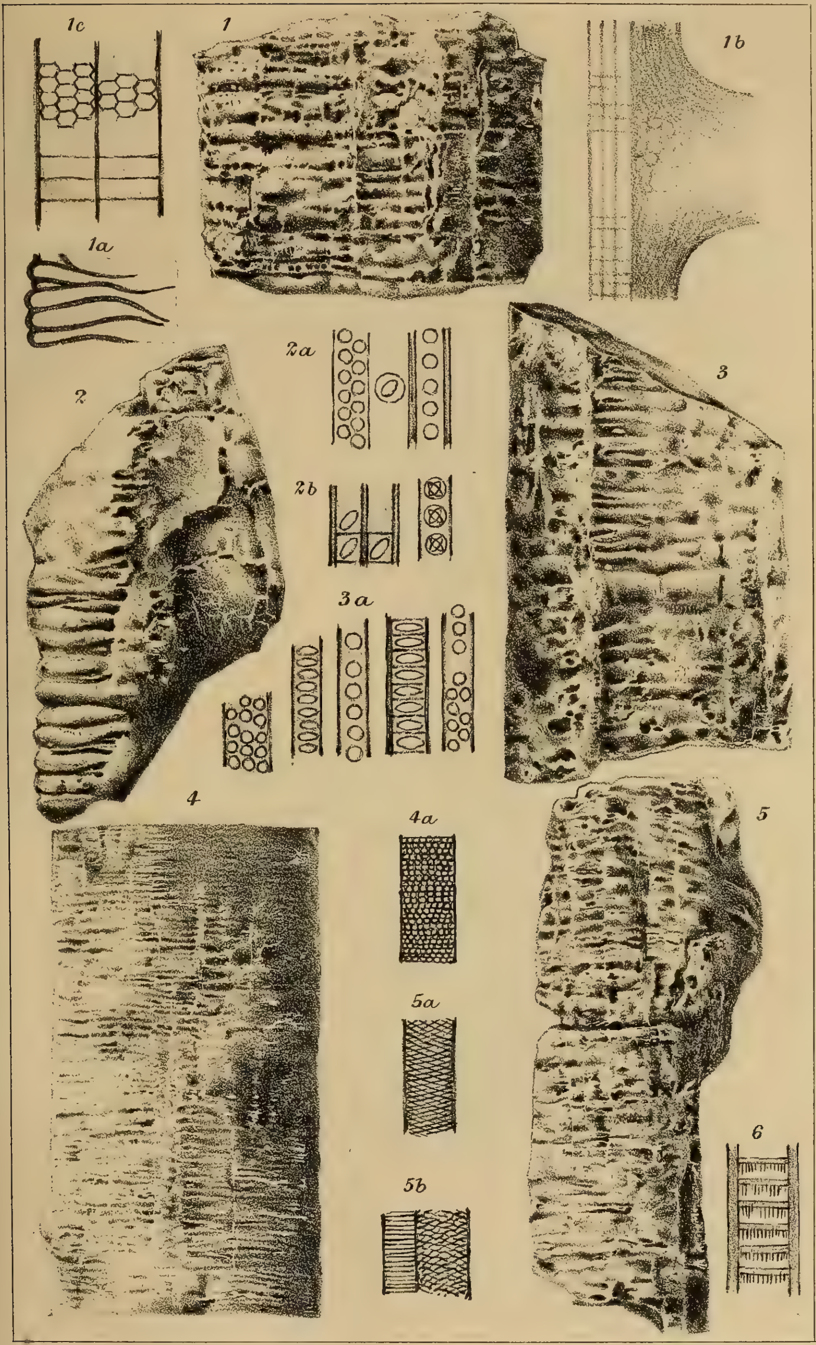
6. Scalariform vessel of *Lepidophloios*.

Plate VIII.

Fig. 7. *Sternbergia*, of Lepidodendroid tree?, natural size; 7 *a*, scalariform tissue.

8. Section of a flattened stem (*Sigillaria*?) 1 foot in diameter, converted into coal, with *Sternbergia*-pith.

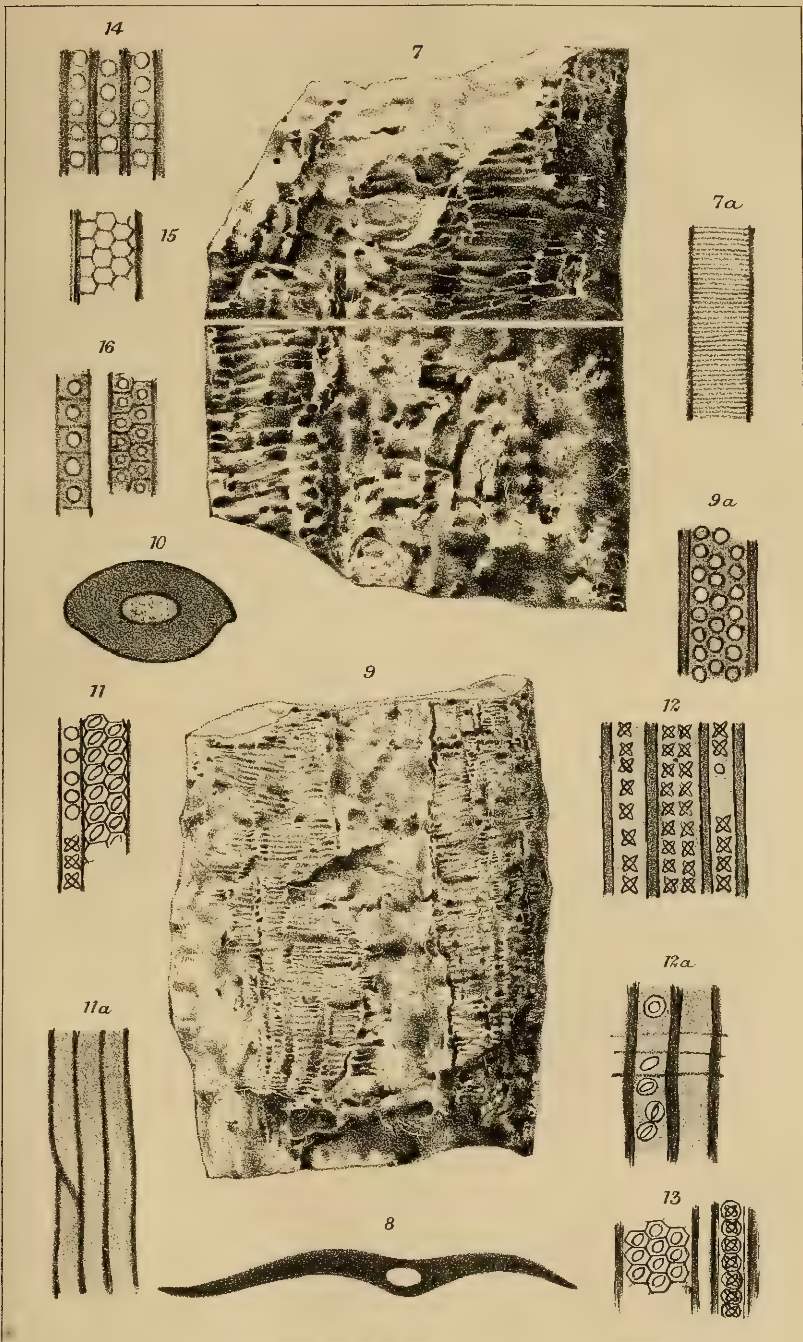
* Manchester Lit. and Phil. Soc. Proceedings, Feb. 1871.



W.G. Smith lith.

Mintern Bros. imp.

STERNBERGIA.



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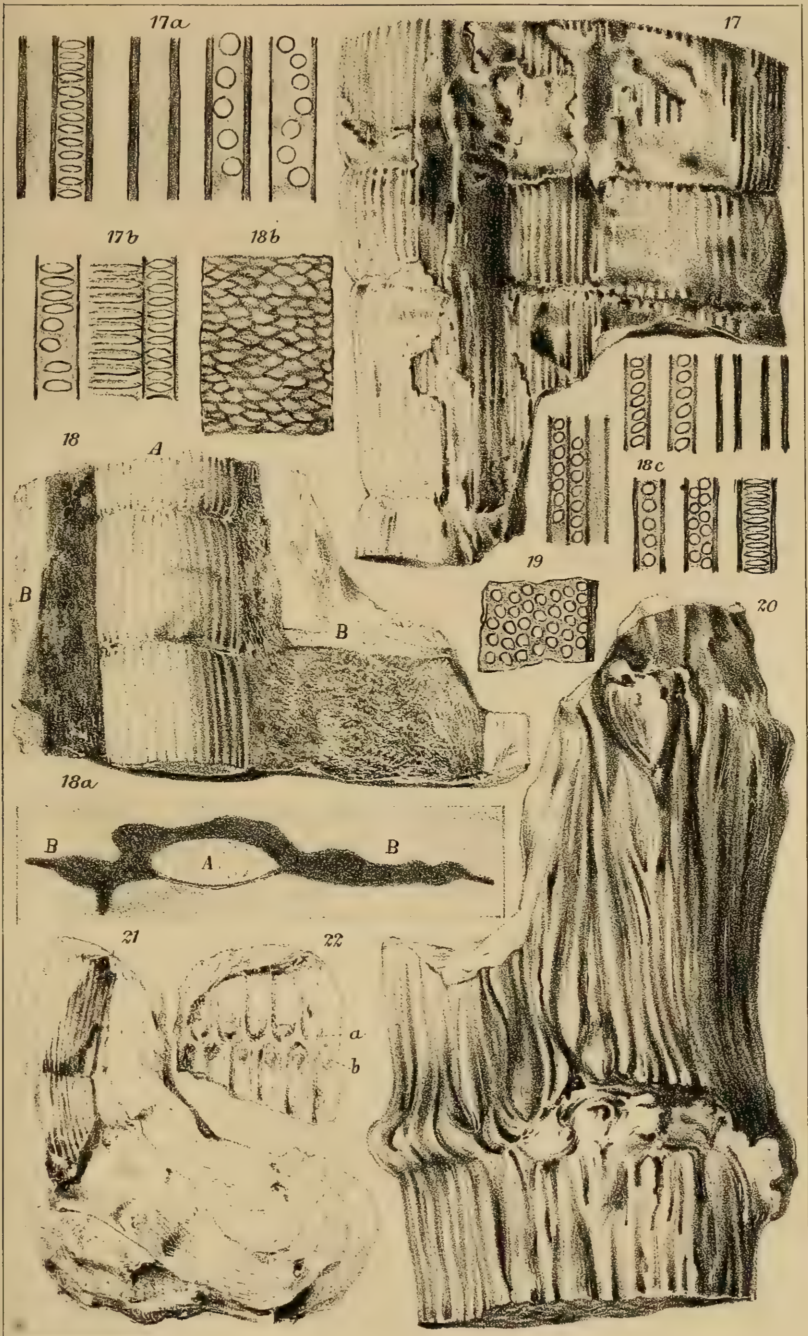

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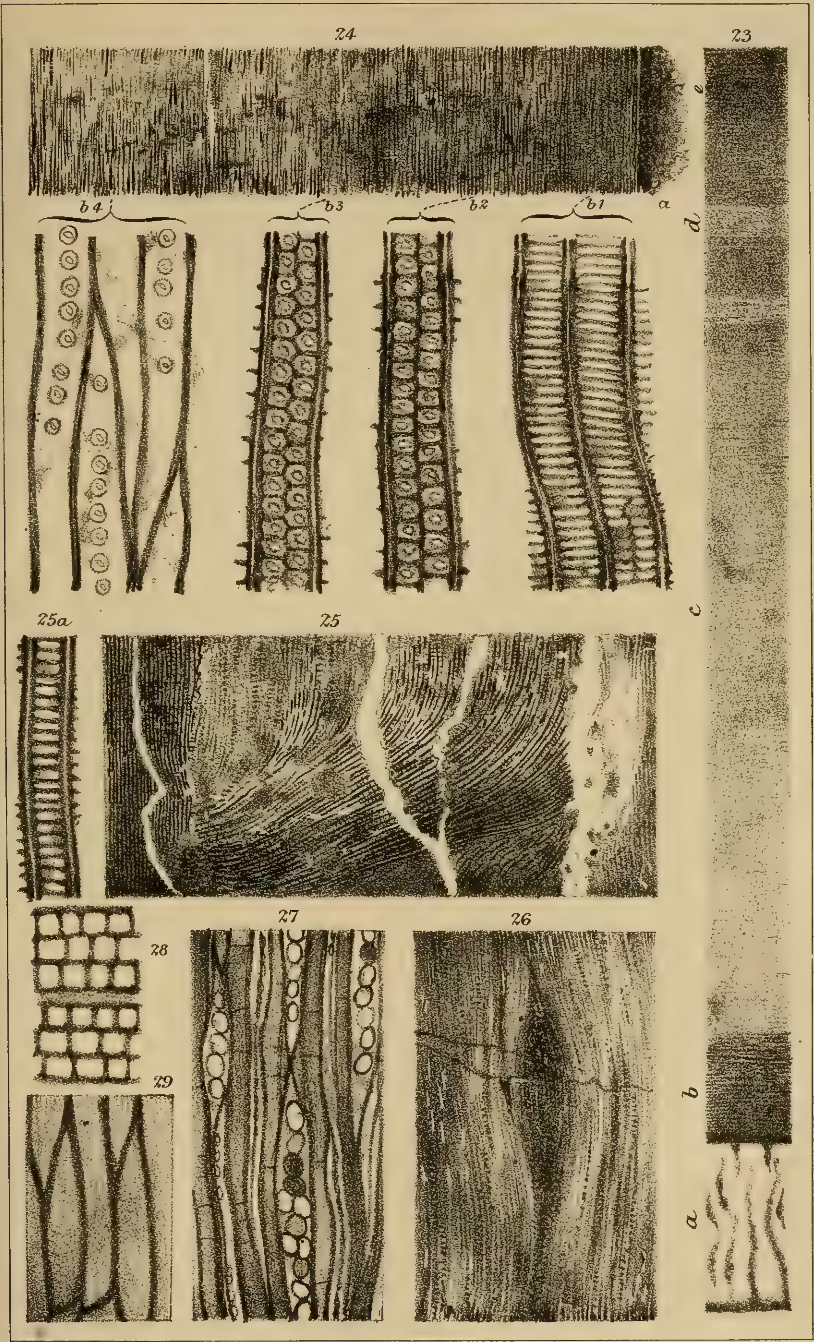
CALAMODENDRON & CALAMITES.



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SIGILLARIA.

Fig. 9. *Sternbergia*, pith of the same, natural size; 9 *a*, discigerous tissue of the same.
10. Another stem, probably Coniferous, with *Sternbergia* pith.
11. Woody tissue of prostrate *Sigillaria*; 11 *a*, bast-tissue of the same.
12. Woody tissue of a *Sigillaria*; 12 *a*, medullary ray.
13. Tissue of a *Sternbergia* similar to fig. 9.
14, 15, 16. Discigerous tissue of erect trees (*Sigillariæ*) in mineral charcoal.

PLATE IX.

Fig. 17. *Calamodendron approximatum*, cast of pith; 17 *a*, 17 *b*, discigerous and scalariform tissue of the same.
18. *Calamodendron* invested with woody tissue: A, pith; B, woody cylinder; 18 *a*, cross section; 18 *b*, cross section, magnified, showing compression of the tissue; 18 *c*, discigerous and pseudo-scalariform tissue of the same.
19. Portion of a multiporous vessel of a true *Calamites*, magnified to the same scale with figs. 17 *a* & 17 *b*.
20. Stem of erect *Calamodendron* (S. Joggins, Nova Scotia), showing its external surface, one-third nat. size.
21. Base of stem of *Calamites* (S. Joggins), showing rhizoma, reduced.
22. Node of *Calamites*, showing scars of verticillate branchlets and of radial processes.

PLATE X.

Fig. 23. Radial section of stem of *Sigillaria* of the type of *S. Brownii*, Dawson, restored, natural size: *a*, pith; *b*, woody cylinder; *c*, cellular inner bark; *d*, fibrous bark; *e*, outer cortical layer.
24. Radial section of the woody cylinder, magnified (letters as above); and portions of the tissues more highly magnified below: *b* 1, inner pseudo-scalariform cylinder; *b* 2, 3, 4, discigerous outer cylinder.
25. Radial section, more highly magnified, showing one of the radiating bundles of vessels (this section has been inverted); 25 *a*, single pseudo-scalariform vessel from radiating bundle.
26. Tangential section of the same stem, showing the woody fibres and one of the radial bundles, and the medullary rays.
27. Tangential section showing woody fibres and medullary rays, more highly magnified.
28. Radial arrangement of woody fibres, magnified.
29. Fibres or elongated cells of the bark (*d*).

Note.—All the drawings of *separate fibres and vessels* in the above figures are on one scale.

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American Journal of Conchology. Vol. v. No. 3.

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F. J. Würtemberger.—Die Tertiärformation im Klettgau, 471 (1 plate).
F. Roemer.—Ueber *Python Euboïcus*, eine fossile Riesenschlange aus tertiärem Kalkschiefer von Kumi auf der Insel Eubœa, 582 (1 plate).
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January 25, 1871.

Richard Atkinson Peacock, Esq., of St. Helier's, Jersey; Arthur W. Waters, Esq., Davos Plaz, Canton of Grisons; R. Koma, Esq., of University College, London; and Ransom Franklin Humiston, Esq., M.A., Professor of Chemistry in Cleveland University, U. S., were elected Fellows of the Society.

The following communications were read:—

1. *On the* Physical Relations *of the* New Red Marl, Rhætic Beds, *and* Lower Lias. By Prof. A. C. Ramsay, LL.D., F.R.S., &c.

If we look upon the Rhætic beds of Europe as a whole, it is evident that they were formed under very different conditions in different areas. Thus this formation on the south side of the Alps, as described by Stoppani, contains a large and well-developed marine fauna, whereas in England, Germany, Sweden, and in other parts of the north of Europe, the strata are much less developed, and the fauna has dwindled, containing fewer forms of life, while most of them are small and some distorted in appearance.

In this paper I propose to inquire into the reason of these peculiarities with regard to the English beds, and to show their relations to the New Red Marl and the Lower Lias in a physical point of view.

I have for some years held that the New Red Marl is physically more intimately connected with the Rhætic beds, and, in some respects, even with the Lower Lias, than it is with our own New Red Sandstone. The absence of the Muschelkalk in England probably attests a break in succession in our Triassic series. I say probably, because the opinion is every day growing stronger that our

Triassic series was deposited in inland waters, partly fresh or salt as the case may have been, whereas the continental Trias was partly, at any rate, deposited in areas connected with the sea. If, between the deposition of the New Red Sandstone and Marl in England, the area in which they occur was not for a time depressed beneath the sea, we have a sufficient reason for the absence of the Muschelkalk. There are, indeed, symptoms of a gap in time between our Bunter and Keuper strata, accompanied by slight indications of disturbance and unconformity; and, at all events, there is in places a very marked overlap of the Marl across the Bunter Sandstone series.

In England there is a perfect physical gradation between the New Red Marl and the Rhætic beds, shown by interstratifications of red, green, and grey marls which, varying in different localities, pass by degrees into limestones, sandstones, and black shales. It is therefore impossible to determine precisely where the Rhætic beds commence in this series; and, indeed, all through the New Red Marl there is a tendency to a repetition of the same sort of deposits as those with which the ordinarily recognized Rhætic beds were ushered in. This is evinced by the frequent local recurrence of green and grey marls, and thin beds of light-grey and whitish sandstones, commonly called the Middle Keuper Sandstones, which, however, occur in many horizons in the New Red Marl.

I have long held, in common with some other geologists, that our New Red Sandstone was probably deposited in an inland lake, and that our New Red Marl was certainly formed in a salt lake*. This belief is founded on the existence of the great deposits of rock-salt common in that formation, on the ground that, such lakes being fed by rivers and having no outflow, concentration of salts ensued by evaporation, and saline deposits were at length formed, in this case consisting chiefly of common salt. To me it seems impossible that solid salt can be deposited in quantity in an ordinary ocean, for the salt in solution cannot be sufficiently concentrated there to permit of deposition. And though wide-spreading cakes of salt have been formed by evaporation in such areas as the Runn of Cutch, yet this seems rather to partake of the nature of an accident than to denote a steady, long-continued train of events like those which marked the deposition of salt in our Keuper series.

Gypsum and other salts accompanying the New Red Marl may also have been formed in like manner; and I consider that the peroxide of iron which stains both salt and marl may also have been carried into the lakes in solution as carbonate of iron, and afterwards deposited as a peroxide through the oxidizing action of the air and the escape of the carbonic acid which held it in solution. It is well

* As far as I know, first proposed by the late Professor H. D. Rogers in an address to the British Association at Glasgow, 1855, p. 5, "On some of the Geological Functions of the Winds, illustrating the Origin of Salt." Only the title was printed; but ever since I have adopted and expounded Professor Rogers's views in my lectures. Mr. Moore mentions "the fresh- or brackish-water deposits of the Upper Trias," Quart. Journ. Geol. Soc. vol. xxiii. p. 458.

known that the peroxide of iron, as a thin pellicle, only incrusts the grains of sand that form the New Red and other red sandstones; and microscopic examination of the New Red Marl proves that the grains or flakes of sandy mud composing it are encased in the same manner *. Both Sandstones and Marls, I believe, have been formed in lakes, and their red colour is connected with this circumstance; for it seems impossible that an oxide of iron could be deposited from solution in an open sea in sufficient quantity to colour sediments red, though common pink mud might be so formed from the mechanical waste of red granite or other rocks. The remains of land-plants in the Keuper series, and the peculiarities of some of the reptiles of the period, tend to confirm the view that the strata were deposited in inland salt lakes. Their footprints prove that they walked over moist surfaces; and if these surfaces had been simply left by a retiring tide, they would generally have been obliterated by the returning flood, in the manner that we see every day on our own sandy shores. It seems to me that the surfaces on which we now find fossil footprints were probably rather left bare by the summer evaporation of a lake; these surfaces were baked by the sun, and the footprints hardened, so as to ensure their perpetuation, before the rising waters brought by flooded muddy rivers again submerged the low flat shores and deposited new beds of silt, just as they do at the present day round the Dead Sea and the Salt Lake of Utah.

The Foraminifera of the Keuper Marls, which are numerous, might just as well have lived in a salt lake as in the open sea †; and the same may be said of *Estheria minuta*. The single fish of our Lower Keuper Sandstone, *Dipteronotus cyphus*, will fall under the same category. The *Microlestes antiquus*, which occurs in the bone-beds of Stuttgart, and in the Red Marls of Watchet, in Somersetshire, according to Mr. Boyd Dawkins ‡, proves nothing except that there was land in the vicinity.

* Mr. Ward, of the metallurgical laboratory, Jermyn-street, at my request discharged the colour from fragments of New Red Sandstone and Marl by an acid solution of protochloride of tin. Both became white. Under the microscope the marl appeared as a very fine-grained sandstone composed of perfectly white minute fragments of silica. In both the grains had evidently been simply coated with a thin pellicle of peroxide of iron. In the sandstone the peroxide of iron was 1·89 per cent.

† Species of Foraminifera are exceedingly variable in form; and many of them have a long range in geological time. They are therefore of little value in helping to the determination of stratigraphical horizons. It may be true, for example, that if the Chalk were entirely composed of Foraminifera it might be difficult to distinguish from deposits now forming in the Atlantic; but if these Atlantic deposits were, like the Chalk, half consolidated, heaved up, and denuded, geologists would not feel at a loss regarding their age. They would miss, in the first place, all the genera of Cephalopoda characteristic of the Chalk, besides numerous peculiar genera and species of Echinodermata, and, perhaps with one exception, all the species of Brachiopoda common in the Chalk. Further, over large areas, they would be apt to find Tertiary strata of various ages intercalated between the Old and New Cretaceous beds, which would at once furnish a clue to men experienced in field geology.

‡ Mr. Dawkins considers that these strata belong to the Rhætic beds; but the marine Rhætic fossils have not been found so low.

I have already said that the New Red Marl of England is more closely related physically to the Rhætic and, in some respects, to the Liassic beds, than to the Bunter strata; and I will now state the stratigraphical phenomena that have led me to form this opinion.

South and south-west of the Mendip Hills, the New Red Marl and the Magnesian Conglomerates at its base lie directly on Carboniferous strata. The Rhætic beds and Lower Lias immediately succeed these, the former lying conformably on, and generally passing into the Red Marl by obvious gradations. On the north, between the Mendip Hills and Tortworth, the Keuper Marls and sandstones, with occasional Magnesian Conglomerates, also lie on Carboniferous strata. North of Tortworth, as far as the Severn, the Marl, very thin and without any Lower Keuper Sandstone, lies directly on Silurian strata; and on the north side of the estuary it lies indifferently on Old Red Sandstone and Carboniferous rocks. Everywhere in these districts it is immediately succeeded by Rhætic beds, which graduate downwards lithologically into the Marls; and these Rhætic beds are invariably followed by true Lower Lias. The same is the case north and north-west of Gloucester, where the Keuper beds lie on Old Red Sandstone; and on the east of this area the upper Marls still pass into Rhætic beds regularly overlain by Lias Clay. It is not till we come towards the south end of the Malvern range, that Bunter Sandstones appear beneath the Marl. On the east side of the Malvern and Abberley range, the Bunter beds are thrown out of sight by a fault; but further north they come out in full force, extending along the flanks of the Permian strata that bound the Forest of Wyre, the Coalbrook Dale country, and the South Staffordshire Coal-field, whence they stretch along the eastern limits of North Wales, to the estuary of the Dee and the Mersey. Thence the full Bunter series skirts the Lancashire, Cheshire, and North Staffordshire Coal-fields, lying frequently on Permian rocks, then passing eastward by Ashbourne towards Nottingham, and along the flank of the Magnesian Limestone northward into Yorkshire *.

East of South Staffordshire the case is different. Round the Warwickshire Coal-field, the Keuper strata, where unfaulted, lie directly either on Permian or Carboniferous beds, with one small exception north of Atherstone, where Bunter pebble-beds appear for about a mile. Some very thin Bunter beds appear on and round the flanks of the Leicestershire Coal-field; but generally the Lower Keuper Sandstones lie directly upon Coal-measures; while further east, round Charnwood Forest, the marl lies directly on Cambrian rocks; and the same is the case with respect to the igneous bosses that rise through the marl further south.

Wherever the New Red Marl seems to attain its complete thickness, it passes into Rhætic strata; and these are always succeeded by Lower Lias, as far as the Rhætic beds have yet been observed. Obser-

* Sometimes the Bunter beds are cut out by faults for a space; but this does not affect the general question.

vations, more or less perfect, confirm this, from the south-western parts of England, northward to the shores of the Tees, all on the direct outcrop between the common Lower Lias and the recognized New Red Marl. Two outliers of Rhætic beds, formerly called Lower Lias, also appear at Bagots Park and near Newborough, north-west of Burton-on-Trent; and I do not doubt that the same strata would be found at the base of the outlier of Lias near Whitchurch, in Shropshire, if the rocks of that country were not so much obscured by glacial drift. In Cumberland, round Carlisle, at the mouth of the Vale of Eden, a great tract of Permian strata is directly overlain by Keuper Marls, which are succeeded by Lower Lias, though as yet no Rhætic beds have been noted in that area, which is also deeply covered by glacial débris and other superficial deposits. In fact, wherever the New Red Marl goes, the Lias follows in apparent conformity; and wherever the examination has been complete, the Rhætic beds are found between them, while the Bunter beds, which, were the series complete, would lie beneath the Marl, are often absent, in which case the Marl rests on Permian or any other strata of older date. The Liassic and Rhætic beds, therefore, appear to act in conformity with the New Red Marl, and in connexion with it; while the last seems to have in England less immediate stratigraphical relation to the New Red Sandstone—a fact possibly connected with the absence of the Muschelkalk in Britain.

Having reached this point of the argument, it is time to consider the palæontological part of the question, in relation to the probable physical geography of the time.

In Stoppani's descriptions of the Upper-Trias fossils of Esino * he gives descriptions and figures of a magnificent suite of fossils from beds which, according to his classification, ought to be the general equivalents of our New Red Marl. Only one of these species, *Anatina præcursor*, passes into his infra-Lias or *Avicula-contorta* zone. The Lower St.-Cassian and Hallstatt beds, on the opposite sides of the Tyrolese Alps, are believed by Hauer and Suess to be the general equivalents of the Keuper strata of Germany, France, and England, and, of course, of the beds of Esino. They number from 600 to 800 species of fossils.

In Stoppani's work on the infra-Lias and *Avicula-contorta* zone † of Lombardy, descriptions and figures of about 75 genera and 200 species are given, consisting principally of Mollusca, with a few Echinodermata, Sponges, &c. The fossils are very nearly quite distinct from those of the upper half of his infra-Lias beds, and of our English Lower Lias generally. The thickness of the strata described, the variety and number of the Mollusca and other forms, together with the luxuriant development and proportions of the individual shells, point to the existence in that area, in the south and east of Europe, and elsewhere of a broad open ocean, fitted for the habitation of a large and flourishing fauna—very different in these respects from the development of the British Rhætic beds, whether we regard their thickness or the fossils they contain.

* Milan, 1858–60. † Milan, 1860–65.

According to lists prepared by Mr. Etheridge for publication in a forthcoming work, the British species in undoubted Rhætic beds may be summarized as follows, omitting the Sutton species. For the substance of the remarks regarding affinities and distribution of the species named I am also indebted to Mr. Etheridge.

Foraminifera, thirteen genera and twenty-seven species; Crustacea 2, viz. *Tropifer lævis* from one of the bone-beds, and *Estheria minuta*, first known in the Keuper Sandstones; one Brachiopod, *Discina Townshendi*, the only one known in our Rhætic strata. Of the forms named in this list, *Lima præcursor* somewhat resembles *L. punctata* of the Lias; *Monotis decussata* occurs at the very top of the Rhætic beds in thin limestone bands, which some writers consider to form the bottom of the Lower Lias. *Ostrea fimbriata* may possibly be *O. irregularis* of the Lias; but oysters are of little value in such an inquiry. *Pecten valoniensis*, also a true Rhætic shell, is a very variable form. *Plicatula interstriata* probably passes into the Lower Lias. *Anoplophora musculoides*, another true Rhætic shell, also occurs with *Monotis decussata* in the thin limestone bands at the top, which some call Lias. *Mytilus minutus* occurs both in the Rhætic and Lower Lias strata. All the Gasteropoda of the Rhætic beds (not including the Sutton species) are peculiar to that formation; and the same is the case with the fish. Of the Reptilia, *Plesiosaurus costatus*, *P. Hawkinsii*, and *P. trigonus* are common to the Rhætic beds and the base of the Lower Lias*. The occurrence of *Microlestes antiquus* in the Keuper Marls is an accident, its remains having been washed into the strata from the neighbouring land†. Of the whole, not more than four species of shells at the most pass into the Lias; and probably this may even be restricted to two. The Saurians have a longer range; and this is very significant.

In this list I do not include the Sutton forms given in Mr. Etheridge's list, fourteen in all, one of which (*Ostrea multicostata*) is also found in the Muschelkalk, and three of which (*Pecten Etheridgi*, *P. suttonensis*, and *Mytilus minutus*) are also Lias species. Few or none of the remaining forms occur associated with the shells of the ordinary Rhætic areas. The Sutton beds lie unconformably on the Carboniferous Limestone, and stratigraphically and lithologically are inseparable from the ordinary Lias limestone. The corals, which Dr. Duncan has examined, occur in small, irregular, broken layers, or rather in occasional white tufaceous limestone patches, at the very

* Since this paper was written, I have been informed by Mr. William Sanders, of Bristol, that he has obtained the centrum of an *Ichthyosaurus* of vast size "in close contact with the thick bone-bed at Aust Passage," apparently identical with *I. platyodon* of the Lower Lias.

† The Mendip Hills and the highlands of South Wales have been recognized as land while the Trias was being deposited, ever since 1846, if not earlier. Sir H. De la Beche ("On the formation of the Rocks of South Wales and South-west of England," vol. i. p. 239 *et seq.*, Mem. Geol. Surv. of Great Britain) considers the dolomitic conglomerates "on the Mendip Hills, for instance," "to have been beaches among islands." See also Ramsay, 'Denudation of S. Wales,' &c. p. 318. Mr. Moore also adopts the island theory, "Abnormal Secondary Deposits," Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 454.

base of the Lias, often crusting the Carboniferous Limestone on which it rests. It is so insignificant in quantity that a few persevering palæontologists might almost carry it away bodily in their bags; and its manner of occurrence has always suggested to me the idea that it was formed in hollows in the rocks, partly by evaporation, between high- and low-water mark. The corals sometimes grew on the Carboniferous Limestone; and the whole by subsidence was afterwards buried underneath the Lias. Mr. Bristow remarks that this mode of formation explains the presence of galena and chert in the tufa*. They have been derived from the Carboniferous Limestone on the land side of the deposit. West of Bridgend, as far as Pyle, the Rhætic beds become sandstones, indicating an approximation towards the margin and shallow water.

Sir Charles Lyell has remarked that "the sandstones and clay of the Keuper resemble the deposits of estuaries and a shallow sea near the land, and afford in the north-west of Germany, as in France and England, but a scanty representation of the marine life of that period†. As regards the scanty marine life, this is true. Mr. Etheridge, in his paper "On the Rhætic or *Avicula-contorta* beds at Garden Cliff" ‡, observes that the Rhætic beds of England and the west and north of Europe, were deposited in shallow seas and in estuaries.

With Sir Charles Lyell's suggestion, as regards the estuarine nature of the Keuper beds of England, I do not agree, while Mr. Etheridge seems to me to be right respecting the conditions under which our Rhætic beds were formed. My reasons for this opinion are chiefly founded on physical considerations, leading to the following conclusions, which form the main object of this paper.

1. The Triassic epoch over a great part of what is now Europe was essentially a terrestrial one; that is to say, the Trias areas of deposition in part, and some of them altogether, were surrounded by continental land. In the latter part of this epoch the Keuper marls were deposited in the British isles in a great lake, fresh or brackish at the beginning; and the same was occasionally true of other areas of northern Europe and its adjoining seas, which lakes were for the most part destitute of outlets to the sea.

2. These lakes gradually got filled with sediments. By and by, through change of amount of rainfall, or through increase of heat, the lake or lakes ceased to have an outflow; that is to say, evaporation was equal to, or greater than, the influx of water.

3. By degrees, through evaporation, the water became salter; concentration of salt or salts in solution ensued; and precipitation of rock salt was one of the results.

* I have examined the Sutton beds with Mr. Bristow, and have no doubt that they are Lower Lias. See "On the Lower Lias or Lias-Conglomerate of a part of Glamorganshire," Bristow, Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 199. See also Mr. Charles Moore, "On Abnormal Conditions of Secondary Deposits," Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 526. Mr. Moore decides the Sutton beds to be of Lower Liassic age.

† Elements of Geology.

‡ Proceedings of the Cotteswold Naturalists' Field Club, vol. iii. 1865.

4. Subsequently by increase of rainfall or decrease of heat, the waters again comparatively freshened, but still remained salt, a fact proved by the occurrence of pseudomorphous crystals of salt in sandy layers interstratified with the marls, up to, and even in, the recognized Rhætic strata. Gypsum also occurs above the bone-bed. These circumstances may be accounted for by the close relation of the Rhætic beds to the ordinary marly series. That Rhætic areas got dried by temporary isolation seems certain; for sun-cracks have been observed in the strata by Mr. Bristow, and also pseudomorphous crystals of salt.

5. During the deposition of the upper part of the Keuper marls, overlaps took place of upper across lower strata. This would necessarily take place in any deep wide lake-basin first half drained by mere evaporation, and again, by a change of conditions, gradually filled with water from which sediments were being deposited across a broader area.

For example, were the rainfall of the area drained by the Jordan to increase gradually, the basin of the Dead Sea would by degrees fill with water, and successive deposits of sediment would gradually everlap each other on the shelving slopes of the lake-basin in which solid salts had previously been deposited. There are examples of this kind of overlap in the New Red Marl of England, in Somerset, Gloucester, Hereford, and Leicester shires.

6. In the British area, sinking of the district took place at or about the time when the lake or lakes got nearly filled with sediment; and the same may have been the case in other European areas. A partial influx of the sea took place over shallow bottoms; and the marine life that accompanied it, and the deposits that ensued, together form the Rhætic beds of England. These marine forms migrated from a true Rhætic ocean, in which the Lower St.-Cassian and Hallstatt beds were deposited. If the Dead-Sea area, by increase of rainfall, got filled up, and if depression of land took place so as to admit the waters of the Red Sea or Mediterranean, analogous results would ensue; for a marine or estuarine fauna would be superimposed in shallow water, on a set of strata containing salt in certain lower deposits. The Dead Sea, like the Keuper, is singularly destitute of remains of aquatic life.

Under these conditions, it is evident that the thin Rhætic beds of North-western Europe might have been deposited in great part in shallow seas and in estuaries, or in lagoons, or in occasional salt lakes of small or great dimensions, separated from the sea by accidental changes in physical geography. Many years ago, while at Lyme Regis, the late Professor Edward Forbes stated to me that the fauna of the White Limestone, at that time called White Lias, reminded him, in its assemblage of forms, of the fauna of the Caspian Sea; and this seems to be a case in point, though not in *all* respects strictly analogous*. The fauna of the Caspian is very small in

* Mr. Moore, speaking of the "White Lias," considers that "the general character of the deposit is such as we might expect to find in a lagoon or inland sea

number of genera and species; and some of the forms are poor and dwarfed. It is a north-sea fauna; and when the area was first separated from the main ocean, it was first freshened by influx of rivers, while it is now again becoming salter by evaporation. The result is the poverty and dwarfing of the forms. In the Black Sea there are misshapen or monstrous forms of Mollusca, stated by Forbes to be due to the freshened state of the water. Both of these cases, relating to what may be called continental seas, bear upon the subject in question, especially since the Rhætic fauna of England is also comparatively poor in genera and species, when compared with the well-developed fauna of Lombardy and other parts of the south and east of Europe.

I now come to a difficult point. It is undoubtedly true in England that the Lower Lias follows the Rhætic beds wherever they go; and though there are symptoms of erosion between them at Penarth and at Curry Rivell, in Somerset*, yet the conformity is, on the whole, so complete, that wherever we meet with the base of the Lower Lias we look for the Rhætic beds below, and as yet we have not been disappointed. The question then arises, how is it that the transition in these areas from the Rhætic to the Liassic forms is so sudden? It is hard to answer this question; but it may perhaps be met by an analogous case. The estuarine and the lagoon beds of the Purbeck and Wealden series commenced in the Oolitic epoch, and ended in the Neocomian or Lower Cretaceous epoch; and the change between the life of the Oolitic and Neocomian and Cretaceous deposits is as great as, and in some respects greater than, that between the Rhætic and Liassic strata; and though the Rhætic beds were not deposited in fresh water, yet, like parts of the Purbeck series, I believe they were formed in shallow water under brackish semi-estuarine conditions which endured for a long period.

In conclusion, I may state that the same kind of reasoning, with differences, applies more or less to other red-coloured and to some calcareous strata of England, including the Permian, Old Red Sandstone, and even the red Cambrian formation. This I hope to treat of in a subsequent memoir. If this idea is true, and if this kind of work be carried out, it must have an important bearing on certain departments of palæontology in a manner already partly indicated by Professor Huxley, and it may throw much light on the distribution of the various forms of animal and vegetable life in time and space. Without it, we must still in great part continue to regard the various formations very much as we might a pack of

in which the beds were being very tranquilly deposited" ("Abnormal Secondary Deposits," Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 470). See this memoir for a great deal of valuable information on these and other deposits. See also memoir by Dr. Wright "On the *Avicula-contorta* beds," Quart. Journ. Geol. Soc. 1860, vol. xvi., and others.

* This kind of erosion was evidently not accompanied by marked unconformity, the result of serious disturbance of the Rhætic beds before the deposition of the ordinary Lias. Estuarine or tidal sea-currents would have been sufficient to produce it when the Lias-sea first came across a slowly sinking area.

cards arranged in order, 1, 2, 3, and so on up to Knave, Queen and King; so that by their marks we should always be able to mention the cards above and below any given number, unless it happened that one or more had been surreptitiously abstracted from their places. The lacustrine, as distinguished from marine formations, do not strictly follow this rule.

Discussion.

Mr. Etheridge thought the question of the nature of the Rhætic beds was to a great extent palæontological. The main point in connexion with them was as to how the British beds were to be connected with those of the Lombardic and Middle European areas. It certainly seemed probable that in this part of the world the conditions of life were different, the deposits being much less in thickness, and the fauna much diminished; and where represented at all the shells occurred in a dwarfed and stunted form. The exact horizon and nature of the Sutton beds had still to be determined.

Mr. Godwin-Austen believed that every mass of red sandstone would ultimately be referred to either a brackish or freshwater origin. A comparison of the ancient and present area of the Caspian Sea would tend to remove any doubt that might remain on the mind of geologists as to the possibility of the existence of such vast internal seas as those which had to be called in to account for these formations. He regretted that former observers had not attached more importance to the duration and extent of those freshwater conditions which were found so commonly to have prevailed between the periods of deposit of the great marine formations. There was another fact to be borne in mind, that even in existing lakes the water at the one end was sometimes completely fresh, and at the other end salt, each of course with a different fauna.

Prof. Rupert Jones said that although there were good grounds for the lake-theory, something might be said for shallow seas. He remarked that sulphate of lime was deposited from sea-water before salt, that oxide of iron might originate from chloride of iron diffused in water whether of lakes or seas, and that the hæmatites of Permian age were probably deposited in the sea. He considered that Foraminifera required great caution when used as criteria, as the varietal forms giving the facies were of more importance than the genera and species. The *Estheriæ* were never marine, although often occurring in plenty in temporary freshwater pools on the seashore. In his monograph of *Estheria* he had said much to substantiate the notion that freshwater conditions often prevailed during the formation of the Keuper. Both in the Old Red Sandstone of the Baltic provinces and in the Lettenkohle and Keuper of Germany, when *Estheria* comes in, *Lingula* dies out. The *repeated* set of formations in the Permian and the Trias precludes their contemporaneity, as supposed by Messrs. Godwin-Austen and Marcou.

Mr. Bauerman remarked that the Hallstatt beds which had been cited as marine contained large deposits of rock-salt.

M. Marcou thought that the difficulties in regarding these beds as of freshwater origin were greater than the author supposed. The absence of fossils in gypsum, though almost universal, was not total. He had himself seen three specimens of *Trigonia* in gypsum from Stuttgart.

Mr. Tate mentioned the discovery by Mr. Burton of marine fossils in the Red Marl, in one instance in combination with vegetable remains. He commented on the sharp demarcation observable in Ireland between the Rhætic beds and the marl below, whereas it was almost impossible to separate them from the Lias above. He doubted, however, whether the true relations of the Rhætic beds were to be worked out in this country. As to the fossils of the Sutton Stone, they were all purely Liassic.

Mr. Burton stated that the fossils from the Red Marl came from a spot about five miles from Retford, in the direction of Gainsborough, but he had not seen them *in situ*. There are, however, no Rhætic beds within some miles.

The Rev. Mr. Winwood, in the absence of Mr. C. Moore, from ill health, inquired whether the author regarded the White Lias as Rhætic, or Liassic.

Prof. Ramsay, in reply, was quite willing to accept marine fossils as coming from the Red Marl. The fact of *Estheria*, a brackish or freshwater form, occurring in certain bands was in favour of his views; as he considered that at intervals the saltness of the water in such a lake as he had suggested must have varied. He could not accept the probability of oxide of iron having been deposited in a large sea-area to such an extent as to colour the sands. All rocks that could be proved to be of marine origin, even when they contained iron, were not stained red unless by infiltration from above. He pointed out that the old area of the Caspian was far larger than the lake in which he had suggested that the New Red Marl had been deposited. If, as was more than probable, there had been during all geological time continental areas somewhat in the same positions as those of the present day, there must have been large areas of inland drainage in which some such deposits as those in question must of necessity have been formed.

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2. *Note on a* Large Reptilian Skull *from* Brooke, Isle of Wight, *probably* Dinosaurian, *and referable to the Genus* Iguanodon. By J. W. Hulke, F.R.S., F.G.S.

[Plate XI.]

It is remarkable that so little is known of the skulls of the Wealden Dinosauria, the more so as their other remains have been procured in some abundance in the south-east of England and the Isle of Wight during the fifty years which have elapsed since Dr. Mantell's discovery of an Iguanodon's tooth in the quarry near Cuckfield. *Hypsilophodon Foxii* is, I believe, the only one the form and a great part of the structure of whose skull are known, and this only recently, from the Rev. W. Fox's unique specimen, first exhibited at the Meeting of the British Association 1868, and described by Prof. Huxley in the 26th vol. of our Journal. Of the skulls of *Iguanodon Mantelli* and *Megalosaurus Bucklandi*, the only parts which have been determined are incomplete mandibles and fragments of maxillæ. The skull of *Hylæosaurus* is still, so far as I can learn, represented by the single small fragment of the base imbedded, at the end of the vertebral column, in the Tilgate-Forest slab, purchased by the British Museum of the late Dr. Mantell, and figured by him in his 'Fossils of the British Museum,' and by Prof. Owen in the 'British Fossil Reptilia;' and the skulls of *Polacanthus Foxii*, *Pelorosaurus*, the *Cetiosauri*, and *Streptospondyli* are altogether unknown.

In August 1865 I saw in the Rev. W. Fox's collection a fossil which he had recently found in Brixton Bay. It was plainly a splendid fragment of what before its mutilation had been a very large skull. A strong impression of its reptilian nature, together with its marked dissimilarity to the skulls of the other orders of this class found in the same formation (Chelonia, Crocodilia, and Pterosauria), led me to assign Mr. Fox's skull to a Dinosaur; and its size pointed to one of the largest, as *Iguanodon Mantelli*.

In September 1869 I myself obtained at Brooke (a locality not far from where Mr. Fox discovered his skull, and one famous for the large number of Dinosaurian remains it has furnished) the hinder part of a skull, which repeated the principal features of that which I had seen in 1865 in Mr. Fox's collection, and which also supplied several parts wanting in his, particularly the occipital condyle, proving my impression of the reptilian nature of his skull to have been well founded.

Knowing Prof. Huxley to have been recently engaged on the osteology of the Dinosauria, I showed him my prize soon after my return to London; and he confirmed my opinion of its probably Dinosaurian nature. A paper upon it from him would have been so valuable that it would have given me the greatest pleasure to have left its description in his hands; but his many and increasing engagements have not allowed this; and, unwilling to withhold any longer from fellow-workers what, I believe, is a distinct addition to the craniology of this interesting order, I now venture myself to bring the skull under your notice. In doing this I am happy to acknowledge my obligations to Prof. Huxley for assistance as valuable as it has been kindly rendered.

The specimen consists of the nearly perfect cranium proper, the facial segment having been broken off across the orbits. The freedom of its outer surface from matrix, its polish, the smoothness of the once rough fractured edges, and the presence of many recent *Serpulæ* upon it show that it had been during a long time lying exposed in the sea before it was thrown upon the shore.

Seen from above (Pl. XI. fig. 3), its outlines are roughly like those of an hourglass, owing to the strong incurve of the temporal regions. The deep temporal fossæ are bounded in front by massive postorbital processes. These in their present abraded state are obtuse four-sided pyramids, the lower side of which looks downwards, and contributed to form the orbit; another side looks backwards, and belongs to the temporal fossa; a third is directed upwards, and forms part of the sinciput; and the fourth, directed forwards, is part of the fractured surface left by the separation of the facial segment of the skull. Behind, the temporal fossæ are limited by the outer and anterior surface of strong, trihedral, divergent, suspensorial processes (*sp*) directed outwards and backwards, from which the quadrate bones depended. The roof of the skull in front is broad and transversely convex, and above the middle of the temporal fossæ it contracts so much that here it might be properly described as crested (*pa*), the sides sloping almost vertically from the mid ridge, with only a slight outward inclination, as low as a horizontal groove running from front to back along the temporal fossa, and marking, perhaps, the meeting of the lower border of the parietal bone with those forming the side-walls of the skull. Behind, the narrow crested part of the roof forks and sends outwards and backwards the usual divergent parietal processes of lacertilian skulls. An obscure serrated transverse line about ·5 inch behind where the facial segment has broken away is, perhaps, the suture between the parietal and principal frontal bone. No parietal foramen is discernible. That part of the parietal bone which roofs the front of the cranial cavity is very dense; it attains a thickness of ·9 inch. The hinder part of the roof is even thicker, but it is much less solid and consists principally of cancellous tissue.

Viewed from behind (fig. 4), the outline of the skull is an inverted triangle. The left suspensorial process, forming the upper and outer angle, on this side is wanting; and the end of the right one (*sp*) is abraded. On the right side the whole of the surface above the foramen magnum is much splintered; but the splinters having become reunited with very little displacement, its form is not much changed. When the floor of the cranial cavity is horizontal, the part of the occipital surface immediately above the level of the foramen magnum looks downwards and backwards, while the greater part of the surface above this looks upwards and backwards, and it makes now an obtuse angle with the sinciput; but as the meeting line of the occiput and sinciput is somewhat crushed in and worn, the angle may originally have been much smaller. This incrushing has been favoured by the presence here of the cancellous tissue already mentioned. The foramen magnum (*f*) is subcordate (in the language of botanists). Its vertical diameter is 1·4 inch, and its transverse one 1·6 inch. Directly above the foramen is a slight mesial swelling, from which a low horizontal ridge is produced outwards. Laterally, below this ridge the surface is gently hollow. The occipital condyle (*ot*) roughly resembles a horseshoe. Its upper surface is deeply grooved. Its transverse slightly exceeds its vertical diameter. It projects considerably behind the general plane of the occiput; and below, at the under surface of the skull, a deep constriction separates it from the parts immediately in front, making it nearly pedunculated.

The base of the skull (fig. 5) offers an extremely irregular surface.

In the middle line, from behind forwards, the basicranial axis exhibits first the under surface of the occipital condyle (*ot*), which is followed by a constriction ·8 long, just mentioned. To this succeed a pair of large, blunt, conical swellings (*bs*), the obtuse summits of which point downwards, outwards, and backwards. They are extensions of the basisphenoid, and they form with the condyle three points on which the skull rests when its base is placed on a flat table, in which position the floor of the cranial cavity is nearly parallel with the plane in which the points lie. Behind, a deep narrow cleft separates the right and left basisphenoidal swellings; in front they join and together form a triangular base, from the front of which ascends a projecting four-sided rod (*bps*), three sides of which are seen at the under surface of the skull, while the fourth is within (in the floor of the cranial cavity). This rod measures at the under surface of the skull 3·9 inches long. It rises obliquely forwards, making with the floor of the cranial cavity an angle of about 40°. Its under surface behind is nearly 1·2 inch broad; it tapers slightly forward, so that at the distance of 2 inches it has diminished ·3 inch. Rather more than the posterior half of this surface of the rod is hollow longitudinally and transversely. In front the hollow contracts, and is followed by a median ridge, of which the base only remains. From the beginning of this ridge forwards the rod rapidly narrows; and here the lower border is fractured, making it probable that there was a thin onward production of bone between the orbits.

Along the sides of this axial rod are arterial and nerve-foramina. The first and second pair of these, reckoned from behind (*c*, *c'*), are respectively the posterior and anterior apertures of a right and left canal tunnelling the basisphenoid and crossing the bottom of the hypophysial fossa, which is the course taken by the internal carotid artery in reptiles. The third pair of foramina (II) are the outlets of two short canals passing forwards and outwards from a transverse depression in the floor of the cranial cavity, situated directly in front of a low transverse ridge, which has the same relation to the hypophysial fossa that the tuberculum has to the sella turcica in the human skull. This transverse depression corresponds, then, to that which in the human skull lodges the optic commissure, and doubtless here subserved the same purpose, the canals continued from it transmitting the optic nerves to the orbit. It follows that the front half of the ascending part of the basicranial axis as it lies between the optic nerves and in front of the tuberculum sellæ contains the presphenoid, the hinder half consisting of the basisphenoid. No traces of the junction of the presphenoid and basisphenoid, nor of this with the basioccipital, are discernible in a longitudinal section of the skull; the sutures which once existed between these originally separate bones have completely disappeared.

At each side of the presphenoid, above the optic canals, in the under surface of the skull is a smooth triangular space, the upper surface of which contributes to form the flat floor of the anterior fossa of the cranial cavity. Its relations show it to be the orbito-sphenoid (fig. 2, *os*). The hinder border of that part of it appearing at the under surface of the skull is bounded by a raised broken edge directed downwards and backwards from the postorbital process towards the basisphenoid. The middle of this edge is crossed by a deep, narrow, horizontal groove continued forwards from a large foramen (v) situated nearly 1 inch behind. This groove may have lodged the ramus ophthalmicus of the 5th cranial nerve. All that part of the broken edge which is above and external to this groove is narrow; it seems to be the remains of the thin bony plate separating the orbit from the temporal fossa; while below and internal to the groove the edge widens into a broad, rough, four-sided mass having mesially and inferiorly the ascending basisphenoidal rod, in front the smooth under surface of the orbito-sphenoid, above the narrow groove for the ophthalmic branch of the 5th nerve, and behind a wide, shallow, vertical groove which descends from the large foramen lately mentioned. This latter, from its great size and its position, can be none other than the aperture which transmits the 5th nerve, the mandibular division of which was probably lodged in the wide shallow groove descending from it. That part of the side wall of the skull which lies in front of this foramen for the 5th nerve, behind the orbito-sphenoid, and which below joins the basisphenoid, must contain the alisphenoid. A narrow channel which ascends immediately behind the wide shallow groove for the mandibular nerve from near the posterior orifice of the carotid canal, and ends in a couple of small foramina nearly at the level of the floor of the cranial cavity, is probably arterial. One inch behind the foramen for the 5th nerve, and at the same level, but separated from it by a buttress, is a depression, at the bottom of which are two openings (fig. 1, VII). These I take to be the auditory fenestræ; and if this view be right, the part of the side wall in front of them, and behind the foramen for the 5th nerve, contains the prootic bone; while behind the auditory fenestræ a buttress ascending from the basis cranii towards the lower border of the suspensorium for the quadrate bone, in front of the exoccipital, has the relations of the opisthotic. In a triangular hollow between this and the exoccipital are the foramina for the 8th and 9th nerves (VIII, IX).

The side walls of the skull behind the foramen for the fifth nerve, corresponding to the hinder half of the temporal fossa, slope outwards more than in front; they project beyond the auditory fenestræ, which they overhang, after the manner of the eaves of a house; and beneath the overhanging eave, and nearly parallel with its outer border, is a wide shallow groove produced from the hollow containing the auditory fenestræ horizontally backwards and outwards to the root of the suspensorial process, which probably lodged the stapes.

The cranial cavity (fig. 2) is long and narrow. Its greatest transverse measurement is in front; and its maximum vertical one is at the middle, nearly above the foramen for the fifth nerve. Two rather broad constrictions divide it into three fossæ. Of these the anterior doubtless lodged the cerebral hemispheres; it opens below into a remarkably large hypophysial pit (*hpf*). The posterior wall of this pit is vertical; it makes a right angle with the floor of the cranial cavity, while the anterior wall slants obliquely forwards. The middle fossa, which is loftier than the anterior, is wider above than below. Assuming it to have lodged the cerebellum and optic tubercles, these dimensions point to a high location of the latter, their position in the reptilian brain. The posterior fossa is the smallest, it has a laterally compressed subcylindrical shape.

It must be borne in mind that in Reptiles we can only approximately deduce the form of the brain from that of the cranial cavity, because, although in this class the brain fills the cranial cavity less incompletely than it does in fish, in which a large interspace exists between the surface of the brain and that of the cranial cavity, yet there is nothing like the coaptation of the brain and its containing chamber which occurs in the higher Vertebrata.

From the foregoing details it will have become apparent that the most striking characteristics of the Wealden skull are :—1, the completeness of the bony brain-case ; 2, the obliteration of the sutures, particularly those of the basicranial axis; 3, its massiveness; 4, the great downward extension of the basisphenoid, with the attendant upward slant of the lower border of the basi-presphenoidal rod.

The completeness of the bony brain-case is an almost unique feature in a reptilian skull, being known only in one other genus, *Dicynodon*. In all other Reptiles the side walls and front of the cranium in advance of the periotic bones are membranous, the ali- and orbito-sphenoid, when present, being rudimentary*. But in this skull well ossified and completely developed ali- and orbito-sphenoids with a presphenoid fill this large space, which in other reptiles remains membranous. The lesser membranous space present between the supraoccipital and parietal bones in some lacertilian skulls (I am not certain whether there is not an indication of it in *Dicynodon*) is also absent from this.

Scarcely less remarkable in a reptilian skull is the disappearance of the sutures, particularly those in the basicranial axis, the rule being that in reptiles the primitive distinctness of the cranial elements persists throughout life. To this rule only two other exceptions are known to me: one of these is the similar skull in Mr. Fox's collection, to which I have referred in the early part of this paper; the other is the singular ornithocephalic reptilian skull discovered by Dr. E. Bunzel, a short description of which was communicated to us last session through Prof. Huxley, who kindly afforded me an opportunity of seeing the original MS. and drawings.

In both these respects (the completeness of the bony brain-case and the disappearance of the sutures) this skull departs from the reptilian type and resembles the ornithic, which is characterized by early obliteration of the sutures and complete ossification. The curious upward slant of the part of the basi-presphenoidal rod visible at the under surface of the skull seemed at first sight to be another ornithic resemblance, the lower edge of the interorbital septum in

* In snakes the side walls of the cranium in front of the periotic bones are formed of downward extensions of the parietal and frontal bones.

Pelecanus having a similar upward slant; but a closer inspection shows that the likeness is not a real one; for in *Pelecanus* the free lower border of the septum, and the floor of the overlying cranial fossa are nearly parallel, the basicranial axis is bent, the front half of it making a large angle with the hinder half of it, while in this Wealden skull the floor of the cranial cavity is nearly straight in its entire extent, and the apparent inclination of the front half of the basicranial axis is caused by the great downward production of the basisphenoidal swellings behind and the bevelling off of the under surface of the basi-presphenoid in front, with a corresponding decrease of its vertical depth forward.

I have already stated my reasons for referring Mr. Fox's skull, and therefore mine, to a Dinosaur; assuming that this opinion is accepted, it remains for me to submit the considerations which lead me to refer it to an *Iguanodon.* I purposely use the indefinite article, because *Iguanodon* is commonly spoken of as if the genus had only one representative, *I. Mantelli,* although the mandibles and also the vertebræ referred to this present variations which make the existence of several species very probable. I wish, however, my reference of the skull to the genus *Iguanodon* to be regarded rather as an attempt awaiting confirmation or correction whenever new and better material for the purpose is discovered. The jaws and teeth, either of which would have determined the reference at once, are lost; and the circumstances of the discovery of the skull deprive us of the presumptive evidence of its nature which its association with other bones might have afforded; so that in seeking for a clue by which to connect it with a particular Dinosaur we are limited to what inferences may be drawn from its gisement, and to what we can learn from the intrinsic features of the skull itself.

As regards the former, the bed from which it came cannot be ascertained; but we know that the locality is rich in remains of *Iguanodon*: and with respect to the latter we find the clue, I think, in the obliteration of the sutures; for these have also appeared to me to be effaced in several mandibles of *Iguanodon* which I have examined.

The loss of the articular end observable in all these has been occasioned by a fracture across the mandible, and not by the dissolution of a sutural union. This is plainly the case in the largest mandible figured by Prof. Owen in his 'British Fossil Reptilia;' and three reptilian mandibular articular bones in the Rev. Mr. Fox's collection, probably of *Iguanodon*, also clearly illustrate this. In other Dinosaurian skulls, or portions of skulls, examined with especial reference to this point, I have found the sutures persistent. They are so in *Hypsilophodon Foxii*, from which this skull is also distinguished by its large size; they persist too in *Scelidosaurus Harrisonii*, of the Lias, and in the Triassic *Belodon*'s skull. Whether they persisted or not in *Megalosaurus* is doubtful; the maxilla, described last session by Prof. Huxley, is not conclusive on this point; but a maxilla of the allied *Teratosaurus*, preserved in the British Museum, proves their persistence in this Saurian. The relative infrequency of Megalosaurian remains in the Isle of Wight (I state this on the authority of a verbal communication from Mr. Fox) renders it less probable that the skull belonged to this Dinosaur than to an *Iguanodon*. In the ornithocephalic skull of *Struthiosaurus*, Bunzel, the sutures also disappear; but its broad rounded occiput, its large downward slanting paroccipital processes (shown in the figures accompanying Dr. Bunzel's description), and the absence of the basisphenoidal swellings so conspicuous in my Wealden skull completely distinguish it from this.

EXPLANATION OF PLATE XI.

Supposed skull of Iguanodon, *from Brooke, Isle of Wight.*

Fig. 1. View of right side of the skull.
Fig. 2. View of interior of the same.
Fig. 3. View of upper surface of the skull.
Fig. 4. View of posterior surface.
Fig. 5. View of under surface: *pa*, parietal crest; *t*, temporal fossa; *sp*, suspensorial process; *ot*, occipital tuberosity; *bs*, basisphenoid; *bps*, basipresphenoid; *os*, orbitosphenoid; *hpf*, hypophysial fossa; *f*, foramen magnum; *c*, posterior opening of carotid canal; *c'*, anterior opening of same; II, V, VII, VIII, IX, foramina of the respective pairs of nerves.

Discussion.

Prof. Huxley congratulated the Society on the progress being made in our knowledge of this interesting group of Reptiles and of their ornithic affinities.

Mr. Seeley remarked on the similarity of the internal cavity of the skull to that of *Ichthyosaurus*. Some of the external characteristics differed much from what he was acquainted with in other Dinosaurian skulls, which, in the base of the skull, more closely resembled those of ordinary lizards. He considered that the affinities of Dinosaurs hitherto demonstrated were in the direction of *Teleosaurus*, from which the position of what were supposed to be the optic lobes in this skull materially differed in being more reptilian. On the whole, from its want of similarity to *Hypsilophodon*, he was not prepared to accept this skull as that of an *Iguanodon*, and thought that some doubt attached to its affiliation with the Dinosaurs.

Mr. Hulke briefly replied, and observed that he had limited his speculations to those which legitimately arose from the facts before him.

De Wilde lith

M & N. Hanhart imp.

REPTILIAN SKULL FROM BROOKE

February 8, 1871.

The following communications were read:—

1. *On the* Punfield Formation. By John W. Judd, Esq., F.G.S., of the Geological Survey of England.

Contents.

I. Introduction.

The existing scheme of classification of geological formations is in the main founded on the study of *marine* strata only. The circumstance that rocks of freshwater and terrestrial origin occupy much smaller areas than those of marine character, doubtless in part accounts for this result, which, however, is to a much greater extent attributable to the fact that the fossils of the former class of strata are much less numerous and less strikingly characterized than those of the latter. With the progress of geological research and its gradual extension over wider areas, the necessity for successive enlargements and modifications of our scale of geological periods has from time to time become manifest. The conclusion, so strongly insisted upon by Mr. Darwin and Professor Ramsay, that unconformities between strata indicate the lapse of enormous periods of time, is being constantly confirmed by the discovery, as fresh districts come under investigation, or old ones are more accurately studied, of formations which more or less completely represent these "breaks." Not less important in its bearing upon geological theory is the fact that old and well-known formations, as they are studied at points more and more remote from the typical district, exhibit new characters, and evidence of having been deposited under widely dissimilar conditions. Thus marine formations are found, not only to exhibit all the variations consequent on changes from littoral to deep-sea conditions, but even to pass into or alternate with freshwater and terrestrial strata and *vice versâ*. So far have discoveries of this kind already advanced, that we shall not be going too far in stating that, in the case of the Mesozoic rocks at least, there is no great thickness of marine strata with the terrestrial and freshwater equivalents of which we are altogether unacquainted.

While treating of the peculiarities of the fauna of the period which lies upon the confines of the Palæozoic and Mesozoic epochs, Professor Huxley has been led to remark that it will ultimately be necessary for geologists to establish two parallel but distinct schemes of classification for strata of different origin, since the breaks between the marine systems do not correspond with those between the freshwater and terrestrial. It is nevertheless clear that the occurrence of terrestrial and freshwater fossils in marine strata (into which they have been carried down), the existence of certain organized beings (as some fish) which live indifferently either in salt or fresh water, the circumstance of the gradual passage between or alternation of freshwater and marine strata, together with the facts of their sequence and the nature of their physical relations, will afford data for correlating, with more or less accuracy, the two schemes of classification. Regarded from this point of view those strata which are of *fluvio-marine* origin, and yield at the same time marine, freshwater, and terrestrial fossils, are of special interest and value to the geologist. One of the most remarkable formations of this character I propose to describe in the present paper.

The first example of a great system of strata of freshwater origin which was clearly recognized by geologists, was the Wealden, the nature of which was demonstrated by Dr. Mantell in 1822. Its exact correlation with the marine formations has, up to the present time, been the subject of frequent controversy; but recent discoveries in France, England, Spain, and Germany have furnished us with many of the data requisite for arriving at definite conclusions upon the subject. In a short sketch read before the British Association at its last Meeting I attempted to show how perfectly the inferences with regard to the age of the Wealden-Purbeck to which we are led by the study of its marine fossils, accord with those drawn from an examination of its physical relations to the great marine systems. From both kinds of evidence I have endeavoured to establish the following propositions:—

1. The deposition of the Wealden strata of the south of England commenced before the close of the Oolitic period; it continued during the whole of the Tithonian, and of the Lower and Middle Neocomian, and only came to an end at the commencement of the Upper Neocomian.

2. The deposition of Wealden strata did not extend to the north of France until the latter portion of the period, and the beds in this area are greatly diminished in thickness, while they alternate with

and, in some cases, are subordinate to marine strata of Neocomian age.

3. The Wealden of northern Germany is the deposit of a different river from that which formed the Wealden of England and France; and the period of its formation, while it commenced at the same epoch, was of much shorter duration, coming to a conclusion before the end of the Lower Neocomian.

In this memoir I propose to describe in detail some of the observations on which these conclusions are founded. Other portions of the evidence I am compelled to defer to a future period, the present state of affairs in France having prevented me from making certain investigations essential to the completion of the subject.

At the *base* of the great freshwater system of the Wealden there is found a series of beds with *fluvio-marine* characters, constituting the well-known "Purbeck Formation." At the *top* of the Wealden there occurs another series of strata of similar character, less known, it is true, but not less interesting and important, for which I propose the name of the "Punfield Formation." These two series of beds, consisting of finely laminated clays, sands, and limestones, while they present many points of resemblance to one another, are very distinct both in mineral character and the nature of their fossils from the purely freshwater and generally brightly coloured beds of the Wealden proper, as well as from the truly marine beds of the Oolite and Neocomian. The Purbeck formation is shown by its stratigraphical relations, and the fossil contents of its marine beds, to have very close relations with the Oolitic System. The Punfield formation is, on similar evidence, clearly referable to a portion of the Neocomian System. In both the Purbeck and Punfield formations, we find evidence of the alternation of freshwater, brackish-water, and marine conditions: while the former affords proof of the gradual transition of the marine beds of the Upper Oolites into the freshwater strata of the Wealden, the latter as clearly indicates the equally gradual return of marine conditions, which, at the termination of the Wealden period, ushered in the Upper Neocomian.

These several formations occur in unbroken sequence as follows:—

Upper Neocomian ("Lower Greensand")	*marine.*
Punfield Formation	*fluvio-marine.*
Wealden	*freshwater.*
Purbeck Formation	*fluvio-marine.*
Upper Oolite	*marine.*

II. Bibliography of the Subject.

Although no special mention of the strata which I am about to describe is found in the earliest memoir (that of Webster*) on the Wealden and Purbeck of the Isle of Wight and Dorsetshire, some of their peculiarities have long been known to local collectors, who have named the more fossiliferous portions the "oyster-beds" and

* Letters in Sir Henry Englefield's 'Isle of Wight' (Trans. Geol. Soc. Ser. 2, vol. ii. p. 37).

"cone-beds." They were certainly known to Dr. Mantell; and specimens of their fossils have long been preserved in local museums.

The strata and their remarkable fossils were casually alluded to by Dr. Fitton in 1836, though their great importance was not at that time recognized*.

It is to Mr. Godwin-Austen, who in the year 1850 laid before this Society a collection of the fossils of Punfield, that geologists are indebted for first calling attention to the great interest attaching to these remarkable beds. The collection excited at the time much notice, and Professor Edward Forbes, then engaged in the preparation of a memoir on the Wealden-Purbeck, which he unfortunately did not live to complete, pronounced that the fauna of these beds (which he recognized as being clearly intercalated in the Wealden series), while it had an undoubtedly Neocomian aspect, included a number of new species, and several forms for which a new genus would have to be created. As we shall see in the sequel, the views of Professor Forbes have been completely substantiated by the labours of subsequent observers.

In his Anniversary Address before this Society in 1851, Sir Charles Lyell made special reference to the remarkable beds at Punfield, and their bearing upon geological theory†; and in all the subsequent editions of his 'Elements of Geology' he has alluded to the subject as one of great importance ‡.

In the Rev. John Austin's little memoir on the Isle of Purbeck, the beds are briefly described §.

Mr. Godwin-Austen, in his celebrated paper "On the possible Extension of the Coal-Measures beneath the South-Eastern part of England" ||, read in May 1855, again referred to the Punfield beds, and founded some arguments on their existence.

In the same year (1855) appeared the Geological Survey map of the Isle of Purbeck, the work of Mr. Bristow, upon which a note points out the existence of marine beds in the upper part of the Wealden, and gives a list of some of the genera of fossils represented ¶.

Mr. Godwin-Austen presented his collection of Punfield fossils to the Museum of Practical Geology, where it was supplemented by the specimens obtained by Professor Edward Forbes and the collectors of the Survey. Mr. Etheridge, fully recognizing the great value and importance of these fossils, not only caused them to be carefully preserved, but, as several of them were of a perishable nature, had careful drawings of them made by Mr. Bone, the Artist to the Survey. Being engaged in the study of the fossils of this age, I some time ago examined this series of fossils, and to my surprise

* Trans. Geol. Soc. Ser. 2, vol. iv. pp. 207 and 228.

† Quart. Journ. Geol. Soc. vol. vii. p. lix.

‡ Manual of Geology, 3rd ed. p. 229 (and all subsequent editions).

§ A Guide to the Geology of the Isle of Purbeck &c., by the Rev John H. Austin, p. 7.

|| Quart. Journ. Geol. Soc. vol. xii. p. 66.

¶ Map of the Geological Survey of England and Wales, Sheet 16.

and delight recognized in them the fauna of the coal-bearing beds of Utrillas, in eastern Spain, which has of late years been made known to us by the works of Vilanova, de Verneuil, Coquand, Collomb, and de Lorière. I should, perhaps, mention that in 1850 no description of these Spanish beds had, so far as I know, appeared.

Believing the subject one worthy of careful study, I have devoted my attention to it for some time past, and embody the results in the present memoir. In the execution of my task I have been furnished with much valuable information and advice by Sir C. Lyell, Mr. Godwin-Austen, Mr. Hulke (who in 1866 examined the beds and made a collection from them), Mr. Wilcox, of Wareham, and my colleagues Messrs. Etheridge, Bristow, and Whitaker.

At the late Meeting of the British Association, I gave a general *résumé* of the subject; and in the recently published work, 'Student's Elements of Geology,' Sir C. Lyell has referred to the beds and figured one of their most characteristic fossils.

III. Sections in the Isle of Purbeck.

At the northern part of Swanage Bay, and immediately below the great chalk ridge of Ballard Down, is a little recess in the cliffs called Punfield Cove (fig 1)*. It is at this point that we find the most interesting exposure of the strata which I propose to describe. Regarding this, therefore, as a typical section, and deriving the name of the formation from the locality, I proceed in the first instance to give a detailed account of the succession of beds at this point.

1. *Punfield Cove.* The strata seen here, in descending order (the whole being nearly vertical), are :—

(1) Upper Chalk with Flints.
(2) Lower Chalk without Flints.
(3) Chalk Marl.
(4) Upper Greensand, with a poor representative of the Gault Clay towards its lower part, the whole being about 100 feet thick.
(5) A representative of the "Lower Greensand," consisting of grey clays alternating with ferruginous sandy beds, generally destitute of fossils, but yielding *Exogyra sinuata*, Sow., and *Panopæa neocomiensis*, d'Orb. The formation is not more than 60 feet thick, and thus exhibits a great diminution from its equivalent in the Isle of Wight. This result is partly due to thinning out, and partly to overlap.

Immediately below we find the series of fluvio-marine beds, which I propose to include in the Punfield formation (see vertical sections, fig. 2) :—

A. Dark blue, finely laminated shales, in part cypridiferous, with thin bands of limestone made up of *Cyrena*, *Ostrea*, &c., and fibrous carbonate of lime ("beef" or "bacon"), like that of the Purbecks. According to Mr. Godwin-Austen these beds are only a few feet thick. At the present time they are completely hidden by the débris from the beds above, and I have never yet had an opportunity of seeing them *in situ*. They appear, however, to resemble in

* See also Sir Henry Englefield's 'Isle of Wight' (1816), plate 29, no. 1.

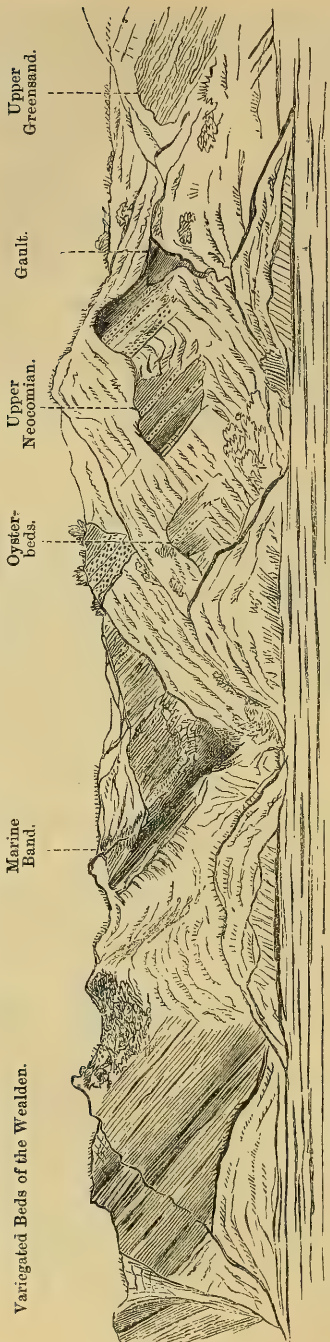


Fig. 1.—*Section exposed in Punfield Cove.*

every respect the beds which are so well developed on the same horizon in the Isle of Wight; and the following fossils are recorded from them by Dr. Fitton.

Cypridea tuberculata, *Sow.*, sp.
—— valdensis, *Sow.*, sp.
Melanopsis attenuata, *Sow.*, sp.
—— tricarinata, *Sow.*, sp.
Cyrena media, *Sow.*, sp.
—— membranacea, *Sow.*, sp.
Cardium ?, sp.
Ostrea, sp.

These beds have been regarded by some geologists as the greatly attenuated representative of the Weald Clay.

B. A series of more or less ferruginous sands passing downwards into interlaminated sands and clays with some seams of lignite, and containing in its middle portion several bands of ferrugineo-calcareous rock, with oysters and other marine shells. This series of beds, which is about 153 feet thick, greatly resembles, in many of its characters, portions of the Bagshot series and of the Northampton Sand. It was in these beds that Professor John Phillips obtained the fossil fruit which he described before this Society in 1858 *.

The *oyster-beds* cannot be conveniently examined *in situ*, as they are exposed in a very inaccessible part of the cliff; but facilities for collecting their fossils are afforded by the great slipped masses which lie lower down and nearer the shore. They consist of sandy ironstones, in places becoming calcareous from the abundance of oysters and other shells, and appear to be very irregular in

* Quart. Journ. Geol. Soc. vol. xv. p. 46.

Fig. 2. *Section of the Punfield Formation, N. side of Swanage Bay.*

Scale 1 in. to 20 ft.

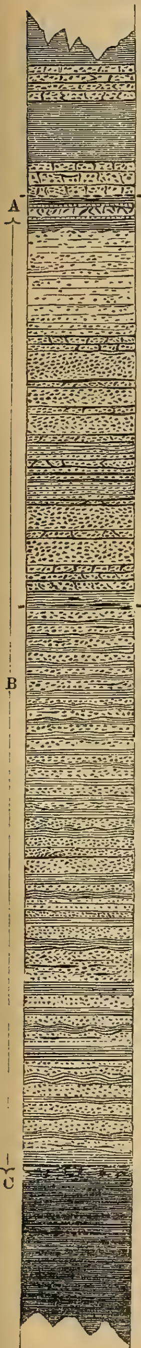
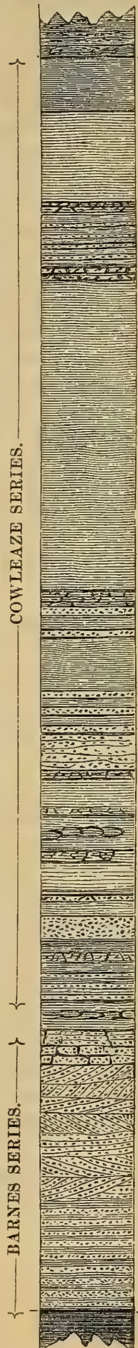


Fig. 3. *Section of the Punfield Formation in the Isle of Wight.*

Scale 1 in. to 20 ft.



their mode of occurrence. Sometimes we find a thick ferruginous rock, the bedding-planes of which are covered with thin layers of oysters; at other times a hard blue-hearted calcareous rock, emitting a fetid odour under the hammer, and almost wholly made up of oysters and other marine shells. The oyster-beds usually contain a large quantity of carbonaceous matter, and in places, indeed, pass into what might be called impure lignite. The thickest of them measures about four feet, and it contains several interstratified bands of clay, which, like the similar beds below, contain many small oysters scattered through it.

The fossils of these oyster-beds appear to be for the most part *marine*. By far the most abundant are two species of oysters, one plain, the other plicated. A careful comparison of a large series of these convinces me that they are dwarfed forms of *Exoyyra sinuata* Sow., and *E. Boussingaultii*, D'Orb. Almost all the shells found in these beds appear to be stunted in their growth, probably from having lived under unfavourable conditions. No specimens of Ammonites have been obtained from these beds, and only one small and doubtful example of a *Vicarya*. The following are the fossils hitherto obtained from the oyster-beds of Punfield.

Exogyra sinuata, *Sow.* (very abundant)
—— Boussingaultii, *D'Orb.* (very abundant).
Pecten, sp. (very small).
Cardium subhillanum, *Leym.* (rather rare).
Corbula striatula, *Sow.* (abundant).
Anomia lævigata, *Sow.* (abundant).
Modiola giffreana, *Pict. et Roux* (rare).

Several small univalves.
Much carbonized wood.

In the same part of the series as the oyster-beds there occurs a bed of Sandstone containing *Cyprides* and casts of *Cyrena*.

C. "*The Marine Band of Punfield.*" This bed, though only 21 inches thick, is of the greatest interest, presenting us as it does with a very considerable marine fauna, and thus furnishing the means of correlating this portion of the Wealden with the series of marine formations. It forms a well-marked feature in the cliff at Punfield Cove, dipping due N. at an angle of 65°. In its general characters it is very similar to the oyster-beds above. The oysters in this bed, which are of the same species as those in the oyster-beds (*Exogyra sinuata* and *E. Boussingaultii*), attain however to a larger size, and approach more nearly to their normal forms than in the latter beds. The specimens of *Corbula striatula* and *Cardium subhillanum* likewise attain to larger dimensions. But besides the shells which occur in the oyster-beds, we find in this band many which are much more decidedly marine, including *Ammonites Deshayesii*, several forms belonging to the new genus *Vicarya*, and species of *Trochus, Natica, Actæon, Actæonella, Orthostoma, Pholadomya*, &c.

The *upper* part of the marine band consists of a hard laminated micaceous sandstone, more or less calcareous, containing much carbonaceous matter and sometimes becoming perfectly black and resembling an impure lignite. This portion of the bed contains but few shells, and passes by insensible gradations into the interlaminated sands and clays above.

The *middle* portion of the marine band is almost wholly made up of oyster-shells, with a few dwarfed specimens of *Corbula, Cyrena* (?), and *Cardium*. Like the upper portion it contains very much carbonaceous matter. I have not obtained from this portion any specimens of *Ammonites* or *Vicarya*.

The *lowest* portion of the marine band to the thickness of 6 or 8 inches is a hard, more or less ferruginous, very shelly limestone of a blue colour, weathering brown at the joints, and containing numerous pebbles or concretions composed of argillaceous limestone. This bed of hard limestone is traversed by some irregular seams of hard blue clay or shale; it contains comparatively little carbonaceous matter, but yields *Ammonites, Vicarya*, and other marine shells. The oysters in this portion of the marine band are sometimes large and approach very closely to their typical forms*.

Almost immediately underlying the marine band are the variegated Wealden Clays and Sands, which in Swanage Bay attain probably to a thickness of nearly 2000 feet, and yield, so far as I know, only the remains of freshwater and terrestrial forms of life.

The following fossils have been obtained from the marine bands of Punfield†.

Teeth of Lamna, sp.
—— Pycnodus, sp.
Ammonites Deshayesii, *Leym.*
Vicarya pizcuetana, *Vilanova*, sp.
—— Lujani, *De Verneuil et Collomb.*
—— Pradoi, *De Verneuil et De Lorière.*
Cerithium Vilanovæ, *De Verneuil et De Lorière.*
—— Pailleti, *De Verneuil et De Lorière.*
Turritella Tournali, *H. Coquand.*
Pleurotoma Utrillasi, *De Verneuil et De Lorière.*
Fusus (?) neocomiensis, *D'Orb.*
Actæon Esqueræ, *De Verneuil et De Lorière.*
—— pradoana, *De Verneuil et De Lorière.*
Actæonella oliviformis, *H. Coquand.*
Trochus Esqueræ, *De Verneuil et De Lorière.*
Natica lævigata, *Desh.*, sp.
—— pradoana, *Vilanova.*
Neritopsis minima, *De Verneuil et De Lorière.*
Orthostoma Verneuili, *Vilanova*, sp.
Exogyra Boussingaulti, *D'Orb.*
—— sinuata, *Sow.* (dwarfed).
Anomia lævigata, *Sow.*
Plicatula asperrima, *D'Orb.*
Perna Rauliniana, *Pictet et Roux.*
Modiola giffreana, *Pictet et Roux.*
Arca cymodoce, *H. Coquand* (young).
Arca, sp.
Cardium subhillanum, *Leym.*
—— impressum, *Desh.*
Astarte, sp.
Isocardia nasuta, *H. Coquand.*
——, sp.
Leda scaphoides, *Pictet et Campiche.*
Tellina? gibba, *H. Coquand.*
Corbula striatula, *Sow.*
Pholadomya semicostata, *Ag.*
Pholadidea (borings).
Serpula.
Numerous small univalves and bivalves, fragmentary and undeterminable.
Much wood and carbonaceous matter.

* Mr. Etheridge is engaged in the preparation of descriptions of those fossils of the Punfield formation which are new to this country.

† Since the reading of this paper, Mr. C. J. A. Meyer, F.G.S., informs me

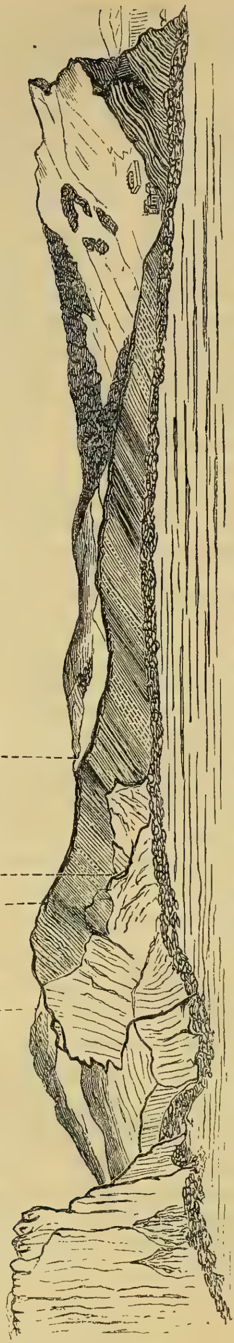


Fig. 4.—*Section exposed in Worborrow Bay.*

2. *Worborrow Bay.* I have not been able to find any inland sections in the Isle of Purbeck which throw light on the Punfield formation. But at the western end of the peninsula, in the cliffs of Worborrow Bay, 11 miles distant from Swanage Bay, we find another exposure of these beds. At this place the Chalk, Chalk-marl, Upper Greensand, and Gault present the same characters as in Punfield Cove, and, as there, are inclined at a high angle (fig. 3) *.

The Upper Neocomian ("Lower Greensand") is represented by about 40 feet of clays, sands, and ironstones. From these beds I obtained a fine specimen of the highly characteristic *Panopæa neocomiensis.*

The Punfield formation is here about 65 feet thick. No trace of the blue clays with limestone bands oyster-beds and "beef" is found in its upper part; but its whole thickness is composed of interlaminated clays and sands, with lignite and bands of ironstone containing a few apparently marine shells. At the base is a very distinctly marked bed of ironstone of a dark reddish-brown colour, containing casts of shells, which were recognized by Prof. Edward Forbes as marine. The presence of this bed is recorded in a note on the Map of the Geological Survey. The general succession of the Punfield-beds at Worborrow Bay is as follows:—

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that he has examined the Punfield section and found a single specimen of the genus *Arca*, the species being indeterminable, some feet below the Marine Band. This discovery is interesting as a fresh proof of the gradual nature of the change from freshwater to marine conditions.

* See also Sir Henry Englefield's 'Isle of Wight,' Plate 37, No. 1.

a. Beds of light-coloured sometimes pinkish sand, in places interlaminated with bands of clay. They contain much carbonaceous matter, seams of lignite and nodules of pyrites..	about 30 ft.
b. Beds of grey and whitish laminated clay (with much lignite in places) and bands of nodular ironstone. These ironstones contain casts of shells, very imperfectly preserved, including *Ostrea*, *Cardium*, *Corbula*, and *Cerithium*. I regard these as the equivalent of the "oyster-beds of Punfield."	30 to 40 ft.
c. Thin well-marked band of ironstone, very hard and dark-coloured, only a few inches thick. This bed is in places crowded with vegetable markings, and contains casts of marine shells. This bed rests directly upon the variegated beds of the Wealden, and seems to represent the "marine band of Punfield."	

3. *Mewps Bay.* At this place, which is $1\frac{1}{2}$ mile W. of Worborrow Bay, the very diminished representative of the Upper Neocomian ("Lower Greensand") is faulted against the variegated beds of the Wealden. The same is the case in Bacon Hole a little farther west.

4. *Lulworth Cove.* This section is about one mile west of the former. On the eastern side we find lying directly upon the variegated beds grey clays with ferruginous bands containing much wood and vegetable matter, and also a few casts of shells, none of which are determinable. There appears to be here no trace of the Upper Neocomian (Lower Greensand), which is probably either quite overlapped by the overlying Cretaceous beds, or has altogether thinned out.

IV. Sections in the Isle of Wight.

The nearest Isle-of-Wight section of the Wealden strata, that of Compton Bay, is situated thirty miles due east of Punfield Cove. As, however, the clearest exhibition of the representatives of the Punfield formation is that in Brixton Bay, a little to the west of Atherfield Point, I propose in the first place to describe this in some detail, and then to point out in what respects the sections of Compton Bay and Sandown Bay differ from it.

Considerable diversity of opinion has existed among geologists with regard to the correlation of the Wealden beds of the Isle-of-Wight with those of the Weald-area of Kent, Surrey and Sussex. While Dr. Fitton * regards the upper grey shales and limestones as representative of the Weald Clay, and the sands and variegated beds below, as equivalent to the Hastings Sand, Mr. Bristow † considers the whole of the Isle-of-Wight series referable to the former subdivision, and believes that the latter is not represented in the island. The manner in which the Wealden beds thin out rapidly, or change their mineral character laterally within short distances, will always render any attempt at correlating their sub-

* Trans. Geol. Soc. Ser. 2, vol. iv. p. 184, *et seq.*

† Memoirs of the Geological Survey, Geology of the Isle of Wight (1862), p. 8.

divisions over a considerable area a very doubtful and difficult task. In the present paper I propose to include in the Punfield formation those beds at the top of the series which present the same mineralogical characters as the typical beds of Punfield Cove, and which, like them, show signs of *fluvio-marine* origin in their intercalated bands of marine shells. The great mass of variegated strata containing only *freshwater* and *terrestrial* fossils I regard as the Wealden proper.

1. *Brixton Bay.* The Punfield strata are seen here between Atherfield Point and Barnes High. They are well illustrated in the detailed section of Professor E. Forbes and Mr. H. W. Bristow *. Their junction with the overlying "Perna-beds of the Upper Neocomian" is fully described by Dr. Fitton, who had a favourable opportunity for observing it in 1847 †; this junction is now concealed. The Punfield strata of the Isle of Wight, which attain a thickness of 230 feet, fall naturally into two groups, which, for the sake of convenience in description, I have distinguished by local names (see vertical section, fig. 3).

A. *The Cowleaze Series,* consisting of dark grey, blue, or green cypridiferous shales and clays, with indurated sandy ferruginous and argillaceous bands, and thin beds of limestone crowded with shells, *Paludina, Cyrena, Cerithium, Melanopsis, Unio,* &c. "Beef," or fibrous carbonate of lime, occurs abundantly in these limestones, which not unfrequently contain marine shells, and are sometimes quite made up of small oysters, when they exactly resemble the well-known "Cinder-bed" of the Purbeck series. It is evident that the Cowleaze series was deposited under conditions very similar to those which prevailed during the formation of the Purbecks. While, however, in the latter the clays are subordinate to the limestones, in the former the limestones are much less developed than the clays. The thickness of the Cowleaze series is about 180 feet; and the best exposure of it is in Cowleaze Chine, where nearly 100 feet of its lower portion is exhibited in a clear section. The Cowleaze beds contain in places plant-remains; and in some of the bands teeth and scales of fish are very abundant. Among the *marine* shells occur *Exogyra sinuata* and *E. Boussingaultii,* both much dwarfed, also *Modiola* (two species), *Cardium,* and *Cerithium.* I am not aware that any Ammonites have been found in these beds in Brixton Bay, though an undoubted specimen was obtained from them at Red Cliff in Sandown Bay. The limestone bands of the Cowleaze series are used locally, like those of the Purbecks, for rough paving.

B. *The Barnes Series.* These beds rise from the shore at Cowleaze Chine, and crop out at the surface at Barnes High. Owing to the superior hardness of their upper beds they make a very marked feature and can easily be traced inland through the island. While

* Memoirs of the Geological Survey, Geology of the Isle of Wight (1862), plate 2. fig. 2.

† Proc. Geol. Soc. vol. iv. p. 198; Quart. Journ. Geol. Soc. vol. iii. p. 293.

in the Cowleaze series the argillaceous element preponderates, the Barnes beds are in great part composed of sand or sandstone, with subordinate bands of clay. The following is the succession of beds in Brixton Bay.

(*a*) Very hard greenish-white sandstone, with many nodules and veins of pyrites; shells numerous in its upper part	1 to 2 feet.
(*b*) Less hard coarse greenish sandstone forming a ledge above the beds below	4 to 6 feet.
(*c*) Yellow false-bedded sand slightly ferruginous in its upper part, carbonaceous in places	25 to 30 feet.
(*d*) The lower portion of the last graduates downwards into interlaminated sands and grey micaceous sandy clays...	15 feet.
(*e*) Yellow and white sands	3 feet

These beds rest on the ordinary variegated strata of the Wealden, which are exposed to a thickness of from 300 to 400 feet; but their base is not visible in the Isle of Wight.

The sandy beds of the Barnes series usually contain but few shells. The top band of sandstone exhibits *Cyrena* and *Unio* in abundance, but, owing to the hardness of the matrix and the decomposed condition of the shells, the fossils are very difficult of extraction. In places the beds contain much carbonaceous matter, with seams of lignite and masses of wood converted into jet or pyrites. One band has yielded marine shells, including oysters, *Cardium*, casts of *Trigonia*, and several univalves. The beds of the Barnes series have furnished to local collectors a rich harvest of reptilian bones *.

It seems not improbable that the thin beds (A) at the top of the section in Punfield Cove represent, in a very attenuated condition, the Cowleaze series of the Isle of Wight, while the beds below (B and C), are an expanded form of the Barnes series.

2. *Compton Bay.* The Punfield strata are here highly inclined, and are broken up by several faults, They are well illustrated in the section of Professor Forbes and Mr. Bristow †. The Cowleaze series, with its *Cyrena*- and *Paludina*-limestones and "beef" and "cinder" beds, is well exposed. Besides the two species of oyster, the marine bands yield *Panopœa plicata*, Sow. (small), *Serpulæ*, and numerous fish-scales. The beds, being repeated on the shore by a fault, afford great facilities for the collection of their fossils. The Barnes series presents its usual sandy characters, and is about 50 feet thick. It contains several beds with plants and insects; but I did not here observe any marine bands in it.

3. *Sandown Bay.* On the south-west side of this bay the Punfield beds are quite concealed, forming low ground covered by vegetation; but on the north-east side of the bay, below the Red Cliff, the strata in question are well exposed. By a recent slip in the cliff the junction of the Upper Neocomian and Wealden is well exposed (1870), and yields the following section.

* Quart. Journ. Geol. Soc. vol. xxvi. p. 3.

† Memoirs of the Geological Survey, Geology of the Isle of Wight, plate 2. fig. 1.

(*a*) Atherfield Clay. Grey clay with usual characters ...	4 to 5 feet seen.
(*b*) *Perna*-beds with usual characters, but more weathered than at Atherfield, and of a brown instead of a green colour; consisting of the following divisions:—	
α. Hard brown sandstone (fossils very abundant). Perna Mulleti, *Desh.* Exogyra sinuata, *Sow.* Gervillia anceps, *Desh.* Panopæa plicata, *Sow.* Modiola. Pecten, sp. Trigonia aliformis, *Park.* Thickness rather irregular but	about 2 feet.
(This bed passes gradually into)	
β. Greenish-grey sandy clay with many fossils	nearly 4 feet.
γ. Bed similar to α, with *Ancyloceras* and other shells (passing in its lower part into greenish-grey sandy clay, and so into)	1 foot.
(*c*) Blue paper-shales of the Wealden	9 inches.
(*d*) —— light-coloured and pyritic..............................	1 foot.
(*e*) Dark-coloured paper shales (with *Cypridea valdensis*) and several layers of nodular ironstone	4 feet?
(*f*) "Beef" 1 inch .... Limestone crowded with *Cyrena* and a few oysters, 6 inches .... "Beef" 2 to 3 inches....................................	9 inches.
(*g*) Finely laminated pyritic clay...............................	9 inches.
(*h*) Ferruginous band almost entirely made up of shells (oysters and small univales)	3 inches.
(*k*) Other beds of dark blue laminated shales, with occasional beds of limestone, imperfectly exposed ...	between 30 to 40 feet seen.

The total thickness of the Cowleaze series cannot be exactly measured in Sandown Bay. In the marine bands I found *Exogyra sinuata*, Sow., *E. Boussingaultii*, D'Orb., *Corbula striatula*, Sow., *Cardium subhillanum*, Leym., with vertebræ and teeth of fish (*Lepidotus*, &c.), and plant-remains. In one of the "Cinder" beds at this place Dr. Fitton found an imperfect but undoubted specimen of an *Ammonites* *, and I have myself obtained what appears to be a fragment of *Ammonites Deshayesii*, Leym. The yellow sands of the Barnes series are seen in Sandown Bay, and where they come to the surface form a well-marked escarpment, that on which Yaverland Fort is built. Here, however, the beds are not favourably situated for examination.

V. Sections in the Weald of Sussex, Surrey, and Kent.

The Wealden strata of this area, presenting few exposures in sea-cliffs, are not so well known as those of the Isle of Wight and Dorsetshire; but there are not wanting indications that, like these latter, they graduate upwards through fluvio-marine beds into the Upper Neocomian, which everywhere *conformably* overlies them.

1. *Leith Hill.* In the Museum of this Society there is a series of fossils from Leith Hill, near Guildford, accompanied by a section in which the marine beds at the base of the "Lower Greensand" are

* Trans. Geol. Soc. 2nd Ser. vol. iv. p. 190.

represented as alternating with freshwater beds full of *Paludinæ* and other Wealden fossils. This series of fossils was presented to the Society by D. D. Heath, Esq.

2. *Hythe.* At this place Mr. Mackeson discovered, about 30 feet below the top of the Weald Clay, beds of limestone crowded with oysters *; and similar beds in a like position have been noticed by Mr. Simms and other observers †.

VI. Relations of the Punfield Formation to the Wealden, Neocomian, and Cretaceous of the South of England.

1. *Unconformity between the Cretaceous and Neocomian.*—We are indebted to the late Captain Ibbetson for first clearly demonstrating the existence of an unconformity between the Cretaceous proper and the Neocomian in the South of England ‡. By a series of careful trigonometrical observations he showed that, while the Chalk, Upper Greensand, and Gault beds in the south of the Isle of Wight are nearly horizontal, the Neocomian and Wealden dip to the east at an angle of about 2°. The effects of this unconformity are most striking, the beds of Cretaceous age overlapping in succession all the beds of the Oolite and Lias, and resting, in Devonshire, on the New Red. The same effect of overlap through unconformity was, at an earlier date, demonstrated in Yorkshire by the labours of Smith and Phillips; and I have shown that the same phenomenon is exhibited in Lincolnshire. The work of the Geological Survey has proved that a similar overlap of the Cretaceous occurs all round the Weald, and throughout the Midland district, so far as the survey has been carried. Every geologist is familiar with the fact that the same phenomenon of unconformity is exhibited between the Cretaceous and Neocomian strata of France and Switzerland. Professor Ramsay has shown from Mr. Etheridge's Tables that this unconformity is accompanied by a very great change between the faunas of the two series of strata §.

2. *Variation in character of the Cretaceous in proceeding from East to West.*—That the Upper Cretaceous does not terminate downwards with the "junction-bed" at the base of the Gault Clay has been noticed by several geologists, who have shown that the sands immediately below that clay contain characteristic species of Gault *Ammonites*. That the same is true of the corresponding beds on the east side of the Paris basin, is shown by the able researches of M. Cornuel, in the department of the Haute Marne ‖. As the base of the true Cretaceous and the top of the Neocomian are thus alike composed of sands which are usually very unfossiliferous, it often becomes a question of great difficulty where the boundary

* Mem. of Geol. Survey, Geology of country between Folkestone and Rye, by F. Drew (1864), p. 6.

† Proc. Geol. Soc. vol. iv. p. 208.

‡ Quart. Journ. Geol. Soc. vol. iii. p. 315.

§ Quart. Journ. Geol. Soc. vol. xx. p. 58.

‖ Bull. de la Soc. Géol. de France, 2e sér. tome. xvii. p. 743; Wiltshire, Quart. Journ. Geol. Soc. vol. xxiv. p. 483, in Discussion.

between them should be drawn. Mr. Godwin-Austen has remarked on the close connexion between the Upper Greensand and the Gault, and is inclined to consider their differences due rather to the *conditions* than to the *time* of deposition. Probably we should be near the truth in representing the Upper Greensand and Gault as one formation, with arenaceous characters prevailing in its lower part, and inconstant and irregularly developed beds of clay in its midst. In Kent these beds of clay are thick, well defined, and sharply separated from the sands above and below; but in the Isle of Wight they are much less strikingly characterized; and as we proceed eastward they thin out and finally disappear in the neighbourhood of White Nore, in Dorsetshire. Thus in the Blackdown beds of Devonshire we have the representatives of the sands above the Gault Clay and those below it brought together, a fact which may account for the anomalous character of the fauna of those beds. It is not, however, improbable that these western portions of the Cretaceous series, like certain similar deposits in the north-west of France, may be of somewhat earlier date than those of the east of England, though continuous with them, and may thus represent the latter part of that great period which must have elapsed between the Neocomian and the Cretaceous. It must be remembered, however, that the *Ammonites* of the Blackdown beds are nearly all well-known Gault species. My friend Dr. Lycett informs me, too, that the supposed correspondence betwen the *Trigoniæ* of the Blackdown beds and those of the Neocomian breaks down on a careful and critical examination of the specimens. It is not improbable that some other of the supposed anomalies of the fauna of the Blackdown beds would also disappear on a more careful examination of the fossils.

3. *Thinning-out westward of the Neocomian and Wealden.*—Nothing can be more striking than the great difference between the thickness of the beds which lie between the Chalk and the Portland in Swanage Bay, and in the section of Man-of-War's Cove and Durdle Cove. This effect is, as we have already seen, partly due to overlap; but in a much greater degree it is owing to the tendency which all these beds have to thin away towards the west. From the very detailed sections published by the Geological Survey * (the work of Messrs. Bristow, Whitaker, and the Rev. O. Fisher), and from my measurements, the accompanying Table has been constructed, which shows in what a very marked manner this attenuation of all the beds towards the west takes place. Of this general tendency the Punfield formation partakes. Mr. Whitaker has recently shown that the lower beds of the Chalk exhibit a similar thinning-out towards the west.

4. *Relation of the Purbeck to the Wealden.*—At the only points where the junction of the Purbeck and Wealden is clearly seen, namely in Worborrow Bay and Mewps Bay, the marls with *Paludinæ*, which form the top of the Purbeck, are seen to pass, by

* Geological Survey in England and Wales, Horizontal Sections, Sheet 56, and Vertical Sections, Sheet 22.

	t side of orth Cove.		Man-of-War Cove.	Ridgeway.	
"LOWER GREEN	feet bsent		feet absent	feet absent	
PUNFIELD FORI	bsent		absent	absent	
WEALDEN	462		172	?	
		in.		ft.	in.
Paludina-Clays	8?		......	5	10
Upper Cypris-Cla	6	7	......	26	4
Unio-Beds	5	2	......	9	7
Upper Broken Sh	3	9	......	10	6
Total Upper	**4**	**6**	......	**52**	**3**
Chief Beef Beds	8	2	......	4	4
Corbula-Beds ...	5	11	......	18	6
Scallop-Beds ...	1	10	......	......	
Intermarine	7	5	......	7	5
Cinder Bed	4	0	......	5	2
Cherty Freshwate	5	9	......	5	6
Marly Freshwater	....		......	6	8
Total Middle	**3**	**1**	......	**47**	**7**
Marly Freshwater	2	3	......	4	3
(Upper Insect-Be	....		......	5	0
Soft Cockle-Beds	8	7	......	27	7
Hard Cockle-Beds	4	7	......	8	11
(Lower Insect-Be	....		......	5	9
Cypris-Freestones	1	10	......	26	7
Broken Bands ...	0	0	......	9	3
Soft Cap	4	6	......	} 6	8
Hard Cap	4	6	......		
Total Lower	**5**	**3**	......	**94**	**0**
PURBECK FORM	3	10	100?	193	10
WEALDEN-PURBE	646		272	......	

Table illustrating the thinning-out Westward of the Neocomian and Wealden Strata.

	Atherfield.	Compton Bay.	Swanage Bay.	Worborrow Bay.	Mewps Bay.	East side of Lulworth Cove.	Man-of-War Cove.	Ridgeway.
	feet	feet	feet	feet	feet	feet	feet	feet
"LOWER GREENSAND"	**802**	**500?**	**45?**	**36**	absent	absent	absent	absent
PUNFIELD FORMATION....................	230	200	160	65	?	absent	absent	absent
WEALDEN	unknown	unknown	1800	725	660	462	172	?
			ft. in.	ft. in.	ft. in.	ft. in.		ft. in.
Paludina-Clays	......	......	18?	13?	11 0	8?	......	5 10
Upper Cypris-Clays and Shales	......	......	47 10	36 9	28 11	16 7	......	26 4
Unio-Beds	......	......	4 9	16 6	8 0	6 2	......	9 7
Upper Broken Shell Limestone	......	......	10 0	7 0	4 3	3 9	......	10 6
Total Upper Purbeck	......	......	**80 7**	**73 3**	**52 2**	**34 6**	......	**52 3**
Chief Beef Beds	......	......	30 0	13 10	6 6	8 2	......	4 4
Corbula-Beds	......	......	33 0	39 9	22 7	15 11	......	18 6
Scallop-Beds	......	......	4 6	2 9	2 4	1 10	......	......
Intermarine	......	......	46 0	8 0	8 7	7 5	......	7 5
Cinder Bed	......	......	8 6	5 6	4 0	4 0	......	5 2
Cherty Freshwater	......	......	28 6	18 3	5 7	5 9	......	5 6
Marly Freshwater	......	......	5 2	1 0	....	....	......	6 8
Total Middle Purbeck	......	......	**155 8**	**89 1**	**49 7**	**43 1**	......	**47 7**
Marly Freshwater	......	......	7 10	12 3	8 0	12 3	......	4 3
(Upper Insect-Beds)	......	......	......	......	....	....	......	5 0
Soft Cockle-Beds	......	......	82 0	62 7	58 8	38 7	......	27 7
Hard Cockle-Beds	......	......	10 0	24 6	24 4	14 7	......	8 11
(Lower Insect-Beds)	......	......	......	......	....	....	......	5 9
Cypris-Freestones	......	......	36 3	26 5	19 10	21 10	......	26 7
Broken Bands	......	......	15 0	14 0	15 0	10 0	......	9 3
Soft Cap	......	......	7 6	5 6	7 8	4 6	......	} 6 8
Hard Cap	......	......	11 3	6 3	17 7	4 6	......	
Total Lower Purbeck	......	......	**169 10**	**151 6**	**151 1**	**106 3**	......	**94 0**
PURBECK FORMATION	......	......	406 1	313 10	252 10	183 10	100?	193 10
WEALDEN-PURBECK	......	......	2366	1104	913	646	272	......

insensible gradations, into the variegated clays and sands of the Wealden. The same is described as taking place in the section (now concealed) of the Ridgway Cutting by the Rev. Osmond Fisher *. It is true that Professor Forbes pointed out that, if we compare the shells of the Purbeck with those of the Wealden, we shall find very few species that are common to both. When, however, we consider the fact that the great majority of the Mollusca and Entomostraca which are regarded as typical of the Wealden have been obtained *only from the higher portions of the series*, the fact will be seen to have but little significance. As is well known, the Purbeck (like the Punfield series) includes certain beds which are of a decidedly marine character and contain shells undistinguishable from common Oolitic species, with an Echinoderm (*Hemicidaris purbeckensis*, Forbes) which, though not occurring in the marine series of this country, is found in the Upper Oolite of the Jura. Not only is the passage of the Portland into the Purbecks a gradual one in the typical country of these formations, but, as Mr. Godwin-Austen has shown, we find at Swindon Purbeck beds actually alternating with the Portland rocks †.

As no break has ever been shown to exist in the succession of Wealden beds in the south of England, we are compelled to conclude that they represent the whole of the vast interval between the Upper Oolite and the Upper Neocomian.

VII. Foreign Equivalents of the Punfield Formation.

1. *"Urgonien" and "Rhodanien" of France, Switzerland, &c.*—That the strata known as "Lower Greensand" in England represent the "Aptien" or upper division of the great Neocomian system of Continental authors has long been recognized by geologists. The very careful study of the fossils of the different portions of the Neocomian by Pictet, Renevier, and other palæontologists has established this correlation in the most satisfactory manner. The beds of white limestone, crowded with shells of the order *Rudistes* (*Chama*, *Anomia*, &c.), and with corals, which constitute the "Urgonien" of D'Orbigny, and are so widely distributed in Southern Europe, have everywhere been recognized, both on stratigraphical and palæontological grounds, as constituting the *middle* portion of the Neocomian system. In the year 1854 M. Renevier, of Lausanne, who has devoted so large a portion of his studies, with the most valuable results, to the beds of this age, showed that between the "Aptien" and "Urgonien" another series of beds with a distinctive fauna was recognizable, for which he proposed the name of "Rhodanien"‡. To this subformation M. Renevier, after a careful personal examination of the strata and their fossils, assigned the "Perna-beds," "Atherfield clay," and "Crackers" of the Isle of Wight, and the well-known "Couche rouge" of Wassy, in the Department of the

* Trans. Cambr. Phil. Soc. vol. ix.
† Quart. Journ. Geol. Soc. vol. vi. p. 464 *et seq.*
‡ Bull. de la Soc. Géol. de France, 2me sér. tome xii. p. 89.

Haute-Marne. Still later M. Lory showed that the relations between the *Rhodanien* and the *Urgonien* were quite as close as those between the former and the *Aptien*. As we thus appear to have in the *Rhodanien* a complete link between the Upper and Middle Neocomian, the boundary between these divisions becomes a perfectly arbitrary one, and great diversity of opinion exists among geologists to which of them certain deposits should be assigned. Among those strata which lie upon the debatable confines of the Upper and Middle Neocomian, we must class the Punfield Formation. But though there may be diversity of opinion as to the artificial scheme of classification best adapted for grouping these strata, their true relative position in the Neocomian series is on palæontological evidence perfectly clear. *Ammonites Deshayesii*, which occurs in the Marine Band of Punfield, is a very widely distributed species and has a restricted and well-defined vertical range, abounding in the higher portions of the Neocomian, but being unknown in the *Urgonien* or any lower bed. *Vicarya Lujani* and several other of the Punfield shells are well-known and characteristic *Rhodanien* forms. All the palæontological evidence points to the confines of the Upper and Middle Neocomian as the true place of the Punfield formation; and it will, I think, be in accordance with the views of a majority of the geologists of authority on this subject to regard the "Perna-beds" as the base of the *Upper* Neocomian, and the Punfield beds as the highest part of the *Middle* Neocomian.

2. *Coal-bearing Strata of Eastern Spain.*—It is, however, in the Spanish peninsula that we find the closest analogues of the Punfield Formation. These beds have, during the last twenty years, been made known to us by the admirable researches of MM. Vilanova, de Verneuil, Collomb, de Lorière, and Coquand. As no description of these beds has yet appeared in this country, it may be of interest to notice briefly their chief features in this place. The recently published very valuable memoir of M. Coquand enables us to do this the more readily*.

The principal exposures of the deposits in question are situated on the confines of the ancient kingdoms of Arragon and Valencia, in the provinces of Teruel and Castellon de la Plana, though less important and outlying masses of the same strata occur in the valley of the Guadalupe and in Catalonia, near the mouth of the Ebro.

In the province of Teruel, where they form three important productive coal-basins, those of Utrillas, Gargallo, and of the Val d'Ariño, the strata, which are more than 1600 feet thick, are divisible into three series, which, however, pass into one another

* De Verneuil et Collomb. Bull. Soc. Géol. de France, 2e sér. tome x. (1853).
Vilanova. Memoria Geognostica (1859).
H. Coquand. Mém. de l'étage Aptien de l'Espagne (1865).
De Verneuil et De Lorière. Fossiles d'Utrillas (1868).
De Verneuil et Collomb. Carte géologique de l'Espagne et du Portugal (Paris 1864).
H. Coquand. Description géologique de la formation crétacée de la province de Teruel. Bull. Soc. Géol. de France, 2me sér. tome xxiv. p. 144 (1868).

by insensible gradations, and contain a considerable number of fossils in common.

The *lowest* of these consists of alternations of limestones, sandstones, and marls, yielding a large series of fossils, by means of which it is referred without doubt to the *Urgonien.* Its thickness is about 500 feet; and it rests indifferently (the *Lower* Neocomian being absent) on all the older rocks. In the Utrillas basin this division contains only jet, but in other districts it furnishes beds of coal. It is in these that the mines of Santa Barbara and la Fuen Gargallo are worked.

The *second* series, consisting of ferruginous sandstones and limestones alternating with sandy clays, is that which contains the same fossils as the Marine Band of Punfield. These beds, although their fauna presents some peculiarities, are doubtless to be referred to the highest portion of the Middle Neocomian. At Utrillas, where they attain a thickness of 530 feet, they contain ten beds of coal, lignite, or jet, which are extensively worked. It is these beds which constitute the *Calcaire à Trigonies* of M. de Verneuil. The fauna of these beds seems to be especially characterized by the presence in great abundance of Gasteropods of a new genus, which has already unfortunately received four names (*Cerithium*, *Omphalia*, *Cassiope*, and *Vicarya*). No less than six species of this genus have been described from Utrillas, three of which occur at Punfield, and one of them in the "Rhodanien" of Switzerland. It is remarkable that there is scarcely a single fossil found in the Marine bed of Punfield which does not also occur in these Spanish beds.

The *third* and highest of these series of Spanish rocks consists of variegated and mottled clays and sands of bright colours (crimson, grey, green, violet, and white), which greatly resemble the Keuper, and were, indeed, long mistaken for it. They are probably in great part of freshwater origin, though a few marine shells have been found in them, which enable us to refer the series to the Upper Neocomian. Their lower portion consists of dark-coloured clays with a pyritous combustible mineral, formerly used for the manufacture of alum. This series, which is 600 feet thick, contains beds of lignite, which are worked in many places. It is overlain by strata representing the Gault and other members of the Cretaceous.

These coal-basins of Eastern Spain have been estimated as being capable of supplying the whole of the peninsula for more than 200 years.

VIII. Conclusion.

The grounds on which I have ventured to suggest that the strata, the nature and relations of which I have endeavoured to illustrate in the preceding pages, are worthy to rank as an independent formation* are as follows:—

* The term "formation" is unfortunately employed by English geologists with two very different significations—either to indicate great groups of strata like the "Silurian" or "Jurassic," or for smaller divisions, like the "Ludlow series," or the "Great Oolite." It is with the latter meaning only I have

1. They present very distinct mineralogical characters, separating them alike from the overlying Neocomian and the subjacent Wealden proper.

2. They are of considerable thickness, attaining a maximum of 230 feet.

3. They present evidence of having been deposited under conditions differing alike from those of the marine Neocomian above and the purely freshwater Wealden below.

4. They yield a considerable marine fauna (between 30 and 40 species being already known), which is remarkably distinct and well characterized.

5. They are the undoubted representatives of a formation which in Spain attains to a vast thickness, and which, alike from its marked palæontological characters and its great economic value, is of great importance.

6. Their relations to the Wealden and Neocomian are precisely analogous to those of the Purbeck formation to the Oolite and Wealden; and they are therefore equally deserving with it of a distinctive title.

At the same time I have endeavoured to show that these beds may be regarded indifferently either as the highest member of the Wealden in our classification of the series of terrestrial strata, or as a portion of the Neocomian in our grouping of the marine series. The application to them of a distinctive name is therefore, although a necessary, perhaps only a provisional expedient; but the same is to a greater or less extent true of most of our geological terms.

Discussion.

The President remarked that the limited amount of freshwater formations in this country was an obstacle to their correlation, and stated that Constant Prévost had endeavoured to correlate the Secondary freshwater and marine formations.

Mr. Godwin-Austen remarked upon the thinning out of the Lower Greensand, especially in France, upon the imperfection of our knowledge of the great Cretaceous formation, and upon the probability of the intercalation of freshwater conditions in the Lower Greensand. The formation at Punfield seemed to present an intercalation of marine between purely freshwater conditions. He indicated how a slight change of level might have intercalated marine conditions in the Wealden. The deposition of the White Chalk and Oolite occupied enormous periods (in both cases purely marine), during which the northern hemisphere was a great northern ocean; and as the distribution of land and water was due to the operation of great cosmical laws, the duration of terrestrial and of the intermediate freshwater conditions was probably of equal length.

Mr. Etheridge observed that out of sixty or seventy species

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employed the word in this paper, the term "system" being applied to the greater groups of strata.

from the deposits in Eastern Spain we have thirty-nine or forty in Britain. The fauna was, indeed, precisely the same. He referred to several of the species, and intimated his intention of describing and figuring those forms which have not been detected in the Spanish deposits.

Mr. Seeley stated that he could not agree with Mr. Judd in his conclusions, and that he objected to the method adopted by him. He had examined all the sections, and was convinced that they showed neither a physical nor a palæontological break, and that the several beds could be so well traced that the base of the section at Swanage was superior to that seen in the section at Brixton, in the Isle of Wight. He identified the shell noticed as a *Vicarya* as a Greensand form. There was nothing in the fossils to indicate a separation from the Lower Greensand, of which he regarded these beds palæontologically as forming a part. Each division was to be traced westwards continuously, but changing in mineral character. Mr. Seeley objected to the correlation of these deposits with others occurring in Spain or any other distant locality, and considered the community of fossils not sufficient to establish such a correlation. He objected also to the introduction of a new term into geological nomenclature.

Mr. Jenkins remarked on the value of Mr. Judd's description of the sections, even if his deductions were to be rejected. He regarded the establishment of a Punfield formation as unnecessary, and cited the Purbeck and Portland beds as examples of analogous freshwater and marine deposits. He indicated that the Weald may be regarded as the freshwater equivalent of the Lower Neocomian. He doubted whether the shell referred to *Vicarya* really belonged to that genus. *Ammonites Deshayesii* was said to have a restricted range in time. Mr. Jenkins remarked that it was very widely diffused, and therefore should have a wide range in time, which would invalidate the argument founded on it.

The Rev. O. Fisher stated that in 1853 he had observed a fault cutting off the Gault from the Punfield beds, and that its position might account for the disappearance of a great mass of Lower Greensand.

Mr. Judd, in reply, said that he did not propose the term Punfield formation as a definitive term, but only as a matter of convenience. He believed that strata could be positively identified by the organic remains contained in them, although the method may have been grossly abused. Physical investigations *alone* led to nothing but confusion, as might be seen by the stratigraphical attempts of the predecessors of William Smith. The name *Vicarya* for the shell which had been referred to was only provisionally adopted, on the authority of De Verneuil and other writers.

2. *Some* Remarks *on the* Denudation *of the* Oolites *of the* Bath District, *with a* Theory *on the* Denudation of Oolites *generally*. By W. Stephen Mitchell, Esq., M.A., LL.B., F.G.S., of Gonville and Caius College, Cambridge.

[Abridged.]

The theory commonly held as to the origin of the Oolite hills of this country is, that the strata of which they are composed were originally deposited in sheets continuous over large areas, that the valleys are *entirely* the result of denudation, which has left the intervening masses standing out as hills, and that it is generally possible to recognize on opposite sides of a valley at the different horizons the individual beds which were formerly continuous across that valley. The author believed that the following theory had equal claims to credence:—

That the sedimentary deposits of any particular Oolitic district were probably originally deposited in continuous beds, but that the limestones in many instances probably never extended beyond the areas they now occupy.

The object of the paper was to show that the Bath district was one of these instances; and the following were the chief points brought under the notice of the Society.

In the Bath district, while the beds of the Great Oolite limestone are for the most part approximately horizontal over the plateaux of the downs, they *thin out* at the edges of the hills. Mr. Sanders in his map of the district has marked the few Oolite hills which come within the map as *everywhere dipping towards the valleys.*

There is no evidence here of a washing away of the underlying Fuller's Earth, and a consequent drop of the limestone, as is suggested by Mr. Witchell to be the case in the Cotteswolds*. The Fuller's Earth might be scooped away for many feet under the limestone before the latter would move. When it did move, it would probably break off and slip or roll down the hill-slope. Here the thinning out is the same when other beds of the limestone underlie; there is no displacement from the general mass. [It is just possible that they may be cases of false bedding, with the layers that were above them swept away; but the author could not see by what agency this would be effected.]

To explain this thinning out, the probable origin of the beds was taken into consideration.

I. *The limestones.*—The commonly received view that the material of the Great and of the Inferior Oolite was accumulated by corals was supported by quotations from Jukes's 'Voyage of the Fly,' and Darwin's 'Voyage of the Beagle.' Recent coral-reefs are described as consisting of "rock fine-grained, only here and there exhibiting any organic structure." They show lamination and a jointed structure; and the bedding round the edges of an island *dips towards the sea.*

* Proceedings of the Cotteswold Nat. Club, 1867.

The structure of the rock varies, being compact, granular, or Oolitic limestone, or loose calcareous sand. Many of these masses are described as "intersected by narrow channels of deep water."

II. *The sedimentary beds.*—These were considered in reference to the influence their accumulation would have on the accumulation of the coral-masses. Many causes will from time to time change both the rate of accumulation and the extent of the area over which the sedimentary accumulation will take place. If such accumulation take place in the same sea with coral-growth, a turbid condition of water may alternately encroach on and recede from the coral-area. These occasional irruptions would then temporarily interfere with the coral-growth. In the case of the permanent encroachment of sediment on a district of coral islands and reefs, *the contour of the gradually depressed islands would be protected by the sediment,* which would also fill in the deep channels between them.

These considerations, it was suggested, may serve to explain the "dip towards the valley" as mapped by Mr. Sanders, or "the thinning out," which is believed by the author to occur. The hills were probably coral islands submerged, and covered up by sedimentary matter. When the whole area, after subsequent elevation, became subject to denudation, the yielding sedimentary matter being swept away left the limestone islands standing as hills.

This naturally leads to the question whether the limestones themselves have suffered denudation. The author thought there can have been but little, if any. He considered *first* the *mechanical* action of water. He pointed out that the Great Oolite is traversed by numerous vertical joints and fissures, which split it up into what may be roughly termed cubical blocks. The surfaces of the joints are generally covered with crystalline carbonate of lime. The rain falling on the plateaux would at once percolate through the surface-soil and "heading," and would pass off in the fissures. There would thus be no accumulation of water, therefore no body of water in motion, therefore no mechanical denudation. Élie de Beaumont's suggestion, set forth in 1843 in his 'Leçons de Géologie pratique,' that where there is no mechanical denudation, there must be accumulation of vegetable soil, has not been objected to in principle, though the extreme lengths to which he carried the idea have been attacked. It is most probable that a protective covering of vegetable mould has everywhere covered these Oolitic hills.

Secondly. With regard to *chemical* denudation, as each block is bounded above and below by a parting of clay, and on its four sides by crystalline carbonate of lime, the author could not see how chemical denudation could take place except in an accidental way.

These remarks apply to the Great Oolite. The Inferior Oolite in this district nowhere forms the summit of a hill; it is only to be seen in sections on the sides of the hills. If it also was formed in detached islands, some of the original edges of these islands may be still hidden from our view by sedimentary matter preserved from denudation by the Great Oolite above; its origin must be dealt with in a locality where it forms the tops of the hills. It may, however, happen that the edges, or one of the edges, of an Inferior-Oolite island may be coincident in position with a Great-Oolite island above.

There remains the question of the meaning of finding on opposite sides of a valley zones containing assemblages of similar organic remains. The author believed that this in no way bears on the question of the original continuity or otherwise of the two sides. If there are beneath the sea two spots (*a* and *b*) near together, having exactly similar conditions for life, the assemblage of forms at both places might be the same, whether *a* and *b* are separated by a channel or not.

In conclusion, the author remarked that, though he had arrived at this idea inductively, yet he believed it would be fair to start with the statement that coral islands when covered up would retain their contour; and it would rest with those who insist on continuous limestone-beds *in all cases* to show why the islands with deep channels between them *must* have been broken up and spread out as a continuous sheet before the sedimentary deposit was accumulated on them. He also expressed his belief that the present view commonly held affords a correct explanation of the phenomena of Oolite valleys in many cases.

Discussion.

Prof. Morris did not consider that the author's views as to the oolitic masses round Bath being originally isolated coral banks with clay beds, although suggestive, were quite satisfactory. He pointed out that the strata on each side the valleys were similar in structure, mineral character, and fossil contents, and were once continuous; and the present intervening deep valleys were rather due to the movements which the area had undergone in producing lines of weak resistance, subsequently assisted by the erosive action of percolating and running water, both in excavating and undermining the harder rocks, so as to cause them to bend towards the hill-sides, or fall in larger or smaller masses on their slopes.

Mr. Seeley thought that Mr. Mitchell was justified in applying considerations drawn from the formation of coral islands to the elucidation of the phenomena under discussion. He maintained that shallow-water limestones must always occur in isolated masses with intervening masses of clay, and that the clay might be washed out, leaving the limestone as hills.

Mr. Whitaker held that when like beds cropped out on the tops or flanks of opposing hills it was a logical inference that the said beds had once spread across the space between, and that there was no need to call in the agency of supposed coral islands to explain the occurrence of isolated masses of limestone, which were perfectly accounted for by denudation, an agency that involved no supposition, and was quite equal to the work.

Mr. Etheridge remarked that the mollusca of the outliers of the Oolites in the Severn Valley were constant in beds at the same relative level. He also referred to the sliding of the oolitic strata of the Cotteswolds upon the subjacent clays as accounting for the dip towards the valleys mentioned by the author. He considered that the valleys had been scooped out by denudation.

The President inquired whether the author was provided with any sections showing the thinning-out of the beds.

Mr. Mitchell, in reply, stated that he had seen both sides of what he regarded as coral reefs. He remarked that his hypothesis had been arrived at by induction, but that the question might be put strongly in a deductive form, by inferring from observations on existing coral reefs that those of the Oolites must have been covered up as islands. He remarked that if the oolitic beds had slipped, as described, upon the underlying clays, they could hardly range on opposite sides of the valleys. He pointed out that the action of water in covering the blocks of Oolite with crystallized carbonate of lime would be protective, and remarked, in reply to Mr. Etheridge, that the surface of the reefs whilst under water was virtually a sea-bottom on which mollusca lived, so that their occurrence at corresponding levels in different hills was not to be wondered at.

February 22, 1871.

John Thornton Harrison, Esq., C.E., 3 Park Place Villas, Maida Hill, and 1 Victoria Chambers, Westminster, and M. Hawkins Johnson, Esq., 379 Euston Road, N.W., were elected Fellows of the Society.

The following communications were read:—

1. *On supposed Borings of* Lithodomous Mollusca. By Sir W. C. Trevelyan, Bart., M.A., F.R.S.E., F.S.A., F.G.S.

[Abstract.]

The author referred to Mr. Mackintosh's paper on perforations supposed to be made by lithodomous Mollusca * in the limestone of Lancashire and elsewhere, and stated that from his examination of specimens in the Society's museum, and of examples of these perforations *in situ*, he was convinced that they are the work of some of the common terrestrial Mollusca, as maintained by him long ago in Jameson's Edinburgh Journal †. He confirmed Mr. Jeffreys's objection to the assumption that these perforations were made by marine Mollusca, founded on the form of the perforations and their range in height, and remarked that length of time is so essential an element in their production that their formation is not likely to be observed even in old quarries.

The author, in conclusion, referred to some remarks made by Mr. Mackintosh ‡ on the "terminal curvature of slaty laminæ" ob-

* Quart. Journ. Geol. Soc. 1869, vol. xxv. p. 280; Geol. Mag. vol. iv. p. 295; and 'Scenery of England and Wales,' pp. 288–398.

† Vol. xl. p. 396.

‡ Quart. Journ. Geol. Soc. 1867, vol. xxiii. p. 323.

served by him in West Somersetshire in 1866, and stated that in 1849 he had himself called attention * to the marks of glacial action shown in the terminal curvatures of slaty rocks in Forfarshire, and suggested that they were to be explained by the progression of a thick covering of ice along the edges of the slaty beds.

Discussion.

Mr. Gwyn Jeffreys read extracts from the Rev. Mr. Hodgson's 'History of Northumberland' (published in 1827), in which these borings in limestone were referred to the action of snails. Mr. Jeffreys considered the foot to be the sole instrument employed by the boring Mollusca in excavating their burrows. He exhibited specimens of Lias from Lyme Regis perforated by *Pholas*, and of hard limestone from Malta perforated by *Lithodomus*, and remarked, in connexion with the notion that asperities on the shell might be boring agents, that the shell of *Lithodomus* is perfectly smooth.

Prof. Ramsay mentioned that he had seen *Helices* taken out of these holes at Tenby by Dr. Buckland, who believed that the snails effected the perforations by the agency of an acid.

Mr. Charlesworth thought that if so much uncertainty could prevail upon such a subject, it threw great doubt upon some of the grandest generalizations of geology. He referred to the evidence connected with the glaciation of the Great Orme's Head, in which the origin of the perforations under discussion was of much importance, Mr. Darbishire maintaining that they were the work of *Pholades*, while Mr. Bonney asserted that they were produced by snails. In the same way the origin of the celebrated borings in the Temple of Jupiter Serapis might be disputed, and the generalization founded upon it rendered doubtful. Mr. Charlesworth noticed the necessarily small proportion of borers to the whole snail-population of Britain, and remarked especially upon the absence of perforations in the chalk districts. He considered that repeated observations were necessary before this snail-engineering could be admitted, and suggested a systematic course of experiments.

Mr. Boyd Dawkins suggested that the carbonic acid exhaled by snails in respiration might act upon limestones, and remarked that chalk weathers too rapidly to preserve the excavations.

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2. *On the probable Cause, Date, and Duration of the* Glacial Epoch *of* Geology. By Lieut.-Col. Drayson, R.A., F.R.A.S.

(Communicated by Alfred Tylor, Esq., F.G.S.)

[Abstract.]

After referring to the evidence of the occurrence of a Glacial Epoch, and to the various hypotheses which have been proposed to

* Jameson's Edinburgh Journal, vol. xlvi. p. 377.

account for it, the author brought forward the following considerations:—

Of the three principal movements of the earth, namely its daily rotation on its axis, its revolution round the sun, and the slow conical movement of its axis of rotation round the poles of the ecliptic, the third is, in the author's opinion, the cause of glacial epochs. The angular distance of the pole of the ecliptic and the pole of the heavens is at all times the exact measure of the obliquity of the ecliptic, or the extent of the Arctic circle upon the earth. There is evidence that during the last 2000 years these two poles have gradually decreased their angular distance, so that, while the pole of the heavens moves round some curve at the rate of about 1° in seventy-two years, it approaches the pole of the ecliptic at a variable rate, at present about 46″ in a century. The author had calculated from the recorded positions of the pole of the heavens during the last 2000 years, the curve traced by this pole with relation to the pole of the ecliptic. He found it to be a circle, the centre of which is 6° from the pole of the ecliptic, and 29° 25′ 47″ from that of the heavens.

Taking this curve as a guide, the author finds that 2000 years ago the angular distance of the two poles was about 24°, giving a climate scarcely different from that now prevailing. 4000 years ago the angular distance would be about 29°, when the climates of high northern and southern latitudes would present much greater seasonal changes than at present; and these changes would go on increasing back to the year 13,000 B.C., at which period the distance between the two poles would be greatest, namely 35° 25′ 47″. This would bring the arctic circle down to latitude 54° 35′ N., that is to a line passing south of Moscow, just north of Berlin, north of Amsterdam, nearly through the middle of Great Britain, and then through Labrador and British Columbia. All the countries north of these places would be subjected to arctic conditions; and these would prevail with even more severity than at present in the winter, whilst from the greater elevation attained by the sun in summer that season would be much hotter than at present, the summer of the lower arctic latitudes being even tropical in its intensity. These extreme changes of climate would prevail, according to the author, during a period of about 15,000 years; that is to say, commencing about 21,000 years ago, the climate would become more and more extreme up to about 15,000 years ago, and then gradually more and more equable to about 6000 years ago.

Discussion.

Prof. Ramsay inquired whether the author's theory involved the recurrence of glacial epochs, and whether he considered the course of the described phenomena to be constant in early astronomical epochs.

Rev. Osmond Fisher inquired whether the curve was founded on observed facts, or whether it was obtained from physical considerations. He also asked whether the line representing the change in the direction of the pole formed a reentering curve, and whether the theory would account for the climate of Greenland in Miocene times. He suggested changes in the form of the earth which must have affected the direction of its axis.

The PRESIDENT remarked upon the difficulty that arose from astronomical theories differing so much among themselves. He referred particularly to Adhémar's theory, and remarked that the difficulty connected with it is, that it invokes a recurrent cause, which must produce similar effects every 21,000 years, whilst there is very little evidence of glacial action during the whole long period of the Tertiary epoch.

The AUTHOR, in reply, stated that he could not go back beyond 30,000 years, but that he thought glacial conditions must recur. He had not astronomical data beyond 2500 years; and these were very vague. The motion would be the same in kind, but uncertain in degree. His theory was based entirely upon observed facts. In laying down the curve, he considered it safe to go as far as the semicircle, as he had observations covering 40°; but he could not say whether the curve would be a reentering one, although it showed a tendency that way, and would certainly be very nearly so. With regard to the change of climate of Greenland, as evidenced by its Miocene flora, he was not sufficiently versed in botany to pronounce an opinion. He remarked, in conclusion, that the distance of the earth from the sun did not seem to affect the climate of the Southern Hemisphere, and stated that Venus is at present suffering under a most severe glacial epoch.

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3. *On* ALLOPHANE *and an* ALLIED MINERAL *found at* NORTHAMPTON. By W. DOUGLAS HERMAN, Esq., Student of the Royal College of Chemistry.

(Communicated by W. W. Smyth, Esq., F.R.S., V.P.G.S.)

THE only English localities at which, to my knowledge, allophane has been shown to occur are the chalk-pits at Charlton, near Woolwich, the Purley downs, near Croydon, and a spot not far from Tavistock, in Devonshire. Dr. Charles Berrill, however, shortly before his death, discovered a mineral much resembling the Charlton allophane in physical properties in a pit opened in the ironstones of the Northampton Sand (beds of Inferior-Oolite age) in the grounds of the Northampton General Lunatic Asylum. It occurs as an amorphous, translucent, somewhat hard and exceedingly brittle mineral, of a yellowish colour inclining to red, and incrusting the surface of a sandstone rock.

The following analyses of a specimen of this mineral presented by Mr. Sharp, of Dallington, to the Museum of Practical Geology fully bear out, I think, its claim to be called allophane. I append, for the sake of comparison, Mr. A. B. Northcote's analysis of a characteristic sample from Charlton.

	Northampton.			Charlton.
	I.	II.	Mean.	
Water expelled at 100° C.	24·70	24·88	24·80	27·11
„ fixed at 100° C.	14·54	14·54	14·54	15·80
SiO_2	23·09	22·92	23·01	20·50
Al_2O_3	31·24	31·42	31·33	31·34
Fe_2O_3	2·35	2·18	2·26	......
FeO	......	......	......	·31
CaO	2·51	2·48	2·49	1·92
MgO	·01	·01	·01	......
(Normal) ...... CO_2	1·28	1·28	1·28	1·69
(As bicarbonate) CO_2	......	......	......	1·04
	99·72	99·71	99·72	99·71

In these analyses the amount of carbonic acid was deducted from the loss on ignition; and in Mr. Northcote's case, in addition, the carbonic acid existing as bicarbonate was deducted from the loss at 100° C.

The excess of silica in the Northampton specimen is probably due to an almost unavoidable admixture of sandstone, upon which the allophane formed an incrustation.

Mr. Sharp, in a paper lately read before the Geological Society of London, and published in the Quarterly Journal of the Society, vol. xxvi. p. 367, speaking of a section of the Northampton Sand in the grounds of the Northampton Lunatic Asylum, remarks:—

"One set of joints in this section have a direction N.W. and S.E.; and the crevices are frequently filled with a soft white material, which, upon analysis by the recently deceased Dr. Berrill (formerly a student at the Royal School of Mines), was shown to be allied to allophane."

The substance here alluded to, a dull, whitish, pulverulent, earthy mineral, that may be polished by the nail, adhering strongly to the tongue, and exhibiting no trace of crystalline structure under the microscope, is by no means rare in many localities both in the ironstones and limestones of the Inferior Oolite of the Midland Counties.

Professor Morris, in his paper on the allophane of Charlton*, apparently alludes to a similar mineral. He says:—During the important investigations (under the direction of Dr. Percy, at the School of Mines) into the chemical composition of the different iron-ores of Britain, a white powder (probably pholerite) was observed associated with some of the clay-ironstone; the following is its analysis by Mr. Dick:—

SiO_2	41·78
Al_2O_3	36·99
HO	14·26
Fe_2O_3	4·51
CaO	·48
MgO	·16
Alkalies undetermined.	
	98·18

* Quart. Journ. Geol. Soc. vol. xiii. (1857) p. 15.

"I have also collected a similar mineral substance occurring on the surface and filling the crevices of the white oolite of Lincolnshire, where this rock is covered by the soft shales, sandstones, and clays belonging to this series. It has probably originated in the same manner as scarbroite and allophane, by the decomposition of some of the mineral substances of the overlying strata."

No analysis is given of this mineral; but, from its geological position and mode of occurrence, it resembles the earthy substance found by Dr. Berrill in the Northampton Sand, although this last, as will be seen from the following tabulated analyses, agrees much more nearly in composition with halloysite or samoite than with pholerite.

Name.	Locality.	SiO_2.	Al_2O_3.	H_2O.		Analyst.
Pholerite	Fins.	41·65	43·35	15·00	....	Guillemin.
"	Darlaston.	41·78	36·99	14·26	Fe_2O_3 4·51, MgO 0·16, Ca 0·48.	Dick.
Samoite	......	31·25	37·21	30·45	MgO ·06, NaO ·06, $CaCO_3$ ·01.	Silliman.
"	......	35·14	31·95	30·80	MgO 1·05, NaO trace, $CaCO_3$ 1·21.	"
Halloysite	Anglar.	39·50	34·00	26·50	....	Berthier.
(dried at 100° C.)	"	44·94	39·06	16·00	....	"
Earthy mineral......	Northampton.	35·19	32·22	29·87	Fe_2O_3 ·02, FeO ·28, CaO 1·72, MgO ·03, CO_2 ·39, SO_3 trace.	The Author.
(dried at 100° C.)	"	43·92	40·22	15·86	....	"

In the analysis of the earthy mineral from Northampton the loss due to the expulsion of carbonic acid was deducted from the loss on ignition, and the increase in weight arising from the oxidation of the ferrous oxide was added to the water fixed at 100° C.

On the supposition that the mineral consists essentially of water fixed at 100° C., silica, and alumina, it would be represented by the formula

$$8 Al_2O_3 15 SiO_2 + 18 H_2O;$$

but if the water that is given off at 100° be considered essential to its composition, it would be expressed by

$$Al_2O_3 2 SiO_2 + 5 H_2O.$$

The mineral dried at 100° is exceedingly hygroscopic, speedily regaining almost the whole of the water it had lost, and that too in well-ground, tightly fitting watch-glasses.

Discussion.

Mr. David Forbes stated that he had found phosphoric acid in the first-mentioned mineral, which was perhaps the cause of its lustre. The mineral was probably not pure allophane.

Prof. Morris suggested a chemical and microscopical examination of the strata above the places in which these minerals occur, which would probably reveal the conditions under which they had been formed. They were probably produced by the decomposition of silicates in the overlying rocks during the percolation of water. This applies also to the Charlton locality.

Mr. Carruthers mentioned that allophane often fills the inflorescence of the Cycads of the Yorkshire Oolite, entirely destroying the vegetable structure, and that it also occurs in clay nodules from the coal-measures. Mr. Carruthers suggested that the decomposition of vegetable matter in clays might aid in the production of the mineral.

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4. Notes *on the* Peat *and* Underlying Beds observed *in the* Construction *of the* Albert Dock, Hull. By J. C. Hawkshaw, Esq., F.G.S.

[Abridged.]

The author described the Albert Dock as extending east and west along the foreshore of the Humber at Hull, for a distance of 4000 feet. The total area excavated was about 30 acres. All the excavations were carried to a depth of at least 8 feet, and in some instances of 27 feet, below the level of low water.

Before the commencement of the excavations the Hessle Clay, peat, and overlying silt were met with in succession on the foreshore, the level of the top of the peat-bed at the west end of the area being about 3 feet above the level of low water, and its thickness from 3 to 4 feet. Eastward the bed followed the undulations of the clay without much variation in general level for half a mile, when it began to dip, attaining a depth of 12 feet below low-water level at the lock-entrance, and then rising again. From this depression of the peat-bed, and the appearance of the overlying silts, the author thought it probable that this had been an old channel of the river Hull, and that the upper part of the peat had been removed by scour. In support of this view he quoted the statements of antiquarian writers.

The peat rested directly on the Hessle clay, into which roots penetrated to a distance of 5 or 6 feet, generally following the direction of vertical joints, which gave the clay a tendency to split into prisms. These joints did not occur in the Purple Clay; and the author suggested that they may have been caused in the Hessle Clay by its drying by exposure before becoming covered with vegetation. The sides of the joints were grey; and this colour pervaded all the clay that was intermixed with the peat and extended for a distance of from 1 to 2 feet into the overlying beds of silt. This grey tint probably resulted from the decoloration of the iron, due to deoxidation by the vegetable matter of the peat.

At its highest level, at the west end of the dock, the peat consisted almost entirely of vegetable matters, including large accumulations of moss, leaves, and masses of brushwood, layers of oak-leaves with acorns, hazel-nuts, and fir-cones. Numerous remains of Coleoptera, chiefly wing-cases, were found. Trunks of oak trees, some of them 60 feet long, were scattered through the peat, and had evidently fallen where they grew; and from the characters presented by most of them, it would appear that they had grown close together. In this part of the bed, at the level of low water, and beneath a thick layer of moss, the remains of a fire were found. The author suggested that, from the small extent occupied by the remains of this fire, it was probably the result of human agency, as, if it had originated by lightning or by the friction of dry branches, it could hardly have been confined to so small an area.

The author inferred that no great change in the relative levels of different parts of the bed has occurred, because at the lowest eastern part the peat had been formed under water, branches and trunks of trees being imbedded in a stratum of grey clay, the wood being much of the same colour as the clay. In one large oak, 5 feet in diameter, there was a hole filled with acorns and hazel-nuts, many of the latter broken open at the end. This the author regarded as the store of a squirrel, and he remarked upon its being the sole trace extant of the existence of squirrels in the forests from which this peat was formed.

With regard to changes of level, the author stated that, whilst in other places an upward movement has been indicated*, the area examined seems to furnish evidence only of depression. Thus the surface of the peat in the supposed old channel of the river Hull is 12 feet below the level of low water, whilst the bed of the present river at South Bridge is only 6 feet below that level. The depression of the forest converted the land on which it grew into a marsh, where soft vegetable matter accumulated rapidly and soon covered up the fallen trees, the soundness of the timber indicating no long exposure to the weather. As the land continued to subside, the marsh was invaded by the waters of a tidal estuary, in which the Mollusca lived whose shells occur in the grey clay overlying the peat, and even in the peat itself. Of these the following forms occur:—*Scrobicularia piperata*, *Cardium edule*, *Tellina solidula*, *Hydrobia* sp., and *Bullina obtusa*, all, except the last, in great abundance.

The arrangement of the trees at the east end of the dock was not such as to indicate that they had been deposited in a current having a constant flow in one direction. The bands of blue clay were bulged out above as well as below the logs; and the author accounted for this by assuming that the logs did not yield to compression like the peat, from which, he thinks, an index of the compressibility of peat might be obtained.

Among the sections accompanying this account, two differ, in showing the Hessle Sand to thin out at the west end of the dock, from the section published in the Society's 'Proceedings'†. When the latter section was made, the excavations for the dock were not completed, and the sand underlying the silt in borings westward

* Quart. Journ. Geol. Soc. vol. xxiv. p. 157.

† Quart. Journ. Geol. Soc. vol. xxiv. p. 182, fig. 14.

was supposed to be a continuation of the Hessle bed, whereas the excavations and subsequent borings showed that the Hessle Sand thinned out at the west end of the dock. To the westward of the west end of the dock the peat, Hessle Clay, and Hessle Sand have been removed by the scour of the Humber down to the surface of the Purple Clay, and the more modern deposits of Humber sand and silt repose directly on the latter. In the section in vol. xxiv. of the Society's 'Proceedings,' above referred to, the lower part of this silt deposit, described as sand in the borings, is, in the writer's opinion, wrongly shown as a continuation of the Hessle-Sand bed. Several borings were made in the foundation for the dock-wall towards the west end of the dock; the thin bed of Hessle Sand reached by these borings was similar in colour to that found at the east end of the dock, where the Hessle Sand also thins out. As the bed diminished in thickness it became similar in colour to the adjoining clays. Good sections, about 500 feet in length, of the junction of the two clays with the Hessle Sand, the latter reduced to a thickness varying from 2½ feet to 5 inches, were exposed in the excavations for the foundations of the lock at the east end of the dock, which were carried down to the surface of the Purple Clay. Throughout those sections the sand was nowhere absent, and the junction with the two clays was very distinct. Where the bed was thick the sand was of a bright yellow colour, much cross-bedded, and composed of fine rounded grains of quartz, mixed with a considerable proportion of grains of chalk. This Hessle sand was probably reconstructed out of the Purple Clay in the same manner that the Hessle sand and gravel at Kelsey Hill have, in Mr. Prestwich's opinion, been reconstructed out of the boulder clays. Two sections, each about 1000 feet in length, show accurately the junction of the Hessle Sand and the Purple Clay. There was no intermingling of the sand and clay. The Hessle Sand was removed from the surface of the Purple Clay for the foundation of the dock-walls, for a width of 30 feet along the lines of these sections. The appearance of the surface of the Purple Clay shows it to have been consolidated before the deposition of the sand. A depression about 6 feet in depth, and apparently due to erosion, crossed the section at right angles. On one side the clay formed a steep face; and the bottom of the hollow was strewed with small gravel and scratched and rolled stones. Sometimes boulders were found on the surface of this clay too large to be removed by the current which probably swept the surface of the clay before the deposition of the Hessle Sand.

The borings taken at the east end of the lock showed the purple clay to be very compact, and free from stones and pot-holes; these borings were taken to ascertain the source of some springs which burst out in the foundations before the excavations were completed. With one exception, they extended to a depth of 58 feet below high water, nothing but the solid clay being met with below the surface of the Purple Clay. The water from the springs was brackish, and was in all cases charged with from 2 to 5 per cent. of reddish-yellow sand; the flow from one spring amounted sometimes to 1500 gallons per minute. For a long time their source was a complete puzzle, as it was not suspected that water could find a passage through the thick bed of Purple Clay. On a boring being made through the Purple Clay, it was proved that the springs had their origin in the lower sand-bed overlying the Chalk; and it is most probable that the water found its way to the surface through the holes of old borings made through the Purple Clay before the work was begun. Several old bore-holes were found, during the course of the excavation, filled with small pieces of chalk.

This bed of sand overlying the Chalk appears to be of some extent in the neighbourhood of Hull. It was 16 feet in thickness where a boring passed through it at the east end of the lock; and the same sand was found by all the borings to the westward which passed through the Purple Clay. It appears to increase in thickness to the east of Hull, as a boring* taken at Blockhouse Mill shows a thickness of 26 feet of sand between the Purple Clay and Chalk. Several thousand yards of this sand were brought to the surface by the springs in the lock; it was of redder colour than the Hessle Sand, but contained, like it, particles of chalk.

Discussion.

The President remarked upon the singularity of the occurrence of a bed of ashes at such a depth in these deposits.

Mr. Gwyn Jeffreys referred to the President's paper on the Kelsey-Hill beds, and remarked on some of the Mollusca obtained by Mr. Hawkshaw.

Mr. Boyd Dawkins mentioned the occurrence of a submarine forest on the coast of Somersetshire, forming a layer of peat, beneath which was a land-surface, on which the forest had grown, and in which flint-flakes were found at Portlock and Watchet on digging through the peat. He remarked on the depression of the coast of Somersetshire within the human period, and suggested that the forest at Hull may have been contemporaneous with that of Somersetshire.

Prof. Morris inquired whether any trees or roots were found as when growing. The shells obtained were estuarine. Prof. Morris remarked on a submerged forest near Whittlesey, with terrestrial plants and freshwater shells imbedded in the overlying clay.

The Author, in reply, stated that the trees had fallen where they grew. No direct evidence of man's presence had been found in connexion with the remains of the fire; but judging from the general appearance of these remains, he could come to no other conclusion than that the fire was the work of man.

* Phillips's 'Geology of Yorkshire,' second edition, p. 27.

March 8, 1871.

Lieut. Lewis de Teissier Prevost, H. M. 47th Regiment, and John Haines, Esq., Vernon Lodge, Addison Road, Kensington, were elected Fellows of the Society; and Dr. C. Nilsson, of Lund, was elected a Foreign Member of the Society.

The following communication was read:—

On the Red Rocks *of* England *of older date than the* Trias. By A. C. Ramsay, LL.D., F.R.S.

In a previous paper* I stated that the red colour which stains the New Red sandstone and marl is due to the presence of peroxide of iron, the iron probably having found its way into the water as a carbonate, which by contact with the air, afterwards became peroxidized, and encrusted the sedimentary grains as a thin pellicle. I further stated that I believed that iron could not have been deposited in this manner in an open sea, but rather in inland isolated waters, and I confirmed this opinion by other facts which tended to prove that our New Red strata were formed in a lake or lakes, which at the period of the deposition of the Keuper marls, were salt.

I now propose to examine the bearing of the red colour due to peroxide of iron in other formations of older date, as to the physical conditions under which those strata were deposited—that is to say, whether they were formed in the open sea or in inland waters. In doing this I will also take into consideration any other circumstances, physical or palæontological, that may tend either to confirm or to throw doubt on the idea stated above. I will not treat of the pretriassic red rocks either in ascending or descending stratigraphical order, but simply in the manner that seems most convenient to illustrate the points at issue. If some of the following passages appear like a partial repetition of arguments used in my previous paper, I can only say that they are brief, and seem to me to be necessary for the proper understanding of the questions I am about to raise.

Old Red Sandstone.—Mr. Godwin-Austen long ago stated his opinion that the Old Red Sandstone, as distinct from the Devonian rocks, was of lacustrine origin. The absence of marine shells helps to this conclusion; and there is nothing to indicate that the fossil fish found in it belonged entirely to marine genera and species. The reverse is the case; for the *Polypterus*, the nearest living analogue of some of them, inhabits the rivers of Africa, and the *Lepidosteus*, less closely allied, is found in the fresh waters of the North American continent. Even though some Old-Red-Sandstone fish have been found in the Devonian rocks of Devonshire and Russia along with marine shells, this proves nothing except that some of them were fitted to live in either fresh or salt water, like various modern fishes.

The Upper Silurian rocks of Shropshire, Herefordshire, Mon-

* On the Physical Relations of the New Red Marl, Rhætic Beds, and Lower Lias (see p. 190).

mouthshire, and South Wales are succeeded immediately by Old Red sandstones and marls; and there is no visible unconformity between them. Occasionally the Silurian rocks are red near the junction with the Old Red Sandstone, as, for example, near Usk, and on the banks of the Sawdde, near Llangadoc, in Carmarthenshire; but this I regard as due to subsequent infiltration from above having stained the strata. Colouring of this kind is by no means uncommon. Thus the Carboniferous Limestone of North Lancashire, which contains hæmatite, is overlain by red Permian sandstone, and both the redness of the limestone and the ironstone itself are considered by Sir Roderick Murchison to be due to infiltration from above. Coal-measure sandstones and shales, when immediately underlying red Permian marls and sandstones, are frequently exceedingly red; and the same is the case with Carboniferous strata underlying the Magnesian Limestone. The last Mr. Ward attributes either to "the action of carbonated water from the limestone above filtering through porous grits and sandstones, and converting the protoxides contained in them into sesquioxides, or by iron being brought from the overlying limstone, in the form of hydrate and carbonate, and redeposited in the rocks below"*. (The Magnesian-Limestone soil is always red, and I consider Mr. Ward's last explanation the most probable.)

The life of the Upper Silurian deposits in Wales, Shropshire, and the adjoining counties continued in full force right up as far as the narrow belt of passage-beds which marks the change from Silurian muddy sands into lower Old Red Sandstone; and this abundance of life is quite irrespective of the occasional red colour of the uppermost Silurian rocks. In the transition beds, on the contrary, genera, species, and often individuals are generally few in number and often dwarfed in form, with the exception, perhaps, of part of the Tilestone, near Llandovery and elsewhere in Carmarthenshire, and a few other places. The more common genera are *Anodontopsis* and *Modiolopsis* of various species, *Orthonota angulifera*, *Cucullella antiqua*, *Grammysia extrasulcata*, various species of *Ctenodonta*, and some small univalves of the genera *Murchisonia*, *Holopella*, *Turbo*, and *Turritella*. At Kington and south of Builth, where true passage-beds occur, the fossils are far less numerous, and almost all of small size, including species of *Modiolopsis* and *Modiola*, *Lingula cornea*, *Platyschisma helicites*, a small *Discina*, and a small *Theca*, a few small Crustacea, *Leperditia*, *Cytherellina siliqua*, and certain undetermined species. In some districts, as, for instance, at Ludlow and near May Hill, the very uppermost Silurian strata also contain seeds of Lycopodiaceæ, and various fragments of undetermined land plants.

The land plants clearly indicate the neighbourhood of land; and the poverty of numbers, and small size of the shells, a change of conditions in the nature of the waters in which they lived.

The fish-remains found in the passage beds, and in the very base

* "On Beds of supposed *Rothliegende* Age, near Knaresborough," by J. Clifton Ward (Quart. Journ. Geol. Soc. 1869, vol. xxv. p. 291).

of the Old Red strata, in which there are no Mollusca, are species of *Auchenaspis*, *Onchus* (2 species), *Pteraspis*, *Cephalaspis*, and *Plectrodus*. These also in the main indicate a change of conditions, which were, I believe, of a geographical kind.

The Eurypteridæ and Pterygoti in England almost entirely belong to the passage-beds; and one, *Eurypterus Symondsii*, is only found in the lower Old Red strata.

The circumstances which marked the passage of the uppermost Silurian rocks into Old Red Sandstone seem to me to have been the following:—First, a shallowing of the sea, followed by a gradual alteration in the physical geography of the district, so that the area became changed into a series of mingled fresh and brackish lagoons, which finally, by continued terrestrial changes were converted into a great freshwater lake, or, if we take the whole of Britain and lands beyond, into a series of lakes; and the occurrence of a very few genera or even species of fish and Crustacea, common both to the fresh and the brackish or even salt waters, does not prove that the Old Red Sandstone is truly marine. At the present day animals that are commonly supposed to be essentially marine, are occasionally found inhabiting fresh water. Thus I am informed by Mr. Murray, of the Geological Survey of Canada, that in the inland fresh lakes of Newfoundland seals are common. They breed there freely, and never visit the sea. The same is the case in Lake Baikal, in Central Asia; and though these facts bear but slightly on my present subject, seals being air-breathing Mammalia, yet in some of the lakes of Sweden it is said that marine Crustacea are found. This may be accounted for in the same way that I now attempt to account for these peculiarities in the Old Red Sandstone strata. These Swedish lakes were submerged during the Glacial period; and being deep basins (scooped out it matters not by what process), while the land was emerging, and after its final emergence, the salt water of the lakes freshened so slowly, that some of the creatures inhabiting it had time by degrees to adjust themselves to new and abnormal conditions*.

Again, we may suppose a set of circumstances such as the following:—If by changes of physical geography of a continental kind a portion of the Silurian sea got isolated from the main ocean, more or less like the Caspian and the Black Sea, then the ordinary marine conditions of the "passage beds," accompanied by some of the life of the period, might be maintained for what, in common language, seems to us a long time. The Black Sea was once united to the Caspian, the two together forming one great brackish lake. The Black Sea is now steadily freshening; and it is easy to conceive that by the closing of the Bosphorus (a comparatively small geographical change) it might be again converted into a fresh lake. At present a great body of salt water is constantly being poured out through the Bosphorus, and its place taken by the fresh water of rivers. At pre-

* For much important information on this subject, see Annals and Mag. of Nat. Hist., 3rd series, vol. i. 1858, p. 50, "On the Occurrence of Marine Animal Forms in Fresh Water," by Dr. E. von Martens. Translated by Mr. W. S. Dallas.

sent, owing to the uncongenial quality of the water, many of the Black-sea shells are strangely distorted, as shown by Edward Forbes.

Or if we take the Caspian alone, as it now stands, as an example, we have a salt inland sea which, according to accepted views, was once united to the North Sea and, possibly, at the same time to the Black Sea, as shown by the Aralo-Caspian deposits, at a time when the Bosphorus was still closed. Changes in physical geography have taken place of such a nature that the Caspian is now disunited from the ocean, while its waters are still inhabited by a poor and dwarfed marine molluscan fauna, and by seals. If by increase of rainfall the Caspian became freshened, evaporation not being equal to supply, it would by and by, after reaching the point of overflow, be converted into a great freshwater lake, larger in extent than the whole area now occupied by the Old Red Sandstone of Europe *. It is even conceivable that the great area of inland drainage of Central Asia, now holding many salt lakes, might in the same manner be so changed that all its lakes would become fresh and widened in extent, thus occupying areas many times as large in extent as all the known European Old Red Sandstone. Under these circumstances, in the Caspian area we should have a passage more or less gradual from marine to freshwater conditions, such as I conceive to have marked the advent of the Old Red Sandstone. When the whole area was fairly isolated from the sea, the sediments might by degrees get into a condition to be coloured red in the manner previously mentioned. We have a case in point in an old inland sheet of water, as shown by the red marls of the Miocene lakes of Central France. In certain of the strata of the Old Red Sandstone, especially in the upper beds, the colour has been here and there discharged in irregular patches, probably through the reducing action of organic matter, and the percolation of water containing carbonic acid.

Mr. Jukes divided the Old Red Sandstone of Ireland into two portions. The lower series is conformable with and adheres to the Upper Silurian strata. The upper series lies quite unconformably on the lower, and adheres to and is conformable with the Carboniferous strata. In Wales and the adjoining counties no such unconformity has been clearly made out and mapped, though Sir Henry De la Beche pointed out that such a division may exist, as shown by the overlap of the upper strata across the lower, proceeding westward from Breconshire into Carmarthenshire and Pembrokeshire. However this may be, the thickness of the Old Red Sandstone is often very great; and this to some minds, taken perhaps in conjunction with unconformity, may present a difficulty to the acceptance of my view. In South Wales and Herefordshire the formation is from 2000 to 7000 or 8000 feet thick, as determined by my measurements carefully levelled in 1843. But on consideration these circumstances do not appear to present any real difficulty. If the great hollow in which the Dead Sea lies were gradually to get filled with fresh water and silted up, 1300 feet would be added above the level of the present surface, without taking into account the depth

* Exclusive of marine Devonian rocks.

of the sea and the deposits that have already been formed; and the upper strata all round would overlap the lower, apparently much as the Old Red Sandstone strata do in Wales and the adjoining counties. If the Caspian and other parts of the Asiatic area of inland drainage got filled with fresh water, the same general results would follow.

Neither does the unconformity mentioned by Mr. Jukes present any insuperable difficulty, assuming his Lower Old Red Sandstone to be represented in England and Scotland, of which as yet there is no absolute proof. It indicates only great disturbance and denudation, while the red colour, and the total absence of fossils till we reach the very uppermost beds of the Upper Old Red Sandstone, point to inland waters. These fossils, it is well known, are terrestrial ferns, *Adiantites* (*Palæopteris*) *hibernicus*, and a freshwater shell, *Anodon Jukesii*, together with the fish *Glyptolepis*.

Permian strata.—I will now proceed to discuss the conditions under which the British Permian strata were deposited. These, it is well known, are usually divided in descending order into Magnesian Limestone or Zechstein, with subordinate Marl-slate or Kupferschiefer, and Rothliegende; and though this division is very convenient for great part of the Continent, it is not with certainty perfectly applicable to the whole of England and some other parts of Europe. If we take the whole country from near Nottingham to Tynemouth, there is no marked line of division between the Marl-slate and the Magnesian Limestone; and all along that range the red rocks on which the limestone series rests are now proved to be Carboniferous sandstones and shales stained by infiltration from above, which thus put on the likeness of Permian marls *. The supposed Rothliegende has, indeed, almost disappeared from the entire area.

The Permian marls, sandstones, conglomerates, and subangular breccias of Leicestershire, Warwickshire, South Staffordshire, Shropshire, and North Wales are as a rule all red, and have no visible connexion with the Magnesian Limestone. In Lancashire, in upper Permian strata, thin beds of magnesian limestone are interstratified with red marls; and these limestones, as Mr. Binney and Mr. Hull state, may represent in time, as they do lithologically, the limestone series in the east and north of England. The latter are also interstratified with two or three occasional bands of red marl, while in Lancashire the limestones have many marl-beds intermingled with, and also both above and below them. Underneath the limestones and marls of Lancashire there are soft red sandstones, of great thickness, generally believed to represent the Rothliegende.

The Permian sandstones on the south and west coasts of the Cumbrian country are red, as are those in the Vale of Eden. In the Vale of Eden the Brockram at and near the base has no connexion with

* The Yellow sands at the base of the limestone beds are generally a residue of sand. The limestone, which is often sandy, rests on shale, which is comparatively impermeable to water. The limestone dips east; the carbonate of lime has been carried away in solution as bicarbonate; and the sand remains.

the Magnesian Limestone, and has been formed in quite a different manner. It is a great brecciated conglomerate composed of angular fragments of Carboniferous Limestone, cemented together by carbonate of lime, and as hard and solid as the Carboniferous Limestone itself. In South Staffordshire, North Staffordshire, Shropshire, on the borders of Wales and elsewhere the Permian strata have the same general characters as those of parts of South Staffordshire and Warwickshire, and consist chiefly of red sandstones and marls with occasional brecciated conglomerates, which I have elsewhere described.

I have given this brief sketch of the distribution and lithological characters of the Permian strata of England, simply to remind my readers of their general nature in various areas, and not because I have any occasion to discuss in this paper any questions connected with equivalent geological horizons of Permian age, or of the disturbances that preceded the deposition of the Permian strata and may have helped to rule their characters.

As with the New Red Marl mentioned in a previous paper *, so I consider that the red colouring-matter of the Permian sandstones and marls is due to carbonate of iron introduced into the waters, and afterwards precipitated as peroxide in the manner previously stated, and for the same reason, that I know none of the great formations of British rocks proved by fossils to be formed of ordinary marine sediment that possess this red colour, except those that have been stained from above by accident. I believe, therefore, that in this circumstance alone we have an indication that these red Permian strata were deposited in inland waters unconnected with the main ocean, which waters may have been salt or fresh, as the case may be.

What other circumstances are there that more or less bear on this question?

First, as regards the plants of the British area, they are land-species, and chiefly of genera common in the Coal-measures, viz. *Calamites*, *Lepidodendron*, *Walchia*, *Chondrites*, *Ullmannia*, *Cardiocarpon*, *Alethopteris*, *Sphenopteris*, *Neuropteris* †, and many fragments of coniferous (?) wood of undetermined genera. These last are occasionally met with in the Permian red beds of many parts of England, generally silicified; and inland waters would be likely to receive fragments of land-plants borne into them by rivers.

This, however, forms no conclusive evidence, since land-plants are not uncommon in the Lias and Oolites.

No Mollusca have yet been found in the red beds of Warwickshire, Staffordshire, Shropshire, Wales, or the Vale of Eden, with the exception of two or three casts of a brachiopod allied to *Strophalosia*, found by Mr. Gibbs and myself in red sandstones near Exhall, in Warwickshire; and these occur along with *Calamites* and other land-plants. In Lancashire, however, near Manchester, *Schizodus* was found by Mr. Binney plentifully in Upper Red Permian marls, in

* On the Physical Relations of the New Red Marl, Rhætic beds, and Lower Lias (*suprà*, p. 190).

† Taken from Mr. Etheridge's lists.

strata sometimes associated with bands of fossiliferous magnesian limestone. No shells of any kind have been found in the so-called Rothliegende of Lancashire, or in the Permian beds in the Vale of Eden, while plants occur in the middle division of that series, as mentioned by Professor Harkness.

The evidence derived from reptilian remains in the red beds, so far as it yet goes, is of the same kind as that afforded by the Keuper sandstones. First we have *Dasyceps Bucklandi* in the Permian beds near Kenilworth; next the footprints mentioned by Professor Harkness in the red sandstones of the Vale of Eden, as occurring at Brownrigg, in Plumpton, and near Penrith; and lastly the numerous footprints described by Sir William Jardine, in the sandstones of Corncockle Moor and other parts of Dumfriesshire, now universally believed to be of Permian age. All of these prints indicate that the animals were accustomed to walk on bare damp surfaces, which were afterwards dried in the sun before the flooded waters overspread them with new layers of sediment, in a manner that now takes place during variations of the seasons in many salt lakes. Pseudomorphs of crystals of salt * in the Permian beds of the Vale of Eden, and deposits of gypsum and peroxide of iron, help to this conclusion, together with the occurrence of ripplings, sun-cracks, and rain-pittings impressed on the beds.

The remaining fossils that require to be considered in the red sandstones and marls belong exclusively to marine genera.

In Lancashire the Lower Permian red sandstones, which Mr. Hull estimates as about 1500 feet thick on the banks of the Mersey and Tame, are unfossiliferous, and the Upper Permian strata, consisting of red marls with bands of magnesian limestone, contain a few true Magnesian-Limestone species, viz. *Gervillia antiqua, Pleurophorus costatus, Schizodus obscurus, S. rotundatus, Turbo helicinus, T. obtusa, Rissoa Leighi, R. Gibsoni, Natica minima*, and some others†. They are all small and dwarfed, and in this respect and the small number of genera they resemble the living molluscan fauna of the Caspian Sea.

In the true Magnesian-Limestone districts of the east of England the case is different. There we find a more numerous marine molluscan fauna, but wonderfully restricted when compared with that of Carboniferous times. From Mr. Etheridge's unpublished lists it may be roughly estimated as follows:—

Brachiopoda. *Camarophoria* 3, *Crania* 2, *Discina* 1, *Lingula* 2, *Producta* 2, *Spirifera* 3, *Spiriferina* 2, *Strophalosia* 4, *Terebratula* 2: in all, 9 genera and 21 species.

Lamellibranchiata. *Aucella* 1, *Mytilus* 2, *Avicula* 2, *Gervillia* 5, *Arca* 2, *Cardiomorpha* 1, *Ctenodonta* 1, *Leda* 1, *Myalina* 1, *Myoconcha* 1, *Pleurophorus* 1, *Edmondia* 1, *Astarte* 2, *Schizodus* 5, *Solemya* 4, *Tellina* 1: in all, 16 genera and 31 species.

Univalves. *Calyptræa* 1, *Chemnitzia* 1, *Chiton* 3, *Chitonellus* 4,

* Harkness, Quart. Journ. Geol. Soc. 1862, vol. xviii. p. 215.

† Taken from Mr. Hull's "Memoir on the Country around Oldham," and corrected for generic names according to Mr. Etheridge's lists.

Dentalium 1, *Natica* 2, *Pleurotomaria* 3, *Rissoa* 1, *Straparolus* 1, *Turbo* 5, *Turbonilla* 4 : in all, 11 genera and 26 species.

PTEROPODA. *Theca* 1.

CEPHALOPODA. *Nautilus* 1.

The whole comprises only 38 genera and 80 species.

All of these are small and dwarfed in aspect, when compared with their Carboniferous congeners, when such there are.

In this poverty and dwarfing of the forms, these Magnesian-Limestone fossils may also be compared with the still less numerous fauna of the Caspian; and though I am not aware that that inland sea contains any Corals or Polyzoa, yet I doubt if the presence of two or three species of *Chœtetes* (3) and *Polycœlia* (2), together with half a dozen Polyzoa and a very small *Cyathocrinus*, would entitle us to assume that it is impossible that they might have lived in an inland salt lake, which, like the Caspian, had previously been connected with the open ocean.

The Magnesian-Limestone series of the east of England may possibly, however, have been connected directly with an open sea at the commencement of the deposition of these strata, whatever its subsequent history may have been; for the fish of the Marl-slate have generically strong affinities with those of Carboniferous age, some of which were undoubtedly truly marine, while others certainly penetrated shallow lagoons bordered by peaty flats. But the Marl-slate fish afford no certain clue to the solution of the problem as to whether in our area and in other parts of Europe they inhabited open sea or isolated inland salt waters. Indeed there is much to be said on the other side of the question from the reptiles found by Messrs. Howse and Hancock*; for the *Lepidotosaurus Duffii*, which was found very near the base of the limestone in marly limestone passing down into Marl-slate, was a Labyrinthodont Amphibian, and *Proterosaurus Speneri* and *P. Huxleyi*, from the Marl-slate, were Lacertilian Reptiles.

Besides the poverty and small size of the Mollusca, the later strata of the true Magnesian Limestone seem to me to afford strong hints that they may have been deposited in a great inland salt lake subject to evaporation. Mr. Sorby, in a paper read before the British Association in 1856, considers that the Permian dolomite was chiefly "derived from comminuted and decayed calcareous organisms, and subsequently altered into dolomite," and "that probably this alteration was effected by the infiltration of the soluble magnesian salts of the sea-water, under conditions not yet clearly explained, during the period when it became so far concentrated that rock-salt was frequently deposited, and that the calcareous salt removed during the change had, by decomposition with the sulphates of the sea-water given rise to the accumulations of gypsum." Gypsum is common in the red marls of the Permian strata and in

* "On a new Labyrinthodont Amphibian from the Magnesian Limestone of Midderidge, Durham," and "On *Proterosaurus Speneri* and *P. Huxleyi* from the Marl-slate of Midderidge, Durham," by Albany Hancock and Richard Howse (Quart. Journ. Geol. Soc. 1870, vol. xxvi. pp. 556 & 565).

other red marls, such as our Keuper beds. Solid dolomite, he goes on to say, still contains "about one-fifth per cent. of salts soluble in water, consisting of chlorides of sodium, magnesium, potassium, and calcium, and sulphate of lime. These, like those in most crystals formed from solution, must have been produced at the same time as the dolomite, and caught in some of the solution then present, which is thus indicated to have been of a briny character."

There are no solid beds of rock-salt in our Magnesian-Limestone series, though I see no reason why pseudomorphous crystals may not occur in the limestones and associated marls.

Mr. Sorby speaks of the Magnesian Limestone as having been formed in sea-water; and I presume he means ordinary open sea. I submit that it may be more probable that all our Permian magnesian limestone was chiefly or altogether formed in an inland salt lake. Under such circumstances it appears to me more likely that carbonates of lime and magnesia might have been deposited simultaneously by concentration of solutions due to evaporation; for I cannot understand how such deposits could have taken place in an open sea, where necessarily lime and magnesia only exist in solution in very small quantities in such a large bulk of water. In the open sea, indeed, we know of the formation of beds of limestone only by means of organic agency. The occurrence of gypsum in the marly strata of the Magnesian-Limestone series helps to this conclusion. I have also observed in some of the lower strata of the Magnesian Limestone, when weathered, that they consist of a number of curious thin layers bent into a number of very small convolutions approximately fitting into each other, like a number of sheets of paper crumpled together, and conveying the impression that they are somewhat tufaceous in character, looking almost stalagmitic, as if the layers, which are unfossiliferous, had been deposited from solution, and not like ordinary organic calcareous sediment.

In an elaborate disquisition on dolomites, in two lectures, Dr. Percy concludes with the following words:—"That dolomite has been formed by the agency of liquids under very ordinary conditions, I have little doubt will be hereafter fully established by direct and indisputable chemical evidence" *. In the 'Geology of Canada' (Logan) Dr. Sterry Hunt has given the results of his chemical investigations bearing on geology, in chapters 17–20. At pp. 575–6 he discusses the subject of dolomites. The passages are too long for quotation; but after explaining various natural processes by which he conceives that mixed carbonates of lime and magnesia may be deposited from solution in salt water, he concludes that "these reactions require inland seas, or basins cut off from communication with the ocean, while, on the other hand, the conditions of the production of carbonate of lime are everywhere found." The chemical arguments are not what first led me to suspect that the Permian magnesian limestone was deposited in an inland salt sea from solution, though I soon after began to entertain the idea, and to search for evidence on the point. It is satisfactory to find that eminent chemists take this view with

* Swiney Lectures, 1864, 'The Chemical News,' p. 89.

regard to other dolomites. That the Magnesian Limestone was deposited in great part from solutions may partly account for the absence of fossils in so much of that formation; and the uncongenial nature of the waters of a salt lake may account for the poverty-stricken character of the whole molluscan fauna.

One other group of red or purple strata remains, older than the Old Red Sandstone, and of this I speak with more doubt; I mean the Cambrian rocks. Neither in North Wales nor in the Longmynd do these rocks afford any indications of life, excepting annelide-tracks and burrows; for, with some other persons, I consider that the so-called trilobite *Palæopyge Ramsayi* is only an accidental marking simulating the form of a trilobite*. The general absence of Mollusca in these strata, and the sudden appearance of shells and trilobites in quantity in the succeeding *Lingula*-flags, indicates a sudden change of conditions. There is perfect conformity between the two formations; but the change of lithological character is rapid, and akin to that which marks the change from Upper Silurian rocks into Old Red Sandstone; only the order of change is reversed. Believing that the red colour of rocks is apt to be connected with their deposition in inland waters, I conceive it to be possible that the absence of marine Mollusca in the Cambrian rocks may be due to the same cause that produced their absence in the Old Red Sandstone. The presence of sun-cracks and rain-pittings in the Longmynd beds favours this suggestion. In Pembrokeshire, however, Mr. Hicks has discovered a *Lingulella* (*L. ferruginea*) and *Leperditia cambrensis* on two horizons, in strata well down in the purple Cambrian series. It is, however, worthy of note that the lowest slaty bed in which the fossil occurs, directly overlies "olive-green grits and shales"†. These may possibly mark occasional influxes of the sea into inland waters, due to oscillations of level. I do not wish, however, to speak positively on these Pembrokeshire strata. It is nearly thirty years since I mapped the country, and I should like again to see the rocks in place before doing any thing more than merely hinting at the subject. It is worthy of remark, however, that the possible inland origin of the Cambrian deposits in general is quite consistent with and throws some light on the statement by Dr. Otto Torell of the occurrence of land-plants in these strata, supposing this statement to be correct.

If I am right in the deductions I have drawn in treating of the red rocks and magnesian limestone of older date than the Trias, some remarkable conclusions may be arrived at in connexion with the inland character of the waters of the epochs to which this and my previous paper on the New Red Marl relate.

The old palæozoic area of Bristol and the Mendip Hills and of adjacent districts now partly concealed by secondary strata stood above water during the whole of the periods of deposition of the Permian and Bunter beds, and was not covered with water till these were more

* "The mythical *Palæopyge*" (Salter, Quart. Journ. Geol. Soc. vol. xxiii. p. 340).

† Geol. Mag. vol. v. p. 306.

or less overlaid with the deposits of the Keuper series. The *Thecodontosaurus* and *Palæosaurus* described by Dr. Riley and Mr. Stutchbury occur in a magnesian conglomerate of Keuper age, which was long considered to be the equivalent of part of the strata now called Permian. My explanation of their stratigraphical position is, that these Dinosaurian reptiles lived upon land moderately elevated all through the Permian and Bunter epochs, and that subsequently their remains were buried in the shingly beds of the Keuper inland sea, which formed the last of a long series of inland continental waters that prevailed over a large part of the territory now called Europe, from the close of the Silurian period onward to the Rhætic beds. First, there are the great lake-formed strata of the Old Red Sandstone; secondly, the Carboniferous formations, to a great extent terrestrial; thirdly, the Permian series; and, fourthly, the Triassic and partly the Rhætic beds; after which, during Liassic times, by subsidence, the sea invaded the land, and a mere group of islands occupied the site of much of what is now Europe. Further, I think it may be proved that the great continental areas of North America and Europe, and even of Asia and Africa, were already sketched out during the long geological period I have indicated, and that the great similarity in lithological character between the Permian and Triassic areas of Europe, America, and India is owing not to any cause producing depositions of red strata from all the waters of the world at these periods, but simply to special conditions of inland continental waters at various epochs of time.

This leads to the important question of the possible continuity of the same types of terrestrial as distinguished from marine life during the whole of this long period. Writers on geological subjects have often been apt to treat of the fossil records of the earth's history as being chiefly marine. If, however, the reasoning used in the foregoing pages is good, then we have a series of records indicating continental land surfaces containing great fresh and salt lakes, extending over a very large portion of all known geological time; and this, as far as time is concerned, possesses a significance quite as great as that of the marine formations, even though some of these inland-formed strata are almost destitute of the remains of life. Geographical continuity of continental land during a period that embraces several great geological epochs implies probable continuity of continental genera, if not of species. The Labyrinthodontia common to all the formations from the Upper Trias to the Coal-measure *Anthracosaurus* bear upon this point. Thecodont Saurians are both of Triassic and Permian age. "*Hyperodapedon, Stagonolepis,* and *Telerpeton,*" says Professor Huxley, "had no stronger affinities with Mesozoic Reptilia than the Proterosauria (Permian), or than some of the Labyrinthodonts of the Coal have with those of the Trias"*; *Telerpeton*, he has little doubt, was altogether terrestrial. Seeing that *Hyperodapedon* is as nearly allied to the living lizard *Sphenodon* as to its Triassic congener *Rhynchosaurus*, he sees no reason why it may not hereafter be "discovered in Permian, Carboniferous, *or even in older rocks*." With this I

* On *Hyperodapedon* (Quart. Journ. Geol. Soc. 1869, vol. xxv. p. 149).

cordially agree. I never could see any sound stratigraphical reason why the strata in the Elgin country that have yielded *Hyperodapedon*, *Telerpeton*, and *Stagonolepis* should be separated from the Old Red Sandstone. The piece of Lias (or Oolite as it used to be called) at Linksfield, to my mind, does not alter the question. Mr. Geikie, in a letter lately received, has no doubt that it is a large erratic ice-borne mass. In Northamptonshire Professor Morris has described a larger erratic mass of Oolite, 380 yards in length, exposed in a cutting in Boulder-clay on the Great Northern railway *. I have seen it, and can vouch for his accuracy. Mr. Judd has since discovered several such masses of erratic Marlstone, some of them even of larger size, in the same county, associated with Boulder-clay, and resting indiscriminately on Oxford Clay, Inferior Oolite, and all the formations between. These I have also seen †. The whole mass near Elgin, which has been largely quarried, seems to me to be of the same nature as the great Marlstone and Oolitic erratics observed by Professor Morris and Mr. Judd. If the *Hyperodapedon* of the Trias is nearly allied to a living lizard, it may very well be equally allied to a lizard of the Old-Red-Sandstone period. In like manner Teleosaurian Crocodilia go down from our times to Liassic or even to Permian times. There can surely, then, be no difficulty in carrying the former two stages lower, to the strata in which *Stagonolepis* and *Telerpeton* occur, and which I still believe to be true Old Red Sandstone; for, as Professor Huxley has well remarked, there is no "necessary relation between the fauna of a given land and that of the seas on its shores" ‡. This applies to geological time as well as to geographical space.

In conclusion, so vast a continental period as that between the close of the Silurian and the end of the Triassic epochs must have witnessed many disturbances of strata, and changes of physical geography, though the actual identity of the continent was not obliterated thereby. I will only give one comparatively modern instance to show how a continent may become changed, but still remain the same continent, notwithstanding great physical alterations involving upheaval of mountains and the formation of great lakes. From Upper-Eocene times to the present day it is certain that a great part of what is now Europe has existed as a continent; and yet the Alps and the Pyrenees have to a great extent been raised since that time; and many vast Miocene fresh lakes in various countries, with a marine interstratification in Switzerland, have been spread across the plains. These also have disappeared, because their consolidated sediments have since been raised in places into mountains.

Finally let me rapidly pass in review what I think we know of terrestrial as opposed to marine epochs in the British and neighbouring areas of Europe.

* Quart. Journ. Geol. Soc. vol. xix. p. 317.

† See Brickenden on the Boulder-clay near Elgin (Quart. Journ. Geol. Soc. 1851, p. 291), C. Moore on the so-called Wealden Beds at Linksfield, &c. (*ibid.* 1860, p. 445), and A. Geikie on the phenomena of the Glacial Drifts of Scotland (extracted from the Transactions of the Geol. Soc. Glasgow, 1863, p. 48).

‡ On *Hyperodapedon* (Quart. Journ. Geol. Soc. 1869, vol. xxv. p. 149).

1. The Cambrian epoch was probably inland and partly fresh water.

2. The Old Red Sandstone, the Carboniferous series (in great part), the Permian rocks and Trias (chiefly), were all formed in inland waters during one long continental epoch. This was by partial submergence brought to an end during the Liassic and Oolitic epochs, when the highlands of Britain formed parts of groups of islands along with other European palæozoic rocks. At the same time true continental land was never far off; for even in the deposits of the Inferior and Great Oolites in Lincolnshire and Yorkshire there is evidence of land and rivers, which land, growing in extent, at length formed by its drainage the great continental river of the Purbeck and Wealden series, as shown by the estuarine and freshwater deposits of England and other parts of Europe. The *Dinosauria* of this continent had their allies in older deposits of Permian and Triassic age. The great geographical areas were the same.

3. A larger submergence closed this terrestrial epoch; and in our northern European areas the sea attained great width and depth during the deposition of the Chalk, and all continental continuity of the old region was entirely broken up.

4. By subsequent elevation of the land above the sea, the fluvio-marine Eocene strata of Western Europe were formed, including in the term fluvio-marine freshwater beds of the whole series together with the London Clay and other formations, all of which were deposited not far from a river-mouth, or at least from shore. With this latter continent there came in a terrestrial fauna almost entirely new, and wonderfully different from that which preceded it. From that day to this, most of Europe has been essentially a continent, and its terrestrial fauna, in a large sense, of modern type.

If, according to ordinary methods (recognized if not absolutely true), we were to classify the *known old terrestrial* faunas (as distinguished from *marine*) of the greater part of North America, Europe, Asia, and probably of Africa, a palæozoic epoch would extend from the Old-Red-Sandstone at least to Purbeck and Wealden times, and a Neozoic epoch at least from the beginning of the Eocene period down to the present day, the Upper Cretaceous times remaining unclassified; while the marine epochs would be tolerably correctly, but provisionally, divided also into two,—one, palæozoic, embracing the formations from Laurentian (or at least Silurian) to the close of the Permian times; and all besides, down to the present day, would form one great Neozoic or later series. The terrestrial and the marine series at their edges overlap each other. In this sense, as regards marine strata, the terms Palæozoic and Neozoic were first used by Professor Edward Forbes; and the rejection of the three terms Palæozoic, Mesozoic, and Cainozoic, as applied to terrestrial faunas, may be inferred from the remarks in Professor Huxley's paper on *Dicynodon*. The great life-gaps between the two terrestrial series may some day be filled up by the discovery of the traces of old continents containing fossilized modifications of forms that accompanied the lapse of time. The generic marine gradations between Palæozoic and later times begin to be discovered even now.

Note.—After the foregoing paper was written I recollected certain red Silurian rocks which I had seen in America, known as the Onondaga Salt-Group, which contain gypsum, salt, and magnesian limestone. I at once surmised that their origin must have been similar to that of the red rocks of Britain mentioned in this and my previous paper on the New Red Marl &c. On referring to Sir William Logan's 'Geology of Canada' (1863), I find, p. 346, that he considers that the gypsum, "hopper-shaped moulds of salt," and other signs show that these rocks, part of which are red marl, "were deposited from waters concentrated by evaporation."

Professor Dana in his 'Manual of Geology' (1863), p. 249, speaking of the same strata, says "that the region which in the preceding period was covered with sea and alive with Corals, Crinoids, Mollusks, and Trilobites, making the Niagara limestone, had now become an interior shallow basin, mostly shut off from the ocean, where the salt waters of the sea, which were spread over the area at intervals—intervals of days or months it may be,—evaporated, and deposited their salt over the clayey bottoms," &c. It is a satisfaction to find myself so far supported by authorities so eminent, though neither of them mentions the red colour as a necessary concomitant of the inland-water condition of the Onondaga deposits.

Principal Dawson, of Montreal, has also published several papers in the Journal of this Society, partly illustrative of the Red Rocks of Nova Scotia. In one of these, "On the Colouring-matter of Red Sandstones and of Greyish and White Beds associated with them" (vol. v. p. 25, 1848), he shows that the colouring matter is peroxide of iron in a fine state of division, and that it is "like a chemical precipitate," and also that the gypsum in these strata is a chemical deposit: and he considers that these and other phenomena may "in some cases serve to distinguish marine from freshwater deposits." He does not, however, argue the case precisely on the grounds advocated in this paper.

Discussion.

Prof. Huxley was pleased to find that the author, on physical grounds, extended some views which he himself had, from other reasons, brought before the Society. He mentioned that there had lately been found in the fresh waters of Australia a remarkable fish, which had been considered to be a *Ceratodus,* but which, in many characters, was very similar to *Dipterus,* and in some respects resembled *Phaneropleuron.* In other respects it was connected with *Lepidosiren.* It was about to be fully described by Dr. Günther. The fact that this remarkable fish inhabits fresh water, he thought, corroborated Prof. Ramsay's argument. He agreed with the author as to his views respecting the terrestrial fauna of ancient times, and was quite prepared for the discovery of mammalian remains in earlier formations than those in which they are at present known. He did not so cordially agree with his views as to the marine fauna. He would carry back the forms from which those of the poesent day are immediately derived to Cretaceous rather than Eocene times. Between the later Cretaceous and the Permian strata there was a well-defined and characteristic set of Mesozoic fossils.

Mr. Etheridge commented on the dwarfed condition of our Permian fauna, which corresponds in the main with that of the Continent, though with fewer genera and species.

Prof. Rupert Jones protested against some of the reasons adduced for regarding some of the areas cited as having been inland lakes, though no doubt such lakes must have existed. He thought that mere colour could not be taken as a criterion. If it were, he inquired why the bottoms of the present lakes were not red? Many of the red rocks were, moreover, full of marine fossils. He contended for the true trilobitic character of *Palæopyge Ramsayi*, and mentioned its occurrence and that of *Lingula ferruginea* in red Cambrian rocks as proving the marine character of the beds. The Magnesian Limestone he also insisted upon as a purely marine and open-sea deposit.

Prof. Morris thought the subject required further consideration before the whole of Prof. Ramsay's views were accepted. The Cambrian beds, for instance, containing great beds of conglomerate, seemed such as could only be due to marine action, and would derive their red colour from the decomposition of the old hornblendic gneiss from which they were derived. With regard to the Red Sandstone, he would inquire whether the colour might not be derived from the decomposition of rocks composed of hornblendic materials. The Old Red Sandstone beds, though in this country containing fishes which might be of freshwater genera, had in Russia the same fishes associated with marine shells; and much the same was the case in the Trias.

Dr. Carpenter had been led to the conclusion that wherever there was an inland sea connected with the ocean by a strait even of moderate depth there was a double current tending to preserve some degree of similarity between the waters of the two, the difference of specific gravity in the Mediterranean as compared with the Atlantic being about as 1·026 to 1·029. In the Red Sea, where so little fresh water came in, and there was an evaporation of nearly 8 feet per annum, the water was but little salter than that of the ocean with which it was connected. In the Baltic there is an undercurrent inwards, which still keeps it brackish; but the influx of fresh water was so enormously in excess of the evaporation, that otherwise it would long ago have become perfectly fresh. Such facts bore materially on the speculations of the author.

Capt. Spratt maintained that in the Dardanelles there was not a trace of such an undercurrent as that mentioned by Dr. Carpenter. In the winter months, when the flow of the rivers into the Black Sea was for the most part arrested by ice, the salt water of the Mediterranean was frequently carried into the inland seas; and these being much deeper than the channel of the Dardanelles, the salt water, by its greater specific gravity, remained in the bottom of the sea of Marmora, so that, while the upper portion of the water and that on the shores were diluted to the Black-Sea density, Mediterranean conditions existed in the deep centre of the sea. If, therefore, the Black Sea had been pure fresh water, the upper portion of the Sea of Marmora would have been fresh also, with its freshwater fauna, whilst the deeps of that sea would be marine.

Dr. Duncan mentioned that in certain coral reefs intersected by freshwater currents, the corals still continued to be formed; so that the existence of dwarfed forms of corals in ancient times was quite consistent with modern facts.

Mr. Forbes commented on the chemical features of Prof. Ramsay's views, and could see no reason why the beds containing iron should not have been deposited in the open sea. Many beds, for instance the Gault, contain more iron than those which are now red, though they may be grey or blue. In sands the grains are often coloured only superficially with iron, probably derived from sulphates. In other cases the sands consist of fragments of rocks already red. There was, in fact, no reason why the beds deposited in the open sea might not subsequently, by oxidation, become perfectly red.

Prof. Ramsay replied to the remarks of the various speakers, and summed up by contrasting the usual colour of marine fossiliferous beds with that of the thick, almost non-fossiliferous rocks of which he had been treating.

March 22, 1871.

A. R. Selwyn, Esq., Director of the Geological Survey of Canada; J. Bridges Lee, Esq., B.A., of Sidney Sussex College, Cambridge, and 115, Ledbury Road, Westbourne Park, W.; the Rev. Thomas Robert Willacy, B.A., of Corpus Christi College, Cambridge; and James Putnam Kimball, Ph.D., of 20 Union Square, New York, were elected Fellows ot the Society.

The following communications were read:—

1. *On the* "Passage-Beds" *in the neighbourhood of* Woolhope, Herefordshire, *and on the discovery of a* New Species *of* Eurypterus, *and some* New Land-plants *in them.* By the Rev. P. B. Brodie, M.A., F.G.S., Vicar of Rowington.

The "Passage-beds" between the Upper Silurian rocks and the Old Red Sandstone, on the outer area of the Woolhope valley of elevation, although they have been already noticed by Sir R. Murchison, Professor Phillips, Strickland, Symonds, and myself, at Hagley, Tarrington, Ledbury, and Perton have not in this district received the full attention they deserve; for although they are of comparatively limited vertical thickness when compared with the finer and more complete sections at Downton and the Ledbury tunnel, they occupy a larger extent round the valley of Woolhope than has been previously recognized, and contain some new and interesting fossils

At Putley, near the road from Ledbury to Woolhope, to the N.E. of the latter village, a remarkable bed of very hard horizontal sandstone, composed mainly of small pieces of quartz in a sandy matrix, overlying a stratum of white and yellow clay, used for making tiles, may be seen in a brickyard to the depth of about 3 or 4 feet, the blocks of sandstone averaging about 2 feet in thickness. I could find no fossils in it, and it had very much the aspect of a volcanic rock; but my friend Professor Phillips, to whom I sent a specimen, recognized it at once, and states that he believes it to have been derived from Trappean and other Plutonic rocks, though it may be presumed to be one of the bands of sandstone belonging to this series. About two miles to the south of Putley, at a farm called "Chandler's," there is a sandstone quarry, which yields large blocks $1\frac{1}{2}$ feet square, having a dip to the north-east, a portion of which is of a very dark colour, almost *black*, similar to the peculiar igneous-looking rock just referred to; and at one place the strata are much contorted, being thrown up in a small anticlinal. From the top of Marcle Hill, for at least three quarters of a mile, in a lane leading to this quarry, on each side of it, there is a thin band of sandstone, running parallel with the road; but no "olive shales" appear above it. Three miles to the north, on Putley common, near Maine's wood, other beds of a close-grained more or less quartzose sandstone occur, in which I found the cast of the larger form of *Lingula cornea*. This seems to correspond with the hard micaceous grit (though there of a purple colour) at the Tin Mills, Downton, which immediately overlies the "olive shales," and contains the large *Lingula cornea* in abundance. The beds were much disturbed, and more or less inclined, as most of the "passage-beds" are here, dipping from the older Silurian rocks of Woolhope, and in the same direction, for the most part on this side. The partial opening was of no great depth, and therefore the thickness of the sandstone visible was of limited extent; but judging from the relative position of the Ludlow formation on the west, and the Old Red Sandstone on the east, the thickness would perhaps be considerable if fairly exposed. A mile or two towards the north-west, near Lower Hazle, between this spot and Tarrington, is a small quarry of thick-bedded variable sandstones, charged as usual with carbonaceous remains, but finer-grained than those already described. On the same line, still further towards the north-west, on the brow of the rising ground called "Hillfoot," similar bands of sandstone are exposed, more or less disturbed, dipping towards the north-east, and underneath them the "olive shales," 3 or 4 feet thick, passing into, and resting on, a thin stratum of sandstone, similar to the section at Perton. The shales are horizontal, and contain in the lower part abundant fragmentary relics of plants, among which are the seed-vessels of *Lycopodium*, and larger fruits (or sporangia) which seem to be quite distinct. I could find no Crustacea; but a longer and careful search would no doubt detect them. I also obtained one specimen of the smaller form of *Lingula cornea*, supposing this species to be identical, which Mr. Symonds thinks it is not. In no other places where the sandstones are present have I observed these shales, except here and at Perton; but probably, though not exposed elsewhere, they extend for some distance in this district, and are to be looked for associated with the sandstones between the Old Red Sandstone and Upper Ludlow rocks. Owing to the very few exposures of rock hereabouts, it is exceedingly difficult to get any thing like a clear and consecutive section. Here and at Putley brickyard there is a want of conformity—the only two places I have noted this; for, as a general rule, the "passage-beds" are conformable to the Upper Silurians. About two miles further on is the better-known quarry at Tarrington. Six to eight beds of sandstone, varying in thickness, colour, and lithological character are exposed here, divided by thin partings of yellow and grey-coloured clay, having a total thickness of about 20 feet, with a rapid dip to the north. I could detect no "olive shales" here; and the only fossils are the usual carbonized fragments of plants, including the characteristic Lycopodites. Some of the blocks of sandstone are of large size, and no doubt form a useful building-stone. The next exposure of the sandstones, including the "olive shales," is at Perton, which I have already referred to in a short paper published in the 'Journal' of this Society*; but as I was unable then to give a detailed section, it may be desirable to add it now in descending order.

	ft.	in.
1. Divided beds of sandstone in thin bands	2	0
2. Dark-coloured brownish shales	3	0
3. Yellow sandstone	1	6
4. Olive shales, brown and green, more or less indurated, but generally very brittle, sandy, and slightly micaceous, and having an irregular fracture	5	0
5. Thin-bedded sandstone	0	5
6. Olive shales, often arenacous, with a thin sandy layer at the base, similar in structure to No. 4	4 to 5	0
Total	16	11

I was only able to make out this section satisfactorily by the aid of a ladder. The upper sandstones thin out rapidly to the south-west, the "olive shales" rising to the surface, but too high up to be reached.

The lowest stratum (No. 6) crops out at the north-west corner of the quarry; and, on the authority of a man who had formerly worked in it, there is a good, thick, serviceable bed of yellow sandstone underneath, though I could see no trace of it. If this should prove correct, it is probably the Downton sandstone. All the sandstones are more or less fossiliferous, and yield the usual remains of carbonized plants, and abundance of Lycopodites. The Crustacea appear to be confined to the "olive shales" (Nos. 4 & 6). I sent up all I procured to Mr. Woodward; and he informs me that the greater number belong to *Pterygotus Banksii*, with the exception of a small tail and three species of *Eurypterus*, viz. *E. pygmæus*, *E. acuminatus*, and *E. abbreviatus*. One specimen of this genus consists of a con-

* Quart. Journ. Geol. Soc. vol. xxv. p. 235, March, 1869.

siderable portion of the body; the others are chiefly fragments of the body, heads, tails, claws, and swimming-feet. I was fortunate enough to discover an almost entire specimen of a new species of *Eurypterus*, which Mr. Woodward has named *E. Brodiei*, and described at the meeting of the British Association at Liverpool. He pointed out that it "differed slightly from all other well-known species in the form of the swimming-feet, in the palpi, but most of all in the form of the thoracic plate"*. It is perfect from the head to the apex of the sharp-pointed tail, and measures 2½ inches in length, and 10 lines in the broadest part of the body, and has a portion of one of the swimming-feet attached"†. These shales contain a species of coral (*Actinophyllum*), not very common; but I could observe no shells, nor the *Beyrichiæ*, and only a few of the *Leperditiæ*, which characterize them elsewhere.

In addition to the Lycopodites, there are other plants, which I sent to Mr. Carruthers for determination; he informs me that, "although very interesting, they are rather fragmentary, and, like most fossil plants, difficult to determine. The best-marked is a dichotomously branching plant, which would be referred to an Alga by most botanists. I believe, however, it is a true *land*-plant, which has had vascular tissue in its composition, and a sufficiently indurated structure to resist decomposition. It may belong to Dawson's genus *Psilophyton*; but more specimens are necessary before this can be decided. There are several bodies which look like seeds, but are more probably sporangia. They are certainly *land*-plants"‡.

I have not been able to find any traces of the numerous fish discovered at Ledbury and Ludlow; but it is possible that a closer and longer search would detect them§. At Prior's Court, about a mile south-west of this spot, there is a small exposure of the sandstones, showing nearly 2 feet of divided beds of yellow sandstone, with carbonaceous remains, resting on the Upper Ludlow, but no "olive shales." At none of these places could I discover the "bone-bed," which has been long since noticed at Hagley, not far from this point on the north-east, first by the late Mr. Scobie, an active member of the Woolhope Naturalists' Field Club, and afterwards by my lamented friend H. E. Strickland, where, many years ago, in company with the latter and Sir R. Murchison, we found the "bone-bed" and numerous remains of *Pterygotus*; but these were in the Ludlow rock, and not in the passage-beds which occur there, according to my friend Mr. Symonds, who states that they are present

* There are in my collection at least three swimming-feet, and two or more thoracic plates, of this new species.

† It is imbedded in a yellow, somewhat soft, micaceous sandstone, connected with the "olive shales."

‡ It need scarcely be remarked that the occurrence of terrestrial plants, some of which may very possibly be new, besides those curious bodies long ago described by Dr. Hooker, and referred by him to *Lycopodium*, is a matter of much interest in strata of this age.

§ Mr. Symonds informs me that he has found a *Pteraspis* there, which is now in the possession of Lord Enniskillen.

at this quarry. He says that the passage of the Upper Ludlow rock, with its "bone-bed," may be observed here into the yellow Downton beds, succeeded by red marls, precisely similar to those in the Ledbury Tunnel. On my first visit to this spot they were not exposed, and were not visible at a later one; and the pit has not been worked now for many years. I cannot, therefore, say decisively whether the "olive shales" are present there *in situ* or not. The "bone-bed" here and at Gamage Ford probably belongs to the lower "bone-bed" which, in Shropshire, is present in the higher portion of the Upper Ludlow, not far below the thicker mass of the Downton sandstone; while another and upper one occurs about the middle of the "olive shales," but it is apparently wanting here. I searched in vain for these "passage-beds" more to the south, near Soller's Hope, where they might be expected to come in, unless a sandy marl, of which a section may be seen in places along the brook which traverses the lower ground, belongs to them. It contains a small *Orthis* and *Beyrichia*, but it most likely belongs to the Ludlow formation. They may or may not be continuous round the whole of the outer limit of the Silurians in the district under review, and I think it probable that here and there they might be detected in road-side cuttings throughout the whole of this area; I hope, at some future time, to be able to investigate this more closely. At any rate, a more considerable extension has been shown, especially to the east of Woolhope; and the presence of the "olive shales," exactly identical lithologically and, to a certain extent, zoologically with the "olive shales" near Ludlow and other places in that neighbourhood, is distinctly proved. On the west, north-west of Woolhope, and south towards Fownhope, there is less chance of observing those "passage-rocks," if they occur there, because there is a very considerable quantity of drift, which would overlie and conceal them. This larger mass of drift, derived mainly from the denudation of the Silurians adjacent, was first noticed by my friend the Rev. F. Merewether, Vicar of Woolhope, who, in a short paper read to the Woolhope Naturalists' Field Club, in October 1870, has shown a thicker and wider extension of drift in this direction, which had not been before noticed. In many spots these "olive shales" are not exposed, though they may be present *in situ*; but, from their soft and friable nature, a considerable quantity has no doubt been denuded, unless protected by the overlying sandstones. As they pass downwards into a more sandy stone, it is probable that there is some sandstone below; to what extent or thickness, it is impossible to ascertain; but it cannot be very thick in the only two places where I have observed them, as at Perton they rest almost immediately on the Upper Ludlow, and at Hillfoot, though not directly overlying it, at least not shown in the section there, the Ludlow shales crop out not far from them. The subordinate sandstone would then seem to be of far less thickness than the more massive sandstone at Downton, Shobden, and elsewhere. The "olive shales" are, no doubt, the equivalents in time of the red and blue marls and greenish shales (No. 12) at the Ledbury tunnel, described by my friend the Rev. W. S. Symonds*, who remarks that "nowhere else could be seen such a view of the 'passage-beds' between the Silurian and Old Red systems;" but, though at no great distance, they are apparently much less developed along the Woolhope border. I visited this fine section when the tunnel was being made, with several members of the Warwickshire Naturalists' Field Club, and I recollect being much struck with it at the time. Formerly these "passage-beds" were classed by Sir R. Murchison with the Old Red Sandstone; but latterly he has denominated them "passage-rocks," which seems altogether more appropriate, as showing their intermediate character between the Old Red and Silurian. Some geologists, however, I believe, still desire to have them restored to their original position in the Old Red. This is a question which I do not pretend to decide, but which future discoveries of other organic remains may definitely settle, if it is not already satisfactorily determined, my object being rather to point out a greater extension of this series around the Woolhope elevation than had been previously recorded.

There are many interesting and important questions connected with all "passage-beds"†, of which several are known to occur between two great epochs of geological time. It is not impossible that certain old defined lines of demarcation will ultimately have to be remodelled or removed, since such transition-periods may be shown to prove a continuity of the geological record; thus all such "passage-beds" may, in fact, be connecting links between one great geological epoch and another, rather than breaks in the continuity of succession.

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2. *On a* New Species *of* Eurypterus (E. Brodiei), *from* Perton, *near* Stoke Edith, Herefordshire. By Henry Woodward, Esq., F.G.S., F.Z.S., &c.

In March 1869, the Rev. P. B. Brodie, F.G.S., communicated to the Geological Society a short account of the occurrence of remains of *Eurypterus* and *Pterygotus* at Perton (see Quart. Journ. Geol. Soc. xxv. p. 235). Mr. Brodie stated that the specimens collected at that time and submitted to me were not considered to be new; in fact they consisted, for the most part, of fragments of *Pterygotus* ‡ (*P. Banksii*) and *Eurypterus* § (*E. pygmæus*, *E. acuminatus*, *E. abbreviatus*, &c.), already noticed by Mr. Salter elsewhere.

Since that communication was read, Mr. Brodie has again explored this locality, and has forwarded to me several parts and an almost entire example of a *Eurypterus*, which differs considerably

* Quart. Journ. Geol. Soc. May, 1860, pt. 2. no. 62.

† This question was ably treated by Mr. Judd, in a paper lately read at the Meeting of the British Association in Liverpool.

‡ See Mem. Geol. Surv. Mon. I. 1859, pl. xii. figs. 22–46, p. 51.

§ Quart. Journ. Geol. Soc. 1859, vol. xv. pl. x. p. 229.

from any species previously examined by me, and of which I beg to subjoin a short notice.

The most perfect specimen, from which the restored outline (fig. 1) is taken, measures $2\frac{3}{4}$ inches in length, and 10 lines in its widest thoracic segment. All the somites are united; and one of the swimming-feet, although injured, is still in place. The head, which is semicircular in outline, measures 4 lines in length by 9 lines in breadth; the eyes are subcentral, and the ocelli nearly central, as in the other species of *Eurypterus*. The first six segments (thoracic) succeeding the head measure together 9 lines in length; commencing with a breadth of 9 lines, they increase at the third segment to 10 lines, and diminish at the sixth segment to 7 lines in breadth. The segments increase in length and diminish in breadth very evenly from the third segment backwards. The borders of all the anterior segments are curved, and the posterior angles slightly produced and acutely pointed.

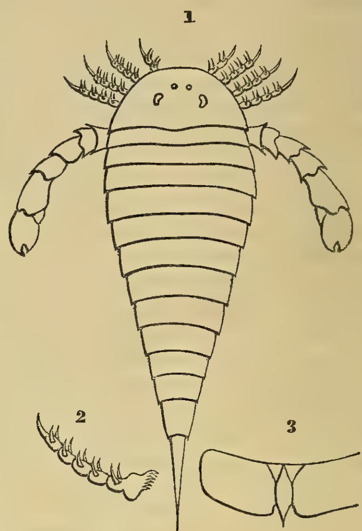

Fig. 1. *Eurypterus Brodiei*, H. Woodw. (outline restored, natural size). Passage-beds from the Uppermost Silurian to the Old Red Sandstone, Perton, near Stoke Edith, Herefordshire.
Fig. 2. Palpus (enlarged).
Fig. 3. Thoracic plate (enlarged).

The six posterior (abdominal) segments diminish in breadth backwards from 6 lines to 2 lines, and increase, in the same direction, in length, from $1\frac{1}{2}$ line to $2\frac{1}{2}$ or nearly 3 lines, the body being terminated by a slender ensiform telson, or tail-spine, 7 lines in length. No sculpture is apparent on the segments or head; but the integument composing the former indicates its tenuity by abundance of plicæ and wrinkles. The thoracic plate (fig. 3) is very characteristic, differing in the form of its median appendage from that of any previously described species. It is 9 lines broad, and $2\frac{1}{2}$ in depth; the median appendage is spindle-shaped in outline, and is $3\frac{1}{2}$ lines in length and $1\frac{1}{2}$ line broad. The swimming-foot is $2\frac{1}{2}$ lines in width, and $\frac{3}{4}$ of an inch in length, exclusive of the basal joint. The species agrees closely, in the form of its swimming-feet, with the American and Russian *Eurypteri*, having the same intercalated plate between the ultimate and penultimate joints, and also the minute terminal palette at the end of the seventh segment.

Numerous detached endognathary palpi occur associated with this form, furnished with short recurved spines (fig. 2) arranged in pairs upon each segment, doubtless referable to the same species. I have proposed to name this form *Eurypterus Brodiei*, after its discoverer*.

DISCUSSION.

Mr. DUNCAN inquired whether any metamorphoses had been recognized among the Eurypteridæ, and, if so, whether the variation in the thoracic plates mentioned by Mr. Woodward might be connected with them.

Mr. WOODWARD, in reply, remarked on the difficulty of distinguishing even the sexes in Eurypteridæ. The thoracic plate in the fossils resembled that of *Limulus*; and the variety might be connected with sex. In some *Slimoniæ* from Lesmahago the only difference to be found was in the thoracic plate; and it had been suggested that this was due to difference of sex. He had already suggested that the small *Pterygotus* and the great *Slimonia* might be only the male and female forms of the same species. On fragmentary remains, however, it was unsafe to attempt to base species; but he thought *Eurypterus Brodiei* was a well-marked species.

Rev. H. H. WINWOOD inquired whether there was any evidence as to *Eurypterus* being freshwater or marine.

The CHAIRMAN (Prof. Morris) observed that the seeds from the passage-beds did not appear to him other than those of land-plants, and had been previously described by Dr. Hooker as spore-cases of Lycopodiaceæ.

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3. *On the* CLIFF-SECTIONS *of the* TERTIARY BEDS WEST *of* DIEPPE *in* NORMANDY, *and at* NEWHAVEN *in* SUSSEX. By WILLIAM WHITAKER, B.A. (Lond.), F.G.S., of the Geological Survey of England.

THE notes from which this paper is made were taken in the summer of 1866. The two sections described are interesting as showing the spread of beds that, but for them, would be thought to occur only in the south-eastern part of the London Basin; and I believe that no detailed description of the French one has been published, whilst the English one has been enlarged since the time of its latest description.

1. *Dieppe.*

The section near Dieppe is noticed by Passy†, in whose time however, the divisions of the "Lower London Tertiaries" were not understood, and various superficial deposits were included with them, the whole being massed under the not very satisfactory name of "Plastic Clay."

Mr. Prestwich has referred to this coast in his paper "On the Woolwich and Reading Series"‡; and to him is owing the most im-

* See British Association Reports, Liverpool, 1870, p. 91.
† Descrip. Géol. du Dép. de la Seine Inférieure, 4to: Rouen, 1832.
‡ Quart. Journ. Geol. Soc. vol. x. p. 129, 1854.

portant addition to the geology of the neighbourhood, the mapping of the London Clay here*, the only part of France, I believe, where it has been found.

In the following description the same numbers have been used for the same beds in the two sections noted, as far as could be.

Westward from Dieppe, along the top of the cliff, there are great hollows and pipes of Tertiary sand and drift, with many slips, the clearest giving the section below:—

1. Gravel, of subangular flints and flint-pebbles.
3. Oldhaven Beds? Fine light-brown, buff, or light-grey sand.

Woolwich Beds.
4. Laminated brown clay.
5. Shelly clay, with a thin layer of shelly stone, over 2 feet.
6. Light grey (whitish) sharp sand, with ferruginous layers, about a foot.
   Grey and brown clayey sand, with peaty layers, especially at bottom, about a foot.
8. Sharp rather coarse sand, whitish just at top, the rest pale greenish and yellowish grey, with iron-stains near the bottom. Some small green-coated flints, and at the bottom a layer of them (9), 6 or 7 feet, resting evenly on

10. Chalk with flints, but not with such marked layers of them as occur a little below.

Further westward the ground falls to the valley of the small river Scie. Beyond the next gap, which is small, there is at the highest part a great hollow, of drift loam, flints, and pebbles, and of the Tertiary beds. All have fallen much, right down to the beach; but at the top at one spot I saw above the fine sand (3) a mass of clay, the lowermost part brown and sandy, the rest of a dark greenish grey, like the bottom London Clay of East Kent. There may be a fault here, as the Tertiary beds seem to abut against the Chalk.

At the top of the cliff beyond the next gap, also small, there was at the time of my visit a very good section reaching for a long way, and showing the following beds:—

1. Flint-gravel.
2. London Clay.
   Evenly bedded alternations of dark-grey and brown shaly clay, brown sand (some like that of the Oldhaven Beds), and loam, 12 or 15 feet.
   Brown clayey sand with thin layers of clay, drying hard, 5 or 6 feet?
3. Oldhaven Beds. Fine light-coloured evenly bedded sand, at one place with a bed of iron-sandstone more than a foot thick. Over 25 feet.

(The beds below much slipped and not easily to be seen, so that some may have escaped notice, for instance No. 4. of the former section.)

Woolwich Beds.
5. Shelly clays, much thicker than before, evenly bedded, divided into two by a dark-grey and greenish clay.
6. A little dark clay with layers of sand.
   Lignite and peaty clay.
   A little grey and ferruginous clay.
8. Sharp buff sand, with concretionary masses of greywether-sandstone (as noticed by Mr. Prestwich) and a few flints.
9. Flints in what seems to be a greenish clay (inaccessible) filling small pipes in

10. Chalk.

* The Greenough Geol. Map of England, south-eastern sheet, 1865.

At one place the sand (3) seems to abut against the beds below, as if from a small fault.

At Varengeville, beyond the next gap, is a like section, the sand (8) and its included masses of sandstone being in great part white, and there are also sandy shell-beds. The Oldhaven sand is hidden by fallen masses from above.

At the next hill the top part of the London Clay contains a bed of buff sand 2 feet thick.

In Passy's work a mass of Calcaire Grossier (?) is figured (plate xix.) as resting unconformably on the beds below. I did not see it; but it may have fallen into the sea since his time.

Inland there is a tile-kiln in the London Clay.

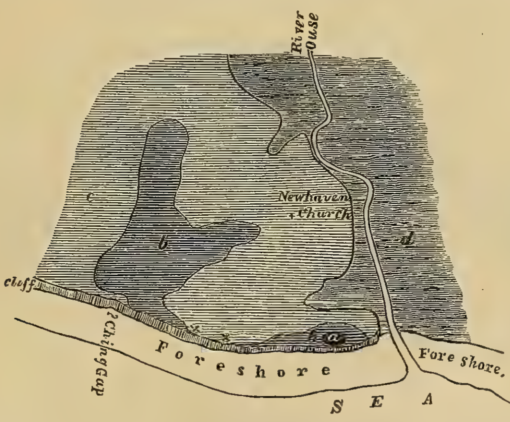
2. *Newhaven.*

The section here was, I believe, at its best when I saw it, the cliff having been then cut back to the highest ground; and for this reason I venture to describe it to the Society, although it has already been described at least five times (three times in the Society's publications), and in all these cases by well-known observers, so that, of course, I shall incorporate their notes with my own.

The shape of the outliers will be seen from the accompanying map (fig. 1), which differs from that of the Geological Survey in separating the Tertiary beds into two masses, instead of joining the whole into one along the face of the cliff. I believe that the mass

Fig. 1.—*Geological Map of the Newhaven Outliers.*

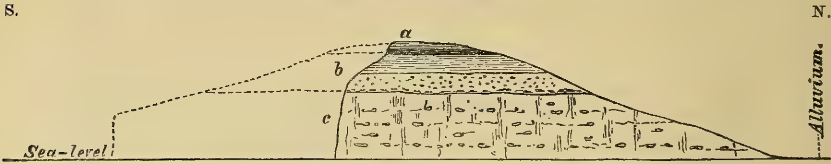
From Sheet 5 of the Geological Survey Map (1864), with alterations (1866). Scale 1 inch to a mile.



a. London Clay. *b.* Woolwich and Reading Beds. *c.* Chalk. *d.* Alluvium. × × Between these points the Chalk is capped by a wash of the Tertiary beds.

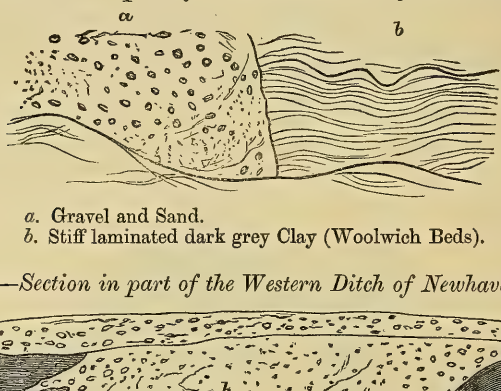
of loam, sand, and flints that occurs along the top of the cliff between the outliers is not in place, but is reconstructed, being simply the wash from either side. Another difference is the colouring as London Clay of a small patch on the more easterly and smaller outlier, to which alone the following notes refer (the other having in the cliff nothing higher than the sand of the Woolwich beds). Most likely at the time when my friend Mr. Bristow mapped it (some 12 or 15 years ago) there was no clear evidence of the presence of this formation, though it was suspected by Mr. Prestwich*.

Fig. 2.—*Diagram Section of the Cliff a quarter of a mile west of Newhaven Harbour.*



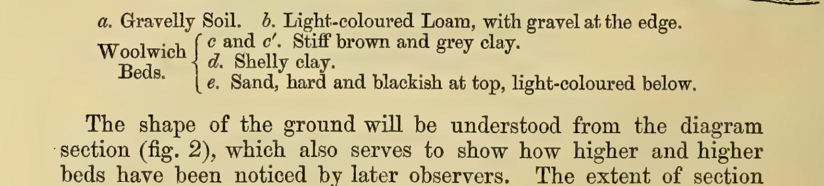
a. London Clay. *b.* Woolwich and Reading Beds. *c.* Chalk. Gravel omitted. The dotted lines show the former continuation of the ground and the beds.

Fig. 3.—*Section in part of the Western Ditch of Newhaven Fort.*



a. Gravel and Sand.
b. Stiff laminated dark grey Clay (Woolwich Beds).

Fig. 4.—*Section in part of the Western Ditch of Newhaven Fort.*



a. Gravelly Soil. *b.* Light-coloured Loam, with gravel at the edge.

Woolwich Beds. { *c* and *c′*. Stiff brown and grey clay.
d. Shelly clay.
e. Sand, hard and blackish at top, light-coloured below.

The shape of the ground will be understood from the diagram section (fig. 2), which also serves to show how higher and higher beds have been noticed by later observers. The extent of section

* Quart. Journ. Geol. Soc. vol. x. p. 83.

described by successive authors is marked by the vertical lines on the right of the following account, except for the irregular cap of gravel, which appears in all but the earliest.

1. Coarse red gravel, mostly of subangular flints, but also with flint pebbles, rather clayey, 10 feet or more.

2. London Clay.
   - Grey and brown clay, sometimes 3 feet.
   - Fine buff sand, passing into
   - Brown and grey loam, passing into
     (10 feet or more, yielding water and causing slips.)
   - Thinly bedded grey and brown clay, a few feet.
   - Basement-bed: flint-pebbles of moderate size in clay and ferruginous sand, about a foot.

Woolwich and Reading Beds. 60 feet or more.
   - 4. Roughly laminated bluish-grey clay (like London Clay) about 4½ feet (8 feet in Mr. Prestwich's section).
   - 5. Shell Beds.
     - Oyster-bed, rather hard, clayey, a foot to 2 feet or more (5 feet in the earlier account).
     - Shelly clays, 2 feet or more.
     - Grey and brown clay, partly sandy, often with a bed of shells in the middle. 2½ feet?
   - 5′. Light-coloured sand, partly pink, with thin layers of clay and traces of vegetable matter, yielding water and causing slips, about 6 feet, passing into
   - 5″. Shell Beds.
     - Grey laminated clay with a few layers of shells, at one part a thin bed of ironstone with casts of shells, about 8 feet?
     - Shelly clay, a few feet.
     - Clay, with shells at bottom, about 2 feet, below which there is generally
   - 6.
     - A hard layer, in great part iron-pyrites? an inch or more.
     - Hard dark sand or clay, a few inches.
     - Thin peaty bed. (These three thin beds vary; sometimes the hard layer is absent, sometimes the lignite.)
   - 7. Pale grey and brown clay, partly lilac-coloured, and with large pieces of selenite, 6 feet or more.
   - 8. Light-coloured sand, mostly of a pale yellowish-green tint. At one part a bright-red mottled bed near the top. In the middle a brown and apparently harder bed, which projects (not accessible).
   - 9. Bottom bed, green-coated and iron-stained flints in greensand, about 2 feet. It is from this bed (or from a local clayey layer at its base) that the *Websterite* has come. It rests evenly on

10. Chalk with flints.

Prestwich, 1854*. (beds 2–9)
Buckland, 1817†, and Mantell, 1822‡ and 1833§. (beds 5–9)
Webster, 1814‖. (beds 5, lower part, to 9)

The beds seem to vary both in thickness and structure, which accounts for the slight differences in the various descriptions.

The top of this small but interesting outlier is crowned by a Bri-

* Quart. Journ. Geol. Soc. vol. x. p. 83.

† Trans. Geol. Soc. (Ser. i.) vol. iv. p. 296.

‡ The Fossils of the South Downs, or Illustrations of the Geology of Sussex (4to, Lond.), p. 257.

§ The Geology of the South-east of England (8vo, Lond.), p. 54. Merely a shorter reprint of the former as regards this section.

‖ Trans. Geol. Soc. (Ser. i.) vol. ii. p. 191.

tish earthwork, or rather by what remains of it, as about half has been lost from the gradual wearing backward of the cliff. When this work was made, the ground must have reached much further south than now, in the form shown by the dotted line in fig. 2, as such works are always on hills.

The fort was far from finished when I saw it; but the unfinished western ditch gave some sections of gravel and loam above and sometimes wedged into the clays of the Woolwich Beds, as in figs. 3 & 4, which represent part of the same pipe (fig. 3 the western side, and fig. 4 the eastern).

3. *General Remarks.*

The Dieppe section seems to show a sort of passage from the Oldhaven Sand up into the London Clay, layers of sand occurring in the latter. There is also sand in the same position at Newhaven, where, however, the Oldhaven Beds are not present.

The sections show the extent of the same beds (insignificant as they are in thickness), or of like conditions, in the Lower London Tertiaries,—the Oldhaven Sand of Dieppe (3) being just like that of East Kent*, the shelly clays of the Woolwich Beds both at Dieppe and Newhaven (5) being the same as those of West Kent (with estuarine shells)†, the thin bed of lignite, peaty clay, or firm sand that occurs throughout Kent occurring also in the sections above described (6), and the lowest sand at both (8) seeming to be the same as that which forms the whole of the Woolwich Beds in East Kent, and occurs in West Kent also‡.

The mottled plastic clays are absent; and the bottom-bed (9) consists of flints partly rolled, as is elsewhere the case where it rests on the chalk—and not of flint-pebbles, as where it rests on the Thanet Beds.

Discussion.

The Chairman (Prof. Morris), in inviting discussion, called attention to the existence of Tertiary beds of similar character near Epernay and Rheims, and in other parts of France.

Mr. Evans remarked on the bearing which this extension of soft, yielding strata had on the excavation of the Channel. The disturbances in the sands and clays might be due to the springs having formerly, owing to the distance of the sea and the river-valley not having been excavated, stood at a higher level, and having thus softened or washed away the bed beneath the gravels.

Mr. Pattison mentioned that in all the combes along the French coast towards Tréport there were traces of soft Tertiary beds and blocks of sandstone.

Mr. Whitaker, in reply to a question from the Chairman, stated that, to the best of his belief, the sandstones at Dieppe were not calciferous. The sands were above the Woolwich beds, and therefore not Thanet sands.

* Quart. Journ. Geol. Soc. vol. xxii. p. 410 (bed 3).

† Mr. Prestwich has given a list of the fossils found at Newhaven.

‡ Quart. Journ. Geol. Soc. vol. xxii. p. 409 (bed 2).

4. *On new* TREE FERNS *and other* FOSSILS *from the* DEVONIAN. By J. W. DAWSON, LL.D., F.R.S., F.G.S., Principal of M'Gill College, Montreal.

[PLATE XII.]

OF the numerous ferns now known in the Middle and Upper Devonian of North America, a great number are small and delicate species, which were probably herbaceous; but there are other species which may have been tree ferns. Little definite information, however, has, until recently, been obtained with regard to their habit of growth.

The only species known to me in the Devonian of Europe is the *Caulopteris Peachii* of Salter, figured in the Quarterly Journal of the Geological Society for 1858. The original specimen of this I had an opportunity of seeing in London, through the kindness of Mr. Etheridge, and have no doubt that it is the stem of a small arborescent fern, allied to the genus *Caulopteris* of the Coal-formation.

In my paper on the Devonian of Eastern America (Quart. Journ. Geol. Society, 1862) I mentioned a plant found by Mr. Richardson at Perry, as possibly a species of *Megaphyton*, using that term to denote those stems of tree ferns which have the leaf-scars in two vertical series; but the specimen was obscure, and I have not yet obtained any other.

More recently, in 1869, Prof. Hall placed in my hands an interesting collection from Gilboa, New York, and Madison County, New York, including two trunks surrounded by aerial roots, which I have described as *Psaronius textilis* and *P. erianus* in my 'Revision of the Devonian Flora,' now in the hands of the Royal Society*. In the same collection were two very large petioles, *Rhachiopteris gigantea* and *R. palmata*, which I have suggested may have belonged to tree ferns.

My determination of the species of *Psaronius*, above mentioned, has recently been completely confirmed by the discovery on the part of Mr. Lockwood, of Gilboa, of the upper part of one of these stems, with its leaf-scars preserved and petioles attached, and also by some remarkable specimens obtained by Prof. Newberry, of New York, from the Corniferous Limestone of Ohio, which indicate the existence there of three species of tree ferns, one of them with aerial roots similar to those of the Gilboa specimens. The whole of these specimens Dr. Newberry has kindly allowed me to examine, and has permitted me to describe the Gilboa specimen, as connected with those which I formerly studied in Prof. Hall's collections. The specimens from Ohio he has himself named, but allows me to notice them here by way of comparison with the others. I shall add some notes on specimens found with the Gilboa ferns, and on a remarkable plant from the Devonian of Caithness, kindly placed in my hands by Dr. Wyville Thomson.

It may be further observed that the Gilboa specimens are from a bed containing erect stumps of tree ferns, in the Chemung group

* Abstract in Proceedings of Royal Society, May 1870.

of the Upper Devonian, while those from Ohio are from a marine limestone, belonging to the lower part of the Middle Devonian.

1. Caulopteris Lockwoodi, n. sp.

(Plate XII. figs. 1 to 3.)

Trunk from two to three inches in diameter, rugose longitudinally. Leaf-scars broad, rounded above, and radiatingly rugose, with an irregular scar below, arranged spirally in about five ranks; vascular bundles not distinctly preserved. Petioles slender, much expanded at the base, dividing at first in a pinnate manner, and afterwards dichotomously. Ultimate pinnæ with remains of numerous, apparently narrow pinnules.

This stem is probably the upper part of one or other of the species of *Psaronius* found in the same bed (*P. erianus*, Dawson, MS., and *P. textilis*, Dawson, MS. *). It appears to have been an erect stem imbedded *in situ* in sandstone, and preserved as a cast. The stem is small, being only two inches, or a little more, in diameter. It is coarsely wrinkled longitudinally, and covered with large leaf-scars (fig. 2) each an inch in diameter, of a horseshoe-shape. The petioles, five of which remain, separate from these scars with a distinct articulation, except at one point near the base, where probably a bundle or bundles of vessels passed into the petiole. They retain their form at the attachment to the stem, but a little distance from it they are flattened. They are inflated at the base, and somewhat rapidly diminish in size. The leaf-scars vary in form, and are not very distinct, but they appear to present a semicircular row of pits above, largest in the middle. From these there proceed downward a series of irregular furrows, converging to a second and more obscure semicircle of pits, within or below which is the irregular scar or break above referred to. The attitude and form of the petioles will be seen from fig. 1.

The petioles are broken off within a few inches of the stem; but other fragments found in the same beds appear to show their continuation, and some remains of their foliage. One specimen shows a series of processes at the sides, which seem to be the remains of small pinnæ, or possibly of spines on the margin of the petiole. Other fragments show the division of the frond, at first in a pinnate manner, and subsequently by bifurcation; and some fragments show remains of pinnules, possibly of fertile pinnules. These are very indistinct, but would seem to show that the plant approached, in the form of its fronds and the arrangement of its fructification, to the Cyclopterids of the subgenus *Aneimites*, one of which (*Aneimites acadica*), from the Lower Carboniferous of Nova Scotia, I have elsewhere described as probably a tree fern †. The fronds were evidently different from those of *Archæo-*

* Memoir on Devonian Flora, Proceedings of Royal Society, May 1870.
† Quart. Journ. Geol. Society, 1860.

pteris *, a genus characteristic of the same beds, but of very different habit of growth. This accords with the fact that there is in Prof. Hall's collection a mass of fronds of *Cyclopteris* (*Archæopteris*) *Jacksoni*, so arranged as to make it probable that the plant was an herbaceous fern, producing tufts of fronds on short stems in the ordinary way. The obscurity of the leaf-scars may render it doubtful whether the plant above described should be placed in the genus *Caulopteris* or in *Stemmatopteris*; but it appears most nearly allied to the former. The genus is at present of course a provisional one; but I think it only justice to the diligent and successful labours of Mr. Lockwood to name this curious and interesting fossil *Caulopteris Lockwoodi*.

I have elsewhere remarked on the fact that trunks, and petioles, and pinnules of ferns are curiously dissociated in the Devonian beds—an effect of water-sorting, characteristic of a period in which the conditions of deposition were so varied. Another example of this is, that in the sandstones of Gaspé Bay, which have not as yet afforded any example of fronds of ferns, there are compressed trunks, which Mr. Lockwood's specimens allow me at least to conjecture may have belonged to tree ferns, although none of them are sufficiently perfect for description.

Mr. Lockwood's collection includes specimens of *Psaronius textilis*; and in addition to these there are remains of erect stems somewhat different in character, yet possibly belonging to the higher parts of the same species of tree fern. One of these is a stem crushed in such a manner that it does not exhibit its form with any distinctness, but surrounded by smooth cylindrical roots, radiating from it in bundles, proceeding at first horizontally, and then curving downward, and sometimes terminating in rounded ends. They resemble in form and size the aerial roots of *Psaronius erianus*; and I believe them to be similar roots from a higher part of the stem, and some of them young and not prolonged sufficiently far to reach the ground. This specimen would thus represent the stem of *P. erianus* at a higher level than those previously found. My idea of the possible connexion of these fragments is represented in fig. 3. Mr. Lockwood's collections also contain a specimen of the large fern-petiole which I have named *Rhachiopteris punctata*. My original specimen was obtained by Prof. Hall from the same horizon in New York. That of Mr. Lockwood is of larger size, but retains no remains of the frond. It must have belonged to a species quite distinct from *Caulopteris Lockwoodi*, but which may, like it, have been a tree fern.

2. Caulopteris antiqua, Newberry.

(Plate XII. fig. 4.)

This is a flattened stem, on a slab of limestone, containing Brachiopods, Trilobites, &c. of the Corniferous Limestone. It is about

* The genus to which the well-known *Cyclopteris* (*Adiantites*) *hibernicus* of the Devonian of Ireland belongs.

18 inches in length, and 3½ inches in average breadth. The exposed side shows about twenty-two large leaf-scars arranged spirally. Each leaf, where broken off, has left a rough fracture; and above this is a semicircular impression of the petiole against the stem, which, as well as the surface of the bases of the petioles, is longitudinally striated or tuberculated. The structures are not preserved, but merely the outer epidermis, as a coaly film. The stem altogether much resembles *Caulopteris Peachii*, but is of larger size. It differs from *C. Lockwoodi* in the more elongated leaf-bases, and in the leaves being more remotely placed; but it is evidently of the same general character with that species.

3. Caulopteris (Protopteris) peregrina, Newberry.

(Plate XII. fig. 5 and 6.)

This is a much more interesting species than the last, as belonging to a generic or subgeneric form not hitherto recognized below the Carboniferous, and having its minute structure in part preserved.

The specimens are, like the last, on slabs of marine limestone of the Corniferous formation, and flattened. One represents an upper portion of the stem with leaf-scars and remains of petioles; another a lower portion, with aerial roots. The upper part is 3 inches in diameter, and about a foot in length, and shows thirty leaf-scars, which are about ¾ of an inch wide, and rather less in depth (fig. 5, *a*). The upper part presents a distinct rounded and sometimes double marginal line, sometimes with a slight depression in the middle. The lower part is irregular, and when most perfect shows seven slender vascular bundles, passing obliquely downward into the stem. The more perfect leaf-bases have the structure preserved, and show a delicate, thin-walled, oval parenchyma, while the vascular bundles show scalariform vessels with short bars in several rows, in the manner of many modern ferns. Some of the scars show traces of the hippocrepian mark characteristic of *Protopteris*; and the arrangement of the vascular bundles at the base of the scars is the same as in that genus, as are also the general form and arrangement of the scars. On careful examination, the species is indeed very near to the typical *P. Sternbergii*, as figured by Corda and Schimper*.

The genus *Protopteris* of Sternberg, though the original species (*P. punctata*) appears as a *Lepidodendron* in his earlier plate (pl. 4), and as a *Sigillaria* (*S. punctata*) in Brongniart's great work, is a true tree fern; and the structure of one species (*P. Cottai*) has been beautifully figured by Corda. The species hitherto described are from the Carboniferous and Permian.

The second specimen of this species represents a lower part of the stem (fig. 6). It is 13 inches long and about 4 inches in diameter, and is covered with a mass of flattened aerial roots lying parallel to each other, in the manner of the Psaronites of the Coal-formation and of *P. erianus* of the Upper Erian or Devonian.

* Corda, Beiträge, pl. 48, copied by Schimper, pl. 52.

4. Rhachiopteris, n. sp.

(Plate XII. fig. 7.)

Along with the above, in Dr. Newberry's collection, is a singular fragment enclosed in a large nodule of chert from the Corniferous Limestone. It shows clearly about 8 inches of the base of an immense petiole, from 4 to 2 inches in breadth, and attached to shreds of tissue, which seem to represent a part of the stem torn away with it. Its structure is preserved, and consists of delicate large-celled parenchyma, with slender bundles of vessels, about eighteen of which are visible. In structure they are very similar to those of the last species; but the scalariform vessels are accompanied by more woody tissue. They are parallel in the distal end of the fragment, but near its base become tortuous and branching. In the part which represents the stem, or possibly part of its roots, they assume the form of cylindrical rods of parenchyma with a central bundle of vessels. In form and outward marking it resembles *R. gigantea* of my Royal-Society Memoir; but in the latter the structure is not preserved. The present specimen must have belonged to a tree fern of grander proportions than either of those previously noticed.

In the cellular tissue of some parts of this great petiole there are numerous round granules, resembling those figured by Corda in his description of *Protopteris Cottai* *, and supposed by that writer to be grains of fossilized starch. Mr. Carruthers has more recently described similar starch-granules in the tissues of an Eocene fern†. Whether the granules in the cells of the present specimen are really remains of starch, or merely rounded siliceous concretions, such as are often found in the cells of silicified plants, I am by no means certain. Perhaps the fact that similar round grains are seen in the interior of some of the woody fibres militates against their organic character. They are certainly not markings on the cell-walls, but spherical bodies contained within the cells; and if starch-grains, they may claim to be the oldest known, being of Middle Devonian age.

5. Nœggerathia gilboensis, n. sp.

(Plate XII. fig. 8.)

Leaf rhombic-obovate, with a broad base. Nerves or radiating plicæ nine in number, not forked, and with fine striæ between them. Length $3\frac{2}{10}$ inches. Breadth $2\frac{1}{2}$ inches.

This leaf occurs in the collections of Mr. Lockwood, from Gilboa. It belongs, without doubt, to the provisional genus *Nœggarathia*, and seems to have been bent in a conduplicate manner, and clasping or decurrent, on a stem or branch. It does not seem to have been a fern; but beyond this I am not inclined to hazard any opinion as to its affinities.

* Beiträge, pl. 49.

† Quart. Journ. Geol. Soc. Aug. 1870.

In addition to this species and the *Caulopteris* above described, Mr. Lockwood's collection contains branchlets of a *Lepidodendron*, apparently *L. gaspianum*, which also occurs in Prof. Newberry's collections from the Corniferous Limestone.

6. Lycopodites, &c.

In his recently published 'Paléontologie,' Schimper (evidently from inattention to the descriptions and want of access to specimens) doubts the Lycopodiaceous character of the species of this genus described in my papers in the Journal of this Society from the Devonian of America. Of these *L. Richardsoni* and *L. Matthewi* are undoubtedly very near to the modern genus *Lycopodium*. *L. Vanuxemii* is, I admit, more problematical; but Schimper could scarcely have supposed it to be a fern or a fucoid allied to *Caulerpa* had he noticed that both in my species and the allied *L. pinnæformis* of Goeppert, which he does not appear to notice, the pinnules are articulated upon the stem, and leave scars where they have fallen off. When in Belfast last summer I was much interested at finding in Prof. Thomson's collection a specimen from Caithness, which shows a plant apparently of this kind, with the same long narrow pinnæ or leaflets, attached, however, to thicker stems, and rolled up in a circinate manner. It seems to be a plant in vernation, and the parts are too much crowded and pressed together to admit of being figured or accurately described; but I think I can scarcely be deceived as to its true nature. The circinate arrangement in this case would favour a relationship to ferns; but some Lycopodiaceous plants also roll themselves in this way, and so do the branches of the plants of the genus *Psilophyton*.

In conclusion, I may state that, when in Edinburgh last summer, Mr. Peach showed me fine and characteristic specimens of rhizomata of *Psilophyton* from the Caithness beds, and also specimens which seem to show that some at least of the fragments from these beds, which have been referred to *Lepidodendron nothum*, belong to a different species, more nearly allied to the *Cyclostigma* of Killercan and Gaspé. Mr. Peach has also branches of a *Lepidodendron* like *L. gaspianum*, a *Cyclopteris* allied to *C. Brownii*, a plant of the nature of *Anarthrocamia* or *Calamites*, a *Stigmaria*, and fragments which may belong to *Sigillaria*, all from the Devonian beds of Caithness.

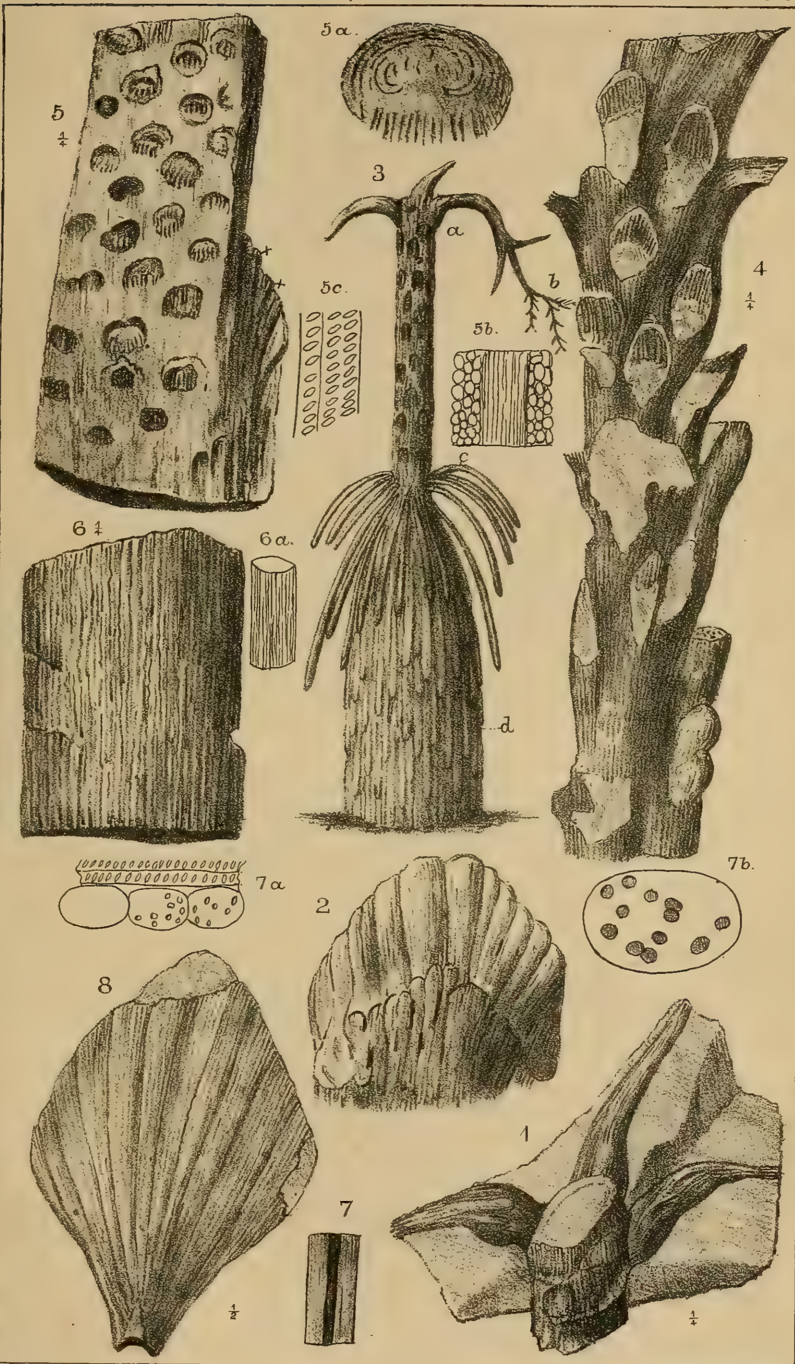
EXPLANATION OF PLATE XII.

Fig. 1. *Caulopteris Lockwoodi*, one-fourth natural size, portion of stem with petioles.

Fig. 2. Leaf-scar, natural size.

Fig. 3. Restoration in part of *Caulopteris Lockwoodi*, reduced: *a*, upper part, with petioles; *b*, remains of pinnæ; *c*, middle part, with diverging aerial roots; *d*, lower part, with aerial roots, perhaps the same with *Psaronius erianus*, Dawson, MS.

Fig. 4. *Caulopteris antiqua*, Newberry, one-fourth the natural size.



R. Mintern lith.

Mintern Bros. imp.

DEVONIAN TREE FERNS & NŒGGERATHIA.

Fig. 5. *Protopteris peregrina*, Newberry, impression of stem, one-fourth the natural size: *xx*, remains of petioles. 5 *a*, scar, natural size, showing bundles of vessels at base; 5 *b*, portion of a vascular bundle, magnified, showing scalariform vessels and cellular tissue; 5 *c*, scalariform vessel, highly magnified.

Fig. 6. Lower part of stem of the same, with aerial roots, one fourth the natural size. 6 *a*, one of the roots, natural size.

Fig. 7. Vascular bundle of *Rachiopteris*, natural size; 7 *a*, portion of the same, showing vascular and cellular tissue, with rounded granules in the cells; 7 *b*, one of the cells magnified, showing contained granules.

Fig. 8. *Næggerathia gilboensis*, one-half the natural size.

Discussion.

Dr. Duncan doubted the desirability of basing generic and specific terms on imperfectly preserved and indistinct specimens, and pointed out the disagreements among botanists that had resulted from so doing. He would prefer calling fossils such as those described "cryptogamous forms from certain strata." He was doubtful also whether the supposed petrified starch was not merely orbicular silex.

The Chairman (Prof. Morris) remarked on the four different conditions exhibited by existing tree ferns:—first, with roots running down the stem; secondly, the lower portion with oval scars; these are, thirdly, further up the stem, rhomboidal vertically; and, fourthly, higher up still, rhomboidal horizontally; so that were the plant fossil, distinct genera and species might be founded upon the different parts.

April 5, 1871.

The following communications were read:—

1. *On a new* Chimæroid Fish *from the* Lias *of* Lyme Regis (Ischyodus orthorhinus, ♂). By Sir Philip Grey Egerton, Bart., M.P., F.R.S., F.G.S.

[Plate XIII.]

The knowledge we have hitherto obtained of the form and structure of the fossil fishes assigned to the Chimæroid family is very limited, being derived solely from the dental plates and dorsal spines, which, from their superior hardness, have resisted the decomposition which has removed the more destructible cartilaginous structures with which they were associated. Whether these old monsters resembled the surviving members of the family in quaint form and bizarre aspect was a matter of conjecture. That they exceeded them in size is a matter of fact. The massive mandibles of *Ischyodus Townshendi* of the Portland age, or the enormous premaxillaries of *Edaphodon gigas* of the Chalk era, sufficiently testify that the possessors of such powerful dental machinery must have been of heroic size compared with the surviving types of the family. The recent discovery of a specimen in the Lias of Lyme Regis, in which a considerable portion of the anterior structures of a Chimæroid is preserved, enables me to advance a step in clearing up the mystery which has hitherto shrouded this subject. It was described to me as a new species of shark, showing the dorsal spine *in situ*, and the upper and lower jaws. From a rough sketch of the specimen forwarded with the letter, I was inclined to think, from the peculiar mode of insertion of the spine, that it might possibly belong to a *Balistes* or a Siluroid fish, certainly that it could not be a shark; but on examining the specimen itself I found the unmistakable dental apparatus characteristic of the Chimæroids, surrounded with shagreen; and then perceived that what was described as the upper jaw of a shark could only be a monstrous form of the singular rostral appendage peculiar to the male sex of the Chimæroids of the present time. The dermal integument has fortunately retained its proper position and outline on the frontal and oral regions, representing a tolerably correct profile of the head. The forehead is characterized by a remarkable prolongation of the skin (Pl. XIII. fig. 1 *a*), extending six inches beyond the frontal cartilages, and terminating in a hook directed abruptly downwards for more than one inch. This structure is very similar to the prelabial appendage found in the *Callorhynchus antarcticus* of the present period. Immediately above this projection, and following the outline of its upper margin, is seen what I imagine to be the homologue of the frontal ossicle of the recent male Chimæroids (1 *b*). In the latter it exists as a small incurved bone, terminating in a kind of pad covered with minute spines; but in the fossil it is developed into a formidable rostrum slightly curved at the base, forming a frontal declivity, and then projecting forwards as far as the extremity of the prelabial appendage above described. Its entire length is five inches and a half, of which the anterior two-thirds are straight. The proximal extremity is attached to the head by means of a rounded condyle, which is received in a hollow of the frontal cartilage—an arrangement which allows of a limited amount of motion in the vertical plane. The underside of the rostrum is thickly beset with tubercles carrying recurved central spines, not unlike the dermal tubercles of some of the recent *Raiidæ*. Similar spine-bearing tubercles, seated on the upper surface of the nasal prolongation, are opposed to the former, so that a fragmentary specimen of this portion of the fish might easily be mistaken for parts of an upper and lower jaw. The tubercles extend in diminished size and numbers along the entire under surface of the organ. The upper surface was covered by coarse-grained shagreen, which probably invested also the sides; but it has perished in these parts, and the coarse fibrous structure of the bone is displayed. About one inch behind the insertion of the frontal spine the orbit is seen. This is of large size, measuring one inch in diameter. Two inches behind the orbit, and in close proximity to the occipital region, the dorsal spine (1 *c*) is situated. Before, however, entering upon the description of this organ, it will be necessary to allude shortly to the anatomical characters of the dorsal fin in the recent spinigerous Chondropterygians. Through the kind assistance of Dr. Günther, of the British Museum (whose extensive knowledge of ichthyology is not surpassed by any living authority), I have been enabled to examine the structure of the dorsal fin in the recent *Acanthias, Callorhynchus,* and *Chimæra.* In the first-named genus, and also in *Cestracion* and *Centrina*, the dorsal fin is supported by a broad cartilage imbedded in the muscular tissue of the back of the fish. The anterior upper angle of this cartilage carries the dorsal spine, projecting into the cavity of the spine itself. The spine has its base planted in the muscular tissue, and is embraced by a fold of skin at the base of the fin. The internal portion of the spine is defined by the absence of the horny covering which characterizes the external parts. This feature is well seen in some of the large fossil Ichthyodorulites. In consequence of this arrangement the spines of these fishes had a very limited amount of freedom, probably not more than could be allowed by the elasticity of the integuments. The case is far otherwise as regards the dorsal spine of *Callorhynchus* and *Chimæra*, specimens of both which genera have been ably dissected for me by Dr. Günther. Here the broad cartilage which supports the dorsal fin, and which carries the dorsal spine on its anterior margin, is external to the muscular tissue, and is enveloped only by dermal integument. The anterior process forming the core of the hollow spine has its lower extremity developed into a rounded articulating surface, which works in a cavity on the upper anterior edge of a strong cartilaginous plate extending upwards from the notochordal axis. A perfect joint is thus formed (1 *d*), enabling the spine to move freely in the vertical plane for nearly one-fourth of a circle, very much as the mast of a barge is lowered and raised before and after passing under a bridge. In short the *Chimæridæ* had a jointed dorsal spine, the *Spinacidæ* and *Cestraciontidæ* a fixed one. I am not aware that this fact has been noticed before; it is one of no small importance in considering the natural affinities of the Chimæroid fishes. In the fossil under description the arrangement of these parts corresponds in all material points with the recent Chimæroids. The dorsal spine, however, was a more formidable weapon. It measures six inches in length from the joint to the apex, by three lines in breadth. It is slightly recurved, and is armed with a single series of uncinate spines pointing upwards on the proximal, and a double series pointing downwards on the distal, margins of the spine. The remainder of the surface is ornamented with fine tubercles arranged in longitudinal lines, and diminishing in size from the base of the spine upwards. Both these and the spines consist of a hard lustrous ganoine, similar in appearance to that composing the tubercles on the rostrum. The articulating facet at the junction of the spine with the body is carried on the base of the cartilaginous core which occupies the cavity of the spine. It differs slightly from the recent analogue in being rather concave than convex, the corresponding articulating surface, on the other hand, being rather convex than concave. A portion of the membranous fin is seen attached to the hinder edge of the spine, and is composed of fine-grained shagreen; impressions are faintly seen in other parts of the specimen, which show that the dermal covering in general was of the same character. The outline of the mandibular region is fortunately preserved, and exhibits a very singular truncated form of lower lip. The labial and mental angles are right angles, and connected by a straight line one inch in length; the upper and lower margins are nearly parallel for a distance of one inch from the mentum; so that the area of the anterior mandibular projection was a square of one inch. The dental apparatus is rather dislocated; but the component parts remaining are well preserved. There is an indistinct impression of the left maxillary plate in its proper position; but its fellow of the right side (1 *e*) is thrown back below the orbit. This measures one inch and a quarter in length by three lines in width, being of slighter proportions than the corresponding denticle of *Ischyodus Egertoni*, which it most resembles. The premaxillaries are absent. The mandibular plates (1 *f*) are reversed, but retain their relative positions. Each measures one inch and a half in length, and is one inch deep at the symphysis. The dental apparatus corresponds in all respects with the characters assigned by me to *Ischyodus*, to which genus I refer this specimen; but as it differs specifically from those already described, I have selected a name signifying its peculiar deviation from the recent types in the size and form of the rostral appendage.

This remarkable specimen has been secured for the fine collection of fossil ichthyology in the British Museum.

DESCRIPTION OF PLATE XIII.

Fig. 1. *Ischyodus orthorhinus*, reduced one-third: *a*, labial prolongation; *b*, frontal appendages; *c*, dorsal spine; *d*, articulation of the dorsal spine; *e*, maxillary plate; *f*, mandibular plates.

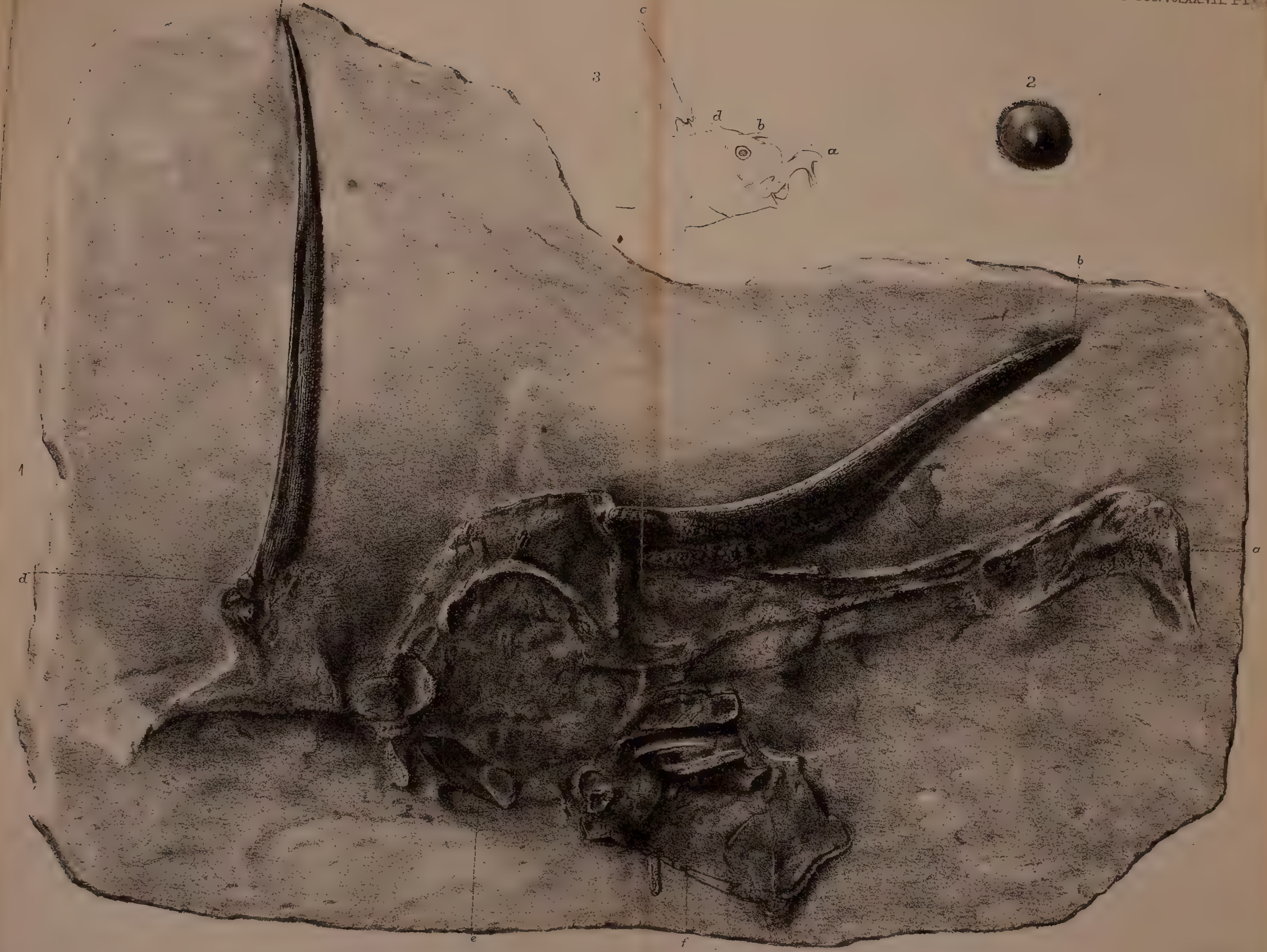
Fig. 2. Rostral tubercle, magnified.

Fig. 3. Outline of the anterior parts of *Callorhynchus antarcticus*, reduced one-half: *a*, labial prolongation; *b*, frontal appendage; *c*, dorsal spine; *d*, articulation of dorsal spine.

Discussion.

Dr. Günther commented on the interest of this discovery, as in no other Sharks is the same articulation of the dorsal spine as that described in the paper to be found. He inquired whether the granulated plate supposed to be dorsal might not be a part of the armature of the lateral line, as in Sturgeons. He thought that the Chimæroids would eventually prove to be intermediate between the Ganoid and Shark types, and that all belonged to one subclass.

Mr. Gwyn Jeffreys inquired what other remains were found with these fishes such as might represent the food, molluscan or otherwise, on which they lived.



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ISCHYODUS ORTHORHINUS. $\frac{2}{3}$

Sir P. Egerton replied that there was no deficiency of pabulum for any kind of fish in the sea represented by the Lias of Lyme Regis. He also made some remarks on another somewhat similar specimen in his own museum. The plate referred to by Dr. Günther, he stated, was symmetrical, and not like the lateral plates on the Sturgeon, which are unsymmetrical. He therefore thought it dorsal.

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2. *On the* Tertiary Volcanic Rocks *of the* British Islands. By Archibald Geikie, Esq., F.R.S., F.G.S., Director of the Geological Survey of Scotland, and Professor of Geology in the University of Edinburgh.—First Paper.

[Plate XIV.]

In the present communication I propose to offer to the Society the first of a series of papers descriptive of those latest of the British volcanic rocks which intersect and overlie our Palæozoic and Secondary formations, and which, from fossil evidence, are to be regarded as of miocene, or at least of older Tertiary, date. Materials for this purpose have been accumulating with me for some years past. In bringing forward this first instalment of them, I wish to preface the subject with some general introductory remarks regarding the place which the rocks seem to me to hold in British geology, and on the nomenclature which I shall use in describing them. These remarks will be followed by a detailed description of the first of a succession of districts where the characteristic features of the rocks are well displayed. Other typical districts will be described in future memoirs.

General Introduction.

1. *Area occupied by the Rocks.*

The rocks to which I propose to direct attention cover many hundreds of square miles in the British Islands. They spread over the north-east of Antrim, from Belfast to Loch Foyle, forming there a great plateau or series of plateaux, with an area of fully 1200 square miles and an average thickness of 550 feet. From Ireland the same rocks are prolonged northwards through the Inner Hebrides. They form nearly the whole of the islands of Mull, Rum, Eigg, Canna, and Muck. They cover fully three-fourths of Skye, and extend even as far as the Shiant Isles. But far beyond our own area they reappear with all their characteristic features in the Faroe Islands, and again in the older volcanic tracts of Iceland. In studying the volcanic phenomena which these rocks present to us, therefore, we are not occupied with limited or local features, but with the records of perhaps the most remarkable period in the history of volcanic action in Europe—records which, in spite of the vicissitudes of later ages, may still be gleaned at intervals over a length of nearly 800 miles. Throughout that great space volcanic activity has long been extinct, yet it remains in full force at the northern extremity in Iceland; and we may perhaps speculate upon the possible continuity of the present Icelandic volcanoes with those which, in Tertiary times, were in action from the Irish Channel far into the Arctic Ocean.

Nor is it merely by the vast basaltic plateaux which are left that the former extent and importance of this Tertiary volcanic activity is to be judged. From the main chain of the Antrim and Hebridean basalts there diverge innumerable dykes, which are found traversing Scotland and the north of England, even as far as the shores of the North Sea. I have elsewhere* given reasons for regarding these dykes as contemporaneous with the Tertiary volcanic series of the north-west, and I shall have much to say regarding them in a subsequent paper. Taken in connexion with the great basaltic plateaux, they furnish us with evidence of a prolonged period of great volcanic activity.

2. *Nomenclature of the Rocks.*

Although the petrography of the volcanic series falls to be described in detail with reference to the localities where the rocks are found, some general remarks are here required, more especially regarding the nomenclature which is to be followed†. For the purposes of a geologist a purely mineralogical or chemical arrangement of rocks is singularly unserviceable. He requires to take cognizance of the geological history as well as of the composition of the rocks; and indeed the latter branch of inquiry is chiefly of interest to him so far as it throws light upon the former. At the same time he cannot afford to dispense with the aid of chemistry and mineralogy; and yet this has only been too frequently the case in this country, where the nomenclature of our igneous rocks remains in much the same state as that in which it was half a century ago. In the course of the researches which are to be described in this paper, I have found it of great service to keep always prominently in view the fundamental geological subdivision of volcanic rocks into *Interbedded* or *Contemporaneous*, and *Intrusive* or *Subsequent*. Each of these two series indicates a distinct variety of volcanic action, the

* Proc. Roy. Soc. Edin. vol. vi. p. 74; Brit. Assoc. Rep. 1867, Address to Geological Section, p. 52.

† The word "trap" or "trappean" has been commonly used in this country as a general term for all these rocks. It has been employed, however, in such various significations that perhaps it had better be discarded as ambiguous, unless we agree to use it solely as a convenient synonym for all truly volcanic rocks which are found in our Palæozoic, Secondary, or Tertiary formations. As all the rocks which I shall have occasion to describe in this series of papers are of volcanic origin—either thrown out at the surface in the form of melted lava, or as loose dust and stones, or injected into different parts of the rocks lying beneath the surface,—I shall employ the word "volcanic;" only premising that if at any time, to avoid unmelodious repetition, the word "trap" is used, it is to be taken in the sense above indicated.

former bringing before us the results of that action as shown at the surface, the latter revealing to us, as no modern volcano can do, some of those features of the action which go on below ground. It will be found, moreover, that between the rocks of each series there is, on the whole, a well-marked petrographical difference. The same species of rock is sometimes found indifferently in either division; but when this occurs, as in the case of the dolerites and basalts, we often learn by practice to discover many little points of distinction, which, when combined, serve to give us a tolerably distinctive type for each of the two great series.

In both of these two leading divisions the rocks occur either as *Crystalline* or *Fragmental.* In the former section are included all the rocks which, like lavas, have been ejected in a melted state; in the latter those which have been thrown out, like ashes and scoriæ, in a fragmentary form.

The Crystalline Interbedded Rocks occur in the form of *sheets* or *flows*, either singly or in consecutive series; they are, in short, old lava-flows, and present the same general structural and textural varieties as modern lavas show.

The Fragmental Interbedded Rocks likewise occur in *sheets*, or *beds* or *layers*; they are the consolidated tuffs, conglomerates, and breccias arising from the ejection and deposition of ancient volcanic ashes and scoriæ.

In the case of the Crystalline Intrusive Rocks I have found the simplest classification to be one based upon the form of the space into which these rocks were intruded and in which they consolidated. Accordingly, I have classed them as 1. *Amorphous masses*, which have been thrust through irregular fractures, and show in consequence no parallel bounding surfaces; the syenites of Skye and Raasay are good examples. 2. *Sheets*, which were thrust between the bedding-planes of older rocks, and which differ from the sheets of the Contemporaneous Crystalline section in altering the beds above them, in showing none of the characteristic slaggy upper and under surfaces found in the contemporaneous flows, and in having some well-marked lithological differences, such as absence of amygdaloidal texture and greater compactness of grain towards the line of contact with the bounding surfaces of other rocks. 3. *Dykes and Veins.* These have resulted from the injection of melted rock along fissures. When the fissure was more or less vertical and straight, the intruded melted rock formed a Dyke; when the crack was on a smaller scale and ran irregularly or branched, either vertically, horizontally, or at any angle, the result was a Vein or series of Veins. 4. In some cases the original orifices remain, which served as the vents by which the volcanic rocks were erupted to the surface. These volcanic pipes are now filled with various kinds of volcanic materials, and are termed *Necks.*

The Fragmental Intrusive Rocks only occur as *Necks* or as *Veins* connected with necks. They consist of agglomerate and tuff, sometimes exceedingly coarse and unstratified, composed of fragments of crystalline volcanic rocks, older tuffs, or of the surrounding strata through which the neck has been blown out.

This general geological classification admits of and requires further subdivisions, according to the petrographical distinctions of the rocks. Thus the Tertiary volcanic rocks which occur as crystalline interbedded sheets may be grouped, according to their mineralogical composition, as *Felspathic* or *Augitic*. In the former group may be included the pitchstones, trachytes, and porphyrites; in the latter the dolerites, anamesites, and basalts. The fragmental interbedded rocks occur as basalt-tuffs or basalt-breccias. The crystalline intrusive series is represented by syenites, quartz-porphyries, pitchstones, felstones, dolerites, anamesites, and basalts. The fragmental intrusive series is shown by necks of basalt-agglomerate.

The dolerites, anamesites, and basalts form the great mass of the Tertiary volcanic rocks of Britain. They occur in vast plateaux, as in Antrim and the Inner Hebrides, also abundantly as dykes, veins, and intrusive sheets. They vary in texture from a coarse crystalline aggregate to fine black basalt, which, in turn, shades into the glassy variety known as tachylite. In interbedded sheets they are columnar or jointed, often amygdaloidal, and then full of zeolites. Closely related to these, and possibly a metamorphosed variety of them, are some rocks in which diallage occurs in place of augite*. Much less abundant are some pale grey rocks, sometimes amygdaloidal, occasionally very porphyritic, composed of a dull plagioclase base, with striated felspar crystals, and for which porphyrite is perhaps the most fitting name. They occur in interbedded sheets in Mull and Eigg. Of the more highly silicated igneous rocks, pitchstone occurs somewhat rarely, and always in the form of veins, except in the old coulée of the Scùr of Eigg, to be described in this paper. Felstone and quartziferous porphyry occur in veins and intruded masses. Syenite is found in veins, and also as huge hills disrupting and overlying liassic rocks in Skye and Raasay. That this syenite belongs to the Tertiary igneous rocks, and may be connected with the volcanic eruptions of the great basalt-plateaux, I hope to show in a future paper. A rock which has been called a trachyte-porphyry occurs in Antrim. I may add that around the syenite-hills of Skye, and possibly also in Mull, there has been developed a local but well-marked metamorphism of the surrounding rocks†.

The tuffs are comparatively small in quantity. They occur as thin lenticular layers between the sheets of dolerite forming the great plateaux, and sometimes, as at Ardtun Head, Mull, and in Antrim, contain recognizable remains of land-plants. In Mull also they are sometimes associated with local beds of black cherry-coal, not distinguishable by any external character from the ordinary fuel of our coal-fields. Necks of agglomerate are of still rarer occurrence. Between the sheets of dolerite thin irregular layers of

* These are seen to the south-east of Ben More, in Mull, and seemed to me to be a continuation of beds which, further west, were ordinary dolerites. In that area also masses of syenite occur; and the impression conveyed by a hasty examination of it was that the volcanic rocks had there undergone subsequent metamorphism, as has happened to the Lias limestones round the Tertiary syenite of Skye. But I propose soon to revisit this interesting district.

† See Quart. Journ. Geol. Soc. vol. xiv. p. 12 *et seq.*

red bole or earth not unfrequently occur. I have noticed similar partings between old lavas at Torre del Annunziata; and in the latter case, at least, they can hardly be regarded as other than the soil which had gathered over the older lava, and was burnt by the overflow of the newer one.

The following tabular arrangement will show at a glance the classification of the rocks which I have adopted:—

Classification of the Tertiary Igneous Rocks of Britain.

	Felspathic Series.					Pyroxenic or Augitic Series.					
	Syenite.	Felstone and quartz-porphyry.	Trachyte and trachyte-porphyry.	Pitchstone.	Porphyrite.	Dolerite.	Basalt.	Tachylite.	Diallage-rock, altered dolerite?	Felspathic tuffs.	Pyroxenic tuffs and agglomerate.
I. INTERBEDDED OR CONTEMPORANEOUS.											
A. *Crystalline.*											
Sheets or beds	..	..	?	*	*	*	*	..	*		
B. *Fragmental.*											
Beds or layers	..	..	..	..	..	..	..	..	..	?	*
II. INTRUSIVE OR SUBSEQUENT.											
A. *Crystalline.*											
α. Amorphous masses	*	*	?	..	..	?					
β. Sheets	..	..	..	..	..	*	*				
γ. Dykes and veins	*	*	?	*	..	*	*	*			
δ. Necks	..	?	..	..	..	..	?				
B. *Fragmental.*											
Necks	..	..	..	..	..	..	..	.	..	..	*

In this Table are inserted only those rocks which I have myself, up to this date, found among the Tertiary series. The list will, no doubt, be enlarged as further investigations proceed†.

3. *Geological Age of the Rocks.*

A few words are needed here in support of the view that all the rocks now to be described are of Tertiary age. In Antrim the well-known position of the basalt above the chalk, and its association with layers containing miocene plants—in Mull the occurrence of a thick bed of chalk-flints, and of the Ardtun miocene leaf-beds‡, at the base of the whole volcanic series, the evident prolongation of the Mull volcanic rocks through the other islands of the Inner Hebrides§,

† I have given a more detailed account of this classification of volcanic rocks, and of the grounds on which it is based, in Chapter xiii. of the forthcoming edition of Jukes's 'Manual of Geology.'

‡ See Quart. Journ. Geol. Soc. vol.vii. p. 90.

§ Following Edward Forbes, I formerly regarded the volcanic rocks of Skye as of Oolitic age, being misled by the way in which the basalts at their base seem the passage of the great system of divergent dykes across faults of every age and through the different geological formations up to and including the chalk—these are facts which make it sufficiently evident that in the north-western part of the British area, along the great hollow stretching from Ireland northwards between the chain of the Outer Hebrides and the Scottish mainland, volcanic action was abundantly manifested in miocene times. Whether the eruptions took place wholly within the miocene period, or whether they extended beyond it, into later ages, remains yet uncertain. That the time during which the eruptions continued was of enormous duration, is shown by several considerations:—(1) The plateaux are made up of many successive sheets, each of which marks at least one, and sometimes more separate eruptions. In Antrim these sheets rise one over another for a thickness of sometimes 900 feet; and how much thicker they may have been cannot now be determined, seeing that the upper part of the series has been removed by denudation. In Mull there is a visible thickness of more than 3000 feet of volcanic beds; yet there, too, the upward continuation of them has been worn away, and there are now no means of measuring what the original total thickness may have been. (2) There occur among the basalts intercalated layers of tuff, clay, and coal, indicating pauses between the eruptions of long enough duration for the growth and accumulation of vegetable matter sufficient, when compressed, to form two or three feet of coal*. The leaf-beds of Mull likewise indicate long and tranquil intervals between the outflow of successive sheets of basalt. (3) But the most striking evidence of the long continuance of this volcanic period is furnished in the island of Eigg, by the occurrence of ancient hollows worn by river-action out of the basalt plateaux, and subsequently filled by the outpouring of fresh lava. The latter bears thus the same relation to the more ancient eruptions that the later coulées of Auvergne do to the old denuded basaltic plateaux of that region.

But not only have the last-erupted rocks been worn away, and all evidence removed as to the time when volcanic action ceased to manifest itself in our area; denudation has since then been so constant and so potent, that even of the whole mass of erupted matter only disconnected fragments remain. Out of the great basaltic tablelands long and wide valleys have been carved to a depth of

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regularly intercalated with the oolitic strata. As pointed out in a subsequent page, I have now learned, however, after continued surveys of the other islands, that this intercalation is deceptive, and that the basalts of Skye are only a prolongation of the miocene basalts of Mull.

* Such beds of coal occur in Mull (see Proc. Roy. Soc. Edin. vol. vi. p. 72). All the coal associated with the volcanic rocks of the Inner Hebrides is of contemporaneous, that is of miocene, date. The so-called oolitic coal of Skye I have now no doubt is of this age; and hence the intercalated strata shown to occur in the volcanic series of Skye on the map of Scotland published by Sir Roderick Murchison and myself, and meant to indicate the strips of coal and associated strata, must be regarded not as oolitic, but as miocene. Their size was necessarily greatly exaggerated, with the view of expressing the bedded character of the igneous rocks.

more than 1000 feet. Some of the noblest hills of the Inner Hebrides are but solitary outliers left standing amid the ruin of the great sheets of solid rock of which they once formed a part. Ben More, in Mull, though more than 3000 feet high, is only a magnificent fragment of the huge pile of volcanic material which formerly swept over what are now the deep glens and fjords of Mull. The long lines of imposing cliff with which the basalt plateaux front the Atlantic all through these islands, from the Fair Head of Antrim to the far headlands of Skye, tell everywhere the same tale of vast and continuous denudation. Great, therefore, as the area is over which these rocks are now to be traced, it covers but a small part of its original extent.

These prefatory remarks may suffice to show the general nature of the subject of which I propose to treat, and I shall now proceed to describe in some detail a district in which some of the phenomena are typically displayed. The area which I have selected for this purpose is the island of Eigg, partly on account of its simplicity of structure, and partly because it presents to us a more striking picture of the vast duration of the Tertiary volcanic period in Britain than any other space of like size with which I am acquainted. My observations are the result of a survey made by me of the island in the year 1864. In this excursion I was accompanied by my friend and former colleague Professor Young, of the University of Glasgow, who devoted himself to the palæontology of the island. It was our original intention to combine our observations in a joint memoir. Circumstances having occurred, however, to delay the proper examination of the fossils, it has been judged expedient to publish, in the mean time, my own observations on the volcanic geology of the island, leaving the oolitic strata and their fossils to form the subject of a future communication.

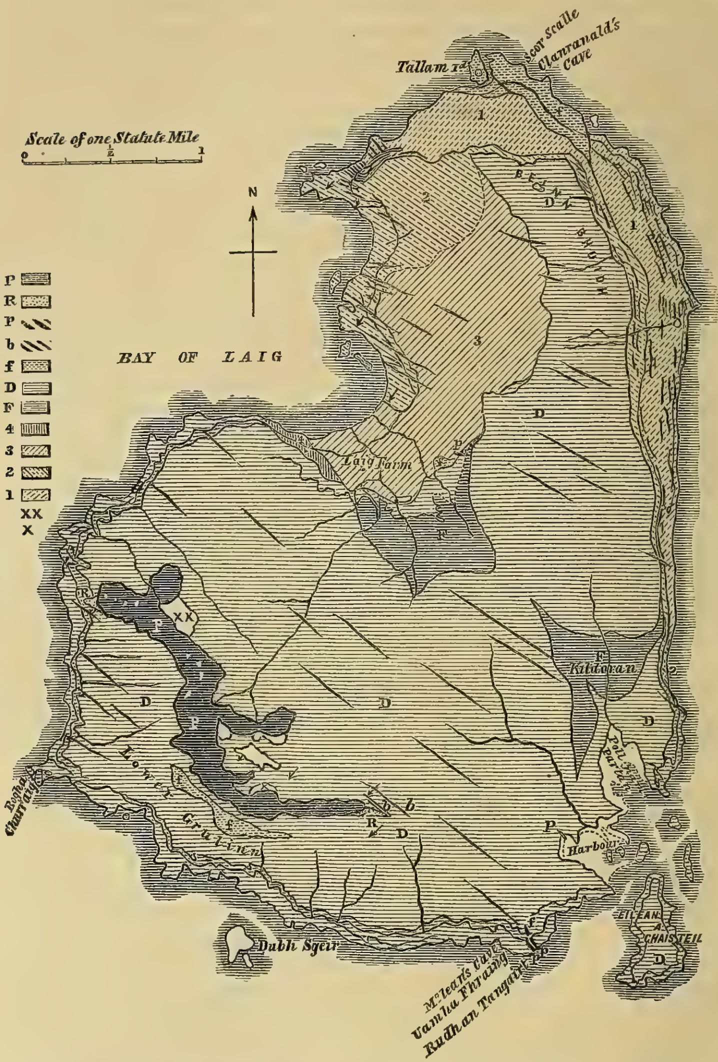
THE ISLAND OF EIGG*.

A. Physical Features and Geological Structure.

In the chain of the Inner Hebrides, broken as it is in outline and varied in its types of scenery, there is no object more striking than this island. Though only about five miles long and from a mile and a half to three miles and a half broad, and nowhere reaching a height of so much as 1300 feet, this little island, from the singularity of one feature of its surface, forms a conspicuous and familiar landmark. Viewed in the simplest way, Eigg may be regarded as consisting of an isolated part of one of the great basaltic plateaux which, instead of forming a rolling tableland or a chain of hills with terraced sides, as in Antrim, Mull, and Skye, has been so tilted that, while it caps a lofty cliff about 1000 feet above the waves at the

* The spelling of the Gaelic names on the map and in this memoir has been kindly revised for me by my friend Mr. Alexander Nicolson, advocate, whose name will be a sufficient guarantee for their accuracy.

Fig. 1.—*Map of the Island of Eigg.*



P. Pitchstone-porphyry *coulée* of the Scùr. R. Outcrop of ancient river-gravel under pitchstone of Scùr. P. Small veins of pitchstone. *b.* Dykes, veins, and intrusive sheets of basalt-rocks. The short black lines traversing the map in a N.W.–S.E. direction are basalt dykes. *f.* Intrusive quartziferous porphyry. D. Bedded basalt rocks with occasional tuffs. F. Bedded porphyrite.

Oolitic Series.
- 4. Clay with *Ammonites*, *Belemnites*, &c.
- 3. Shales and Limestone bands with *Cyprids*, *Cyclas*, *Ostrea*, &c.
- 2. Thick white and yellow Sandstones with plants.
- 1. Shales and Limestone bands with *Cyprids*, *Cyclas*, *Mytilus*, and teeth and bones of Reptiles.

× ×. Loch Beinn Tighe. ×. Loch a Bhealaich.

→ General dip of the rocks.

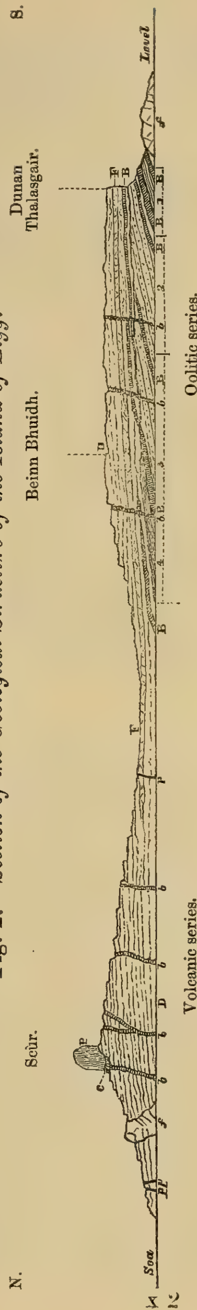
north end, it slopes gently along the length of the island to the south end. In the southern half of the island, however, the ground rises, owing to the preservation of an upper mass of beds, which denudation has removed from the northern half of the island. On this rising part of the plateau stands the distinguishing feature of the island, the strange fantastic ridge of the Scùr of Eigg. Seen from the north or south, this portion of the island looks like a long steep hill-crest, ending in a sharp precipice on the east. But when we get to the east side, the precipice is seen to be the end of a huge mountain-wall, which rises vertically above the basalt plateau to a height of more than 350 feet. It will be seen from the accompanying map (fig. 1) that this ridge of the Scùr corresponds with the area occupied by a mass of pitchstone, and that while the basaltic rocks cover the whole of the rest of the southern half of the island, they gradually rise towards the north, and successive beds of the oolitic series make their appearance until, at the cliffs of Dunan Thalasgair, the latter cover the greater part of the surface, and leave the volcanic rocks as a mere stripe capping the cliffs.

In the accompanying section (fig. 2) the general structure of the island is represented.

B. Literature of the Subject.

Several geologists have published descriptions, more or less detailed, of the mineralogy and geology of this interesting island. In the year 1800 Professor Jameson gave a brief account of the different rocks noticed by him in Eigg; but he did not attempt any description of its geological structure, further than to notice that one variety of rock occurred above or below another. He was then full

Fig. 2.—*Section of the Geological Structure of the Island of Eigg.*



P. Pitchstone of Scùr. *c.* Ancient river-gravel. *pp.* Pitchstone veins. *ff.* Intrusive felstone &c. *bb.* Dolerite and basalt dykes and veins. B. Intrusive dolerite and basalt sheets. D. Bedded dolerites and basalts. F. Porphyrite bed. 1–4. Oolitic rocks, as shown in the Table at page 289.

of belief in the theories of Werner; and as he had found fossil-shells in one of the sandstones of the island, he went on to speculate on the probability that the basalt, which alternated with these sandstones, would eventually be found to contain fossils*. The most detailed account of Eigg which has yet appeared, is that published by Dr. Macculloch in 1819†. He pointed out the clear order of succession of the rocks shown by the cliff-sections, and noticed some of the more marked varieties, both among the stratified and the igneous series. He showed also the relation of the secondary rocks to those of Skye and the rest of the western islands, and connected the igneous masses with those of the surrounding regions. Although he visited the island at least twice, he seems to have contented himself with the examination of those portions which were easiest of access. Hence some of the most interesting features of the island escaped his notice. About twenty years later Mr. Hay Cunningham communicated to the Wernerian Society a short but interesting paper upon the geognosy of Eigg. He gave some details as to the petrography of the igneous rocks, but added nothing to our knowledge of the geology, his remarks on the origin and position of the igneous rocks beiug founded on a misconception of the twofold interbedded and intrusive character of these masses‡. Hugh Miller, in the course of a cruise among the Western Islands, spent some time at Eigg. His attention was more particularly directed to the fossil-contents of the oolitic strata, of which he made a collection, and which he has to some extent described. He did not add any new facts to the known geology of the island§.

C. Oolitic Series.

Although the detailed account of the Oolitic rocks of Eigg falls to be given in a subsequent paper, some brief reference to them may be inserted here. Measured from the sea-level at Tallam to the base of the overlying sheets of basalt in the cliff at Dunan Thalasgair, the stratified rocks attain a thickness of probably not less than 600 feet; though, owing to the way in which they are split up by intruded sheets of basalt, and concealed by landslip-rubbish, their depth cannot be precisely determined. As the general

* Jameson's 'Mineralogy of the Scottish Isles,' vol. ii. pp. 36–47.

† Macculloch's 'Description of the Western Islands of Scotland,' vol. i. pp. 507–522.

‡ Hay Cunningham, Mem. Werner. Soc. vol. viii., 1839. This author insists that the igneous rocks of Eigg, as well as those of Scotland generally, were erupted and consolidated beneath the surface, there being no proof, according to him, that any of the basalts ever flowed out as a stream at the surface. With regard to the Scùr of Eigg, he says, "it can be confidently asserted that it exists as a great vein, which has been erupted through the older plutonic rocks"—a statement which has generally been accepted, but which, as will be shown in this paper, is wholly inadequate and incorrect.

§ See his 'Cruise of the Betsy,' p. 31 *et seq.*; 'Sketch-Book of popular Geology,' p. 137. Several foreign geologists and mineralogists have noticed the rocks of Eigg. Necker de Saussure gave a detailed description of the mineralogy of the Scùr ('Voyage en Ecosse,' ii. p. 449 *et seq.*).

dip of the rocks of the island is from north to south, the Oolitic series is best seen at the north end, whence its different groups of strata slope northward, until they finally disappear under the volcanic series at the Bay of Laig. The following section shows the order of succession among these rocks :—

Dolerites, basalts, &c. of the plateau.
(4) Clay, with ammonites, belemnites, &c., seen for a short space on the beach of the south side of Laig Bay.
(3) Estuarine shells and limestone with *Cyclas*, *Cyprides*, *Ostrea*, &c.
(2) Thick white and yellow sandstones, in some places abounding with fragmentary plants, and at other parts strongly calcareous, with numerous casts of *Cyclas*, &c.
(1) Estuarine shales and limestones, with fossils similar to those in No. 3, and with reptilian bones.
Base of series not seen.

From the general character of these beds, I am inclined to regard them as on the same horizon with the estuary beds of Loch Staffin, and with those which in Raasay come in between the Lias and the Tertiary volcanic rocks—that is, as belonging to the Lower Oolites. But this subject will require further consideration when the fossils have been determined.

D. Volcanic Series.

The Oolitic strata of Eigg are overlain by a cake of igneous rocks, which, though it caps the northern cliffs, dips southward with the underlying strata, until it reaches the sea at Laig Bay on the west side, and at Kildonan on the east. North of a line drawn between these two places the igneous capping has been reduced by denudation to a mere narrow strip, forming the tableland of Beinn Bhuidh; south of the same line, it covers the whole breadth of the island. Yet, although the general inclination of the igneous and aqueous rocks is in the same direction, a careful survey of them shows that the former lie unconformably upon the latter. At the south side of the Bay of Laig, the basalt-rocks rest upon the clays of group No. 1. As the former are inclined at a slightly less angle than the latter, they soon creep over their edges, so as to lie upon the shales and and limestones No. 2. These continue as far as Dunan Thalasgair; but there the basalts, after slowly creeping over their denuded edges for nearly two miles, overlap them, so as to come upon the massive sandstones of group No. 2. The apparent conformity, therefore, of the volcanic rocks with the Oolitic strata of the inner Hebrides, which has led to the belief that the volcanic phenomena were of Oolitic age, is in reality deceptive. I shall on other occasions have to point out the varied horizons on which these volcanic masses rest.

The igneous rocks of Eigg may be most conveniently described under three heads :—

1. The Basalt-plateau, marking the oldest eruptions.
2. Intrusive bosses, sheets, dykes, and veins.
3. The pitchstone *coulées* of the Scùr, a relic of the last eruptions.

1. The Basalt-Plateau.

The cake of volcanic rocks which has been referred to as overlying the Oolitic strata consists of a succession of beds, varying in thickness individually from a few feet to at least 50 or 60 feet, and having a united depth of not less than 1100 feet. They consist of dolerites, anamesites, and basalts, porphyrites, and tuffs or breccias. That they are the result of the outpouring of volcanic material at the surface, and not of its intrusion among the other rocks beneath the surface in other words, that they are interbedded or contemporaneous and not intrusive or subsequent masses, is shown by the internal texture of the crystalline rocks, and by the associated tuffs. Admirable sections are everywhere obtainable along the line of cliffs by which the island is almost continuously girdled.

a. Dolerites, Anamesites, and Basalts.

By much the larger part of the beds of the basalt-plateau consists of basaltic rocks (dolerite, anamesite, or basalt). These varieties of the same great family of volcanic rocks possess the same characters in Eigg which they retain throughout the Inner Hebrides and Antrim. The dolerite usually appears as a crystalline granular mass, passing on the one hand through anamesite into basalt, and on the other into a coarse aggregate, which shows on its weathered surfaces large crystals of augite. It is seldom that the rock becomes so black and compact as to deserve the name of basalt, except in the dykes to be afterwards described. Examined microscopically, these rocks fully bear out the observations of Zirkel on the presence of a non-crystallized matrix in basalt-rocks*. They occasionally abound in minute needles of apatite, which, along with the beautifully striated felspar, form a matted network of crystals, through which olivine, augite, and titaniferous iron are scattered. In some specimens the decomposition of the minerals is well illustrated. It may be added that these rocks very closely resemble, in composition and texture, the crystalline intrusive augitic rocks in the Scottish Carboniferous series—so closely, indeed, that no line of separation, so far as I have yet seen, can be drawn between them.

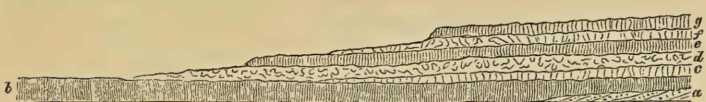
The bedded arrangement of the basalt-rocks, so characteristic of the vast miocene volcanic region from Antrim to Iceland, is well seen in Eigg. Along the cliffs at the north end of Beinn Bhuidh, and again along the south-western shore, the succession of beds is shown in noble vertical sections, while all over the southern half of the island the terraced or step-like hill-sides, formed by the outcrop of the beds, are everywhere visible. Even from a distance, therefore, the interbedded nature of these volcanic rocks can be readily determined. The beds range in thickness from perhaps 20 to 50 or 60 feet. They seem quite continuous when looked at from the sea, as they band the precipices with parallel stripes of darker and lighter

* See his Mikroskopische Untersuchungen über die Basaltgesteine. Bonn, 1869.

brown; and their continuity is still further indicated by the slender lines of bright herbage which have taken root along the decaying upper or under surfaces of the flows. Yet, on closer examination, we find them not unfrequently to die out, the place of one bed being taken by another, or even by more than one, in continuation of the same horizon. This is particularly noticeable along the cliff-line on the east side of Beinn Bhuidh. There is considerable diversity in the colour and texture, as well as the structure, of the different beds. Some of them, in which the rock is more compact and weathered, are divided by vertical joints, which in some cases increase in number till the rock acquires a rudely columnar structure. This may be admirably seen along the coast north of the harbour, where a long line of columnar cliff shows in some places curved and radiating columns. Other beds are formed of a dark compact amorphous mass, usually amygdaloidal, and occasionally very markedly so. A not infrequent variety occurs in the form of a dull green amygdaloidal and scoriaceous rock, in which balls of more compact material are wrapped, as it were, in a softer decomposed base. At the south end of the island, a peculiar band of rock occurs, in which the process of weathering reveals a succession of layers, a few inches thick, formed of nodular pieces of compact blue anamesite or basalt, with a bright red crust. These layers lie a few inches apart, in a soft, dirty-green, crumbling, and often highly amygdaloidal rock. The band in which these features are seen runs as an intercalation, about 3 or 4 yards thick, among the sheets of hard crystalline anamesite.

As an illustration of the bedded arrangement of these rocks, and of the way in which they succeed each other along the same horizontal plane, reference may be made to the accompanying diagram (fig. 3) of part of the cliff-section north of Kildonan, on the east side of the island.

Fig. 3. *Diagram of interbedded Volcanic Rocks on the east side of Island of Eigg.*



g. Compact jointed dolerite. *f*. Dull dirty-green decomposing amydaloidal dolerite. *e*. Compact crystalline dolerite, more finely jointed than bed *g*. *d*. Pale grey porphyrite. *c*. Dolerite, which a little further north is formed of several beds. *b*. Columnar dolerite. *a*. Oolitic strata.

The tests by which the true interbedded or contemporaneous character of the flows of the doleritic plateau can be determined are well exposed in Eigg. 1st. The upper and under surfaces of the successive flows have very commonly a rough slaggy character, even when the central portion is compact and crystalline. In this respect they perfectly resemble sections of recent lava-streams, such, for example, as those exposed along the Bay of Naples, around Torre del Annunziata. In some cases the slaggy upper part of one bed and the corresponding lower part of the bed above it seem to pass into each other, although the general bedded structure of the whole remains very marked at a little distance. Here and there, as at the north end of Beinn Bhuidh, illustrations are afforded of the elongation of the cavities along the upper surface, showing the direction in which the lava was moving before it finally cooled and consolidated.

2nd. Some of the beds are coarsely amygdaloidal throughout. In the kernels are found the usual minerals which result from the decomposition of basalt-rocks—mesotype, stilbite, calc-spar, amethyst, chalcedony, quartz-crystals, &c. And it is to be remarked, in Eigg as elsewhere throughout the Western Islands, that the abundance of the amygdaloidal minerals is proportioned to the amount of alteration which has been undergone by the general matrix of the rock in which they lie.

3rd. Although the interbedded sheets are sometimes seen to die out along the line of cliff, they never penetrate or otherwise disturb each other. This feature is one which has not been recognized by previous writers on the igneous rocks of the Inner Hebrides. It has been lost sight of among the proofs of intrusion furnished by so many of the basaltic sheets; and thus the "trap" or "overlying rocks" of Skye and the other islands have come to be regarded as typical examples of intrusive igneous masses, and described and figured as such in innumerable text-books. Yet no fact is more absolutely certain than that the vast mass of the basaltic rocks of these regions consists of interbedded sheets, which flowed out, one over another, at the surface, and have no intrusive characters. They are traversed, however, by intrusive sheets and dykes, as will be pointed out in the sequel.

4th. The occurrence of intercalated tuffs, volcanic breccias, and layers of burnt soil in Eigg, and of shales with remains of land-plants and seams of coal in the other islands, completes the proof that the basaltic beds forming the great plateaux, must be regarded as of interbedded or contemporaneous origin—that is, sheets which were poured out as lava above ground, and not injected among older rocks below.

β. *Porphyrite.*

Under this term I include a well-marked bed, forming a conspicuous band along the range of cliffs which flank the plateau of Beinn Bhuidh (see figs. 2 and 3). It lies near the base of the volcanic series. Owing to the flatness of the beds and to denudation, it has been uncovered, so as to stretch over most of the bottom of the hollow between Kildonan and the Bay of Laig. But I did not find it in the southern half of the island. This rock is of a pale grey colour. It consists of a finely crystalline felspathic base, through which a few small plagioclase crystals and grains of titaniferous iron can be seen with the lens. Examined with the microscope by transmitted light, it is found to consist of a base of plagioclase felspar, in minute, somewhat decomposed crystals, with abundant black grains of titaniferous iron, and a brown, much decayed mineral, which may be augite. The higher part of the bed, at Dunan Thalasgair is darker in colour, and, when examined microscopically, has much the character of an anamesite. Indeed the whole rock might be regarded as a highly felspathic basalt-rock in which the ferruginous silicates are poorly developed.

This rock is, as a whole, strongly amygdaloidal, the cavities in the upper part of the bed being sometimes so flattened and elongated as to impart a kind of fissile texture to the mass. This is more particularly to be noted at the precipice of Dunan Thalasgair. Throughout a considerable part of the bed, the calc-spar and zeolites of the kernels have disappeared, and the rock has resumed its original vesicular aspect.

γ. *Tuffs, Breccias, &c.*

One feature which distinguishes the Tertiary volcanic series of Britain from those of earlier geological periods is the comparative paucity and thinness of the intercalated beds of fragmentary materials. Among the contemporaneous igneous masses of the Silurian, Old Red Sandstone, Carboniferous, and Permian periods we find within our own borders enormous beds of tuff and volcanic breccia or conglomerate; but among the great basalt-plateaux of our north-western tracts such intercalations are represented by mere thin infrequent layers. This appears to be the case at least from the south of Antrim to the north of Skye—the most important tuffs in that extended area, so far as I am aware, being those of the cliffs at the Giant's Causeway. In Eigg this comparative insignificance of the fragmental as contrasted with the crystalline or lava-form rocks is characteristically maintained. Throughout the greater part of the cliff-sections one bed of dolerite or basalt follows another without the intervention of any dividing layer of tuff or other deposit. Here and there, indeed, between the beds, we not unfrequently meet with a thin irregular seam of red earth, which, when fine, might be called bole. In the cliff below Dunan Thalasgair, for example, several of the dolerite-beds are not only covered by this substance, but seem to pass into it. This may be observed also throughout the Inner Hebrides, and conspicuously along many parts of the Antrim coast-line. I have recently observed a precisely similar red parting between several of the lava-streams which have been laid open by the sea, and by artificial excavations, between Naples and Pompeii; and I may add that it is likewise to be observed between the sheets of melaphyre interbedded with the lower carboniferous rocks of Kinghorn, in Fife. In all these cases I regard this red layer as marking a surface of the igneous rock, decomposed into clay or soil by exposure, and subsequently heated and altered by the overflow upon it of the next sheet of molten material.

At the north end of Eigg, along the cliffs of Beinn Bhuidh, a bed of coarse doleritic or basaltic breccia is interstratified with the other volcanic rocks of the plateau. It consists of a red gravelly matrix of dolerite débris, in which are imbedded angular and subangular fragments of various igneous rocks, sometimes a foot and a half long. Again, at the south end of the island, opposite the rock called Dubh Sgeir (Black Skerry), the dolerites contain a breccia which swells out rapidly from a few inches to 6 or 8 feet in thickness; it is a rough nodular bed, varying in colour from a dirty green to a dull red, and consisting of rude angular and subangular pieces of various dolerites, but more particularly of that on which it lies, imbedded in, or wrapped round by, a greenish more or less crystalline paste, veined with calc-spar.

2. Intrusive Bosses, Sheets, Dykes, and Veins.

The Oolitic rocks, as well as the basalt-plateau which lies upon them, are pierced by many intrusive masses of igneous rock. These are all crystalline rocks, no example of any intrusive fragmental mass, such as the agglomerate of necks, having yet been noticed. While in the interbedded series the order of superposition furnishes us at the same time with the relative age of the volcanic beds, among the intrusive rocks we have no certain guide to relative antiquity, save the obvious examples where one rock cuts through another. Nor is it easy to discover any means of ascertaining how far the intrusive masses were coeval with, posterior, or anterior to those of the plateau. The dykes, indeed, must be newer than the interbedded rocks already described; for they are found cutting through even the highest of the sheets of the plateau, as well as the intrusive sheets near or at the base. There is reason to think that the pitchstone-veins are yet more recent. But without attempting any chronological arrangement, let me here describe the intrusive rocks of Eigg, in accordance with the nomenclature above proposed, as capable of classification after the character of the mould into which they have been intruded.

α. *Amorphous Masses or Bosses.*

Only three amorphous intrusive masses were observed by me in Eigg; but they possess considerable interest, inasmuch as they serve to throw some light upon the age of similar masses in Skye. They consist of felstone (that is, a supersilicated felspar rock, with a little free quartz), and thus stand out strongly marked from the surrounding basic basalt-rocks. The largest and most characteristic forms a range of bold cliff, from 150 to 200 feet high, at the extreme north end of the island. It appears to have risen approximately along the bedding of the Oolitic strata, and thus to form of itself a large rude bed. It consists of a pale grey quartziferous porphyry, traversed by horizontal and oblique veins of basalt. It is quite columnar in places; and as the sea has here and there hollowed out caves at the base of the cliff, the roofs of these recesses expose the truncated ends of the columns. This rock closely resembles some of the finer-grained parts of the quartziferous porphyries of Skye and

Raasay. On the southern declivity, which shelves away from the base of the Scùr, the interbedded dolerites are traversed with an irregular band of intrusive rock, which weathers into a succession of rounded knolls along the slope above the ruined hamlet of Lower Grulinn. This rock varies considerably in different places. For the most part it has a grey porphyritic base, resembling that of the grey porphyry of the Scùr; in some places, however, it becomes darker and heavier, and assumes more the character of a doleritic rock. Possibly more than one variety of rock may here have been erupted along the same line. The third intrusive mass of porphyry is shown on the map a little to the east of Laig farm. It is a compact, yellow, quartziferous rock, resembling some parts of the first-named mass, and weathering with a platy texture. Its exact relations cannot be here made out; but it cuts through the basalt-rocks, and is thus later than they are.

Although the full importance of the intrusive bosses of felstone and quartziferous porphyry in the Tertiary volcanic series cannot be properly understood from the structure of Eigg, yet the examples which occur there are of interest, inasmuch as they are found associated with and penetrating the basalt-rocks, and thus serve to indicate the true relations of other masses which have invaded the Liassic and Oolitic strata of the Inner Hebrides at a distance from the main mass of the basalt-plateau.

β. Sheets.

Geologists are familiar with the often-quoted illustrations given by Macculloch of the way in which the trap-rocks of Skye have been thrust between the planes of the secondary strata, so as to run for a long way strictly parallel to them, appearing as regularly interstratified beds, and then to break across the strata, thereby revealing their true intrusive character*. I have already remarked that these features, which are characteristic of a certain horizon in the volcanic series, have been very commonly transferred to the whole of that series, which is cited in consequence as a kind of classical example of the intrusive nature of trap-rocks. In reality, however, the intrusive sheets are almost wholly confined to the lower portion of the igneous series, and they are quite subordinate in number and extent to the great interbedded sheets of the plateau.

So far as I have yet been able to ascertain, it is only the basalt-rocks which are ever found counterfeiting the parallelism of the true flows. The petrographical character of these rocks does not, then, differ essentially from that which they manifest when they occur as interbedded sheets. Yet, as a rule, they are more compact and closer-grained, never slaggy, and seldom amygdaloidal. Although the rock is finely crystalline thoughout, the upper and lower edges of each sheet are more close-grained than the central

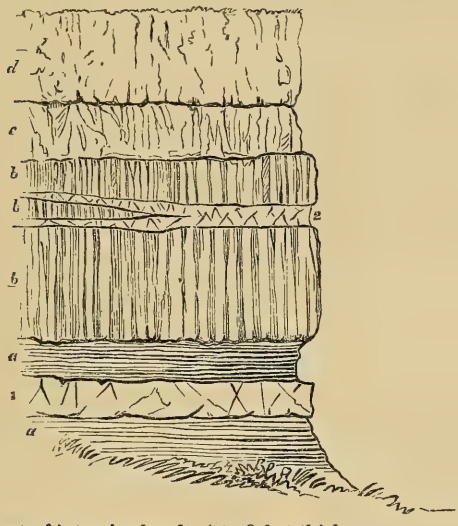
* See in particular plate xvii. of his 'Western Islands,' where numerous illustrations are given from the east coast of Trotternish.

parts. The abundant vertical joints only rarely assume a prismatic or rudely columnar arrangement. Hence, though it would often be difficult or impossible to discriminate the intrusive from the interbedded rock in hand-specimens, the distinctions between them are well maintained when we have a cliff-section before us. This similarity and difference become readily intelligible when we regard the two forms as in reality and originally proceeding from the same source, their distinction being due to the different conditions under which they were respectively consolidated; and we then perceive why the intrusive sheets should lie chiefly at the base of the interbedded series. The former are portions of the Tertiary lava which, unable to force their way to the surface, escaped laterally along the lines of least resistance. The increasing mass of the great overlying sheets of the plateau would oppose more and more the rise of the fluid lava, save from the main volcanic vents. Such portions of the latter as were driven up through cracks would often meet less resistance in trying to force their way along the bedding-planes of the secondary strata, or between these strata and the overlying igneous series, or between the lower beds of that series, than in breaking through the thick and compact volcanic mass above. Hence it is that, in nature, the intrusive sheets are in reality found where we might expect to meet with them. These statements involve, no doubt, only the most elementary knowledge. Yet the want of a due appreciation of this knowledge, and of its application in the field, has led to grave misconceptions as to the age of the volcanic rocks of the Inner Hebrides—misconceptions in which I have myself fully shared. I am naturally anxious, therefore, to point out that, while their intrusive relations have been fully recognized, the pseudo-interbedded character of the intrusive sheets at the base of the great basaltic plateaux of our west coast has been confounded with the true interbedded character of the sheets forming the plateau above, and that hence the inference regarding the intercalation of contemporaneous volcanic rocks among the secondary rocks of the Hebrides is without foundation. There is no evidence of any truly contemporaneous volcanic rock, so far as I have yet ascertained, in any of the Liassic or Oolitic rocks of that region. The basalt-plateau, viewed as one great sheet, rests alternately on Cambrian, metamorphosed Lower Silurian, Liassic, Oolitic, and Cretaceous rocks, and unconformably upon them all, from Antrim to the north of Skye. Here and there, where it happened to be laid down upon more or less horizontal strata, it shows at its base intrusive sheets which seem to run parallel with it, as well as with the secondary strata, between which they have been thrust. And thus has arisen the apparent gradation of the Oolitic groups of Skye into an upper volcanic series—a gradation, however, which is quite deceptive, and which disappears when, after wider examination, we come to recognize the true intrusive character of the intercalated sheets, and the real unconformability of the basalt-plateau alike upon Palæozoic and Secondary formations*.

* The suggestion of Edward Forbes regarding the probable Oolitic date of the

In Eigg the intrusive sheets at the base of the volcanic series are much less strikingly exhibited than in Skye, Raasay, and Mull. Some good sections occur, however, at the north end. In the lowest group of the Oolitic series, as exposed on the shore and on the low cliff to the east of Blarmor, there is an abundance of thin sheets of anamesite, which, sometimes coincident with, sometimes traversing the bedding-planes of the shales and limestones, harden the strata along the line of contact. At that locality the succession of the rocks is somewhat obscured by the effects of some large landslips; and similar disturbance extends all along the eastern flanks of Beinn Bhuidh. In one of the streamlets, coming down from that side of the plateau,

Fig. 4. *Section of Interbedded and Intrusive Volcanic Rocks, on the East Coast of Eigg.*



1. Sheet of intrusive basalt, 4 to 6 feet thick.
2. Sheet of fine-grained anamesite, 2 to 4 feet thick.

a. Calcareous pale yellow shelly sandstone (Oolite).
b. Columnar fine-grained anamesite or basalt, traversed by intrusive sheet (2).
c. Dull amorphous fine-grained anamesite.
d. Pale grey porphyrite.

near the Rudh nan tri Chlach, and which is known as the Ault na horsta mian, more than twenty intrusive sheets of dolerite, anamesite, or basalt may be counted among the shales and limestones. They are sometimes mere thin horizontal veins, not six inches thick; and they

igneous rocks of Trotternish, in Skye, must thus be abandoned (see Quart. Journ. Geol. Soc. vol. vii. p. 104). I adopted his views in my first examination of Skye; and my reference of the volcanic rocks of Skye to an Oolitic date must likewise be set aside (Trans. Roy. Soc. Edin. vol. xxii. p. 648; see also Proc. Roy. Soc. Edin. vol. vi. p. 72, where this change of view is indicated).

seldom exceed six or eight feet. But perhaps the best examples are to be seen along the cliffs to the south of Rudh nan tri Chlach. At this part of the coast, owing to the southward slope of the surface of the tableland of Beinn Bhuidh, the greater part of the overlying basalts is absent, and only the porphyrite and the underlying beds form the capping of the cliffs above the Oolitic rocks. The section (fig. 4, p. 297) represents the succession of rocks there to be seen, and shows how the intrusive sheets may be intercalated either with the Oolitic strata or with the older parts of the doleritic series.

γ. *Dykes and Veins.*

Another mode of escape to the pent-up molten rock was furnished by long straight fissures and by irregular winding cracks—the former giving rise to dykes, and the latter to veins. I reserve for a future paper a full consideration of that remarkable feature of the Tertiary volcanic rocks, the long parallel dykes. With regard to those which occur in Eigg, I may remark that they are not remarkable for numbers or other peculiarities, but that they exhibit many of the characteristic features of the dykes which range from the basaltic plateaux of the Hebrides across Scotland and the north of England. They run, as a rule, persistently from north-west to south-east, varying in breadth from a few feet to a few yards in breadth. They consist either of a close-grained anamesite or of basalt, and sometimes contain large grains of olivine. They cut across even the newest of the sheets of the plateau, as may be seen along the terraced slopes that descend from the Scùr. But in some of the cliff-sections, as, for example, below Bideann Boidheach and on the east side northwards from Kildonan, they may be seen rising through the lower, but stopping short of the higher beds of dolerite. That truncation may not indicate that where it occurs the dykes are older than the interbedded flows which cover them, but only that the fissures through which they rose did not extend further upward, or at least did not receive an injection of lava into their upper parts. At the same time, there can hardly be any doubt that the dykes as a whole are contemporaneous with the eruptions of the plateau, some of them belonging to earlier, others to later stages in the long volcanic history. No dyke has been observed cutting the pitchstone of the Scùr; but several are covered unconformably by that rock (see fig. 10).

The igneous veins by which the rocks of Eigg are traversed do not differ in origin from the dykes; but their smaller size and irregular form enable us to group them by themselves, and to note among them some characteristic features which are not found, or at least found much less distinctly, among the dykes. The veins may be arranged in two groups, according to their component rock, viz.:—1st. Basalt veins; and, 2nd. Pitchstone and Felstone veins. This classification may be regarded as also a chronological one, since there is reason to believe that the former group is older than the latter.

1. *Basalt, Anamesite and Dolerite Veins.*—These are closely connected both with the dykes and with the intrusive sheets, into either of which any vein may pass, or from which any vein may proceed. They commonly consist of a very compact finely crystalline rock, often paler in colour than that of the interbedded basalt-rocks, even where these are most close-grained. These features may be well seen along the coast-sections to the north of Kildonan. Among the veins of that as well as of other localities, a minutely amygdaloidal texture is occasionally observable, the small kernels being arranged in lines parallel with the sides of the vein and most marked along its centre. The grain of the rock usually becomes very close towards the edge of the vein, passing sometimes through various stages of flinty basalt into bright black lustrous tachylite. The most perfect example which I observed of this difference between the texture of the central and outer parts of a vein occurred in a vein which traverses the basalts on the east side of the Beinn Tighe—one of the outlying hills of the Scùr ridge. The rock is of a dark, very fine-grained basalt, which along the walls of the vein assumes a vitreous aspect, and sends out a loop or thread of black pitchstone-like tachylite into the surrounding interbedded basalt (fig. 5). The marginal crust of tachylite varies in thickness in different veins, ranging from one-third to about one-eighth of an inch. Sometimes it shades into the basalt within; in other cases it forms a pellicle, which cracks off in weathering. It is one of the most opaque rocks I have ever encountered; in several slices of it which I have had prepared for microscopic examination and reduced to extreme thinness, I am unable to get any light sent through, even at the edges.

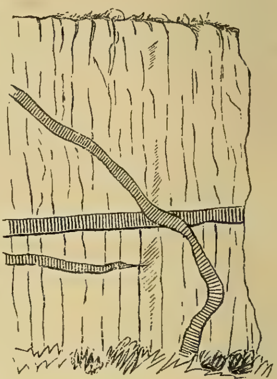
Fig. 5. *Plan of Basalt Veins with Tachylite edges, East Side of Beinn Tighe, Eigg.*

The veins run vertically, horizontally, or at any angle, and branch or unite, swell out or diminish, in a capricious manner. Their close texture and abundant joints make them weather differently from the rocks which they traverse. This, added to a frequent difference of colour, renders them a conspicuous figure along the coast-cliffs of Eigg (see fig. 6). Some striking illustrations occur on the east side of the island north of Kildonan, and also on the great precipice below Bideann Boidheach, where the pale thread-like veins may be distinguished even from a distance as they rise along the sombre face of the cliffs.

2. *Pitchstone and Felstone Veins.*—Although nearly the whole of the veins in Eigg are protrusions of doleritic rock, there occur a few in which the rock is pitchstone and, in one case at least, felstone. That these veins are, on the whole, later than those just described

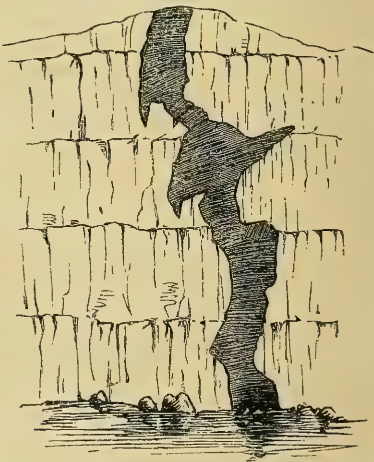
may be inferred from the fact that the pitchstone of the Scùr, as will be shown in the sequel, is much younger than the rocks of the basaltic plateau. The pitchstone of most of the veins differs, indeed, microscopically from that of the Scùr; but the latter varies greatly even within itself, so that, though no evidence exists of any pitchstone vein having ever been connected with the rock of the Scùr, we may, provisionally at least, class all the pitchstones together as the latest of the igneous rocks of Eigg.

Fig. 6. *Basalt Veins traversing interbedded Dolerites, Kildonan, Eigg.*



Four separate veins of pitchstone have been noticed in Eigg. The best-known and most clearly exposed veins are two which traverse the dolerite beds at Rudh an Tangairt, near the famous Uamha Fhraing, or Frank's Cave, on the south side of the island. The eastern vein (fig. 7) consists, in its upper part, not of pitchstone, but of a pale compact quartziferous porphyry or felstone, like that of Scorr Scalleadh*. It is exceedingly hard, splintering under the hammer with a metallic sound. It weathers with a yellowish or reddish tint, which extends for an inch or two into the stone, and shows numerous cavities, resulting apparently from the decomposition of felspar crystals. Towards the margin of the vein it assumes a laminar texture, in plates which are in a general sense parallel to the walls of the vein. Examined in thin section with the microscope, this rock shows a curious confused mass of minute needle-like or hair-like bodies, with opaque partially decomposed grains of pyrites, or possibly titaniferous iron, and a still more decomposed brown mineral. The texture closely resembles that of some of the pitchstones. The vein has a thickness of about $2\frac{1}{2}$ feet, and

Fig. 7. *Vein of Pitchstone traversing Dolerite, Rudh an Tangairt.*



* An engraving of this vein is given by Jameson in his work already cited, vol. ii. p. 45. The felspathic rock he terms "hornstone;" it is called "chert" by Macculloch, and "porphyritic compact felspar" by Hay Cunningham. It differs in minute structure from evey other rock with which I am acquainted, and, as stated in the text, more nearly resembles pitchstone.

runs across the dolerite beds with a trend from N. 10° W. Descending the upper part of the cliff, the vein continues downward; but the porphyry is replaced by pitchstone, which descends to the beach. A detached portion of the former rock is involved in the latter; but it is hardly possible to decide here which is the newer mass, or if they are not of contemporaneous origin*.

The portion of the vein filled with pitchstone runs with a much less even course and regular thickness than the part filled with porphyry. The pitchstone suggests the idea of intense liquidity, as it seems to have thrust itself into every minute crevice of the crack in the dolerites up which it rose. Its path is somewhat tortuous; and its width varies from a few inches to 2 feet or more. Sometimes its walls are upright and parallel like those of a dyke; but in a little distance this feature disappears, and the pitchstone bends now to one side, now to the other, along the irregularly jointed surface of the dolerites. At the margin of the vein it is deep jet-black, and as glassy and lustrous as bottle-glass, but much more brittle; away from the edge it assumes the ordinary dull resinous lustre of pitchstone, while in the middle, where the vein is broadest, the rock takes a porphyritic texture. Examined microscopically, the outer or jet-black obsidian-like part of the vein is a perfect glass, of a pale brown colour, this hue being equally diffused as a tint through the mass, and not arising from the abundance of coloured crystals. I have not been able, even with a magnifying power which renders an object one five-thousandth of an inch in diameter clearly visible, to resolve this coloured matrix into component crystallites, grains, hairs, or any other structure. It is traversed by minute cracks, which, along with elongated cavities, run in one general direction parallel with the sides of the vein. On either side of these cracks the colour has in some cases been bleached out of the rock for a short distance; in others the colour is intensified into a deep brown. The cavities vary from one two-thousandth of an inch or less up to one fiftieth of an inch or more, sometimes empty, sometimes filled with a brown colouring-matter.

Fig. 8. *Pitchstone filling a cavity in Dolerite, Eigg.*

About four yards west from the vein just described a second vein of pitchstone is seen traversing the compact close-grained dolerite or anamesite of the cliffs. At the upper part of the cliff a detached portion (which, however, is probably only a part of the vein) fills up a cavity like a pot-hole, about a foot broad (fig. 8). It is traversed by numerous divisional planes, which run parallel with the sides of the cavity, and converge towards its bottom in such a way as to look

* Hay Cunningham found liquid bitumen in cavities of this rock.

like a mass of rather viscid pitch which had been spilt at the top of the cliff, and had slowly flowed into and filled a cavity in the rocks. This detached portion of pitchstone has the same bright deep jet-black or bluish-black colour and obsidian-like texture noticed in the previous vein. A little below it the main portion of the vein descends the lower part of the cliff, and crosses the beach from N. 25° W. to S. 25° E., with an average width of $1\frac{1}{2}$ to 2 feet. Its external parts, as in the previous example, are black and quite glassy; the central portion possesses the common dull resinous lustre and dark-green colour characteristic of pitchstone. A thin section of the latter part of the vein, placed under the microscope, shows that the base of the rock is a nearly colourless homogeneous glass, through which are scattered abundant black or greenish hairs of some ferruginous silicate arranged singly and in oblong tufts. The individual hairs of each tuft are not feathered, like those of the Corriegills pitchstone of Arran. It is to the abundance of these particles that the dark colour of the rock is due.

A third, less distinctly traceable vein of pitchstone traverses the dolerites on the beach at the harbour. There is the same difference of texture in it as in the Rudh an Tangairt veins. The black brittle obsidian-like portion, when examined microscopically, shows a deep rich-brown homogeneous glass, with numerous small kernels, some of which are filled with an amber-coloured substance (bitumen?). Except for its much deeper colour and the presence of coloured kernels instead of much more minute elongated vesicles, the minute texture of this rock is analogous to that of the east vein. The dull dark-green portion is markedly porphyritic, and is mixed up, even in hand-specimens, with the more glassy variety. Under the microscope it shows considerable opacity, but on extremely thin edges and in certain less deeply coloured portions is found to consist of a thickly aggregated mass of minute black hairs, less distinctly separated than those of the Rudh an Tangairt vein, and imbedded in a glass mostly of a dark-green or black colour, but here and there colourless. The colouring-matter is therefore not entirely dependent in this rock upon the abundance of the hair-like particles. Large crystals of a beautifully striated felspar are scattered through the rock, also kernels filled with a brown or amber-coloured substance, as in the black part of the vein.

A fourth pitchstone occurs on the roadside, a little to the east of Laig Farm, and seems to be connected with the intrusive boss of quartziferous porphyry there. It differs considerably in external aspect from the other veins, being of a pale-green or greenish-grey colour, and thus resembling at first sight the pale slag of an iron-furnace. The base is minutely granular, and shows a few scattered felspar crystals. Under the microscope this rock appears as a pale-brown glass, through which are scattered abundant minute cavities, short dark bodies resembling the "hairs" already described, but less definitely formed, and crystals of an orthoclase felspar.

Petrographically considered, the pitchstone veins of Eigg present us with three varieties:—1st, those formed of a colourless glass and owing their dark hue to the abundant included hair-like aggregations of a ferruginous silicate; 2nd, those formed of a coloured glass in which the colouring-matter is impalpably diffused; and, 3rd, those formed of a coloured glass where the hue is further intensified by the abundance of included "hairs."

3. Pitchstone and Porphyry Coulées of the Scùr.

That feature of the island of Eigg which renders it so remarkable and conspicuous an object on the west coast is the long ridge of the Scùr. Rising gently from the valley which crosses the island from Laig Bay to the Harbour, the basaltic plateau ascends south-westwards in a succession of terraces, until along its upper part it forms a long crest, from 900 to 1000 feet above the sea, to which it descends on the other or south-west side, first by a sharp slope, and then by a range of noble precipices. Along the watershed of this crest runs, in a graceful double curve, the abrupt ridge of the Scùr, terminating on the north-west at the edge of the great sea-cliff (975 feet), and ending off on the south-east in that strange well-known mountain-wall (1272 feet high) which rises in a sheer cliff nearly 300 feet above the basalt-plateau on the one side and more than 400 feet on the other. The total length of the Scùr ridge is two miles and a quarter, its greatest breadth 1520, its least breadth 350 feet. Its surface is very irregular, rising into minor hills and sinking into rock-basins, of which nine are small tarns, besides still smaller pools, while six others, also filled with water, lie partly on the ridge and partly on the basaltic plateau. No one, indeed, who looks on the Scùr from below, and notes how evenly it rests upon the basalt-plateau, would be prepared for so rugged a landscape as that which meets his eye everywhere along the top of the ridge. Two minor arms project from the east side of the ridge; one of these forms the rounded isle called Beinn Tighe (968 feet), the other the hill of A chor Bheinn.

Singular as the Scùr of Eigg is, regarded merely as one of the landmarks of the Hebrides, its geological history is not less peculiar. The natural impression which arises in the mind when this mountain comes into view for the first time is, that the huge wall is part of a great dyke or intrusive mass which has been thrust through the older rocks*. It was not until after some time that the influence of this first impression passed off my own mind, and the true structure of the mass became apparent.

The ridge of the Scùr, though formed of one great mass of rock

* Hay Cunningham, in the paper before quoted, remarks:—"In regard to the relations of the pitchstone-porphyry of the Scùr and the trap-rocks with which it is connected, it can, after a most careful examination around the whole mass, be confidently asserted that it exists as a great vein which has been erupted through the other Plutonic rocks—thus agreeing in age with all the other pitchstones of the island." Macculloch leaves us to infer that he regarded the rock of the Scùr to be regularly interstratified with the highest beds of the dolerite series ('Western Isles,' i. p. 522). Hugh Miller speaks of the Scùr of Eigg as "resting on the remains of a prostrate forest."—*Cruise of the Betsy*. p. 32.

very different from those around it, in reality consists of two distinct varieties of rock, pitchstone and felstone-porphyry, arranged in distinct and, in a general sense, horizontal beds. Looked at from the east side (Pl. XIV. fig. 1) this feature is not clearly marked; for the great cliff seems then to consist of one homogeneous mass, except a marked columnar band running obliquely along the base of the precipice. If, however, the side is viewed from the south, the bedded character of its component rocks becomes a conspicuous feature. Along the noble cliffs on that side the two varieties of rock are strongly distinguished by their contrasting colour and mode of weathering, the sombre-hued pitchstone standing up in a huge precipice striped with columns, and barred horizontally with bands of the pale-grey porphyry, which seems sunk into the face of the cliff. At the south-east end of the ridge the beds are very distinct. Further west of the precipices to the south of the Loch a Bhealaich, the dark pitchstone which forms the main mass is divided by two long parallel intercalations of grey porphyry, and two other short lenticular seams of the same material (see Pl. XIV. figs. 2 & 3). It is clear from these features, which are not seen by most travellers, who pass Eigg merely in a steamer, that the Scùr is in no sense of the word a dyke.

But although the Scùr is thus a bedded mass, the bedding is far different from the regularity and parallelism of that which obtains among the interbedded basalt-rocks below. Even where no intervening porphyry occurs, the pitchstone can be recognized as made up of many beds, each marked by the different angle at which its columns lie. And when the porphyry does occur and forms so striking a division in the pitchstone, its beds die out rapidly, appearing now on one horizon, now on another, along the face of the cliffs, and thickening and thinning abruptly in short distances along the line of the same bed. Perhaps the best place for examining these features is at the Bhealaich, the only gully practicable for ascent or descent, at the south-eastern face of the ridge.

By much the larger part of the mass of the Scùr consists of pitchstone. As a rule this rock is columnar, the columns being much slimmer and shorter than those of the basalt-rocks. They rise sometimes vertically, and often obliquely, or project even horizontally from the face of the cliff. They are seldom quite straight, but have a wavy outline; and when grouped in knolls here and there along the top of the ridge, they remind one of gigantic bunches of some of the palæozoic corals, such as *Lithostrotion*. In other cases they slope out from a common centre, and show an arrangement not very unlike that of a Highland peat-stack.

The pitchstone of the Scùr differs considerably in petrographical character from any other of the pitchstones of the island, and indeed from any other pitchstone which I have yet met with in Scotland. Its base is of a velvet-black colour, and is so much less vitreous in aspect than ordinary pitchstone as to have been described by Jameson and later writers as intermediate between pitchstone and basalt*.

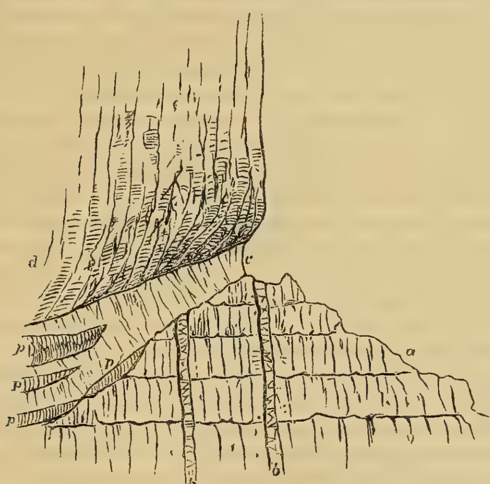
* 'Mineralogy of the Scottish Isles,' vol. ii. p. 47. See also Macculloch, 'Western Isles,' vol. i. p. 521, and Hay Cunningham, 'Mem. Wern. Soc.' vol. viii. p. 155.

It has a minutely granular texture, and is usually strongly porphyritic, with crystals of orthoclase, sometimes a quarter of an inch in length.

That portion of the mass which forms the eastern end, or Scùr proper, shows under microscopical examination a much less perfect glass than any of the veins above described. With a $\frac{1}{5}$ object-glass the rock seems to be made up of a confused aggregate of short pale fibres or hairs matted together. These are much more minute, and proportionally thicker than the hair-like bodies in the veins, and they are so abundant as to form apparently the whole or nearly the whole of the rock. At the opposite extremity of the ridge, the rock of Beinn Bhreac is less porphyritic. Examined with the microscope it shows a similar, but rather coarser texture, through which, in addition to the orthoclase, there are diffused small crystals of a delicately striated felspar*.

The grey porphyry, which occurs in beds and forms a subordinate part of the mass of the Scùr ridge, is usually a somewhat decomposed rock. Where a fresh fracture is obtained it shows a fine-grained, sometimes almost flinty, grey felspar base containing clear granules of quartz, and facets of a glassy felspar, probably orthoclase. In some places the rock is strongly porphyritic. Although the line

Fig. 9.—*Section at the base of the Scùr of Eigg* (*east end*).



of separation between this porphyry and the pitchstone is usually well defined, it is sometimes so obscure, and the two rocks so shade

* The notes given above of the microscopic structure of the Eigg pitchstones are the results of merely a preliminary examination. I hope to be able eventually to form materials for an essay on the minute structure of the pitchstones of Scotland.

into each other, that it is then difficult to regard the porphyry as other than a peculiar and decomposed modification of the pitchstone. This is particularly to be observed under the precipice at the east end of the Scùr. At that locality the pitchstone is underlain by a band of very hard flinty porphyry, varying in colour from white through various shades of flesh-colour and brown into black, containing a little free quartz and crystals of glassy felspar. Where it becomes black it passes into a rock like that of the main mass of the Scùr. Such pitchstone parts of the bed look like kernels of less-decomposed rock. The lower six feet of the porphyry are white and still more decomposed. The relation of the mass is shown in fig. 9, where the basalt-rocks of the plateau (*a*) are shown to be cut through by basalt dykes (*b*, *b*), and overlain by the porphyry (*c*) and the pitchstone (*d*). In the porphyry are shown several pitchstone kernels (*p*, *p*). It is deserving of remark also that in different parts of the Scùr, particularly along the north side, the bottom of the pitchstone beds passes into a dull grey earthy porphyry, like that now under description. Reference has already been made to the occurrence of the pitchstone vein at Laig road along with quartziferous porphyry, and also of similar porphyry and pitchstone filling the same vein at Rudh an Tangairt. Hence, between these two rocks there appears to be in Eigg a close relationship both as to origin and age.

Although the Scùr of Eigg is thus evidently the product of different flows, subsequent to the eruption of the highest of the now visible basalt-beds, it was separated from these latter eruptions by an enormous lapse of time. This point, which is as yet a unique feature in Hebridean Geology, I was so fortunate as to ascertain during my survey; and though I have elsewhere* announced the fact, I wish now to adduce the evidence upon which the conclusion is based. My observations show that what is now the great ridge of the Scùr was formerly a river-valley, that this valley was filled with successive flows of pitchstone-lava, that this river-silt, gravel, and drift-wood were buried under the eruptions, and that after long subsequent denudation the surrounding hills have been worn away, and the river-valley, by virtue of the superior permanence of the vitreous lava which occupied its course, has been left standing now as the highest ridge of the district.

A little attention to the form of the bottom over which the rocks of the Scùr have been erupted suffices to reveal the fact that between the basalt-beds of the plateau and the pitchstone sheets of the Scùr there is a marked discordance, since the latter lie upon a denuded surface of the former. Let us take a section at any part of the ridge, and this feature will be made clear. At the little tarn of the Bhealaich, already referred to, a section may be seen, where the base of the pitchstone on the north side is at least 200 feet above its base on the south side. Here, as everywhere else, the basalt-veins are abruptly cut off along the denuded surface on

* See my 'Scenery of Scotland viewed in connexion with its Physical Geology,' p. 278.

which the pitchstone rests. Again, at the east end of the Scùr the pitchstone wall is placed not fairly on the crest of the dolerite-plateau, but on the south side of it. This cannot fail to arrest the notice of every observer, even from a distance (see Pl. XIV. fig. 1). It shows us not only that the rocks of the Scùr were erupted along a hollow or valley, but that only the north or north-eastern side of that valley is now preserved.

Allusion has been already made to two minor tongues of pitchstone which project to the north-east from the main ridge of the Scùr, and form small hills. Even in these offshoots the same evidence of want of sequence between the rock of which they are composed and the underlying basaltic sheets is clearly exposed. In Beinn Tighe, for instance, the northern projection, a section taken across the isle from east to west shows the basalts at a much higher level on the one side than on the other. These offshoots appear to have been originally either recesses of the main valley, or tributary valleys descending into it, and to have been buried and preserved under portions of the coulées of the pitchstone lava which overflowed from the main mass.

Underneath the eastern end of the precipice of the Scùr, on its southern or lower side, a bed of fragmentary materials is found to intervene between the pitchstone and the dolerites. The base of the pitchstone dips into the hill, forming the roof of a small cave. The under surface of the pitchstone is tolerably smooth, but undulating, and shows the ends of the columns as a polygonal reticulation over the roof. The breccia is a pale-yellow or grey felspathic rock, like the more decomposing parts of the grey porphyry of the same cliff. Through its mass are dispersed great numbers of angular and subangular pieces of pitchstone, some of which have a striped texture. Fragments of basalt, red sandstone, and other rocks are rare; and the bed suggests the idea that it is a kind of brecciated base or flow of the main pitchstone mass. A similar rock is found along the bottom of the pitchstone on both sides of the ridge (*c*, in fig. 9). At some points where this breccia is only a yard or two in thickness, and consists of subangular fragments of the various dolerites and basalts of the neighbourhood, along with pieces of red sandstone, quartz-rock, clay-slate, &c. The matrix is in some places a mass of hard basalt débris; in others it becomes more calcareous, passing into a sandstone or grit in which chips and angular or irregular-shaped pieces of coniferous wood are abundant*. A little further east, beyond the base of the Scùr, a patch of similar breccia is seen, but with the stones much more rounded and smoothed. This outlier rests against the denuded ends of the ba-

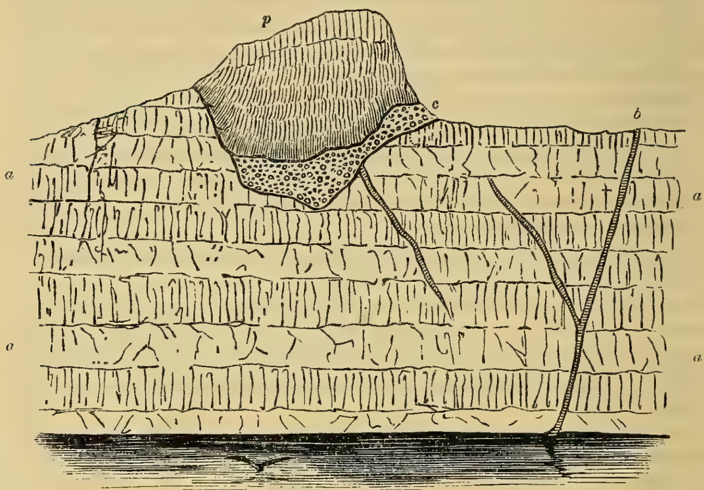
* The microscopic structure of this wood was briefly described by Witham (Foss. Vegetables, p. 37), and two magnified representations were given to show its coniferous character. Lindley and Hutton further described it in their 'Fossil Flora,' naming it *Pinites eiggensis*, and regarding it as belonging to the Oolitic series of the Hebrides—an inference founded perhaps on the erroneous statement of Witham to that effect. William Nicol corrected that statement by showing that the wood-fragments occurred, not among the "lias rocks," but "among the débris of the pitchstone" (Edin. New Phil. Journal, xviii. p. 154).

salt-beds forming the side of the hill. Its interest arises from the evidence it affords of the prolongation of the old valley eastward, and consequently of the former extension of the precipice of the Scùr considerably beyond its present front.

It is at the extreme north-western extremity of the pitchstone ridge, however, that the most remarkable exposure of the ancient river-bottom is now to be seen. Sweeping along the crest of the plateau the ridge reaches the edge of the great precipice of Bideann Boidheach, by which its end is truncated, so as to lay open a section of the gravelly river-bed along which the pitchstone flowed.

The accompanying diagram (fig. 10) represents the natural section there exposed. Rising over each other in successive beds, with

Fig. 10.—*Natural Section at the Cliff of Bideann Boidheach, north-west end of the Scùr of Eigg.*



a a. Bedded dolerites and basalts. *b b.* Basalt dykes and veins. *c.* Ancient river-bed filled with conglomerate. *p.* Pitchstone of the Scùr.

Hay Cunningham, in the paper already cited, states that the fossil wood really lies in the pitchstone itself! The actual position of the wood, however, in the breccia and conglomerates underlying the pitchstone is beyond all dispute. I have myself dug it out of the bed. The geological horizon assigned to this conifer, on account of its supposed occurrence among Oolitic rocks, being founded on error, no greater weight can be attached to the identification of the plant with an Oolitic species. Our knowledge of the specific varieties of the microscopic structure of ancient vegetation is hardly precise enough to warrant us in definitely fixing the horizon of a plant merely from the examination of the minute texture of a fragment of wood. From the internal organization of the Eigg pine, there is no evidence that the fossil is of Oolitic age. From the position of the wood above the dolerites and underneath the pitchstone of the Scur it is absolutely certain that the plant is not of Oolitic but of Tertiary date.

a hardly perceptible southerly dip of 2°, the sheets of dolerite, anamesite and basalt form a mural cliff about 700 feet high. Nowhere in the island can the bedded character of these rocks and their alternation of compact, columnar, amorphous, and amygdaloidal beds be more strikingly seen. They are traversed by veins and dykes of an exceedingly close-grained, sometimes almost flinty, basalt. But the conspicuous feature of the cliff is the hollow which has been worn out of these rocks, and which, after being partially filled with coarse conglomerate, has been buried under the huge pitchstone mass of the Scùr. The conglomerate consists of water-worn fragments, chiefly of dolerite and basalt, but with some also of the white Oolitic sandstones, imbedded in a compacted sand derived from the waste of the older volcanic rocks. The grey porphyry, so conspicuous at the east end of the Scùr, here disappears and leaves the conglomerate covered by one huge overlying mass of pitchstone.

An examination of the fragments of rock found in the conglomerate on which the great pitchstone ridge of Eigg stands, affords us some indication of the direction in which the river flowed. The occurrence of pieces of red sandstone, which no one who knows West-Highland geology can fail to recognize as of Cambrian derivation, at once makes it clear that the higher grounds from which they were borne could not have lain to the south or east, but to the north-west or north. From the fragments of white sandstone we may with some probability infer that the course of the stream came from the north, where the great white Oolitic sandstones rise to the surface. In short, there seems every probability that this old Tertiary river flowed southward through a forest-clad region, of which the red Cambrian mountains of Ross-shire and the white sandstone cliffs of Raasay and Skye are but fragments, that it passed over a wide and long tract of the volcanic plateau which has been so worn away that it now remains in mere islets left standing out of the deep Atlantic, that since then mountain and valley have alike disappeared, and that in Eigg a fragment of the river-valley has been preserved solely because it has been sealed up under streams of vitreous lava which could better withstand the progress of waste. Thus the Scùr of Eigg, like the fragments of the older basalt-plateaux of Auvergne, remains as a monument, not only of volcanic eruptions, but of a former land-surface, now effaced, and of the irresistible march of those slow and seemingly feeble agencies by which the denudation of a country is effected.

4. Summary of the Volcanic Geology of Eigg.

In conclusion let me briefly summarize the more important contributions made by the geology of Eigg to the history of the Tertiary volcanic rocks of Britain.

1. The volcanic rocks of this island rest unconformably upon strata of Oolitic age.

2. They consist almost wholly of a succession of nearly horizontal interbedded sheets of dolerite, anamesite, and basalt, forming an

isolated fragment of the great volcanic plateau which stretches in broken masses from Antrim through the Inner Hebrides.

3. These interbedded sheets are traversed by veins and dykes of similar materials, the dykes having the characteristic north-westerly trend with which they pass across the southern half of Scotland and the north of England. Veins of pitchstone and felstone, and intrusive masses of quartziferous porphyry, like some of those which in Skye traverse or overlie the lias, likewise intersect the bedded basalt-rocks of Eigg.

4. At least two widely separated epochs of volcanic activity are represented by the volcanic rocks of Eigg. The older is marked by the bedded basalts and by the basalt veins and dykes, which, though, strictly speaking, younger than the bedded sheets which they intersect, yet probably belong to the same continuous period of volcanic action. The later manifestations of this action are shown by the pitchstone of the Scùr. Before that rock was erupted, the older basaltic lavas had long ceased to flow in this district. Their successive beds, widely and deeply eroded by atmospheric waste, were here hollowed into a valley traversed by a river, which carried southward the drainage of the wooded northern hills. Into this valley, slowly scooped out of the older volcanic series, the pitchstone and porphyry *coulées* of the Scùr flowed. Vast, therefore, as the period must be which is chronicled in the huge piles of volcanic beds forming our basalt-plateaux, we must add to it the time needed for the excavation of parts of those plateaux into river-valleys, and the concluding period of volcanic activity during which the rocks of the Scùr of Eigg were poured out.

5. Lastly, from the geology of this interesting island we learn, what can be nowhere in Britain more eloquently impressed upon us, that, geologically recent as that portion of the Tertiary period may be during which the volcanic rocks of Eigg were produced, it is yet separated from our own day by an interval sufficient for the removal of mountains, the obliteration of valleys, and the excavation of new valleys and glens where the hills then stood. The amount of denudation which has taken place in the Western Highlands since Miocene times will be hardly credible to those who have not adequately realized the potency and activity of the powers of geological waste. Subterranean movements may be called in to account for narrow gorges, or deep glens, or profound sea-lochs; but no subterranean movement will ever explain the history of the Scùr of Eigg, which will remain as striking a memorial of denudation as it is a landmark amid the scenery of our wild western shores.

DESCRIPTION OF PLATE XIV.

Fig. 1. View of the Scùr of Eigg from the east.
2. View of the Scùr from the south.
3. View of the precipice of the Scùr to the south-west of the Loch a Bhealaich.

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2

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G.R. De Wilde. del. et lith. Mintern Bros imp

VIEWS OF THE SCÛR OF EIGG.

Discussion.

Prof. Haughton inquired whether Mr. Geikie's attention had been called to the Mourne Mountains in Ireland, which seemed to present some analogous phenomena to those described in the paper. In the Mourne district were dykes of dolerite, pitchstone, glossy basalt, and other volcanic rocks of the same constitution as those of Antrim. He believed that a chemical examination of these rocks in different districts would prove their common origin. The evidence in Antrim was conclusive as to their Tertiary age in Ireland; and he was glad to find that the view of their belonging to a different age in Eigg was erroneous.

Prof. Ramsay had hitherto believed in the Oolitic age of these trap-rocks in Eigg, but accepted the author's views. The interbedding of volcanic protrusions among the Lower Silurian beds in Wales was somewhat analogous. He was glad to find the history of these igneous rocks treated of in so geological a manner, instead of their being regarded from too purely a lithological and mineralogical point of view. The great antiquity of these Middle Tertiary beds had, he thought, been most admirably brought forward in the paper, as well as the enormous amount of denudation; and he would recommend it to the notice of those who had not a due appreciation of geological time.

Mr. Forbes hoped that the geologist would remember that his father was a mineralogist. It was refreshing to find a paper of this kind brought before the Society, as it was to be regretted that the details of mineralogy were so little studied in this country when compared with the Continent; and this he attributed to the backward state of petrology (admitted by Mr. Geikie) in this country. He quite agreed in the view of the Tertiary age of these rocks. With regard to the terminology employed by the author, he objected to the use of the word dolerite, as distinct from basalt; basalt properly comprised, not only dolerite (the coarse-grained variety) and anamesite (the finely-grained variety), as well as true basalt, but also tachylite (the glassy variety), which was frequently confounded with pitchstone. All four names merely referred to structure, and not to composition.

Mr. Geikie, in reply, stated that he had not examined the Mourne Mountains. He had not in any way wished to disparage mineralogy, but, on the contrary, had attempted to classify the different rocks according to their petrographical characters. He used the term dolerite in the same sense as the German mineralogists, both as the generic name for the whole series, and also for the coarser variety of basalt.

4. *On the* Formation *of* "Cirques," *and their bearing upon* Theories *attributing the* Excavation *of* Alpine Valleys *mainly to the* Action *of* Glaciers. By the Rev. T. G. Bonney, M.A., F.G.S.

The following paper is an attempt to examine how far a theory which during the last few years has obtained more or less support from many very eminent geologists, can be applied to one of the most remarkable features in several mountain-valleys. Although "cirques" are more commonly associated with the Pyrenees, they are by no means infrequent or on a small scale in the Alps; and as I know the former mountain-chain only at second hand, I shall confine myself to the latter, and to those instances which I have personally examined.

In venturing to treat of a subject so full of difficulty, and to oppose the opinions of persons far more eminent than myself, I may venture to plead as my excuse that I do not write without some experience of mountain-regions, seeing that I have twelve times visited the Alps, have wandered, generally on foot, over almost the whole chain, and have had during many of these journeys this subject of mountain-sculpture especially present before my mind, so as to be constantly on the watch for evidence bearing upon the various theories that have been advanced.

First let me briefly describe a few of the most remarkable cirques, beginning with the Creux de Champs.

This is an approximately semicircular amphitheatre on the northern face of the Diablerets, forming the head of a short glen terminating the valley of La Grande Eau, which joins the Rhone at Aigle. Vast precipices of limestone and shale enclose it, which are crowned with short wide glaciers, and surmounted by the blunt peaks of the Diablerets, the highest of which reaches an elevation of 10,666 feet above the sea. The floor of this glen, though encumbered with moraine stuff, and intruded upon by the great taluses beneath the precipices, is tolerably level, and is probably about 4000 feet above the sea*. Above the slopes an almost unbroken wall of limestone rock rises for at least 2000 feet; shales, alternating with narrower bands of limestone, then reduce the precipitousness and produce the ledges whereon the glaciers rest; and, finally, the limestone peaks rise like broken battlements on the summit of the wall. From these snow-laden ledges numerous streams gush down the rock, some mere white threads of spray, others turbid cascades, whose volume varies with the hour of the day and the state of the weather. Speaking in general terms, we may say that for an arc of about 80° this cirque is enclosed by a nearly vertical wall of precipices rising full 5000 feet above its comparatively level floor. The strata exposed, though here and there contorted, and in one place at least folded, lie on the whole pretty evenly, and appear to dip gently a little south of west.

The Fer-à-Cheval.—This cirque differs from that last described in being situated just on one side of a large peak, and in opening into

* The Hotel des Diablerets, at its mouth, is 3832 feet; and the fall of the valley-bed is not rapid.

rather than forming the head of a valley; it is really a semicircular recess in one of its walls, between the towers of the Pointe de Tenneverges and the lower summit of the Tête Noire.

The base of the former mountain consists of a vast mass of compact limestone, which also (as in the former case) sweeps round the cirque in a wall of precipices full 1000 feet, and often more, in height. This, in the Pointe de Tenneverges, is surmounted by slopes, marking doubtless the presence of more shaly strata; and these are capped by another vast mass of limestone with more frequent partings, which is crowned by the actual peak. Above the wall of the cirque, and excavated in the lower part of this limestone and in the subjacent shale, is an upland glen which leads up to the Col de Tenneverges (8154 feet).

In the neighbourhood of the Fer-à-Cheval, as in the Creux de Champs, the strata, though occasionally locally contorted, are on the whole tolerably horizontal; and it too is remarkable for the number and beauty of its waterfalls. In the spring and early summer, "every notch along the serrated line of crag becomes the birthplace of a waterfall, from the tiny thread of spray which quivers in every breeze and dances irresolutely down the sombre crag, to the furious torrent plunging in one bold leap from top to bottom of the deepest precipice, and announcing its presence with a voice that emulates the thunders of the sky" (Wills, *The Eagle's Nest*, p. 34)*.

The Croda Malcora.—The cirque of the Croda Malcora, high up among the crags of the dolomitic mass that culminates in the Sorapis, has been termed "another Gavarnie" by Messrs. Gilbert and Churchill†, though to myself it appeared to present the distinctive features of a cirque less conspicuously than the two described above. Its rocky floor is broken into a series of irregular steps, supporting some patches of snow and glacier; it is, however, enclosed by a magnificent wall of dolomitic crags, probably not less than 1000 feet in height. The cascades here, so far as I remember, can only be conspicuous after heavy rain or in the spring time; for in summer the upper crags are almost bare of snow, and dry. Time did not allow me to enter it; but I obtained an excellent view into it from a short distance away. The same district of the Ampezzo offers several instances of glens with a cirque-like formation; among these are one of no great size but with steep sides, nestling beneath the great peaks of Monte Tofana, and a most singular one, well seen from the summit of that mountain, termed the Croda di Lagazoi, which I can only compare to a rude amphitheatre with walls of rock instead of masonry, through which a complete breach has been made at one of the vertices of the ellipse.

The Creux du Vent (Jura).—The Creux du Vent, near Noiraigue station on the Val Travers railway, is reported to be the finest example of a cirque in the Jura. It is thus described by Mr. Ball:—"a

* The neighbourhood, in which are several magnificent ranges of precipices, is well described by the same author. Alpine Journal, vol. ii. p. 49.

† The Dolomite Mountains, p. 407.

mountain nearly level at the top, which derives its name from a singular hollow, nearly two miles in circumference and 1000 feet deep, lying near to the summit." To this I add my own note*. "It is excavated in a mass of banded limestone and shale, the strata lying horizontally in the face of the cliff, except at the more southern extremity, where they curve upwards. All down the cliff are distinct traces of the erosive action of many streamlets. The floor of the valley below is a level basin, as though it had once held a lake." This was written at the railway station, whence there is a fine view of the cirque.

Am Ende der Welt, Engelberg.—This cirque is at the termination of the Horbis Thal, a glen descending into the Aa valley just above Engelberg. Less grand than either the Fer-à-Cheval or the Creux de Champs, it is still a striking object, and exhibits the same peculiarities of a comparatively level floor, of enclosing precipices, and of numerous waterfalls. The strata in the precipices, which are perhaps about 1500 feet high, are moderately horizontal on either side, but much contorted in the middle. The walls of the cirque, when it is viewed from the lower end, appear to be crowned with sloping alps, and these to be surmounted with a line of limestone crags. Speaking more correctly, it forms a sudden step or break in the level of an upland valley which lies between two great spurs of the Rothstock *massif*, and carries the drainage of the Graussen glacier to the Aa.

It would be easy to multiply examples of cirque-like glens, similar though inferior to these; but as they would exhibit no fresh features of importance I pass on to my last case, which satisfied me that only one explanation could be offered of their formation.

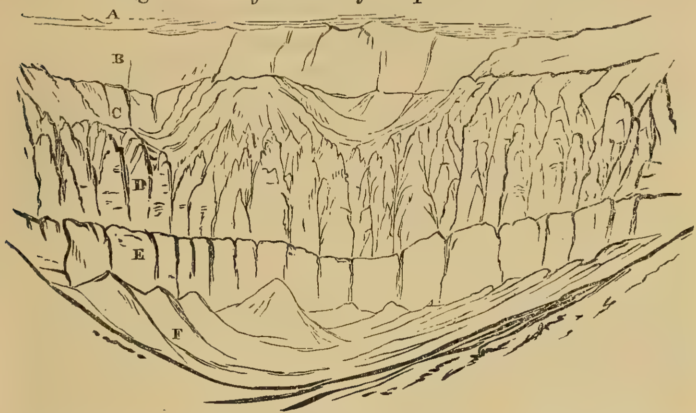
The Cirques of the Rothstock.—As the traveller bound from Engelberg for the Surenen Pass gains the rugged pastures of the Blacken Alp (5833 feet), he sees gradually opening out on his left hand, not one, but two fine cirques cut out of the highest part of the Rothstock *massif*. They are separated by a spur from the peak named Rothschutz on the Federal Map, and are very similar in appearance, though the eastern one is on the whole the finer of the two. Its other extremity is the Blackenstock (9587 feet), and from this summit to the Rothschutz (9278 feet) runs a line of crags not much inferior in height. The chord joining these two points is about 2800 yards long, and the sagitta of the arc about 650 yards; but the spurs projecting from the two extremities give a more semicircular appearance to the cirque than these measurements would suggest.

Above the usual taluses of débris rises a high band of cliffs of a hard yellowish-grey limestone, which supports a still loftier belt of a reddish rock, doubtless a rather sandy and coarse calcareous shale; over this is a sort of terrace-shelf or slope, hollowed out into small combes; and then rises another barrier of limestone cliffs, forming the lip of the cup-like hollow. Clouds prevented me from seeing the sky-line in more than one place; but it is nowhere more than a few hundred feet below the peaks named above. For the same reason, I

* Central Alps, p. 5.

cannot attempt to give any accurate estimate of the height of the cliffs; but the two lower stages appeared to me together not less than 500 feet. The strata lay tolerably horizontal, only curving upwards somewhat in the western part of the western cirque. The

Fig. 1.—*Rough sketch of Cirque in Rothstock.*



A. Clouds concealing peaks. B. Limestone cliffs. C. Shaly slope, with small combes and snow-beds. D. Shaly cliffs furrowed by streamlets. E. Limestone cliffs, occasionally slightly grooved by streamlets. F. Floor of cirque with talus-heaps at side.

most remarkable thing about the cliffs was the belt of reddish shaly rock, which was furrowed by a vast number of little gorges, which were often only a few yards apart and occasionally united, so that this part of the cliff really looked like a badly ploughed field set up on end. Down these gorges, many of them dry in August, little rills descend from the snows on the ledges and in the combes above, which have generally made some trace corresponding with their size on the harder limestone below—sometimes a mere stain, sometimes a well-marked groove.

What explanation, then, are we to give of these rocky recesses with their steep, almost vertical sides, and floors often comparatively level?

To avoid misconception, let me premise that in adopting any one explanation, I do not mean to absolutely exclude all others, but merely select the one which above all others accounts for the existing physical features. Thus, for example, were I to attribute a valley to the erosive action of a glacier, I should not intend to exclude upheaving forces, denudation by waves, currents, and rivers, &c., all of which may have had much influence in preparing the surface for the glacier, but only mean that the glacier has effaced all, or almost all, the tool-marks of these preceding agencies—just as, when speaking of a statue as carved by a chisel, we take no note of the crowbars, wedges, picks, blast-powder, and other appliances which were employed to quarry the block before it was placed in the sculptor's hands.

(1.) I dismiss at once any theory of "craters of upheaval," by which some distinguished geologists have attempted to account for valleys which approach the cirque form, such as that of La Berarde*, because, after examination of this and many others, I can conceive of no theory of upheaval or fracture which could leave them in a state at all resembling their present one. That a valley like the one at La Berarde, to say nothing of these cirques, should be a "crater of elevation' appears to me a physical impossibility.

(2.) Can these cirques be explained by any theory of marine erosion, and compared with the coves which we not unfrequently find on the sea-coast? Though possibly this explanation might be applied to some cases, I do not think it will fit all or nearly all that exist. After seeing how little effect the sea has in the Fjords of Norway, I cannot attribute the Fer-à-Cheval or the Creux de Champs in these remote and sheltered valleys to marine erosion, whatever effect the waves may once have had in blocking out the main features of the Alpine peaks†.

(3.) Can we call in the intervention of glaciers, now so much in favour as nature's carving-tools among geologists? and may these cirques be regarded as results of what Mr. Ruskin would call "minor fury of ice-foam"‡? We shall perhaps best answer the question by considering first this particular case:—whether, assuming that glaciers have been principal agents in the excavation of Alpine valleys, we can suppose the cirques to have been formed by them; and second, whether the assumption just made, that glaciers have been principal agents in the excavation of Alpine valleys, is a correct one. Now, if these cirques are the result of glacial erosion, they were either fashioned (*a*) by a glacier which took its rise in them, or (*b*), like the concavities in the course of a river, by the action of a passing ice-stream. The first of these suppositions appears to me physically impossible. Granting, as we must do, to begin with, some kind of hollow or slight combe on the mountain-side in which the snows could collect and form a *névé*, the erosive action on this part would always be very slight (for the ice here is less compact than that below); the friction would be that due to the weight alone of the superincumbent ice||, and, what is most important, there is but little grit between it and the subjacent rock; for comparatively few stones are engulfed in the *névé* of a glacier. I can conceive it possible that if a glacier, after wearing away a stratum of hard rock, reached one in which erosion proceeded more rapidly, it might deepen its angle of descent to some degree in the upper stratum also; but I cannot conceive that precipices more than a thousand feet high could be thus

* In Dauphiné. See Forbes's 'Norway and its Glaciers,' p. 259.

† My own examination of mountains has led me to conclusions very different from those advocated by Mr. Mackintosh in his 'Scenery and Geology of England and Wales,' although I think it possible that some peaks and ranges may have originated in insular fragments.

‡ Geol. Mag. vol. ii. p. 50.

|| Friction $\propto$ normal pressure; in many of the lower parts of a glacier, normal pressure at any point = weight of column of ice above that point + a pressure derived from ice behind.

produced; and we must remember that in the most conspicuous of those described above, the most compact rock forms the lowest stage. To this question of cliffs in the bed of a glacier I shall return again; for the present we may venture to assert that it is mechanically impossible for a glacier to sink into its bed so as to excavate a cirque on so gigantic a scale. (*b*) But may they have been produced at some bend in the ice-stream like the concavities in a river's course? The Creux de Champs and Am Ende der Welt certainly cannot be thus explained, because they are at the head of deep well-marked lateral glens about a mile and a half long. The two cirques near the Blacken Alp are inexplicable on this theory; for the spurs from the Blackenstock and Rothschutz would effectually shelter them from the action of any glacier descending from the Surenen Pass (7562 feet); and indeed the general contour of the ground suggests that their recesses would be among the feeders of its *névé*, the rise from the Blacken Alp to the last ridge leading to the Pass being comparatively gentle. The Fer-à-Cheval would offer less resistance to this explanation than any other cirque, as it is on the concave side of the elbow of a valley; but as existing glaciers do not appear to produce such marked effects in turning corners in their present beds, we may fairly require much corroborative evidence before venturing to apply this explanation here.

There remains then the wider question to consider, Are we justified in supposing glaciers to have been the principal agents in the excavation of the Alpine valleys? To prevent mistakes, let me state that I do not now purpose to deal with that particular case of this theory which is advocated by several distinguished foreign geologists, and with so much ability in this country by Professor Ramsay, viz. the excavation of lake-basins by glaciers, but rather with that wider view to which, among others, Professor Tyndall has more than once given the support of his experience and talent, especially in a paper published in the Philosophical Magazine*.

If we assign to glaciers any large share in the excavation of valleys, we may fairly ask that the main contours should lend themselves readily to this explanation, just as those of a river-valley, although somewhat modified by other meteoric action, suggest running water as the tool that has principally fashioned them. Now, as a rule, in the upper parts of Alpine valleys, where the glacial action may be supposed most recent, and therefore least affected by other denuding agents, we are struck by the steepness of the last few miles up to the watershed, as compared with the inclination of the rest of the bed. I will only mention a few instances out of many—for the fact must have struck all travellers—and will select the first from the Dauphiné Alps, not only because it is a district very familiar to myself, but also because the valley of the Vénéon runs, for its whole extent, with one most unimportant exception, through remarkably hard crystalline rocks. Measured on the map, this valley is about twenty miles in length from the spot where the river debouches into the small plain above the Romanche, near

* Phil. Mag. Ser. 4. vol. xxiv. p. 169.

Bourg d'Oisans, to the head of the Glacier de la Pilatte. This glacier occupies an extensive glen, guarded on one side by the huge precipices of the Ailefroide (12,877 feet), on the other by a nameless mass, the highest peak on which is probably about 12,000 feet. The lowest point in the loop-like crête connecting these two portals is about 10,800* feet above the sea. The exact height of the foot of the glacier I do not know; but probably 6800 feet is an estimate rather above than below the truth; for the ascent from La Bérarde (5702 feet), $3\frac{1}{2}$ miles down the valley (on map), is not great. Measuring in the same way, it is just two miles from the Col du Sélé to the foot of the glacier (=10,560 feet). Neglecting the odd hundreds, which we are justified in doing, as the lower part of the glacier is flat, we have a fall of 4000 feet in 10,000 feet. From La Bérarde to St. Christophe, $6\frac{3}{4}$ miles (=35,640 feet), the fall is 879 feet, nearly 25 in 1000 feet. From the latter place to Venosc (3363 feet), a distance of about $3\frac{3}{4}$ miles, the fall is 1460 feet; and from Venosc to the opening of the valley, perhaps about $4\frac{1}{2}$ miles, the fall must be 950 feet; for the descent afterwards to Bourg d'Oisans (2380 feet) is but slight. The fall of the valley between La Bérarde and St. Christophe is rather more than is given by the difference of the two stations, as the latter place stands some height above the stream, and this may a little affect the next measurement below.

The result of this is, that the fall of the valley-bed during the first two miles (measured on the map) is 40 in the 100, and after that, for the remaining 17 miles of its course, its fall is always considerably less than 10 in 100. Moreover, in that uppermost portion, the slope very perceptibly increases as the watershed is approached, so that the last few hundred feet, whether of snow or rock, are of formidable steepness, the ascent to the only accessible point (the Col du Sélé) being a stiff bit of rock-climbing. The same configuration is exhibited by most of the tributary glens that join the main valley—by one, the Vallon de la Bonne Pierre, leading up to the Col des Ecrins, to an even greater degree. Three of these are of considerable size†, and must in former times have brought down immense tributary glaciers; they join the main valley at or below La Bérarde; and yet there is not any marked deepening or widening of the valley caused by the great increase of the ice-stream.

Take, again, the glacier on the north side of the *crête* of the Râteau (fig. 2); how could it have excavated that cliff which rises full 2000 feet above it? while, as if to make the puzzle greater, within a mile to the west, begins the Glacier du Mont de Lans, which covers a vast plateau, about 11,000 feet in height, sloping gently to the north. Here the glacier reclines like a white cloth upon a table, protruding a few tongues of broken ice into two or three comparatively shallow notches that have been worn out in its northern edge.

* The Col du Sélé is 10,814 feet, mean of B. P. (Tuckett) and Bar. (W. Mathews); and several other parts of the ridge are of much the same height.

† The Vallons des Etançons, de la Muande, and de la Selle.

Fig. 2.—*Diagram of Le Râteau.*

P. Precipice of Le Râteau. P′. Rocky Spurs with precipices towards Glacier. S. Steep snow slopes. G. Glacier. ➡→ Snow-basin leading to Glacier du Mont de Lans.

If, then, it be conceded that the *névé* of a glacier can settle down so fast that the uppermost mile or two of its bed shall be almost a cliff compared with the remainder of the stream, and we thus account for the configuration of such valleys as those above named, and, on a smaller scale, those in which lie the Brenva, Miage, and Argentière glaciers near Mont Blanc, the Unter-Grindelwald and Lauter Aar glaciers in the Oberland, the Trift glacier near Zermatt, and dozens more which could be easily named in all parts of the Alps, how are we to explain such contradictions as the Mont de Lans, the Théodule, the Gorner (between Monte Rosa and the Strahlhorn), and the Titlis glaciers? or such anomalies as the low opening of the Ampezzo Pass (about 5000 feet) among the towering summits of the Drei Zinnen, Cristallo, and Geiselstein*? Surely it is far safer to suppose that the glen, by whatever cause fashioned, gave rise to the glacier, rather than the glacier to the glen.

But perhaps it will be urged that the greater steepness of the heads of the valleys may be explained by the fact that, in the gradual retreat of the ice-streams since the glacial epoch, they have been exposed to erosive action for a longer time than the lower parts; and so the glaciers, in comparatively recent periods, have steepened the slope of their upper glens. The suggestion is plausible, and might be supported by an appeal to tarns like those of the Lago Bianco and Nero on the Bernina Pass, and by occasional flat

* All about 10,000 feet above the sea.

plains near the ends of existing glaciers, which might be presumed to be filled-up lake-basins; still these cases of glacial erosion, if such they be, are on a very small scale compared with the amount of denudation that this hypothesis requires; and there are many others, as, for example, in the Val del Campo and Val Viola*, where the great heaps of moraine stuff show the glaciers to have long remained just filling up the whole of a lateral valley, without any marked effect on the bed behind.

This difficulty is increased when we examine the bed of an existing glacier, a thing which the rapid diminution of some of the Oberland glaciers during the last few years has made possible. The surface of the Unter-Grindelwald glacier was (July 1870) about 100 feet lower, and the extremity had retreated full 500 feet higher up the steep hill-side, than in 1858. Formerly it descended to the level of the valley; it now rests on a low cliff of rock; and its stream no longer gushes out from an ice-cave, but runs deep in a rocky gorge. This shows that the glaciation of a valley, and the cutting a gorge in its bed may be simultaneous. (The Rosenlaui glacier affords another example of this.) It can now be seen that the final icefall descends over three or four steps of hard limestone; the last, and perhaps the tallest of these, together with what we might call the first flag of the valley-floor, being at present exposed. If, then, the glacier has made these steps, if it is plastic enough to mould itself to them (which it is not in all cases), surely it ought, at the base of each wall, to have worn out considerable hollows, analogous to the pot-holes at the foot of a cascade. But there is nothing of the kind to be seen; the rocks, beautifully polished and scratched in many places, exhibit the usual contours, and after forming an irregular lumpy terrace, showing often "Stoss- and Leeseite," round away to the next cliff.

The steps, not uncommon in valleys, such as those in the Val Formazza, and that which is visible from near Landro, in the glen which descends from under the Drei Zinnen to the Dürren See, present similar but still greater difficulties in accepting the hypothesis of glacier erosion.

Again, how are valleys such as those of the Pusterthal or the Upper Etschthal, to be explained on a theory of glacial erosion? The former is a well-marked and generally wide trench, about fifty miles long, extending east and west from Mühlbach, where the Rienz turns sharp to the south, to Sillian on the Drave (to say nothing of any further extension to the Gailthal). For the most part it is enclosed by mountains 8000 or 9000 feet high; and the flat Toblach plateau, which parts these rivers and forms the watershed between the Adige and the Danube, is 3951 feet above the sea, "sloping gently, almost imperceptibly," in either direction. No one who has seen this great trough, whose sides are steep mountains, rising 4000 feet or more on either hand, whose base dips

* Valleys connecting, on the Italian side, the lower parts of the Bernina and Stelvio Passes.

gently* from a central plateau to opposite points of the compass, can conceive it to have been excavated by a glacier.

In consequence of these reasons, in addition to those already advanced by Sir R. Murchison, Sir C. Lyell, Mr. Ball, M. Favre, &c., I venture to maintain that it is impossible for glaciers to have excavated cirques, and difficult to understand how they can have excavated valleys. I now take one step further, and shall endeavour to show that, if they excavated the valleys, they must also have excavated the cirques. Consider, for example, the case of the Creux de Champs. This is not, as it at first sight appears, in a lateral glen, but at the true head of the Grande-Eau valley. The principal excavating agent, be it ice or water, must have always followed the line of the present drainage of the cirque, and not of that from the lower alps of the Col de Pillon.

Efface the cirque, replace in imagination the vast mass of material which has been scooped out of the heart of the Diablerets between Ormond Dessus and the peaks of the mountains fill up the valley of the Grande Eau, far above the village just named to near the level of the Col de Pillon, there will then be a rather regular and shallow trench, bounded on the one side by the Tornette chain, on the other by the Diablerets' *massif*, a far huger block than now. From this the western and north-western drainage, whether in a liquid or solid form, would have descended, chiefly along the valleys mentioned above, and partly by the small glen west of the Oldenhorn, which, at the present day, has a cirque-like configuration, while only a little would have been supplied by the low alps of the Col de Pillon. Any glacier, therefore, which excavated the Grande-Eau valley below Ormond Dessus must have received its chief ice-affluent from the direction of the present cirque; and I am convinced that no one who has seen the locality could ever attribute the formation of the two parts of the valley above and below this village to different agencies. If, then, we have established that the excavation of a cirque by a glacier is mechanically impossible, the cirque, if not prior to it, must have been excavated by some other agent since the ice-period. But if the streams have been able to remove this enormous amount of débris above Ormond Dessus, how can we account for their comparative inefficiency below? If they have been so active here, and in a few other glens, how is it that they have been practically inactive in the Rhone valley and its other tributaries, and in the great majority of Alpine valleys? Above all, how are we to account for the presence of moraines in the cirque itself?

The same remarks would apply to the Fer-à-Cheval and Am Ende der Welt, whose floors join, were it possible, even more uniformly with those of the main valleys, in which signs of glacial action are still abundantly visible.

The conclusion then seems to me inevitable, that the cirques, and

* The levels of points in the valley are, Mühlbach 2542 feet, Untervintl (9½ miles) 2502 feet, Bruneck (14 miles) 2686 feet, Niederndorf (14 miles) 3784 feet, Toblach 3951 feet, Innichen 3701 feet, Sillian (14 miles) 3611 feet.

therefore the valleys themselves, were mainly excavated before the glacial epoch, and that the effect produced upon them by the glaciers was, comparatively speaking, superficial*.

It remains therefore to ask, what agent, or agents, have produced these remarkable natural amphitheatres, and those minor and less perfect copies so common in the limestone districts, though not wholly confined to them?

In the descriptions of these cirques, attention has been called to the numerous streamlets seaming their cliffs, which were most of all conspicuous in the two under the Rothstock peaks.

Running water, in falling over a cliff, notches the edge, grooves the face, and undermines the base with its spray. Its action is partly mechanical, partly chemical. If then its erosive power be considerable (as when the stream is unusually silty), or if the rock yield slowly to meteoric agents (such as rain and frost), it will cut a gorge, as is commonly the case with glacier streams, and especially in crystalline rocks.

If, however, the water be generally pure, and the rock be easily affected by these other agents, the cliff will recede very slowly and uniformly, as at the Staub-Bach, near Lauterbrunnen, or, at most, will be modified into a crescentic hollow, as at the Nant Dant, near Samöens.

If, then, we have a number of small streams acting in this way, we shall get a cliff formed which will be either a straight wall or, since the streams towards the middle will probably be larger and more nearly perennial than those at the side, an amphitheatre.

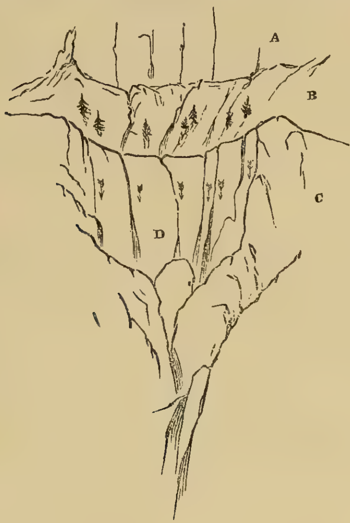
The instances to which I have referred have exhibited this process on a grand scale; the annexed diagram (fig. 3) exhibits the same on a small one. It is taken from a little cirque or, rather, a recess

* Two arguments often advanced to show the excavating power of glaciers appear to me of doubtful value. The vast quantity of mud and silt borne down by the stream from a glacier is adduced as a proof of its destructive power; and it is argued "so many cubic yards of silt deposited annually, so many of rock removed annually *from the bed of the glacier*." But is this the fact? There is often abundance of fine gravel on the surface of a glacier, which has not come from the bed; and I am convinced that a very large portion of the silt borne out by the stream does not come from the subjacent rock, but from the blocks which, after being detached by frost, &c. from the mountains on either side, fall in vast quantities upon the surface of the glacier; many of these are engulfed on their downward passage, and must be crushed to powder in that gigantic mill, of which the quern is rock, the rubber ice.

Again, it is assumed tacitly that as the glaciers were once enormously greater than at present, their erosive powers would be proportionately greater. But this may not be hastily assumed. The erosive effect of a glacier on its bed must surely depend far more on the grittiness of its under surface than on the weight of the ice. A child with a bit of sandpaper would scour rust away from iron faster than a man with a smooth rubber. Now it must be remembered that the more the hills are covered with snow, and the valleys filled with ice, the fewer peaks will project, and the less rock can fall upon the glacier's surface; and so its very bigness will make it the worse file. I believe this remark to be especially applicable to a country like Scandinavia. The scouring power of clean ice cannot be great; for Mr. Hopkins determined experimentally that the coefficient of friction of solid ice upon rather rough sandstone was tan 20°, the same as that of polished marble.

high up in the limestone cliffs above the Aa-valley, on the left bank, a short distance below Engelberg. Here six or seven small streams issue from the rock, and have worked out a hollow only a few dozen yards wide, yet of the true cirque type.

Fig. 3.—*Small Cirque near Engelberg.*



A. Limestone Cliffs. B. Shaly bank with some trees &c., out of which the streams break. C. Limestone cliff. D. Cirque. ⇒→ Cascade.

The conditions, therefore, most favourable to the formation of a cirque are :—

(1) Upland glens, combes or terraces, so shaped as to give rise to and to maintain many small streams.

(2) Strata, moderately horizontal, over which these streams fall, which, by their constitution, yield considerably to the other forms of meteoric denudation.

(3) These strata must nevertheless allow of the formation of cliffs; and thus perhaps the most favourable structure is thick beds of limestone, with occasional alternating bands of softer rock.

Probably some favourable configuration of the ground must be also assumed at the beginning: if a glen ended in a cliff, it would doubtless be more readily cut into a cirque; but whether this is always needed, or what cause has made the cliff, I do not now attempt to investigate. I venture to submit that I have proved that glaciers cannot have produced the cirques, and that (since these cirques cannot be postglacial) they have not, to any great extent, excavated the Alpine valleys. To assign to each agent its due share in the task of erosion in the Alps (and in all other mountain-regions that I have seen) appears too complicated a problem to be solved with the means at present at our disposal; my own belief, after many years of observation, is, that subterranean forces (whether of upheaval or depression, by folding and fracturing the strata), sea, air, frost, rain, streams, and glaciers have all played their part in this task of mountain-sculpture. Perhaps it may be possible some day to approximate to the work done by the first two; but the more I examine the Alps the more convinced I become that the next four have been the chief agents in producing the present configuration of their valleys, and that the effect of the last in the list has been superficial. Earth-forces, like Titanic hands, have moulded and broken, the sea has planed, the heat and cold have split like wedges, rain and rivers have chiseled and sawn, while the glacier rasp has rounded edges and filed down protuberances, but has done comparatively little among the harder rocks to deepen or excavate.

[P.S. Since the above paper was read, Mr. E. Whymper's 'Scrambles amongst the Alps' has been published, in which are some very important remarks upon the question of glacier-erosion. Professor Tyndall, in his recent work 'Hours of Exercise in the Alps,' appears to speak rather less confidently with regard to his theory than in the paper quoted above.]

Discussion.

Mr. Whitaker suggested an analogy between the cirques and the combes in our own limestone countries.

Mr. Geikie regarded the cirques as analogous to the cwms of Wales and the corries of Scotland. They were not, however, confined to limestone districts, but occurred also in gneiss and granite rocks. He thought that the shape was much influenced by the bedding and jointing of the rocks, as there was an evident connexion between these and the shape of the cwms. He could not, however, see his way to account for the vertical cliffs surrounding the cirques.

The Rev. T. G. Bonney, in reply, observed that though cirques were not confined to limestones, the finest instances occurred in such rocks. When cirques occurred in crystalline rocks, the talus was usually much larger than in limestone.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPER.

On the STRUCTURE *of the* CRAG-BEDS *of* SUFFOLK *and* NORFOLK, *with some* OBSERVATIONS *on their* ORGANIC REMAINS. By JOSEPH PRESTWICH, F.R.S., F.G.S., &c. Part II.—THE RED CRAG OF ESSEX AND SUFFOLK.

(Read May 20, 1868 *.)

THE superposition of the Red Crag upon the Coralline Crag is clear. The points on which there are some differences of opinion relate chiefly to questions of structure and to the relation of the Crag-beds of Suffolk with those of Norfolk. Like the Testacea of the Coralline Crag, those of the Red Crag have been the object of assiduous research on the part of Mr. Searles Wood †, whose list leaves little to be added, except the more special determination of their local distribution. To Mr. Searles Wood, jun.‡, also, we are indebted for an elaborate account of the different stages into which he considers the deposit should be divided, to the Rev. Mr. Fisher for a paper on its relation to the Mammaliferous Crag §, and to Mr. S. V. Wood for a subsequent paper on the structure of the Red Crag ‖. To the palæontographical papers I shall have occasion to refer presently.

The Red Crag of Suffolk covers an area of about 300 square miles. It is, however, so overlain by the sands and clays of the Boulder-clay series, that generally it is only on the sides of the valleys which intersect the district that the Crag-beds come to the surface and are to be seen. The places where they are best exposed are on the slopes of the hills skirting the rivers Orwell and Deben, and in the cliff-sections at Bawdsey and Felixstow. As before mentioned, the Red Crag occupies an excavated area in the Coralline Crag, wrapping round the isolated reefs of the latter, filling up the hollows between them, and lying nearly on a level with the conterminous Coralline Crag. Whilst the Coralline Crag consists essentially of light-coloured calcareous beds with an admixture of siliceous sand, the Red Crag consists of a base of siliceous sands with more or less of the peroxide of iron and a few thin seams of clay. They form such an extremely variable series that I have failed to observe any definite order of succession in the various beds of the lower series, or to recognize the "Beach-stages" of Mr. S. Wood, jun. I would divide them into two groups only—the lower one characterized by the prevalence of

* For the discussion on this paper see Quart. Journ. Geol. Soc. vol. xxiv. p. 462.

† Palæont. Soc. Trans. 1848–56. ‡ Ann. & Mag. Nat. Hist. March 1864.

§ Quart. Journ. Geol. Soc. vol. xxii. p. 19. ‖ *Ibid.* p. 538.

oblique lamination, without permanent or definite order of succession in the beds, and the upper by more persistent horizontal bedding. Shells abound in the lower, and are rarer in the upper division.

The general features of the Red Crag are too well known to require more than brief mention. In the central area there occurs at the base of the lower division a bed of phosphatic nodules (the so-called "coprolites"), varying in thickness from a few inches to one or two feet. This bed is slightly developed between Manningtree and Harwich. At Dovercourt I have found remains of it with its characteristic fossils on the top of the cliff; but it is in the district between the rivers Orwell, Deben, and Alde that it is most largely developed, and most profitably worked *. This bed often has an underlie of large blocks of London-clay Septaria, and of large, entire, and fresh-looking flints derived from the Chalk. In this shingle are also found a considerable number of the larger shells entire, particularly an abundance of *Cardium edule*, *Pectunculus glycymeris*, *Cyprina islandica*, *Trophon antiquum*, &c., whilst the Septaria are drilled by boring mollusks, and both Septaria and flints are covered with *Balani*. Large pebbles of siliceous sandstone, balls of concretionary dark fossiliferous sandstone, rolled and worn bones or teeth of Cetacea, Sharks, &c., and occasionally fragments of the older rocks, are also met with in this bed. At a pit at Trimley, near Felixstow, I found subangular fragments of Lower Greensand *chert*, a large fragment of *red granite*, and fragments and pebbles of *siliceous sandstones*. Although this shingle and accompanying fragments of the older rocks are generally confined to the base of the Red Crag, large blocks of angular flint and seams of phosphatic nodules occasionally occur in the overlying beds. Quartz pebbles are met with in the Red Crag, but they are rare.

This basement bed sometimes thins out †, and at other times divides into two beds separated by a foot or two of shelly crag. Sometimes also thin seams of phosphatic nodules occur 3 or 4 feet above the lower bed, and separated from it by a bed of comminuted shells, as at Foxhall, Waldringfield, and, in places, at Sutton. Dispersed nodules may, in fact, be found through the whole of the Red Crag.

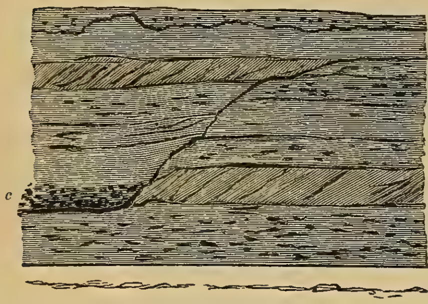
Above this basement bed are a series of beds more or less fossiliferous, forming with it the lower division of the Red Crag, which is generally from 10 to 15 feet thick, and rarely attains a thickness of from 20 to 25 feet. These beds are very irregular, not persistent for long distances, often mere lenticular masses, and are marked by the more or less constant occurrence of oblique lamination. This lamination has not a constant direction. It varies to almost all points of the compass. The dip is generally from 12° to 32°. A common dip is about 22°, N.W., N.N.W., and N.E. It is in the upper part of the lower division that false bedding is most general.

* Particularly in the district which surrounds the central mass of the Coralline Crag of Sutton.

† In the cliff at Bawdsey this basement bed is altogether or almost wanting, whereas half a mile inland it attains a thickness of from 2 to 3 feet.

Sometimes the lower beds have been eroded previously to the deposition of overlying beds, as in the following section at Ramsholt (fig. 6).

Fig. 6.—*Section in the Red Crag at Ramsholt.*



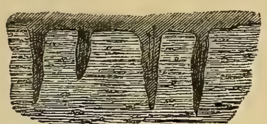
In one instance only have I seen ripple-marks preserved in the Red Crag. This occurred in the cliff at Bawdsey, where the argillaceous laminæ of one bed retained each a ripple-marked surface, which in the section showed like the crumpled leaves of a book (fig. 7).

Figs. 7 & 8.—*Sections in Bawdsey Cliff.*

Fig. 7.

Laminæ of ochreous clay and of shelly sand.

Fig. 8.



Bed of laminated clay and sand (*b*) with cracks at top filled with clay from *a*.

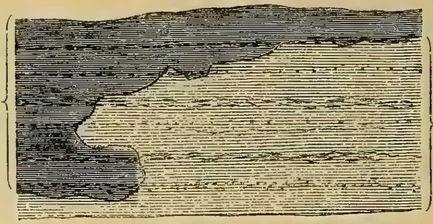
Another feature noticeable at times in the same cliff shows that probably the shoals of the Red-Crag sea were occasionally left dry—their surfaces fissured by the sun and air, and the cracks filled with the materials of the bed afterwards thrown down upon them (fig. 8).

Elsewhere a crag-seam has been pressed down into an underlying bed, and the upper part afterwards removed as in fig. 9.

Fig. 9.—*Section in Bawdsey Cliff.*

The oxide of iron, to the presence of which the Red Crag owes its distinctive name, is at places so abundant as to give rise to large tabular masses of very ferruginous sandstone and in places to concretionary masses of limonite. Its introduction seems often to have been subsequent to the formation of the beds. At some places the same bed presents a stained and an unstained portion, as in the following section* (fig. 10).

Fig. 10.—*Section in the Cliff at Walton.*

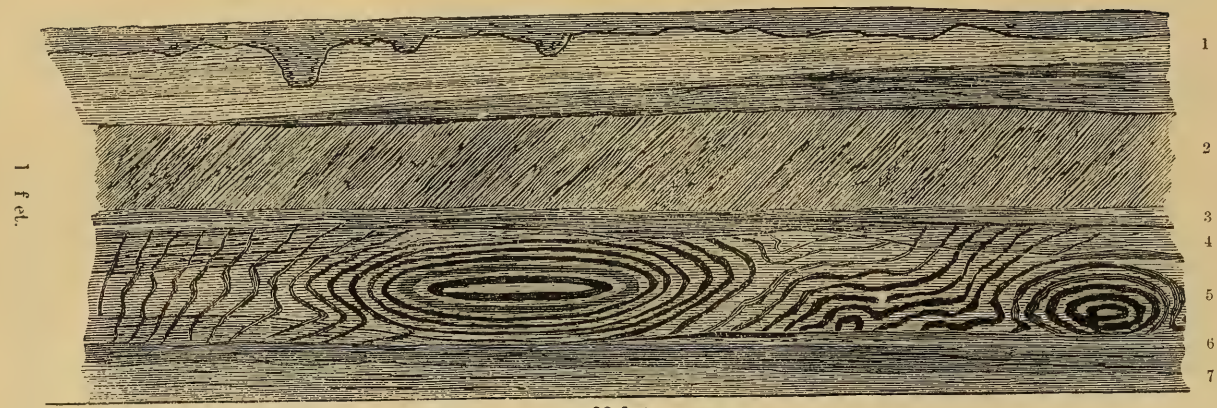


The most remarkable result, however, arising from the presence of iron in these beds is exhibited in a pit near Butley Abbey (fig. 11). Here the iron has segregated, not in distinct and separate seams or nodules, but in large sections of the sands, throughout which it has produced a pseudomorphous structure affecting the arrangement of the beds themselves, which show on the one hand the concentric layers due to the mineral action, and on the other the lamination due to the bedding. The masses thus affected are as much as from 30 to 40 feet in horizontal diameter, whilst their vertical diameter is but from 3 to 4 feet. The appearance at first sight is as if the beds had been disturbed or reconstructed; but a closer examination shows that the lines of stratification extend through all the concentric ferruginous rings. Nevertheless the stratification is subordinate to the action of segregation, which has so modified and moulded the beds that the rings or, rather, coats of segregation, when sufficiently consolidated, intersect the slightly consolidated sands and grit just like planes of cleavage in the older rocks, and cause the detached layers to peel off in accordance with the structure superinduced by the presence of the iron, and intersect the bedding at various angles. These concentric rings pass indifferently through beds of sand, grit, and crag, but are cut off sharply or are lost when they come into contact with a seam more highly and entirely ferruginous. It is the most illustrative instance of this kind of action of such magnitude in beds of this class that has come within my knowledge.

From Walton to Aldborough the lower division of the Red Crag abounds in shell-remains, the greater part comminuted, but with many entire and single valves usually placed with their concave side downwards. Some double shells, especially of *Mytilus edulis*, *Astarte*, *Tellina*, *Mactra*, and *Corbula*, occur, but they are not common. With the exception of the old shore at Sutton, with its *Mytili* and

* Possibly the deep ferruginous colour of the Coralline Crag (*g*) at Sutton is due to a staining received from encircling beds of Red Crag since removed.

Fig. 11.—*Section in a Pit on the Common about half a mile west of Butley Abbey.*



1. Light coloured crag. 2. Very ochreous crag.
3 & 7. Ferruginous crag and iron-sandstone. 4 & 6. Shell-beds.
5. Light coloured horizontal crag with ferruginous concentric bands.

Pholades, it would not be easy to fix upon a place in the Red Crag where the Testacea are on the spot where they lived*. We meet everywhere with finely comminuted shells and fragments of shells, with here and there a band of more perfect specimens, or a few such specimens dispersed amongst the comminuted fragments. Mr. Searles Wood, however, considers that at Walton the conditions were such that many of the Crag Testacea lived on that spot. Notwithstanding the great number of shells occurring in the Red Crag, the abounding and characteristic shells consist of a few species only, and the larger proportion are more or less rare. Some species occur in countless numbers, such as *Cardium edule*, *Pectunculus glycymeris*, *Tellina obliqua*, *T. crassa*, *T. prætenuis*, *Mytilus edulis*, *Pecten opercularis*, *Mactra solida*, *M. arcuata*, *Cyprina islandica*, *Lucina borealis*, *Purpura lapillus*, *Trophon antiquum*, *Nassa granulata*, *N. reticosa*; while of many only a few specimens have been found, and of some only one or two specimens. In places, especially as we recede from the centre of the district, the beds become almost devoid of shells, or they occur only in patches. This may be partly owing to the original absence of shells, but it may also be due to the removal of the shells by percolation of rain-water through the beds; for at places where the beds are consolidated by iron, casts of shells are occasionally met with, as in some pits between Woodbridge and Grundisburgh and elsewhere.

Mr. Searles Wood has given all the species he has procured from the rich localities of Sutton, Walton†, Bawdsey, Foxhall, and Newbourne. These localities are indicated by initials in the lists of Red- and Norwich-Crag fossils; and therefore separate lists are not required. I have added some other localities.

Although some species are common throughout, there are many which have only a limited distribution, and which give to various localities their peculiar assemblages. This will be evident from the general list at the end, as well as from the following local lists of specimens, formed by me during occasional visits to the district.

From the pit near the Butley Oyster Inn.

Astarte Basterotii.
—— compressa.
—— Omalii.
Cardita senilis.
Cardium angustatum.
—— decorticatum.
—— edule.
Corbula striata.
Cyprina islandica.
Diplodonta astartea.
Loripes divaricata.
Mactra ovalis.
Mya arenaria.
Mytilus edulis.
Nucula Cobboldiæ.
—— nucleus.
Pecten opercularis.
Saxicava arctica.
Solen siliqua.
Tellina crassa.
—— lata.
—— obliqua.
—— prætenuis.
Dentalium costatum.

* Mr. A. Bell has obligingly given me a list of 54 species of Red-Crag shells which he has found double. They are marked *d* in the general list.

† See also Mr. Wood's separate list from Walton in Quart. Journ. Geol. Soc. vol. xxii. p. 542.

Buccinum undatum.
Cancellaria costellifera.
Calyptræa chinensis.
Littorina littorea.
Natica.
Nassa granulata.
—— propinqua.
—— reticosa.
Purpura lapillus.
—— tetragona.
Ringicula buccinea.
Trophon antiquum.
—— costiferum.
—— gracile.
Trochus granulatus.
—— papillosus.
Turritella incrassata.
Voluta Lamberti.

Balanus crenatus.

The following is a list of shells furnished me by the late Dr. Woodward, by whom they were collected at Chillesford Stack-pit in 1863. The distance between the pits is one mile; and they are both on the same level. Even in this short distance the distribution shows a marked difference *. Some species rare or absent in the last pit are common in this one:—

From the Chillesford Stack-pit.

Astarte Omalii.
Cardium angustatum (common).
—— edule.
—— venustum.
Mactra arcuata (common).
—— ovalis (common).
—— subtruncata.
Mya truncata.
Mytilus edulis.
Nucula Cobboldiæ.
Pecten opercularis.
Pectunculus glycymeris (common).
Tellina crassa.
Tellina obliqua (common).
—— prætenuis (common).
Buccinum undatum.
Littorina littorea.
Natica catena.
—— clausa.
—— multipunctata.
Purpura tetragona.
Trophon antiquum.
—— ——, var. contraria.
—— gracile.
Turritella incrassata.

To these I may add—

Leda myalis.
Nassa reticosa.

The following is also on the same authority:—

From a pit at Hollesley.

Cardium angustatum.
—— edule (frag.).
Mactra.
Mya arenaria.
Pecten.
Pectunculus glycymeris.
Tellina prætenuis (pair).
Buccinum tenerum.
Capulus ungaricus.
Cerithium.
Nassa granulata.
—— reticosa (common).
Natica.
Purpura lapillus.
Trophon antiquum.
—— ——, var. contraria.
—— gracile.
Turritella incrassata.

Between Chillesford and Aldborough a range of hills consisting of a ridge of Coralline Crag, against both flanks of which the Red Crag abuts, runs from Orford to Iken. On the eastern side of this ridge there is on the whole a greater paucity of species. In one pit

* *Tellinæ*, so very abundant generally in the Crag, do not occur at Walton, or are at all events extremely rare.

the Red Crag may be seen capping the Coralline Crag; and I have there collected the following fossils :—

Pit one mile east of Sudbourne Church.

Astarte obliquata.
Cardium edule.
Mactra ovalis.
Mya truncata.
Mytilus edulis.
Pecten opercularis.
Tellina obliqua.
Cypræa europæa.
Littorina littorea.
Nassa granulata.
Purpura lapillus.
Turritella incrassata.

To these a list of the late Dr. Woodward adds :—

Artemis lentiformis.
? Cardium Parkinsoni.
Venus fasciata.
Buccinum undatum.
Natica catena.
? Trochus zizyphinus.
Trophon antiquum*.

Proceeding northward there is a Crag pit, now little worked, just at the back of Aldborough, in which the following fossils are found :—

Ballast-pit (near the gas-works), Aldborough.

Abra.
Cardium edule.
Cyprina islandica.
Lucina borealis.
Mactra ovalis
—— subtruncata.
Mya arenaria.
Mytilus edulis.
Pecten opercularis.
Pectunculus glycymeris.
Tellina obliqua.
—— prætenuis.
Buccinum undatum.
Littorina littorea.
Purpura lapillus.
Trophon antiquum.
Turritella communis.

Balanus crenatus.

Large double shells of *Mytilus edulis* are not uncommon in this pit.

A slight cutting on the railway one mile N. of Aldborough passes through a thin bed of Red Crag with an abundance of *Tellina*, *Mactra*, and *Cardium*. And in a cutting by the side of the road to Saxmundham, on the hill one mile from Aldborough, Mr. Evans and myself have collected the following species :—

Roadside one mile west of Aldborough.

Cardium edule.
Leda myalis.
Lucina borealis.
Mactra ovalis.
Mya truncata.
Mytilus edulis.
Pecten opercularis.
Tellina obliqua.
—— prætenuis.
Calyptræa chinensis.
? Clavatula linearis.
Nassa.
Natica hemiclausa.
Purpura lapillus.
Scalaria clathratula (large).
Turritella communis.

Balanus crenatus.

Echinocyamus pusillus.

In addition to these, Mr. Fisher mentions *Buccinum undatum*.

These few lists will serve to show the shells generally most common in the Suffolk Crag pits.

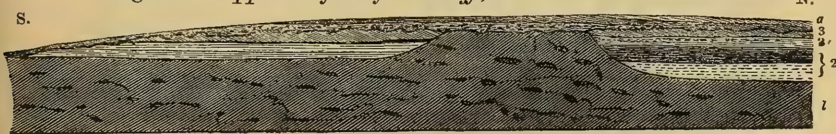
* Mentioned also by Mr. Fisher.

The next pit northward is that on Aldringham Common (known as the Thorpe Pit). As this, however, belongs to the so-called Norwich Crag, we will proceed first to describe the upper division of the Red Crag in the typical Sutton district, before commencing with the district further north.

The upper division of the Red Crag I have formerly designated, owing to the want of all fossils in the neighbourhood of Ipswich, as the "unproductive sands" of the Red Crag; but this, although it holds good in the neighbourhood of Ipswich, cannot, if I am right in its correlation, be applied as a general rule. Mr. Searles Wood, jun., and Mr. Fisher, have also both noticed the presence of an upper and more horizontally bedded division of the Red Crag, and have remarked upon the difficulty at times of drawing a line of separation between this and the underlying beds, owing to the extent of erosion and denudation which had taken place immedidiately preceding the deposition of the upper bed*. There is great difficulty (in many cases amounting almost to impossibility) in showing where the line of separation really is placed. Where beds of soft sand or loam are superimposed one upon the other, whatever may be their difference of age, they must, when deposited under water, tend to intermingle at the point of junction, as I have shown in the case of the Loess in the neighbourhood of the Reculvers, where it seems to pass gradually down into the Thanet Sands. Therefore the apparent passage of two soft beds is unimportant when elsewhere a decided line of separation can be shown to exist. Where the upper division of the Red Crag reposes quietly upon the lower one, the similarity of lithological character and colour is such that the only cause for separating them seems to be the absence generally of organic remains in the upper division. But this is not a persistent feature, as there are places where this division contains shells, some of them of a marked character, to which we shall refer presently †.

Some appearance of this upper division may be seen in the cliff at

Fig. 12.—*Upper 25 feet of the Cliff, Walton-on-the-Naze.*



a. Gravel. 3. Grey clay. 3'. Light coloured sand.
2. Crag beds. *l.* London clay.

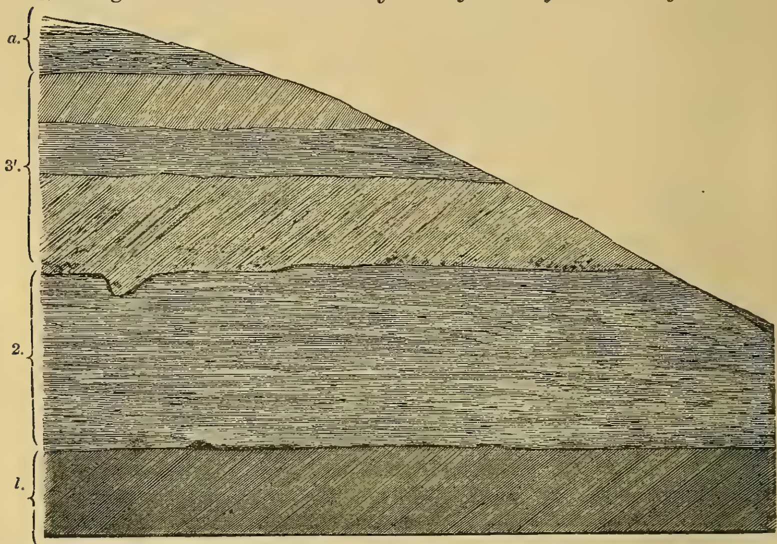
* I do not, however, interpret all the sections given by Mr. Wood (Ann. & Mag. Nat. Hist. March 1864, pp. 3 & 4) in the same way that he does. I include in the upper division of the Crag some beds which he considers to belong to his "Lower Drift."

† The line of division often shows best under certain conditions of weathering and moisture.

Walton (fig. 12), where a bed of unproductive sands overlies the shelly beds, and subtends them on to the London clay in a direction from N. to S.

In the railway-cutting between Woodbridge and Martlesham, this upper division is more developed, and the lower division presents a slightly eroded surface (fig. 13).

S. Fig. 13.—*Section in Railway-cutting south of Woodbridge.* N.



a. White sand and gravel, 3 feet.
3'. Upper Red Crag, yellow sands with a few patches of shells at base, 15 feet.
2. Lower Red Crag, shelly, 12 feet. *l.* London Clay.

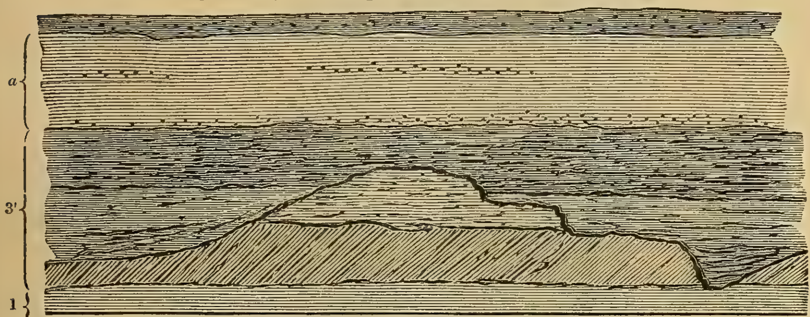
The erosion of the lower division now becomes marked both to the eastward and northward of this place. Some well-marked instances may be seen in the cliff at Bawdsey (fig. 14), and again at Shottisham (fig. 15).

Fig. 14.—*Section in Bawdsey Cliff.*

Fig. 15.—*Section half a mile west of Shottisham Hall.*

It is apparently this upper division of the Red Crag which reposes on the eroded surface of the Coralline-Crag pit by the roadside between Sudbourne and Iken (fig. 16).

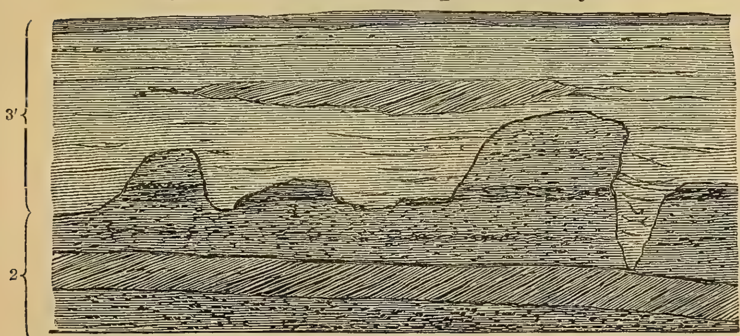
Fig. 16.—*Pit by side of road 1¼ mile N.N.E. from Sudbourne Church.*



a. Light-coloured sands with fine gravel. 3'. Ferruginous and yellow sands. 1. Coralline Crag.

The same feature with relation to the Red Crag is again visible, though not so clearly, at Aldborough (fig. 17).

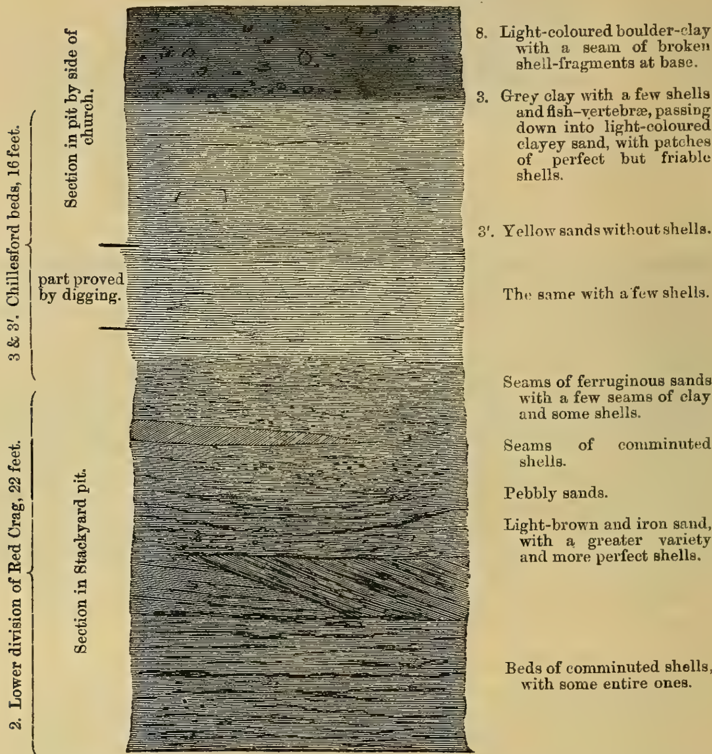
Fig. 17.—*Section in Ballast-pit, Aldborough.*



3′. Brown sands with few shells and pebbles: upper division, 10 feet.
2. Shelly Red Crag: lower division, 10 feet.

The sandy beds of the upper division of the Red Crag do not usually exceed from 10 to 15 feet in thickness, and pass upwards into or are succeeded by the Chillesford Clay. This sequence is well shown at Chillesford, where I had a trench dug in the upper pit by the church down to the Red Crag, so connecting it with the Stackyard pit. The general section thus taken is as under (fig. 18).

Fig. 18.—*Section at Chillesford.*



The fossils of these Chillesford, or upper Red Crag, sands are often very few; and some portion of them may in this district be derived from the destruction of the lower division, in the same way that in the lower division we find fossils derived from the Coralline Crag. At Chillesford-Church pit, however, we get the fossils proper and peculiar to these sands, as it is evidently the spot where they lived*. At Walton a thin seam of undeterminable shell-fragments occurs in places at the base of these sands. At Newbourne I could not distinguish between the few fossils of these sands and those in the beds beneath. At Chillesford Stack-pit *Scrobicularia piperata* is stated by Mr. Searles Wood to be found in the upper part of the

* For lists of these fossils see Quart. Journ. Geol. Soc. vol. v. p. 350, and vol. xxii. p. 545; also the general list.

section in association with other shells of the Chillesford series, such as *Cyprina islandica*, *Mactra ovalis*, *Mya truncata*, *Tellina obliqua* *T. lata*, and *T. prætenuis*, in sands resting upon beds of the Re Crag.

I have collected in these upper beds at Bawdsey cliff:—

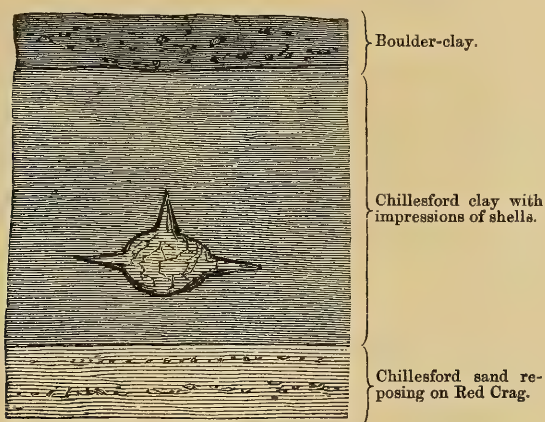
Astarte compressa.
Cardita scalaris.
Cardium edule.
Cyprina islandica.
Lucina borealis?
Mactra solida.
Mya arenaria.
Mytilus edulis.
Pecten opercularis.
Pectunculus glycymeris.
Tellina obliqua.
—— prætenuis.
Nucula Cobboldiæ.

Buccinum undatum.
Littorina littorea.
Nassa reticosa.
Natica catena.
—— hemiclausa.
Trophon antiquum, var. contraria.
Turritella communis.

Sphenotrochus intermedius.
Vertebræ of fish.
Teeth of shark.
Claws of crab.

Owing to the presence of derived fossils, and the similarity of lithological characters of this division in the Red-Crag district proper, it will require special and careful search to determine its fauna in this area. Most of the shells are probably in common; but the variation in physical conditions, independently of other circumstances, will be found, no doubt, to have brought in fresh species.

Fig. 19.—*Section in Chillesford brick-pit.*



These sands are succeeded by laminated grey clays, the lower parts of which are seen at Chillesford-Church pit, but are better developed at Chillesford brick-pit. The clay is there fossiliferous; but the shells are all in the state of casts and impressions in the clay. The following species are recognizable:—

Arca.
Cardium grœnlandicum.
Cyprina islandica.

Leda myalis.
Nucula tenuis.
Tellina lata.

I had always been told that large bones were occasionally found in these clays; but it was not until this last winter that any were brought to my notice, when I was informed that the bones of some large animal had been discovered; and on visiting the pit in company with Mr. Gwyn Jeffreys, I was shown the vertebral column of a great whale at a depth of 8 feet from the surface, and lying at right angles to the face of the section. These vertebræ were exactly in the position in which they might have been left at the death of the animal—each vertebra lying a few inches apart from its neighbours, owing to the removal of the cartilaginous matter between them. About seven vertebræ have been taken out; and it is to be hoped that a further portion of the skeleton may yet be discovered *. Fig. 19 is a sketch of this pit.

As this clay forms an important link in the correlation of the Suffolk with the Norfolk Crags, I will, before touching upon the latter, proceed to trace it from south to north through the Red-Crag area.

Commencing at the furthest point south, the bed of clay (see fig. 12, bed 3) overlying the sands at Walton-on-the-Naze should probably be referred to this zone. In mineral character it closely resembles the Chillesford clay; and it contains in places, as it does again further north, fragments and pieces of wood, but I could here find no traces of shells. In the Ipswich and Woodbridge districts this clay is not seen, and the gravels of the Boulder-clay series repose immediately upon unproductive Chillesford sands or on the Crag. The clay is met with on the hills in the neighbourhood of Felixstow, and again near Hollesley; but it is at Chillesford that it is best developed and becomes fossiliferous. It may be traced capping the hills between Sudbourne and Iken. Some time since, there was a good section in a pit half a mile north of Black Walks, in the direction of Iken. A laminated clay, 8 or 10 feet thick and full of the casts of the following shells, there overlies a bed of light-coloured sands, under which, at a depth of a few feet, the Red Crag was reached in a trench I had dug:—

Cardium grœnlandicum.	Nucula tenuis.
Leda myalis.	Tellina lata.

And in the same clay at the pit at Low Farm we found:—

Cardium grœnlandicum.	Scobicularia piperata.
Leda myalis.	Turritella communis.
Nucula Cobboldiæ.	

There was formerly a pit on Webber's Whin Farm, a mile and a half W.S.W. from Aldborough Ferry, where the fossiliferous Chillesford sands occurred, and with them a group of shells to which elsewhere special attention has been directed by Mr. Fisher †, by whom this bed has been termed the *Mya*-bed, from the abundance

* Dr. Crisp has since ascertained it to be an entire whale 31 feet long. (Brit. Assoc. Rep. 1868, Trans. Sect. p. 61.)

† "On the Relation of the Norwich Crag to the Chillesford Clay or Loam" (Quart. Journ. Geol. Soc. vol. xxii. p. 19).

of that shell in it. When I again visited it lately to collect more of the fossils, I found it sloped over.

The clay contained numerous impressions of the same shells as at Iken, and in the same condition ; but in the sand the shells themselves were preserved, mostly double and in the position in which they lived. They consisted of:—

Cardium. Nucula or Leda.
Mya truncata. Tellina.

Crossing the Alde, the hill at the back of Aldborough is capped by the Chillesford clay, with the sands under it, and we again find it at the brick-pit near Warren House, one mile N. of Aldborough; but in neither of these places have I found any fossils. Their relation at the latter place, both to the Red Crag and Coralline Crag, is clear, as shown in the following theoretical section:—

Fig. 20.—*Section from the Railway to the High-road, near Warren House:* height about 25 feet.

a. White sands and gravel.
3. Chillesford Clay.
3′. Chillesford Sand.
2. Red Crag.
1. Coralline Crag.

The shell-bed on the side of the road to Saxmundham shows also, apparently, the same relation to the Chillesford Clay, if we may judge by a bed of clay which crops out near the top of the hill.

These Chillesford clays form with the underlying sands the upper division of the Red Crag.

Before leaving this district, I must direct attention to some sections of much interest, both on the score of old physical geography and in evidence of the dependent relations of the Red to the Coralline Crag. To the first of these sections attention was originally directed by Sir Charles Lyell in 1838. In his description of the Crag at Sutton, Sir Charles pointed out that in the Bullock-yard pit on Mr. Colchester's farm the Red Crag abuts against the Coralline Crag, and that the latter is perforated by *Pholades,* showing the existence of an old cliff, and that this cliff was subsequently submerged and covered up with Red Crag. The further opening out of this section and some other sections on the opposite side of the hill show that there are two submerged cliffs, that they pass round the hill, and that the mass of Coralline Crag, forming the higher part of the hill, has been an old reef in the Red-Crag sea. We have additional evidence also showing how great was the denudation and removal of the Coralline Crag, the *débris* of which is profusely scattered in some adjacent beds of the Red Crag. The facts were of so much interest that I resolved to have a properly levelled section taken of the whole ground; and for that purpose I applied to Mr. P. Bruff, C.E., of Ipswich. This gentleman very kindly offered me the gratuitous services of his assistant, Mr. Miller, to run a level from the river Deben to Shottisham; and I am indebted to him for the careful levels and plan given in Pl. VI.

This survey has furnished the data for my section at Sutton, where the old cliffs and shore-lines are shown (map and sections, Pl. VI.),

Fig. 21.—*Section in Bullock-yard pit, Sutton* (D, Pl. VI.).

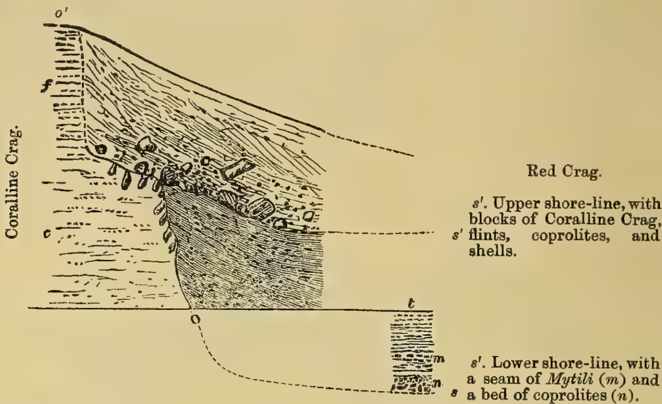
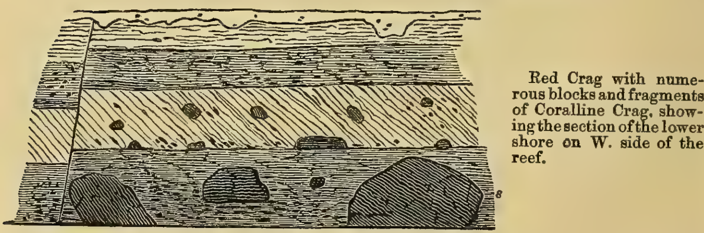


Fig. 22.—*Section in the same pit, but at right angles to the above.*

Fig. 23.—*Section of pit* (C, Pl. VI.) *near the Barn.*



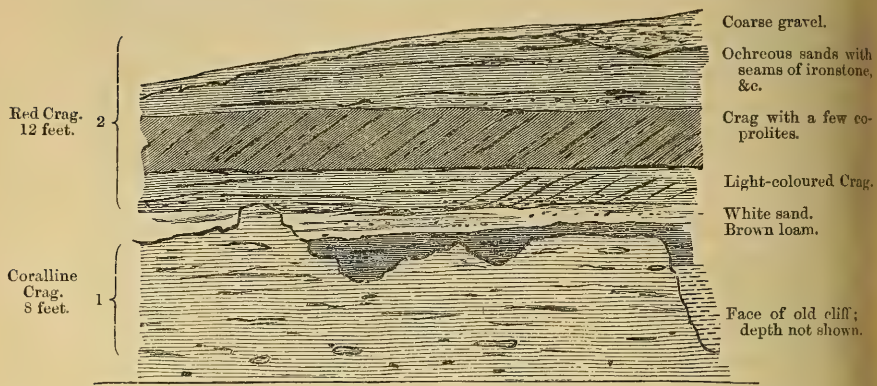
while the details of them as seen in two of the pits are given in figs. 21, 22, and 23. The upper shore-line s' is 31 feet above high water of the river Deben, which can vary but little from that of the sea on the adjacent coast, from which this part of the river is only five miles distant. The upper cliff (*o′*, fig. 21), which is not well exposed, is about 12 feet high, and must formerly have been higher, as blocks of the consolidated bed of Bryozoa capping the hill higher up are found at its base. They may have toppled over the brow of the old cliff, or been detached and carried a short distance by ice-action. At all events it is evident, from the way in which the blocks of Coralline Crag, 1, 2 in fig. 22, have impressed and squeezed up the lower layers of Red Crag in which they rest, that they fell on the spot where they now lie whilst the Red Crag was in course of formation, and that the upper part of the Red Crag was deposited subsequently to the fall of the blocks. The larger of these angular blocks of Coralline Crag may weigh more than a ton. In addition to these large blocks there are many smaller ones—some perforated by Annelids, and others covered with *Balani* (*B. crenatus*). Together with these are a number of pebbles of flint, some coprolites, and some large masses of angular and unworn flints. Interspersed with this coarse shingle are an abundance of shells (chiefly *Mytilus edulis*) with both valves. The *Pholas*-perforations commence at the top of the upper shore, and pass over the brow of the lower cliff, *o*. A few feet back from the face of the section the Coralline Crag rises to the surface of the ground.

To ascertain the position of the lower shore-line, I had a trench dug at the bottom of the pit and below the level of the upper shore, *s′* (fig. 21). I found the Red Crag to extend about 4 feet deeper, and at its base a shingle composed of phosphatic nodules and of large flints, over which there was a thin bed of *Mytilus edulis*, almost all with the two valves, and apparently in the spot where they lived. This shore-line is 22 feet above high-water mark. Its character is better seen in a pit (G) situated on the other side of the old reef, 350 yards west of the pit D (see Pl. VI.). The details of this pit are given in fig. 23. On the upper shore in pit D I found only two large blocks of Coralline Crag; but on this lower shore the blocks were many, whilst numerous smaller fragments were dispersed throughout the section, showing the removal of the adjacent Coralline Crag to have been more active at the commencement of than further on in the Red Crag period. Flints and phosphatic nodules are dispersed here and there. Apparently this pit is at a rather greater distance than pit D from the old submerged reef.

The occurrence of these transported blocks of Coralline Crag is peculiar to these pits. There are, however, few other pits so near as these to the Coralline Crag; and the upper bed of the Coralline Crag is here also more compact than elsewhere. But although the débris of the Coralline Crag is nowhere else so abundant, it may nevertheless be detected in most of the pits of the Red Crag in this district. Small pieces and fragments of the harder seams of the Coralline Crag, together with its Corals and Bryozoa, are extremely common in the Red Crag at Waldringfield, one mile direct from Sutton. I have also found worn fragments of the Coralline Crag in the Red Crag at

Bawdsey and Felixstow. Flat pieces of the thin limestone seams of the Coralline Crag are common in the Red Crag around Tattingstone, where the same reef-like structure of the Coralline Crag is shown at Park Farm (fig. 24); and I have found some small fragments even in the Red Crag at Walton.

Fig. 24.—*Pit at Park Farm, Tattingstone, near Ipswich.*



Another old Coralline-Crag reef forms the nucleus of the ridge of hills from Gedgrave and Orford to Iken and Aldborough. The Red Crag abuts against its flanks, and its summit is capped by the Chillesford clay; but although the Red Crag can be traced close up to these hills, the cliff-line is nowhere exposed. At the same time the erosion of the Coralline Crag adjacent to this old reef during the Red-Crag period is seen in the section given in fig. 15. It is probably the littoral zone of an old shore connected with a higher part of this reef or islet that is indicated by the *Mya*-bed of Mr. Fisher.

Having described the Red Crag and Chillesford series in their typical and special area, and followed them as far as Aldborough, we come to more debatable ground. Some geologists have referred the crag at the Aldborough ballast-pit to the Norwich Crag, and others to the Red Crag. The next sections, however, which are only two miles further north, present far more definite characters. Their relation to the Norwich type cannot be doubted; and to that group they have always been referred. It remains now to be seen whether there are sufficient grounds for considering the Crag in the area north of Aldborough to be newer than the Red-Crag series, or whether it is to be considered a synchronous deposit, with differences of character depending upon local conditions.

We have already noticed three ridges of Coralline Crag—one at Tattingstone, a second at Sutton, and a third extending from south of Orford to Iken and Aldborough. The first two are small, and the Red Crag wraps round them without any change of character. The third is more important and makes a greater break in the Red Crag, which nevertheless reappears on its eastern flank, although with characters somewhat modified. The Coralline-Crag ridge appears to be further prolonged from Aldborough nearly to Sizewell; and it is on the northern side of this that we find the marked change in the newer Crag. From this point the characteristic land and freshwater features of the Norwich beds set in, and the typical Red Crag is no longer met with.

Let us therefore see what relation the more northern Crag bears to the Chillesford Clay, and in what the difference in organic remains from the Red Crag consists.

The cliff at Thorpe is now overgrown; but the Boulder-clay appears in pits a short distance inland. At Sizewell traces of crag may be seen in the cliff; and a few years since the digging of a well * brought to light additional specimens, of which I collected:—

Fossils from Sizewell Cliff.

Astarte compressa.
Cardium edule.
—— interruptum.
Cyprina islandica.
Lucina borealis.
Mactra ovalis.
Mya arenaria.
Mytilus edulis.
Nucula Cobboldiæ.
Tellina obliqua.
—— lata.
—— prætenuis.

Cerithium tricinctum.
Conovulus pyramidalis.
Nassa incrassata.
Natica hemiclausa.
Paludina lenta.
Purpura lapillus.
Trochus Kicksii.
Turritella communis.

——

Base of horn of deer, in precisely the same condition as Red-Crag specimen.

together with fragments of Coralline Crag drilled by boring-shells and Annelids and covered with *Balani*.

A mile and a half W.S.W. from Sizewell is the well-known pit on Aldringham common, generally known as Thorpe pit. Here, again, no superposition is seen. The Boulder-clay caps the hill between this pit and Sizewell; and the Chillesford Clay appears on higher ground to the westward. At Sizewell the crag is more or less ferruginous, like the Red Crag; but here it is light-coloured, like the Norwich Crag. The following is a list of the shells that my friend Mr. Evans and I have collected there on various occasions:—

List of Fossils from Thorpe pit, near Aldborough.

Abra obovalis?
Astarte gracilis.
Cardium edule.
Corbula striata.
Cyprina islandica.
Donax trunculus.
Lucina borealis.
Mactra ovalis.
Mya arenaria.
Mytilus edulis.
Pecten opercularis.
Pectunculus glycymeris.
Solen siliqua.
Tellina lata.

Tellina obliqua.
—— prætenuis.
Buccinum undatum.
Cerithium tricinctum.
Calyptræa chinensis.
Conovulus pyramidalis.
Littorina littorea.
Natica.
Paludina lenta.
Purpura lapillus.
Scalaria grœnlandica.
Trophon antiquum.
Turritella communis.
—— incrassata.

* There was 20 feet of unproductive sands above the shell-bed.

Balanus crenatus.
Claw of crab.
Vertebræ of fish.
Platax Woodwardii.
Raia antiqua.

Some undeterminable mammalian bones and fragments of deers' horn have also been found by Mr. Evans.

The next pit to the north is at Bulchamp, near Wangford, ten miles distant, the intervening country presenting, as usual, low hills of Boulder-clay and unproductive sands. Some years since, a section nearly 20 feet deep was well exposed (fig. 25); now little is to be seen.

Fig. 25.—*Pit near Bulchamp Union.*

In appearance and colour the pit is precisely like a Red-Crag pit; and it will be observed that we have here a repetition of the marks of erosion which we have noticed between the two divisions of the Red Crag in the Sutton district; or it may only be an eroded shoal in the lower division, as at Ramsholt (fig. 6). The shells I have found there are as under:—

List of Fossils from Bulchamp-pits of the Union. (See also the general list.)

Abra alba.
Actæon Noæ.
Astarte.
Cardium edule.
Corbula nucleus.
Cyprina islandica.
Leda myalis.
Mactra ovalis.
—— subtruncata.
Mya arenaria.
—— truncata.
Mytilus edulis.
? Panopæa norvegica.
Tellina lata.
—— obliqua.
—— prætenuis.

Scrobicularia piperata.

Buccinum undatum.
Cerithium tricinctum.
Conovulus pyramidalis.
Bulimus.
Littorina littorea.
Natica catena.
Paludina lenta.
Purpura lapillus.
Trophon antiquum.
Turritella communis.
Scalaria grœnlandica.

———

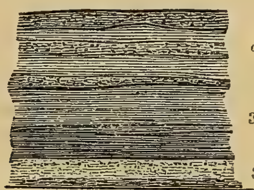
Balanus crenatus.
Claw of crab.
Vertebræ of fish.

The level of this pit is very little above that of the river. There is no superposition with any other bed; but I consider there are indications of the Chillesford Clay on higher ground between it and Wangford.

There is another pit one mile south of Wangford, again without superposition and but little above the level of the river. It presents very similar features to the pit on Thorpe common, the beds being light-coloured and pebbly. The common shells are *Cardium edule*, *Mya arenaria*, *Littorina littorea*, *Purpura lapillus*, and a few others.

Passing thence to the N.E., we find in the cliff at Easton Bavent, from one to two miles north of Southwold, a section of much interest, as it shows distinctly the relation of the Chillesford Clay to the so-called Mammaliferous or Norwich Crag. The section some years since was remarkably clear, and presented the following features (fig. 26).

Fig. 26.—*Cliff at Easton Bavent.*



Along part of the cliff I found no organic remains in the clay; but at the more northern end of the cliff I met with them at one spot in considerable abundance—many with double valves and in the position in which they lived. *Leda myalis* was common. The following is a list made on a first and on a subsequent visit with Mr. Jeffreys:—

Fossils from the Chillesford Clay (3, fig. 26), *Easton Bavent.*

Astarte compressa.
Cardita scalaris.
Cardium edule.
Corbula.
Cyprina islandica.
Leda myalis.
Lucina borealis.
Mactra ovalis.
—— subtruncata.
Mytilus edulis.
Nucula Cobboldiæ.

Tellina lata.
—— obliqua.

——

Buccinum undatum.
Littorina littorea.
Natica cirriformis.
Purpura lapillus.
Turritella communis.

——

One leaf-impression.

while in the pebbly sands which here underlie the Chillesford Clay, sometimes in immediate contact with it, and at other times separated by 2 or 3 feet of light-coloured sand, we have found:—

Fossils from the Crag Bed (3', fig. 26), *Easton Bavent* (*Southwold*).
(See also the general list.)

Abra obovalis.
Artemis lincta.

Astarte borealis.
—— compressa.

Cardium edule.
Circe minima.
Corbula striata.
Cyprina islandica.
Leda myalis.
Lucina borealis.
Mactra ovalis.
—— subtruncata.
Mya arenaria.
Mytilus edulis.
Nucula Cobboldiæ.
Pecten opercularis.
Tellina lata.
—— obliqua.
—— prætenuis.
Buccinum tenerum.
—— undatum.
Conovulus pyramidalis.
Littorina littorea.
Natica catena.
Purpura lapillus.
Trophon antiquum.
Turritella communis.
Balanus crenatus.

There are also here found remains of

Platax Woodwardii.
Vertebræ of fish.
Mastodon teeth.
Raia antiqua.
Balæna vertebræ.

In the Museum of the Geological Society there is, amongst the specimens presented by Capt. Alexander, a rolled Coralline-Crag coral from Southwold.

There are pits at Henham and Yarn Hill, to the N.N.W. of Southwold, which yield a similar but poorer group of fossils from sand-beds which are also below the Chillesford Clay.

Fossils from Yarn Hill (including Mr. Fisher's list).*

Astarte borealis.
Cardium edule.
Cyprina islandica.
Mactra subtruncata.
—— ovalis.
Pinna.
Tellina obliqua.
—— lata.
—— prætenuis.
Cerithium tricinctum.
Littorina littorea.
Natica catena.
—— Guillemini.
Paludina lenta.
Purpura lapillus.
Ringicula buccinea.
Succinea oblonga.
Trophon antiquum.

This completes the series of the Crag-pits in Suffolk. Those of Norfolk will be described in the next part of this paper.

Organic Remains.

It is evident that the organic remains of the Red Crag must be divided into two categories—the one of fossils proper to the formation, and the other of fossils derived from other formations. Generally the extraneous fossils of any deposit are few; but in the case of the Red Crag they constitute a very important section and require a careful elimination. Mr. Searles Wood communicated a paper to the Geological Society in 1859†, in which he expressed an opinion that:—

53	species of	Testacea	were possibly derived from the Coralline Crag.
2	„	Cirripedia	
8	„	Zoophytes	

* Quart. Journ. Geol. Soc. vol. xxii. p. 26.
† "On the Extraneous Fossils of the Red Crag," by S. V. Wood, Esq., F.G.S. (Quart. Journ. Geol. Soc. vol. xv. p. 32).

12	species of	terrestrial Mammalia	probably derived from Upper Tertiaries.
7	,,	Cetacea	
2	,,	Ziphioid Cetaceans	
2	,,	Fish	
10	,,	Testacea	
3	,,	Mammalia	probably derived from Middle Tertiaries.
8	,,	Fish	
3	,,	Mammalia	probably derived from older Tertiaries.
4	,,	Reptiles	
20	,,	Fish	
24	,,	Testacea	
5	,,	Crustacea	
2	,,	Echinoderms	
1	,,	Zoophytes	

Of the origin of the fossils from the older Tertiaries (London Clay) there can be no doubt, as they are well-known species of that formation, and have the mineral condition proper to it. The number of Crustacea and of Fishes derived from that source could now be even largely increased.

With regard to the origin of the mammalian remains, Mr. Searles Wood expresses an opinion that the land-mammalia "are certainly intruders into the Crag, to whatever period they may be assigned." In his paper on the extraneous fossils of the Red Crag, he considers some of them to be of Middle-Tertiary age, but that the majority belong to the Upper Tertiaries, and are of older date than the Red Crag. He also suggests the questions whether the large fish-teeth from Suffolk may not be from beds of the same Miocene age as those of Malta; and he raises the same question with regard to the remains of *Hippotherium* and *Hyænodon*.

In 1840, in 1846, and lastly in 1856, Professor Owen * described various mammalian fossils of the Red Crag; and he came to the conclusion "that the majority of them are identical or closely correspond with the Miocene forms of Mammalia, and especially with those from the Eppelsheim locality described by Professor Kaup. In Suffolk, as in Darmstadt, we find *Mastodon longirostris* (*angustidens*), *Rhinoceros Schleiermacheri*, *Tapirus priscus*, *Sus palæochœrus*, and *Cervus dicranocerus* associated together in the same formation; and with these Miocene forms of extinct Mammalia in the Red Crag we have likewise the Cetaceans, which most closely resemble the Miocene species of that order previously recognized in the Crag or Molasse of the Continent."

In 1857, Dr. Falconer published an important paper on the species of Mastodon and Elephant occurring in a fossil state in Great Britain. To this paper are appended some interesting remarks on other mammalian fossils of the crag †. He established the identity of the Crag-Mastodon with the *M. arvernensis* of Auvergne and Velay. With regard to the Crag-Rhinoceros, he considered that the teeth present no character, so far as they have been described, inconsistent with their being referred to the so-called *R. megarhinus* of the

* Ann. & Mag. Nat. Hist. vol. iv., 'British Fossil Mammalia,' and Quart. Journ. Geol. Soc. vol. xii. p. 217.

† Quart. Journ. Geol. Soc. vol. xiii. pp. 347–360.

south of France and Italy. After reviewing the other species of Mammalia, he states that "they agree generally, as far as the species have been well determined, with the great Pliocene fauna of Italy, as exhibited along the valleys of the Po and Arno; but it must, at the same time, be freely admitted that the materials upon which the determination of many of the species of the Red-Crag Mammalia at present rests are so scanty and undecisive that the identification either way, whether as Miocene or Pliocene forms, must be regarded as little more than approximate." He proceeds to say:—

"There are other considerations which corroborate the Pliocene view of the mammalian fauna of the Crag. The debatable species referred by Professor Owen to Miocene origin all belong to genera that are common to the Miocene and Pliocene periods, such as *Mastodon*, *Rhinoceros*, *Tapirus*, *Sus*, *Cervus*, and *Felis*; but of the more remarkable types which are limited to the Upper Miocene deposits, and which abound in them all over Europe, such as the *Dinotherium*, *Chalicotherium*, *Aceratherium*, *Anchitherium*, *Amphicyon*, &c., not a single remain has ever been cited as having been found in the Crag-deposits. The question naturally arises, how does it happen, if the majority of the Red-Crag Mammalia are Miocene, that there has been this selective admixture of species of long-termed 'Miocene' genera in the Crag, and why the exclusion of the strictly characteristic genera?"

Professor Huxley, in a paper* on the Cetacean fossils termed *Ziphius* by Cuvier, read before this Society in 1864, shows the relation of the Suffolk fossils to those of the Antwerp Crag.

Mr. Ray Lankester†, in a communication to the Society in 1865, described some interesting new fossils from the Red Crag, and, in speaking of the sources of the mammalian fossils of the Red Crag, also states, "as an extension or modification of the views which had been formerly advanced, chiefly by Mr. Searles Wood," his conclusion that the mammalian remains 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 earlier Pliocene bed"‡.

* Quart. Journ. Geol. Soc. vol. xx. p. 388. † *Ibid.* vol. xxi. p. 221.

‡ The recent papers of Prof. Owen (Pal. Soc. 1869) and of Mr. Ray Lankester (Quart. Journ. Geol. Soc. Nov. 1870) enable us now to give a more complete and correct list of the Vertebrate remains found in the Red Crag:—

Land.	Marine.
Castor veterior, *Lank.*	Balænodon affinis, *Ow.*
Cervus dicranoceros, *Kaup.*	—— definita, *Ow.*
Equus placidens?, *Ow.*	—— emarginata, *Ow.*
Felis paroides, *Ow.*	—— gibbosa, *Ow.*
Hipparion.	—— physaloides, *Ow.*
Hyæna antiqua, *Lank.*	Belemnoziphius compressus, *Huxl.*
Mastodon arvernensis, *Cr. & Jo.*	Carcharodon megalodon, *Ag.*
—— (tapiroides?, *Cuv.*).	Choneziphius Packardi, *Lank.*
Rhinoceros Schleiermacheri, *Kaup.*	—— planirostris, *Lank.*
Sus antiquus?, *Kaup.*	Delphinus.

While, therefore, all agree in considering the mammalian remains generally to be extraneous fossils, there is a difference of opinion, but not a great one, with respect to their age and origin. Some small portion of these fossils are doubtless of the age of the Red Crag. Unlike the great proportion of the Mammalian and Cetacean remains, which possess so peculiar a fossilization, are so dense and so worn that they show at once their extraneous origin, some of the large Whale-vertebræ and some of the small fish-vertebræ are so little mineralized and worn that they cannot be considered derived fossils*. At the same time the very circumstance that a portion of the Cetacean remains are, like the land Mammalian remains, heavily mineralized and worn, makes one cautious how far that mineralization and that wear should be construed as a proof of extraneous origin.

The discovery by Mr. Colchester (*ante*, p. 117), in the pit which he opened at Sutton, of teeth of *Mastodon*, *Rhinoceros*, &c., with Cetacean remains, all of the same species as those found in the Red Crag, and, like the latter, in a shingle-bed at the very base of the Coralline Crag, shows that some of these remains of the Red Crag may have been derived directly from the Coralline Crag, although they may have to be carried yet further back in the geological series †; while I consider it probable that some will be found to be of the age of the Coralline Crag itself.

Mr. Darwin describes ‡ eight species of Cirripedia from the Red Crag, of which six are living and two supposed to be extinct.

Edward Forbes § described six species of Echinoderms, one of which only he identified with a living species; but one is probably derived from the Coralline Crag; *Echinocyamus suffolcensis* is probably only a variety of the *E. pusillus*; and *Echinus Henslowii* he thought might be related to an undescribed species from Iceland. This would give one extinct to three living species.

Land.	Marine.
Tapirus priscus, *Kaup.*	Lamna.
Ursus arvernensis, *Cr. & Job.*	Otodus.
Megaceros hibernicus ?	Phocæna.
——	Squalodon (antverpiensis ?).
To these I would add	Trichecodon Huxleyi, *Lank.*
Elephas (meridionalis ?).	Ziphius angulatus, *Ow.*
	—— angustatus, *Ow.*
	—— compressus, *Ow.*
	—— gibbus, *Ow.*
	—— medilineatus, *Ow.*
	—— planus, *Ow.*
	—— tenuirostris, *Ow.*

* The finest series of the extraneous fossils of Red Crag I know of is that forming part of the valuable collection of Red-Crag fossils in the possession of Mr. Whincopp, of Woodbridge, who has devoted much time and care to secure the many rare specimens brought to light by the Coprolite-diggings which for the last few years have been carried on so actively in the neighbourhood of Sutton and Woodbridge.

† In the same way it is probable that the dark sandstone nodules, with casts and impressions of shells, so common in the Red Crag at Bawdsey, Sutton, &c., may have been derived indirectly through the Coralline Crag.

‡ Pal. Soc. 1854. § *Ibid.* 1852.

The four Corals, the Bryozoa, and the Foraminifera found in the Red Crag must be looked upon with doubt in presence of its richer neighbour the Coralline Crag, which has evidently contributed so largely to its stock*.

Mollusca.—Mr. Searles Wood describes in his monograph 239 species of shells. Of these he considers that 53 species are probably derived from the Coralline Crag, leaving 176 proper to the Red Crag†. A certain number of these latter were formerly considered to be extinct species; but the important researches in deep-sea dredging carried on of late years by Mr. Gwyn Jeffreys and others have shown that many of the species formerly supposed to be extinct still exist in the deeper parts of the Atlantic and Mediterranean. Many species, also, which were considered to be distinct are now regarded as varieties.

With a view to the modifications in the relations of the Red-Crag fauna to the recent one which these changes render necessary, Mr. Jeffreys has kindly gone through the list I had tabulated from Mr. Wood's monograph, added some new species, eliminated the varieties, and identified the species found to be now living.

On the question of the species which are to be considered extraneous, there is still considerable difference of opinion. Mr. Jeffreys justly states that "the question of which species may be extraneous or derivative is at present in an unsatisfactory state." It is a difficulty which has been felt by all observers, from Mr. Charlesworth to Mr. Wood. For my own part I should be almost disposed to regard the greater number of the species found in the Crag of Suffolk and not in the Crag of Norfolk as derived from the Coralline Crag. So large a proportion of the latter has been destroyed, and, as it were, incorporated into the Red Crag, that I can conceive even certain species of the older deposit being now found only in the newer one. It would, however, be too much to assume such an origin for so large a proportion of these fossils. In the following list I have considered the fact of any species being found also in the Norwich Crag a sufficient reason for removing it from the list of extraneous fossils. As a rule I have also regarded the species found at Walton‡, together with those occurring in the Sables

* Prof. Duncan has recently described (Geol. Soc. April 1871) a new coral from the Red Crag of Waldringfield, which he has named *Solenastræa Prestwichii*.

† Mr. Wood now reduces the number of extraneous shells to 25; and Sir Charles Lyell reestimates the extinct species as under:—

	Total Number.	Not known as living.	Percentage of shells not known as living.
Bivalves	128	31	25
Univalves	127	33	
Brachiopods	1	1	

(See 'Student's Elements,' p. 178.)

‡ The circumstance even of a fossil occurring at Walton does not exclude the possibility of extraneous derivation; for I have found fragments of thin limestone from the Coralline Crag even there.

jaunes of Antwerp and not in the Sables gris, with such species as survived to the glacial period in England, as species proper to the Red Crag. I doubt whether the circumstance of a shell being found double in the Red Crag is sufficient to identify it with that deposit, as, from the compactness of portions of the Coralline Crag, I see no reason why many should not have been transferred from one to the other without break.

Species probably derived from the Coralline Crag.

Terebratula grandis.
Astarte Burtini.
—— Basterotii.
—— mutabilis.
Cardita senilis.
Cardium decorticatum.
Chama gryphoides.
Cyprina rustica.
Diplodonta dilatata.
? —— rotundata.
Donax politus.
Erycinella ovalis.
Gastrochæna dubia.
Hinnites Cortesyi.
Leuconopsis Lajonkaireana.
Limopsis aurita.
Ostrea princeps.
? Panopæa Faujasii.
—— plicata.
Pecten dubius.
Pholadidea papyracea.
Venus ovata.
Cæcum mammillatum.
Cancellaria mitræformis.
Chemnitzia costaria.
Conopleura Maravignæ.
Dentalium costatum.
Erato Maugeriæ.
Nassa labiosa.
—— prismatica.
? Natica varians.
Odostomia plicata.
Pleurotoma carinata.
—— semicolon.
Pyrula acclinis.
Rissoa costulata.
Scalaria foliacea.
—— fimbriosa.
—— varicosa.
Terebra inversa.
—— canalis.
Trochus Kicksii.
—— villicus.
Trophon alveolatum.
—— consociale.
Vermetus intortus.

I feel that much uncertainty must still attach to such a list; and I may remark that Mr. Jeffreys takes the lesser number of 13 species as derived.

Allowing for this element, the result is that the species found in the Red Crag are as under:—

Number according to Mr. Wood's list	239
New species added by Mr. Jeffreys and Mr. Bell	79
Species regarded by Mr. Jeffreys as varieties........................	45
Species for the first time identified as recent by Mr. Jeffreys	46
Extraneous species..	46 ?

Excluding the varieties and extraneous species, this leaves as proper to the Red Crag 234 species, composed as under:—

Total species.	Living species.	Extinct species.	Proportion of extinct species.
234	216	18	7·7 per cent.

or, including the extraneous species:—

273	240	33	13·7 per cent.

With regard to geographical distribution, Mr. Jeffreys shows that the great majority, viz. 150 species, are still found living in British seas; whilst of the 55 species not found living in British seas 32 are now restricted to more southern, and 23 to more northern seas—showing, with respect to the Coralline Crag, a gain of 9 northern, and a loss of 33 southern species.

The total number of species common to the Red Crag and to the Coralline Crag is	186
Or, deducting extraneous species	46
	140

This gives a percentage of species common to the Red and Coralline Crags of about 62. Or, looking at the percentage of living species in each, the difference between them is much less, taking even the smaller percentage due to the exclusion of the extraneous species.

In the Coralline Crag	84	per cent. of living species.
In the Red Crag	92	

Conclusion.

In the former part of this paper, I remarked that the Coralline Crag had, during its latter stages, been subject to a process of slow elevation, but probably without rising above the sea-level. It had, however, emerged above the sea at the commencement of the Red-Crag period, as evinced by the shore-line at the base of the Red Crag at Sutton (see Pl. VI.), when the Coralline-Crag reef or islet stood some 40 feet or more above that shore-line. The difference of level between the lower shore-line and the surface of the London Clay under the Red Crag in the adjacent district is not more than a few feet, whence the Red Crag must have been accumulated in a shallow sea. Mr. Searles Wood, Jun., considers that the lower division of the Red Crag is arranged in successive beach-stages. There seems to me, on the contrary, to be an absence of definite order; and the lamination and bedding which he considers referable to beach-action, I think may in all cases be referred to the variable bedding and oblique lamination produced by the shifting of shoals and sand-banks at the bottom of the Red-Crag sea, as was the case with the upper division of the Coralline Crag (*ante*, fig. 3, p. 120). Mr. Wood, Sen., has already expressed his opinion that the peculiar stratification of the Red Crag must be owing to the constant shifting of the sands and shingle caused by variable and changing currents; and this is also the opinion of Mr. Jeffreys. Shoals may have been formed and removed in part or wholly by a change of currents, just as now is of constant occurrence off the present Suffolk coast.

This sea was not only shallow, but was studded with reefs of Coralline Crag, amongst which strong and shifting currents set in; whilst in winter the more distant Chalk and Tertiary shores were fringed with ice, which, as it floated off, carried away large, massive flints, and deposited them in the Red Crag (fig. 21). In the same way ice-borne blocks and fragments of the Coralline Crag were carried from the

Sutton (and possibly the Sudbourne) reef, and scattered over the bed of the Red-Crag sea (fig. 23). The circumstance of the occurrence of large masses of flint, covered with *Balani*, and of pebbles derived from distant formations indicate transport, probably by ice-action; for the flints are of considerable size and perfectly unrolled. They seem to have been dropped where they are found; and it is a question whether the *Balani* with which many of them are covered may not have been attached on the coast before their removal. This removal necessarily requires a certain depth of water, as also would the accumulation and reconstruction by sea-currents of the mass of sand and comminuted shells forming a great portion of the Red Crag. The character of the fauna of the Red Crag is in accordance with these conditions. *Littorina littorea*, *Purpura lapillus*, *Cardium edule*, *Pholas crispata*, *Teredo norvegica*, and *Mytilus edulis* clearly indicate shore-lines; whilst the several species of *Astarte*, *Trophon*, *Turritella*, *Cardita*, *Nucula*, together with the common *Pectunculus glycymeris*, *Pecten opercularis*, *Mactra ovalis*, and others, are confined to the laminarian and deeper zones.

If we suppose a shoal to have been formed in one part of this sea-bed, and subsequently, owing to a change in the currents, to have become subject to a scouring action in another direction, the top of this shoal would be thrown forward in successive laminæ, steep in proportion to the velocity of the water, and thus form oblique lamination, such as is so common in the Red Crag. Fresh currents may afterwards have removed other shoals and spread them over these obliquely laminated beds in a series of horizontal layers, which, in their turn, may have been scooped and hollowed out, and the depression filled by a newer accumulation—a case not at all uncommon in the Red-Crag district. This, again, may have been planed down and re-covered obliquely by a fresh removal of adjacent shoals. In this way we may have an infinite number of repetitions of the same materials. This constant shifting and re-adjustment of materials would, at the same time, lead to the heavier portions, such as the bones, the pebbles, and the phosphatic nodules, being thrown down and left behind when the lighter materials were removed, and would thus tend to accumulate them in the basement beds where we now generally find them.

The consequence of these reconstructions is that a large proportion of the shells are worn or broken, and the mass of them are finely comminuted. The presence of some entire and double shells shows that there were more sheltered places. That there were also intervals of repose and quiet is evident from the circumstance that thin horizontal seams of very finely laminated clays and sand were occasionally formed; these we find interstratified at places with the beds of shelly crag.

I have mentioned that, at Bawdsey, I found a bed of micaceous sandy clay with laminæ covered by ripple-marks, which laminæ were continued in regular succession for a thickness of several feet. They were formed probably in shallow water (fig. 7). In some cases beds of clayey sands seem to have been raised above the sea-level, or exposed during certain states of the tides till the surface became dried and fissured so as to form wedge-shaped cavities filled with the materials of the beds which were accumulated above them (fig. 8). In beds deposited under such circumstances, subject to such constant removal and reconstruction, it is not surprising that it is difficult to find one in which the shells of the period exist *in situ*. Possibly some of the beds at Walton were less frequently disturbed, or may have been deposited under rather more tranquil circumstances than elsewhere; still most of those beds are full of comminuted shells, and many of them show oblique lamination, so that they also were subject to the action of tides and currents. With a sea of this character, and with shoals and reefs of the soft friable Coralline Crag exposed to its action, a large destruction of the latter was inevitable; and the shells of that deposit must consequently have been transferred in great numbers to the newer beds of the Red Crag formed around it. To what extent this may have taken place it is not possible yet to say. I quite agree with Mr. Searles Wood, that a large number of the shells found in the Red Crag have had this origin; but although we can feel little doubt on the subject, yet as the shells are mostly single valves, and the staining given by the Red Crag assimilates them to its own fossils, it is difficult to distinguish those which are derived from those which belong to the deposit. When we meet with the entire or the rolled fragments of Bryozoa or some of the rare corals, evidently derived from the Coralline-Crag beds, there can be no doubt of their origin. Still it is clear that a considerable number of shells lived in the Red-Crag sea, and that a certain number of new species were introduced. Many species of bivalves are found double; but this is not always a proof that they are not extraneous.

I believe also that a large proportion, if not all the coprolites (so called) of the Red Crag were derived from the Coralline Crag, as detached ones are found not unfrequently in its mass, and a bed of them was found to underlie it at Sutton, at the only place where its base has been exposed (*ante*, p. 117).

The direction of the currents, judging from the nature of the foreign materials found in the Red Crag, seems to have been from the east to south-east. Though the sea was open to the north, the communication with the south was probably cut off. Innumerable *Balani* covered the blocks of Septaria and flint scattered on the London Clay and Chalk-shores of this Red-Crag sea. *Pholades* abounded on its water-line; and we have seen at Sutton and elsewhere that *Mytili* were common in its shallow waters, while other genera found shelter in bays and any tranquil places. I can see no distinction in the organic remains, from the base of the Red Crag to the top of the lower division. The like abundance of species of *Pectunculus*, *Mactra*, *Tellina*, *Cardium*, *Fusus*, *Natica*, *Purpura*, &c. occurs almost throughout, modified by situation, and having a distribution sufficiently independent in character to show that it could scarcely have been dependent upon one source alone, and that a derivative one, for its fossils, but that there were banks and feeding-grounds for the various species of Mollusca, which served as centres from which they spread, but, in spreading, retained at the same time evidences of the grouping they had when living.

After the deposit of the lower division of the Red Crag a subsidence of some 10 or 12 feet took place, and a new line of cliff, on a higher level, was formed at Sutton. Even the rise of the tides might almost be determined; for we know that the *Pholas crispata*, the borings of which are spread over the upper shore and top of the lower cliff, lives only between water-marks. The perforated space occupies a zone about 5 or 6 feet deep (see fig. 21).

The increased prevalence of oblique lamination in the upper part of the lower Red Crag leads to the supposition that the sea was gradually silting up. To this, however, succeeded a movement of subsidence causing the erosion, by fresh submarine currents, of the surface of the lower division, and, as the subsidence gradually continued, to the accumulation of the upper division of the Red Crag.

From the circumstance of the lower part of these upper sands being formed of the débris of the previously deposited lower Red Crag, the mineral character is very similar; but in the ascending series, formed as the sea-bed gradually became more depressed, the sands are finer, they lose their red colour, and they pass upwards into fine micaceous sands and grey clays, in which the Testacea are constantly found on the spot where they lived.

These sands and laminated clays (the Chillesford series) covered up and levelled the whole of the various beds beneath them, spreading over them all through Suffolk and Norfolk.

The difference of age which the distinctive characters of the Red and Coralline Crags might suggest does not hold when each is viewed separately in relation to the fauna of the present period. There must have been other causes than mere lapse of time and descent to account for this variation in their respective faunas; and this probably was owing both to the variation of the level of the bed of the sea, to which we have directed attention, and by which many of the deeper-water Mollusca must have been destroyed within our area, and also to the influx of more northern or north-easterly currents, and the increased cold, indicated by the physical phenomena, bringing in a more northern fauna. It is a question of temperature rather than of time.

The absence of essential difference of age between the two crags is also apparent in their correlation with the two upper Crags of Antwerp, with both of which they show a close relationship—the lower one of the two being probably of the age of the Coralline, and the upper one having a near analogy with the Red Crag.

		Antwerp beds, number of species.	Species common to the Antwerp beds and the Red Crag.	Proportion of Red-Crag species.
Scaldisien	Sables jaunes	197	138	74 per cent.
	Sables gris ...	187	122	65 „
Diestien ...	Sables noirs..	228	61	26 „

Common to the Sables jaunes and gris 139, or 75 per cent.

We will, however, consider more fully the relations of the Belgian

Crags with those of England after treating of the Norwich Crag. On the latter subject we must make a few observations in reference to that portion of it which extends into Suffolk. I have shown that the Red Crag S. and S.W. of Sudbourne and Iken is separated from that to the northward by a ridge of Coralline Crag, and that the fossils of the Red Crag take then a more littoral character and already present at Aldborough a somewhat intermediate type—the rich fauna of Sutton and Walton having gradually become poorer, though the shells are still all Red-Crag species, and that species of *Mactra*, *Mya*, *Mytilus*, and *Cardium* have become more common. After passing Aldborough the Crag puts on another type; the littoral shells, especially *Littorina littorea*, *Mya*, and *Mactra*, largely predominate; but still, out of 44 species I have found in the pits between Aldborough and Southwold, there are only two which are not found in the Red Crag:—the one, *Paludina lenta*, being a freshwater and therefore a local shell *; the other, *Astarte borealis*, being a shell of northern type, which here first makes its appearance, and whose range may have been restricted by the Thorpe ridge of Coralline Crag.

The Mammalian remains found at Thorpe and Southwold cannot be compared with Red-Crag fossils, which are mostly extraneous. At the same time I would call attention to the occurrence of the teeth of *Mastodon* in the Coralline Crag of Sutton, in the Red Crag of the same district, and in the Crag at Southwold.

Further the stratigraphical relation of the beds is alike in the two districts. At Chillesford and Iken we find the Chillesford clays and sands overlying the Red Crag; and in the same way we find at Southwold a crag, which is probably the equivalent of the upper division of the Red Crag, immediately underlying clays which contain similar fossils to those in the Chillesford district. It is possible, also, that in the northern area, as well as in the southern, there are two subdivisions, of which the beds at Wangford and Thorpe may be the lower, whilst those at Bulchamp or Southwold may represent the upper.

In my next communication, I propose tracing the same horizon of the Chillesford Clay into Norfolk, and to show its relation to the Crag-beds of that district and their relation to the Crags of Suffolk.

* Mr. A. Bell has since found this shell in the Red Crag at Waldringfield.

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THE GEOLOGICAL SOCIETY OF LONDON.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

April 26, 1871.

Robert Russell, Esq., of the Geological Survey of England and Wales, was elected a Fellow of the Society.

The following communications were read:—

1. *On a* New Species *of* Coral *from the* Red Crag *of* Waldringfield. By P. Martin Duncan, M.B., F.R.S., F.G.S., Prof. Geol. King's Coll. Lond., &c.

The solitary specimen of a compound Madreporarian which forms the subject of this communication, was found by Mr. Alfred Bell at Waldringfield, and was sent to me for description. The coral is interesting, because it belongs to a reef-forming type which has lasted from the Eocene to the present day, and which, doubtless, some day or other, will prove to be much more ancient.

The specimen had been considerably rolled and worn before its deposition amongst the other materials constituting the Red Crag, and it must therefore be regarded as a *remanié* fossil. It becomes, therefore, rather important that the geological age of the form should be determined; but as its mineralization affords no assistance in this inquiry, any satisfactory results must depend upon the correct appreciation of its palæontology.

Genus Solenastræa, Milne-Edwards & Jules Haime, 1848.

Solenastræa Prestwichi, sp. nov.

The corallum is short, and the corallites are crowded.

The upper surface is very irregular, and the corallites differ in size.

The corallites enlarge rapidly after having originated as buds.

The epitheca is very stout, and is strongly marked by transverse ridges and intermediate depressions.

The costæ are visible on the upper surface of the corallum.

The calices are unequal, usually circular in outline, shallow, with stout margins. They project but slightly.

The columella is well developed and large.

The septa are in six systems, and there are three cycles of them in each. The primary and secondary septa are nearly equal, and reach the columella. The septa of the third cycle are small, and do not reach far inwards. The endothecal dissepiments are oblique and scanty.

Diameter of calices $\frac{1}{20}$ to $\frac{3}{20}$ inch.

The *Solenastrææ* no longer inhabit the European seas, and no trace of them occurs in the dredgings of the North Atlantic Sea, of the Lusitanian coasts, and of the Mediterranean. They are not deep-sea forms, but are compound epithecate and exothecate corals suited for reef-building.

They abound in the reefs of the Red Sea, of the Indian and Great Ocean, and amongst the West-Indian reefs.

The fossil species have been found in the following localities:—

Eocene—Fort Saint Pierre, Ghent*.

Oligocene—Monte Grumi, Montecchio Maggiore, Monte Viale, and Monte delle Carrioli, in the District of Castel Gomberto, in the Vicentin†.

Brockenhurst and Roydon, in Hampshire‡.

Miocene—The Faluns, and Miocene of Turin and of Styria§.
Miocene of Antigua‖.

Raised Reefs—Red Sea¶.

The new species differs from the Eocene type by having a well-marked columella, and in its septal arrangement.

Its small number of septa distinguishes it from the Oligocene forms.

The well-developed columella and the septal number associate the new species with the Miocene *Solenastræa turonensis*, Ed. & H., of the Faluns, Turin, Styria, and Antigua, and with the recent *S. Bournoni*, Ed. & H., Antilles, *S. Forskælana*, Ed. & H., Red Sea, *S. sarcinula*, Ed. & H., Indian Ocean, and *S. Bowerbanki*, Ed. & H., Singapore. The closest alliance is with the West-Indian recent

* *Solenastræa Verhelsti*, Ed. & H., is found amongst the Upper Miocene of the West Indies.

† *Solenastræa conferta*, Reuss, and *S. columnaris*, Reuss, Pal. Stud. über die älteren Tertiär. der Alpen. Wien. Akad. der Wissensch. 1867.

‡ Pal. Soc. Lond. P. M. Duncan, 1866.

§ *Solenastræa turonensis*, Ed. & H. Hist. Nat. des Corall. vol. ii. p. 488.

‖ "Foss. Corals of West Indies," Quart. Journ. Geol. Soc. Dec. 1867, and previous papers.

¶ *Solenastræa gibbosa*, Ed. & H. *op. cit.* p. 496.

form *S. Bournoni*, Ed. & H.; and *S. turonensis*, Ed. & H., of the Faluns is the nearest fossil associate of the new form.

The great change in the physical geography of the European seas at the close of the Miocene epoch, when they no longer possessed coral-reef areas, will account for the extinction of the species described in this communication; and the previous extension of those areas facilitates our comprehension of the distribution of the *Solenastrææ* in Miocene times, and in the existing reef-faunas.

This new crag-coral was not a member of the London-clay coral-fauna; for no reef-building forms exist in the remains of that assemblage. It belonged to the rich reef-building fauna which succeeded that which was associated with Nummulites, and which lasted in Europe until the progressive upheaval of the Alps and Western Europe, together with the subsidence of the great northern barrier, determined the destruction of the assemblage of species by altering the requisite external physical conditions*.

Discussion.

Mr. Etheridge remarked that the origin of this interesting fossil seemed uncertain. It appeared, however, to be derived from some other source, and not to have originally belonged to the Red Crag. In England the genus was hitherto unknown in beds newer than those of Brockenhurst. The presence of this single specimen showed how much we had still to learn with regard to the Crag formation. It was to be hoped that the coral might eventually be found attached to some organism from which its age might be determined.

Prof. T. Rupert Jones remarked that he should be glad to hear of more corals being discovered in the so-called Coralline Crag. He inquired whether cœnenchymatous corals were necessarily reef-corals, observing that this coral was referred to the Miocene on account of its presumed reef-forming character. He added that some of the Foraminifera of the White Crag had the aspect of existing western Mediterranean forms, and thus supported some of Prof. Duncan's remarks.

Mr. Gwyn Jeffreys observed that the distinction between the fauna of the Coralline and Red Crag was every day diminishing. The appearance of the fossil seemed to betoken its derivative character. Like other speakers, he complimented Mr. Alfred Bell on his great intelligence in the collection and study of Crag fossils.

Prof. Duncan, in reply, maintained that the differences between deep-sea and reef-building corals were well established. Around modern reefs in the deeper sea the forms were quite distinct, and the deep-sea corals never presented the cœnenchyma distinctive of the reef-building forms. This, he suggested, might be connected with the difference in the amount of sea-water with which they were brought into contact, which in the surf was much greater than in the almost motionless depths of the sea.

* The species will be figured in my monograph of the Brit. Foss. Corals, Pal. Soc., which is about to be completed.

2. Notes *on the* Minerals *of* Strontian, Argyllshire.

By Robert H. Scott, Esq., F.R.S., F.G.S.

When I first proposed to visit Strontian, in the year 1866, I consulted two well-known Scotch geologists as to my chance of picking up minerals there. The two authorities directly contradicted each other. One, who was a professed mineralogist, stated that he had spent three weeks there, and that nothing whatever *new* was to be found there. The other was more encouraging, and informed me that whatever I found was nearly sure to be new.

Greg and Lettsom enumerate a fair series of specimens from the locality; but the experience I have gained as to their accuracy as regards Irish localities, leads me to be somewhat dubious of receiving all their statements as absolutely correct for out-of-the-way districts, such as Strontian.

The longest list which has been printed is that given by Mr. Hall in his Mineralogical Directory, and it is as follows:—

Apophyllite.	Calcite.	Pyromorphite.
Asbestos.	Galena.	Sphene.
Baryte.	Garnet.	Strontianite.
Blende.	Harmotome.	Talc.
Brewsterite.	Pyrites.	Zircon.

This list contains no notice of the various feldspars, of which there are certainly two, Orthoclase and a clear anorthic feldspar, in the granite, or of the Hornblende and other pyroxenic minerals which occur in the syenites and crystalline greenstones of the district, and of which fine, though not perfectly crystallized, specimens, are easily to be had. Nor does it mention Natrolite in geodes in the trap-dykes, or Schorl, or either of the micas, white and black, although very large plates of the former are found on Ben Resipol associated, as usual, with the garnets for which that mountain is famous.

These latter minerals I have myself seen *in situ*. Furthermore there appear to be some doubtful species in the list; of these I would only enumerate three, Apophyllite, Talc, and Zircon. No analysis is given of any of the three from this locality in any of the recognized text-books of Mineralogy. Apophyllite I have never detected among the gangue of the lead-mines. This of course does not prove much. Talc certainly does not occur anywhere near Strontian itself; and although from the analogy between the geology of the district and that of Donegal, in Ireland, I might fairly expect to find it, I could never trace any beds which bore the slightest resemblance to those in which so much Talc and Steatite have been discovered in the north-west of Ireland. I myself believe that the name of Talc has been loosely given to the large plates of white mica to which I have alluded, an error in nomenclature so very common in collections of Cornish minerals.

As to Zircon I have searched for it most carefully, and can only say that, as Greg and Lettsom admit the crystals from Criffel said to be Zircon to be really Sphene, I believe a similar qualification might with advantage be given to the alleged occurrence of Zircon at Strontian, and that it is as yet *not proven*.

The foregoing statements however, are, of much less interest than the information which can be gained about the minerals for which the locality has been so long known. These are Strontianite, Harmotome, Brewsterite, and Calcite. They are all found in a lode which runs along the edge of the granite, in many places one wall being granite and the other gneiss. The latter rock presents in the neighbourhood of the lode a remarkable porphyritic appearance, caused by the abundance of large crystals of Orthoclase which it contains *.

The mines were first worked more than 150 years ago, by the Duke of Norfolk and Co. Then the York Building Company in 1722 took a lease of them from Sir Alexander Murray, of Stanhope, the proprietor. This gentleman had done a great deal to develop the resources of that district of Argyllshire. He obtained the services of a Mr. Bruce to survey the property; and an elaborate map of the district was published by him in 1733. Sir Alexander announced the Strontian mines as the most wonderful discovery of the age. The miners built a town at the place which they called New York. The only other point of interest about the history of the mines is that strontia was first recognized as a distinct alkaline earth by Crawford in 1790. Klaproth and Hope independently of him, and of each other, investigated its properties in 1793.

The original mines are four in number, and are at a level of from 600 to 800 feet above the sea, They are all in Glen Strontian; their names are Fee Donald, Bell's Grove, Middle Shop, and Whitesmith. Of these the three latter have been allowed almost entirely to fall in. The only workings which have been carried on of late years have been at Fee Donald and, to a slight extent, at Bell's Grove. The ore is Galena containing very little silver. At Fee Donald there is a tradition of an antimony lode not now worked; and there is a record of a *steel*-ore very rich in silver; but no specimens of either of these are procurable.

The only minerals worth notice at Fee Donald are Calcite, especially Paper-spar, and Morvenite, the latter being rare.

At the other three mines minerals are very abundant; but unfortunately it is impossible at present to ascertain from what levels they are derived. The different species are almost entirely confined each to its own mine, or rather to its own rubbish heap; for it is only in these heaps that they occur.

At Bell's Grove, Harmotome and Morvenite are extremely abundant, the opaque variety of the mineral being the commoner. At Middle Shop, Harmotome is not found, but Brewsterite appears either on decomposing granite or on calcite. At Whitesmith the rubbish heaps yield small fragments of Strontianite, associated with Brewsterite, though I have never found the two minerals on the same specimen. The larger curved crystals of Brewsterite are usually on Heavy Spar.

Whitesmith is by far the deepest of the mines, but it is also the highest up the side of the mountain.

There is nothing particularly new to be noticed about these mine-

* During a recent visit to Norway I found this type of gneiss to be very abundant in that country, where it is known as "eye-gneiss."—Oct. 1871.

rals. As regards the general character of the gangue of the mine, we are struck by the absence of Fluor, and the comparative rarity of Blende and Heavy Spar. The last-named species we might fairly expect to be present in considerable abundance, as baryta is present in such large quantity in the Harmotome and Brewsterite.

During the last six years a new mine, called Corrantee, has been opened, at a distance of some two miles westward from Whitesmith, but at the other side of the hill. It is, however, apparently on the same lode that is worked in Glen Strontian, but is situated entirely in the gneiss. I first visited this mine in 1866, and noticed the presence of the barytic Zeolites. Since that time some very beautiful specimens have been obtained from it, notably of Calcite, in the form of scalenohedrons terminated by rhombohedrons, and coated with Harmotome.

Among other specimens I found some crystals of Harmotome closely resembling those from Andreasberg, in fact true Cross-stone. These were irregularly distributed over a mass of very acute scalenohedrons of Calcite, and associated with minute hexagonal prisms apparently terminated by a basal plane, and perfectly transparent. When I first noticed these crystals I felt sure that I had discovered a new locality for Brewsterite; but on testing the mineral in the blowpipe I found that it did not swell up, and that it gave a simple baryta-flame. The borax-test proved abundantly that it was a Zeolite. These results made me suspect that it was only a new form of Harmotome.

Not being myself able to analyze it, from want of time, I requested my friend Dr. J. E. Reynolds, Keeper of the Minerals in the Royal Dublin Society, to examine it.

He detected that the termination of the prisms is not a single plane, but consists of two planes inclined to each other at a very obtuse angle.

He therefore broke up a large specimen, picked out carefully all the crystals which exhibited this peculiar termination to the prisms, and subjected them to analysis.

He only succeeded in obtaining 1·5 gramme of the mineral by this method, a quantity quite insufficient for a complete analysis, inasmuch as, owing to the necessity of determining the alkalies, he was obliged to decompose the mineral by acid, and therefore could not ascertain the amount of water present.

The following Table gives the best analyses of Strontian Harmotome which have as yet been published; and it will be seen how closely Dr. Reynolds's analysis agrees with them.

	A.	B.	C.	D.
SiO_2	47·74	47·52	47·60	48·02
Al_2O_3	15·68	16·94	16·39	17·42
Fe_2O_3	0·51	......	0·65	
BaO	21·06	20·25	20·86	20·17
CaO	......	......	......	trace
KO	0·78	1·00	0·81	0·62 (KO and NaO together)
NaO	0·80	1·09	0·74	
HO	13·19	13·45	14·16	13·77 (water and loss).
	99·76	100·25	101·21	100·00

Of these, A is by Damour; it is of Harmotome, the opaque variety. B, by Rammelsberg, is probably of the same; it is simply called Harmotome from Strontian by him. C is by Damour; it is one of two analyses of Morvenite, by which he established the identity of Morvenite with Harmotome. D is Dr. Reynolds's analysis.

From this it appears that these crystals are a particularly pure form of the mineral, being nearly perfectly free from alkalies; and they certainly deserve a name, to the full as much as Thomson's Morvenite does.

The only special interest which they possess is crystallographical. In all the crystals of Harmotome figured by either Dufrénoy or Dana the termination of the prisms is quadrifacial. Dufrénoy mentions that occasionally a very obtuse quadrangular pyramid is found, similar to that which sometimes occurs in Anatase; and Descloiseaux, in his recent paper* on the crystallography of the species, has determined the angle between the opposite faces of this pyramid to be 178° 20′. Dana gives in his last edition such a pyramid.

I have not myself been able to measure the angle between the faces of the dihedral termination of the prisms which I now submit to the Society; it is an extremely obtuse one; and it seems probable that they will ultimately turn out either to be two of the four faces spoken of by Descloiseaux, or else the faces of the brachydome corresponding to that pyramid.

In conclusion I would only draw attention to the specimens which I have brought down, as evidence that the neighbourhood of Strontian is still almost as promising a field for the mineralogist as any in these islands.

Discussion.

Mr. W. W. Smyth mentioned the wonderful collection of minerals from Strontian which had been brought to the Great Exhibition of 1851, which gave a most striking idea of the mineral riches of the locality. The occurrence of such a series of different substances in one locality in the granite was almost unparalleled, though in the Andreasberg mines, in clay slate, they were to some extent rivalled. The features, however, differed in the two places, more silver and a greater number of zeolites being present in the Hartz mines.

Mr. D. Forbes observed that Harmotome occurred also at the Kongsberg silver-mines in Norway, at a distance from granite. He thought it remarkable that these crystals of peculiar form occurred in the same spot and in connexion with crystals of the same substance but of the ordinary form.

Mr. Davis remarked that Celestine was also to be placed on the list of the minerals from Strontian. Harmotome had been found in the same form of double crystals at Bodenmais in Bavaria.

Mr. Scott stated, in reply to a question from the Chairman, that the mineral had not been as yet optically examined, but that if he could procure more of it he should be happy to place it at the dis-

* Ann. des Mines, 4th ser. tom. ix. p. 339.

posal of any gentleman who would examine it. As regarded the idea that Harmotome usually occurred near the surface, he could give no information about the old mines, as they had been allowed to fall in; but most certainly the new specimens from Corrantee came from surface-workings. He was very glad to learn from Mr. Davis that Celestine had been found at the locality; and he felt sure that careful search would double or treble the number of species known to occur there. With reference to what had fallen from Prof. Smyth, he could fully corroborate his observations as to the difference between the forms of Calcite associated with Harmotome at Andreasberg, in the Hartz, and at Strontian. It was remarkable that the general facies of the crystals of Calcite occurring at Corrantee, where the lode was entirely in the gneiss, differed from that usually observed in the old mines in Glen Strontian, which were partly in the granite and partly in the gneiss.

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3. *The* PROBABLE ORIGIN *of* DEPOSITS *of* "LOESS" *in* NORTH CHINA *and* EASTERN ASIA. By THOMAS W. KINGSMILL, Esq.

(Communicated by Prof. Huxley, F.R.S., V.P.G.S.)

THE Baron F. von Richthofen, in an able and interesting Report* of a journey undertaken under the auspices of the General Chamber of Commerce at Shanghai, alludes to the enormous area covered by the light-clay deposits of North China which he found at Chinkiang and Nanking, on the Yangtsze, and throughout almost the entire area of Honan and Shansi. Beyond the area mentioned by the Baron, they seem to extend into Shantung, to cover a large portion of Northern Anhwei, and, according to Pumpelli, to reach to North Chihli and Mongolia. The formation appears to answer in a great measure to the Kunkur formation of India, and in all probability extends far into the elevated plains of Central Asia. The name of "Loess," taken from the similar deposit in the valley of the Rhine, has been applied by the Baron von Richthofen to this formation; and to it as a distinctive name, independent of any theory as to its formation, there does not seem any objection. So many different opinions have been held as to the origin of the Loess of the Rhine, that it is not surprising a similar difference should exist in regard to the vastly more extensive deposit of Eastern Asia. The latter, however, though almost identical in structure and composition with the former, differs widely from it in position, inasmuch as it is by no means confined to the valleys of the great rivers, but stretches almost uninterruptedly over the raised tablelands of Central and Northern China. Like the Rhine-Loess it contains a large percentage of earthy carbonates mixed with impalpable siliceous sand, and the ordinary constituents of clay. There is little to be added to

* No. III. Report on the Provinces of Honan and Shansi, fol. Shanghai, 1870.

the Baron's description of the deposit* more than to say that in places the carbonates have segregated from the mass in nodules of fantastic shapes, which show, from the vertical position of their major axis, their subsequent origin. These nodules are of importance in a description of the mass, as, in the neighbourhood of Chinkiang at least, they seem to divide the whole formation into at

* The following is Baron von Richthofen's description of the deposit, extracted from the Report already cited (pp. 9, 10):—

"The Loess is among the various substances which would commonly be called loam, because it is earthy and has a brownish yellow colour. It can be rubbed between the fingers to an impalpable powder, which disappears in the pores of the skin, some grains of very fine sand only remaining. By mechanical destruction, such as is caused by cartwheels on a road, it is converted into true loam. When in its original state it has a certain solidity, and is very porous, and perforated throughout its mass by thin tubes, which ramify like roots of grass and have evidently their origin in the former existence of roots. They are incrusted with a film of carbonate of lime. Water, which forms pools on loam, enters therefore into loess as into a sponge, and percolates it without in the least converting it into a pulp or mud. The loess is everywhere full of organic remains; but I have never seen any other but land-shells, bones of land-animals, and the numberless impressions of roots of plants. It is not stratified, but has a strong tendency to cleave along vertical planes; therefore, wherever a river cuts into it, the loess abuts against it, or against its alluvial bottom-land, in vertical cliffs, which are in places 500 feet high; above them the slopes recede gradually in a series of terraces with perpendicular front faces. Where the river reaches the foot of such a wall, the progress of destruction is rapid; the cliff is undermined, and the Loess breaks off in vertical sheets, which tumble into the stream, to be carried down by the water. . . . . The beds of the affluents which join the river in these places are no less deeply cut into the Loess, and ramify into its more elevated portions like the roots of a tree, every small branch a steep and narrow gulch. . . . . It gives habitation to millions of human beings. . . . . They live in excavations made in the [precipitous walls of] Loess.

"As regards the mode of origin of this formation, the Loess of China, like that of Europe (where it exists on a comparatively small scale), has been supposed to be a freshwater deposit. This supposition is erroneous as regards the Loess of Northern China, because it extends equally over hills and valleys, and does not contain freshwater shells. Others have therefore considered it as a marine deposit. This view is more erroneous even than the former, because it would presuppose the whole of Northern China to have been submerged at least 6000 feet beneath the level of the sea in a recent epoch, while there is abundant evidence to prove that such has not been the case. Nor can the theory, current in Germany, that the Loess of that country was produced by glacial action, be at all applied to the Loess of Northern China, from various obvious reasons too lengthy to explain here. Unbiased observation leads irresistibly to the conclusion that the Loess of China has been formed on dry land. The whole of that vast country, which was covered by a continuous sheet of Loess before this had undergone destruction, was one continuous prairie, probably of greater elevation above the sea than the same region is now. The Loess is the residue of all inorganic matter of numberless generations of plants that drew new supplies incessantly from those substances which ascend in moisture and springs, carried in solution to the surface. This slow accumulation of decayed matter was assisted by the sand and dust deposited through infinite ages by winds. The land-shells are distributed through the whole thickness of the Loess; and their state of preservation is so perfect that they must have lived on the spot where we now find them. They certainly admit of no other explanation than that here hinted at, of the formation of the soil in which they are imbedded. The bones of land animals and chiefly the roots of plants, which are all preserved in their natural and original position, give corroborative evidence."

least three successive beds, showing that, contrary to the Baron's idea, the mass is really stratified, though the uniform character of its constituents and their extremely mobile nature have for the most part effaced any decided marks of deposition.

To account for the origin of the formation, Baron von Richthofen has started the extremely ingenious explanation that the beds of the Chinese Loess have been formed on dry land, his principal reasons for this assumption being that the beds contain remains of land-shells and land-animals to the exclusion of marine or even, so far as known, freshwater species, and that no depression of the eastern portion of the continent is sufficiently recent to allow of their deposition under the surface of the sea.

I shall deal with these objections in reverse order, and afterwards state some reasons against the subaerial theory.

Evidence of late depression in North China.—First, the Baron states that there is evidence to prove that the north of China has not been submerged to the depth of 6000 feet within a recent geological epoch. Without arguing as to the difficulty of proving a negative of this sort, I shall only state that to my mind there is abundant evidence, irrespective of the Loess itself, to prove that China, as far north as the Yellow River (beyond which my personal experience does not extend), has since the commencement of the Tertiary period been the scene of very considerable depression. Proofs of this, I believe, are to be found in the upper Nanking sandstones and conglomerates and their succeeding rocks. These sandstones, in almost perfectly horizontal strata, stretch from the south of Nanking through northern Anhwei as far at least as Ting-yuen-hien in the Fung-yang prefecture, being especially characteristic at Luchow-fu, in the centre of this district. The upper portion of these rocks I believe to represent the Tatung gravels of Baron von Richthofen. These Tatung gravels extend through the south-western portion of Anhwei, forming in many localities the bed of the present valley of the Yangtsze, are seen in still greater development in Hupeh, as at Hwang-chow and Wuchang-hien, and probably reach as far west as Ichang, at the foot of the gorges of the upper Yangtsze. I have met with them myself at San-kia-tientsze, some thirty miles from Fung-yang-fu, in the north-east of Anhwei province, where they form a bold escarpment looking over what was at one time the Yellow Sea, but now constitutes the alluvial plain of Kiang-peh. I do not know how much further in either direction these beds extend; and, besides, I wish to confine myself to facts within my own observation. If local conditions at Kiukiang on the Yangtsze are to be trusted, these gravels pass upwards into the Kiukiang laterite, a deposit occupying likewise a considerable area in Anhwei, Kiangsi, and Hupeh.

It seems improbable that these rocks, which extend over so large a space, are otherwise than marine, though at present no fossils have been collected in them. The bold escarpments of the hills on either side of the Yangtsze occur in localities where it seems impossible to ascribe them to fluvial action. They are much more suggestive of ancient coast-lines. They are, besides, not confined to the valley of the Yangtsze; the elevated sandstone plain of northern Anhwei is in places defined by escarpments of the older mountain-chains, rising abruptly from its surface. The traveller in this district is, in fact, forced to the conclusion that he is passing over an ancient sea-bottom, the mountain-masses of the older Devonian and Carboniferous formations forming islands, rising in lines of irregular cliffs, which from their indented outline betoken a long-continued period of depression.

These rocks are succeeded by the Loess. Before its deposition they seem to have been partially, though slightly, denuded, denoting probably some change in the physical conditions of the adjoining land.

What is true of the four provinces adjacent to the Yangtsze is probably true, likewise, with regard to the others over which the Loess extends. There was, at some time subsequent to the upheaval and denudation of the Carboniferous and apparently Triassic rocks, a period of considerable depression in, at least, Central China. The deposition of the Loess probably marked its close.

I have assumed the age of the sandstones and gravels to be *Tertiary*, principally from their position, overlying all the older rocks, and because comparatively little denudation has occurred in either them or the older rocks since their deposition. As stated above, the evidence of fossils is as yet wanting; but we may hope to see it supplied. The main fact of the depression antecedent to the deposition of the Loess may be regarded, however, as proved.

Structure of the Loess.—The other argument adduced in support of the subaerial theory, as stated above, is founded on the internal evidence of the deposit. Baron von Richthofen holds that the Loess is unstratified; this, so far as relates to the absence of apparent layers of deposition, is true, as it is likewise of the Loess of the Rhine. As in the latter, however, the beds of calcareous nodules point to an apparent stratification of materials. In this respect, as in others to be pointed out, it bears a close mechanical resemblance to chalk, though in mineral composition very different from that rock. The occurrence of land-shells and remains of land-animals is looked upon as a strong proof in support of this theory. The fossil origin of these exuviæ, however, is more than doubtful. The Loess is perfectly pervious to water; to use the Baron's own words, "It is perforated throughout its mass by thin tubes, which ramify like the roots of grass, and have evidently their origin in the former existence of roots." As a fact, streams seldom or never flow on the surface of the Loess; they take by preference underground courses, or work for themselves deep valleys, penetrating into the mass in all directions, like branches from the stem of a tree. This mass has, besides, a tendency to cleave in vertical planes, enabling thereby the smallest streams to penetrate its mass; so readily, moreover, is it acted on by water, or even by aqueous vapour, that I have in my possession specimens which disintegrated in the moist air of a Shanghai summer, and which have since rearranged themselves at the bottom of the drawer in which they had been placed. These facts render the presence of terrestrial remains of easy explanation, without accepting the theory of subaerial formation: a shell or other animal relic has only to drop into a fissure or be carried down by a stream of water during a flood; the soil around readily adapts itself to its shape, fills its interstices, and, in fact, in a short time loses so completely all trace of having been disturbed, that the shell or other substance becomes a pseudo-fossil. On the other hand, if the foreign substances were really contemporaneous with the mass, they would most probably be found constituting the centre of aggregation in the calcareous nodules spoken of. I have broken open probably some hundreds of these, and never found a trace of fossils. The Loess, as I have suggested above, bears, in some respects, a mechanical resemblance to chalk. These are the extreme fineness of the particles of which it is composed, the presence of vertical tubes leading downwards from the surface, and the occurrence of nodules like the "pot-stones" in the chalk, with their major axes vertical. The large amount of carbonate of lime in its composition is also worthy of note in the comparison. All these reasons seem to suggest a similar origin for the two formations—namely, on the bed of a tranquil sea.

Baron von Richthofen (I believe rightly) rejects the theory of the Loess being of freshwater origin, as requiring a freshwater lake of such enormous proportions that we cannot believe in its existence at any period. The shape of the older mountain-chains, and their peculiar weathering, he argues, forbid the supposition of glacial action. (See my former paper, Quart. Journ. Geol. Soc. vol. xxv. p. 137.)

Materials of the Loess.—In stating some of my grounds for coming to the conclusion that the Loess is a true marine formation, I have incidentally mentioned many objections to its subaerial origin as suggested by Baron von Richthofen. There are, however, others of even stronger nature. Its chemical composition, consisting, as it does, mainly of silicates of alumina and of free silica in the condition of impalpable sand, does not correspond with that of the inorganic elements of plants growing on its surface. Granting, however, that the earthy carbonates and a portion of the silica could be derived from such a source, whence could the plants themselves derive these elements, but in turn from the soil on which they grew? Lime, potassa, magnesia, iron, and silica might, then, so long as the plant had access to subjacent formations, or was supplied by springs from below, have been deposited in a superficial layer; silica might even, as suggested, have been conveyed by the medium of dust-storms; but whence could the silicate of alumina be derived? A superficial layer not altogether dissimilar, might, as suggested, be formed so long as the plants had access to subjacent rocks. Once, however, removed from contact with them, these inorganic elements of the plants could only be supplied from the soil itself. Rivers are inadmissible, as their action would have been to disintegrate, not to build up; springs, from the peculiarities of the formation, cannot rise to its surface. There is, finally, no known means by which these inorganic matters could have been supplied from the atmosphere. The layer formed by one generation of plants would, in effect, have been absorbed by the next without any addition being possible.

Dust-storms, however, have been suggested as a source of supply. Unless these passed over deposits of the Loess itself, I know of no other source for the necessary ingredients. Clay would not be acted on by the wind; sand, of itself, would not suffice to form the peculiar mixture of ingredients; limestone rocks have never, to my knowledge, been so disintegrated by the action of the atmosphere as to become reduced to dust capable of being transported in the manner suggested. The means are therefore utterly inadequate to the end.

Easy removal of the Loess by rain.—There are, however, other grounds of objection. Had the Loess been formed as dry land, there is no reason why it should not only have utterly ceased to increase, but should be actually undergoing a rapid destruction. There is evidence sufficient to prove that its waste now is greater than at former periods, owing to the ignorant destruction of the trees with which, tradition states, it was once covered. This destruction has increased the frequency and force of the annual floods; but as long as rain fell or rivers ran, denudation of one sort or other must have been going on. Denudation above the sea-level is, in fact, as necessary an accompaniment of running water as is deposition below it. When it is remembered how sensitive is the Loess to the slightest contact with water, and that ever since the emergence of the Loess district from the waves every stream within its limits must have been continually engaged in the work of denudation, the difficulty of accepting the subaerial theory becomes a practical impossibility.

Marine origin of the Loess.—Rejecting, then, as untenable the theories which would assign a glacial, freshwater, or subaerial origin to this peculiar formation, little remains except to class it as marine. As yet, except in its peculiar structure, such as its mechanical resemblances to chalk, an undoubted deep-sea formation, no internal evidence has been discovered to guide us to this conclusion. Specimens of the clay were sent by Mr. Pumpelli to the United States, and examined microscopically by Mr. Edwards; except, however, some small green crystals, pronounced not to be organic, nothing peculiar presented itself. There are here no means of making microscopic examinations, and but few for scientific operations of any kind; inductions have therefore to be founded on what, under more favourable circumstances, would be deemed insufficient proof, trusting to subsequent rigid investigation to prove or disprove their truth. The real origin of the Loess will probably be proved by the close examination of its microscopic structure; but even this must be to a certain extent taken in connexion with its external conditions, as Microzoa may readily be of derivative origin.

Probable Geological relationships of the Loess.—The assumption of a marine origin for the Loess of eastern Asia leads up to most important geological deductions. It extends, as has been stated above, from the south of the Yangtsze, in the prefecture of Chinkiang, far into

Mongolia in the north, and from Anhwei on the east to an unknown distance west, in all probability far into Central Asia. It rises in portions, as in Shansi and Mongolia, to a height of about 6000 feet over the present sea-level, forming at that elevation a deposit upwards of 1000 feet deep. At its southern extremity, in Kiangsu, it does not at present rise more than about 200 feet, though apparent fragments in the sides of the hills rise possibly to 400 feet. Over the raised plain of Anhwei it has been greatly denuded, and probably to a considerable extent rearranged. We must therefore believe in a general depression of Eastern Asia, at least from the latitude of 30° to 45° north and from 90° to 120° east longitude. This, however, is not all: South China, though probably never entirely submerged during the Tertiary epoch, shows in its valleys some traces of marine deposits of that age. Cambodia and Siam, as well as Birmah, with their fossil forests and beds of animal remains, have probably joined in the downward movement. The Sewalik hills, in India, seem to point to an elevation of some 6000 feet since the Miocene period. If Captain Montgomerie's pundit is to be believed, the plain of Lhasa, upwards of 11,000 feet over the sea-level, tells a similar tale. It may therefore be assumed that within the Tertiary epoch the whole of eastern Asia underwent a movement of depression and subsequent elevation. At the point of greatest depression, North China (except perhaps a few summits, such as the Ho-shan, in Shansi) was under the level of the sea; South China formed a group of deeply indented islands, representing the ancient boundary-chains of the southern provinces. During the time of depression, while land was still near, the Luchow sandstones and Tertiary gravels were deposited; afterwards, in the bed of a comparatively deep and tranquil sea, and at a distance from shore sufficient to have allowed all but the most impalpable particles to have already subsided, the Loess beds were thrown down.

Sufficiently startling, however, as is this induction, we can by no means stop there if we accept the premises. One of the most remarkable features in the geology of the chain of islands which bound on the west the great Pacific Ocean, is the enormous development of sandstones and coal-beds, accompanied with conglomerates of various sorts. Some of these beds, as at Takosima, near Nagasaki, in Japan, and at Apes' Hill, near Taiwan, in Formosa, are rich in fossil remains; the coal-beds of Borneo are also known to have yielded characteristic fossils. Beginning, then, with Borneo,—stretching through the Philippine Islands,—continuing on through Formosa and probably the Loochoo Islands,—occurring again in Kiushiu, Niphon, and Yesso, in Japan, and extending as far as the coal-field of Dui, in Saghalien, we find a series of beds of sandstone, coal, and conglomerate agreeing generally in geological structure, and yielding, at such distant spots as Borneo, Formosa, and Kiushiu, characteristic fossils of apparently Mid-Tertiary age.

If we accept the submergence theory for Eastern Asia during this period, we must look elsewhere than to the present continent for the supply of materials for these very extensive deposits, as well as for the forests which have nourished these by no means insignificant coal-fields, whether we describe them by their horizontal or vertical extension. The small island of Takosima, which contains in a thickness of about 450 feet three beds of coal, averaging from 6 to 8 feet in thickness each, is an instance of the latter. The great length of the chain, some 50 degrees of latitude, is sufficient proof of the former.

The mechanical structure of the beds forces us to believe in the near proximity of a continent during their deposition. Sandstones, conglomerates, and coal itself may all be accepted as proofs of littoral conditions. Shut out from the west, we must therefore turn to the east as the probable source whence these beds derive their immediate origin. In this surmise we have, however, other grounds of probability to argue from. Darwin's theory of fringing coral-reefs marking a period of depression has long been accepted by many of the most able of geologists. Assuming it as proved, we are almost of necessity led to the belief in a great Pacific continent during comparatively recent geological time. If we assume that its depression was coincident with the elevation of the remarkable volcanic chain of the west Pacific islands, we may assume that these marked its western shores. Along these shores the greatest Tertiary coal-field in the world was deposited, while at a distance the finer sediment of its streams was thrown down over Eastern Asia in the form of Loess.

Geologists have been ready enough to accept great depressions during the Tertiary epoch, but have hitherto hesitated in pointing out the necessary counterbalance which must have existed between the areas occupied by land and water. I have therefore, at the risk even of being thought to a certain extent an innovator in the science, pointed out a few of the facts which have influenced me in placing the counterbalance within the limits now occupied by the Pacific Ocean.

Discussion.

Prof. Ramsay remarked that the author had not proved that the Loess he described was really stratified. He could not agree with his views of the inland escarpments he mentioned having been old coast lines. It was only accidentally that sea cliffs had any connexion with the line of strike of the strata, whereas inland cliffs always followed the strike. He thought the phenomena were rather in accordance with a long exposure of the land to subaerial influences than with the Loess having been of marine origin. Even in England, in those parts which had long been free from marine action, beds of brick-earth had been formed. He also instanced the plains of Picardy as exhibiting a vast extent of such subaerial beds.

Prof. T. Rupert Jones thought that the area treated of by Mr. Kingsmill was too large to have its geology explained merely by reference to rain-wash and valley deposits. Whatever his low-level Loess might be, the higher accumulations of loamy deposits, stated to be 1000 feet thick at an elevation of 3000 feet, and regarded by

Mr. Kingsmill as the quiet water sediments of a great gulf with the Miocene conglomerates and sandstones of Nanking and elsewhere for its marginal equivalents, appeared to require a different explanation. All loess need not be of river origin; in oscillations of land marine deposits must be carried up to great heights; and, referring to Mr. H. M. Jenkins's determination of the marine origin of the Loess of Belgium, Prof. Jones thought it highly probable that some at least of that in China may have been similarly formed.

Mr. Hughes said that the author appeared to have grouped together all the superficial deposits of a vast area without explaining very clearly the grounds upon which he identified those deposits at distant points. He did not prove that what he called the shore deposit was marine, or that it was of the same age as the loam which he described, and which Mr. Hughes thought, from the description, was far more likely to be subaerial.

Mr. Evans and Mr. Etheridge suggested the probability of much of the so-called Loess having been brought down from higher loamy beds, possibly derived from the decomposition of limestone rocks containing sand and clay, and redeposited by the action of rain.

May 10, 1871.

Dr. Henry Nyst, of Brussels, was elected a Foreign Member, and Prof. G. Dewalque, of Liége, a Foreign Correspondent of the Society.

The following communications were read:—

1. *On the* Ancient Rocks *of the* St. David's Promontory, South Wales, *and their* Fossil Contents. By Professor R. Harkness, F.R.S., F.G.S., and Henry Hicks, Esq. *With Descriptions of the New Species*, by H. Hicks, Esq.

(Plates XV. & XVI.)

In an early edition of Siluria (1854) there is a figure of a specimen of *Paradoxides Forchhammeri*? Angel., from the black slates of North Wales. In the third edition of the same work (1859) the same figure occurs, with the remark "locality unknown, probably from Pen Morfa, near Tremadoc, North Wales." In this edition there is also a note with reference to the occurrence of this form, stating that "only one species of *Paradoxides* has yet been found in Wales; although the specimen is imperfect, Mr. Salter believes it to be identical with *P. Forchhammeri* of the alum slates of Andrarum in Scania."

In the last edition of Siluria (1867) the same figure is named *Paradoxides Hicksii*; its locality is indicated as "near Dolgelly, North Wales;" and it is further stated that "this fossil has been found both at Dolgelly and in Pembrokeshire, about a hundred feet above the lowest black Lingula-slates."

Respecting the discovery of another form, *Paradoxides Davidis*, Salter, in Pembrokeshire, the late Mr. Salter has described this species, and named the locality whence it has been obtained*.

In this memoir a Table is also given of the strata which make up the "Lingula-flags in Wales;" and Mr. Salter has described the lower portion of this series as a "thick mass of black shales very uniform in its upper part, but with hard sandstones in the lower, probably accumulated in a deep sea." The fossils of the Lower Lingula-flags are stated to be "*Lingulella*, rare, *Olenus*, common, *Agnostus*, common, *Paradoxides Davidis*" †.

Subsequently Mr. Salter, in a communication entitled "On some New Fossils from the Lingula-flags of Wales," described and figured several new forms of Trilobites, a *Theca*, and a large Sponge obtained from the dark-coloured rocks of Porth-y-Rhaw by Mr. Hicks ‡.

In this memoir a section is given of the fossiliferous rocks, showing their relation to the purple and green sandstones on which they repose.

In 1865 Mr. Salter alludes to the occurrence of "Some additional Fossils from the Lingula-flags;" and a note on the genus *Anopolenus* is appended to this communication by Mr. Hicks §. The lower portion of these Lingula-flags affording the additional fossils, and also those previously referred to, were designated by Messrs. Salter and Hicks, in a paper read at the British Association in 1865, the "Menevian group."

In 1867 a new form of *Lingulella* (*L. ferruginea*, Salter), from the Lower Lingula-flags of St. David's, was described; and the occurrence of a variety of the same, *Lingulella ferruginea*, var. *ovalis*, Hicks, which had been obtained from the underlying red rocks, was alluded to ||.

In this communication of Messrs. Salter and Hicks we have the first indication of the presence of fossils in the purple and green rocks of the St. David's promontory, upon which the Lower Lingula-flags are superposed.

In 1868 Messrs. Salter and Hicks gave an abstract having reference to the occurrence of some new fossils from the Menevian group (Lower Lingula-flags); and in 1869 a detailed description was given of these fossils ¶.

The discovery of fossils in the dark-coloured Lower Lingula-flags

* Quart. Journ. Geol. Soc. vol. xix. p. 275.

† This description of the Lower Lingula-flags was correct so far as then recognized in North Wales; but it does not include that very important portion at the base, which has since been separated by Messrs. Salter and Hicks, and named the Menevian group. *Paradoxides Davidis* belongs to this group, and should not be associated with *Olenus*, the typical genus of the Lingula-flags proper.

‡ *Op. cit. suprà*, vol. xx. p. 233.

§ *Op. cit. suprà*, vol. xxi. p. 477.

|| *Op. cit. suprà*, vol. xxiii. p. 339.

¶ *Op. cit. suprà*, vol. xxiv. p. 519, and xxv. p. 51.

of Pembrokeshire by Mr. Hicks induced other geologists to seek for similar fossils among the equivalents of these rocks in connexion with the Lower Lingula-flags, which repose conformably upon the upper portion of the purple rocks forming the Merionethshire anticlinal.

In reference to the rocks which rest upon the purple strata on the east side of this anticlinal, Mr. Plant communicated a memoir entitled "Notes relating to the Discovery of Primordial Fossils in the Lingula-flags in the neighbourhood of Tyddyngwladi's Silver-lead Mine." An abstract of this was published in the Quart. Journal of the Geol. Soc. in 1866; and the memoir appeared *in extenso* in the Trans. of the Geol. Soc. of Manchester. A list of fossils obtained from the Lower Lingula-flags of this portion of Merionethshire was given by Mr. Plant; and this list exhibits a series having a very intimate relation with that containing the fossils obtained by Mr. Hicks from Porth-y-Rhaw, near St. David's.

The Lower Lingula-flags of the valley of the Mawddach, Merionethshire, are seen occurring between hard dark-grey shale-beds, which afford *Oleni*, and the highest member of the purple rocks of the anticlinal; and the Lower Lingula-flags here are conformable to the deposits above and below them. In their mineral nature they have great affinity to their equivalents near St. David's, consisting of what Mr. Salter termed "sandstones probably accumulated in deep water."

The strata at Porth-y-Rhaw, which are rich in Trilobites, contain no red or purple rocks associated with them, but are grey in colour at their base, being banded by light and dark shades, and black in their upper portion; and it is in the latter that fossils are most abundant.

Beneath the grey beds, and having the same inclination as the Lower Lingula-flags (Menevians) there is, in the St. David's promontory, a great development of rocks, which exhibit red, purple, green, and greenish-grey colours. These rest upon a conglomerate composed of quartz pebbles, of various sizes, cemented together by a reddish or purple sandy matrix.

The beds upon which the conglomerates rest are greenish in colour, and these are supported by rocks of rather peculiar characters.

In many spots they have an aspect which so nearly resembles syenite that it is, at first sight, very difficult to make out their true nature; for they appear to be made up of crystals imbedded in a base of quartz. When, however, these apparent crystals are carefully examined, they are found to be, for the most part, angular fragments of quartz, not possessing the proper crystalline form which this mineral assumes. Some of the fragments have a subangular outline; and a few even manifest a distinctly rounded surface. The matrix in which these fragments are imbedded does not exhibit a crystalline arrangement, and contains a very large proportion of silica as a constituent. The chemical composition of a specimen of these rocks has been kindly determined by Dr. Blyth, of Queen's College, Cork, and is as follows:—

Silica	78
Alumina	16·5
Lime, soda, and iron	5·5
	100

The proportion of silica afforded by the foregoing analysis much exceeds that which is obtained from rocks having a syenitic nature.

These quartziferous rocks form an E.N.E. and W.S.W. course; and near the centre of this ridge is the city of St. David's.

The arrangement of these rocks, which seem to be quartziferous breccias, is rather indistinct. In the immediate neighbourhood of St. David's, and also near Clegyr Bridge, about a mile E. from St. David's, they have associated with them irregular bands of hard greenish-coloured ashy-looking shales, considerably altered in character, but in many instances possessing distinct traces of foliation. Bands of this shale have also been met with in well-sinkings in St. David's*.

Differences prevail in the characters of the rocks which repose upon the central ridge, those on the S.S.E. side presenting an aspect somewhat different from those on the opposite side. This difference seems to have resulted from faults which have brought various rocks of the purple and green series into contact with the quartziferous breccias.

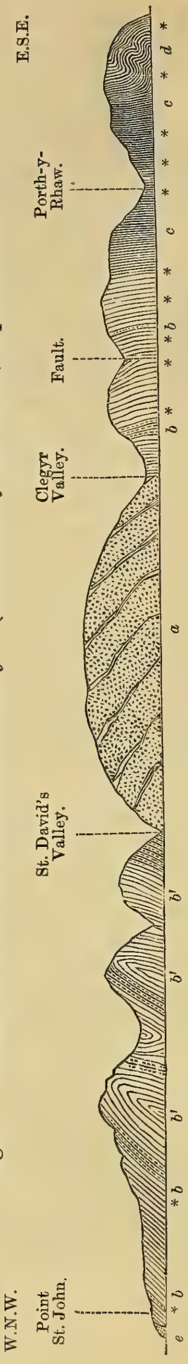
The quartziferous breccias on the S.S.E. have, for the most part, resting upon them quartz rocks of a greenish-grey colour and compact nature. These possess many of the features of hornstone, and they are intersected by closely approximated joints. They have, however, a distinct S.S.E. dip at a high angle, usually about 80°; and in this position they are well seen in the neighbourhood of Clegyr Bridge, where their strike is parallel to the axis of the quartziferous breccias.

On following the line of strike of the hornstones for a short distance towards the W.S.W., these rocks are found to disappear. At the ruins of Nun's Chapel, about a mile W.S.W. from Clegyr Bridge, the compact quartz rocks are seen; but immediately beyond this all traces of them are lost, and a greenish flaggy sandstone appears at Porth Clais Harbour resting *against* the quartziferous breccias.

The connexion between the quartziferous breccias and the greenish flaggy sandstones at Porth Clais Harbour results from a fault, having a throw-down on the E.S.E. side, by means of which rocks newer than the compact quartz rocks, or hornstones, are brought into contact with the quartziferous breccias. At Porthlisky, a little to the

* Since this paper was read, I have been fortunate enough to find two or three spots in the ridge where the bedding is distinctly shown, and where the shales are seen alternating with the more massive quartziferous beds. The strike of the beds is from N.W. to S.E., and hence quite discordant to the overlying Cambrian series, in which the strike is from N.E. to S.W. This ridge, therefore, must represent a more ancient group of rocks than the Cambrian, occupying a position equivalent to that of the Laurentian group in Canada.—H. Hicks.

Fig. 1.—*Section across the St. David's Promontory.* (Corrected by Mr. Hicks, September 1871.)



a. Laurentian. *b'.* Cambrian altered. *d.* Lingula-flags.
b. Cambrian (Longmynd). *c.* Menevian. *e.* Trap.
* Beds which have yielded fossils. The dotted Cambrian beds are conglomerates.

W. of Porth Clais, purple sandstones, which will be shown to be higher in the series than the greenish flaggy rocks, strike against the quartziferous breccias, affording further evidence of the occurrence of a fault in this neighbourhood.

It has been stated that at the ruins of Nun's Chapel the compact quartz rocks are in connexion with the quartziferous breccias.

At this locality there are seen resting, apparently conformably, on the compact quartz rocks, conglomerates already referred to as being composed of large and well-rounded masses of quartz imbedded in a purple matrix. These conglomerates, as here seen, are about 30 feet in thickness.

The same conglomerates are well shown near Clegyr Bridge, where they appear to be conformable to the underlying compact quartz rocks, their dip being towards the S.S.E., at about 80°. In this locality the thickness of the conglomerates amounts to about 60 feet.

On the N.N.W. side of the axis of the quartziferous breccias no compact quartz rocks are recognizable; but some fine-grained yellowish beds of a soft and decomposing nature are seen in contact with the quartziferous breccias, and are succeeded by purple conglomerates.

The section on the S.S.E. side of the axis exhibits a good development of greenish flaggy sandstones identical with those alluded to as occurring at Porth Clais Harbour; and these sandstones are conformable to the conglomerates on which they rest. The greenish flaggy sandstones have been worked, especially at Caerfai; and a small quarry of them is also seen on the E. side of the stream below Clegyr Bridge. These rocks have a thickness of about 400 feet; and on the N.N.W. side of the axis the greenish flaggy sandstones also occur, resting conformably on the conglomerates.

On the S.S.E. side of the ridge the greenish flaggy sandstones have above them red shaly beds, agreeing in their inclination with the strata on which they repose; and these red shaly beds have afforded the earliest traces of organic remains which have been hitherto discovered in the St. David's promontory. These remains consist of *Lingula ferruginea*, Salt., a form previously mentioned, another and larger *Lingulella*, a *Discina*, and a new species of *Leperditia* of considerable size, *L. cambrensis*, Hicks.

These red shales occur on both sides of the quartziferous ridge. They are seen on the N.N.W. side, in Ramsay Sound, where fossils have also been obtained from them near Castell. A small fragment of a Trilobite has likewise been met with in the red shales of this locality; but this fragment was not sufficiently distinct to allow of the form being satisfactorily determined.

On the S.S.E. side of the ridge the fossiliferous shales are seen at Porth Clais Harbour; and in this spot also fossils occur*. They are likewise seen under the ruins of Nun's Chapel, at Rhoscarrylhuyd, and also at Caerfai and Mill. These red fossiliferous shales have a thickness of about 50 feet.

On the S.S.E. side of the axis, reposing conformably on the fossiliferous red shales, purple sandstones having occasional green bands associated in them occur, somewhat coarse in grain. These purple sandstones are about 1000 feet thick; and hitherto no fossils have been obtained from them. These sandstones are now being largely worked, the stone used in the restoration of the Cathedral of St. David's being obtained from them. They afford large blocks, which dress well.

On the N.N.W. side of the axis the thick purple sandstones are represented by deposits having more varied colours. On the E. side of Ramsay Sound, where the fossiliferous red shales occur, these are seen to be succeeded by greenish sandstones, upon which are rocks reddish in colour passing upwards into a series of purple strata. Greenish sandstones rest upon the purple strata; and above these are purple-coloured beds, having within them red layers. These varied-coloured sandstones represent the thick purple sandstones on the S.S.E. side of the axis; and they are also almost unfossiliferous, so far as present observations go.

The thick purple sandstones of the S.S.E. side of the St. David's promontory have superposed conformably upon them yellowish- and grey-coloured sandstones and shales. In the lower portion of these yellow-coloured rocks there have been found remains of a large and new form of sponge, *Protospongia major*, Hicks. These strata, which have some conglomerate beds associated with them, have also afforded Trilobites, one of which appertains to a new genus, and the other forms are new species. These are *Plutonia Sedgwickii*,

* Davidson on the Earliest British Brachiopoda, Geol. Mag. vol. v. p. 306.

Hicks, *Conocoryphe Lyellii*, Hicks, *Microdiscus sculptus*, Hicks, *Agnostus cambrensis*, Hicks, *Protospongia fenestrata*, Salter, *Theca antiqua*, Hicks, and *Paradoxides Harknessi*, Hicks.

The yellowish-coloured sandstones and shales are well seen on their line of strike in most of the headlands which intervene between Porth Clais Harbour and Caer-bwdy. The principal spot from which fossils have been obtained is the second headland E. of Porth Clais Harbour. The same rocks can be seen also between Folly and Trelerwr. Their thickness amounts to about 150 feet; and on the N.N.W. side of the axis their equivalents occur in a nearly allied form, being yellowish-grey sandstones.

Succeeding these are grey rocks with purple bands, which pass upwards into purple and red sandstones and shales; and from these *Lingulella ferruginea*, var. *ovalis*, *Conocoryphe solvensis*, *Paradoxides Harknessi*, and several of the other species have been obtained between Solva and Whitchurch. The total thickness of the two series on the S.S.E. side of the axis is about 700 feet. On this side of the axis these rocks are intersected by lines of faults, which run parallel to their strike; and one of these extends from the coast a little S. of Folly through Trelerwr. These faults have downthrows on their S.S.E. side, which have reduced very materially the absolute thickness of those rocks on this side the promontory.

On the E. side of Ramsay Sound, and on the N.N.W. side of the axis, the equivalents of the grey and purple sandstones do not seem to have been affected by faults; and here they have a thickness of about 1500 feet.

On this side of the ridge also the grey and purple sandstones have their representatives in the form of grey, purple, and red flaggy beds.

On the S.S.E. side the grey and purple sandstones have, resting conformably upon them, grey grits, which contain *Paradoxides aurora*, Salter, and *Conocoryphe bufo*, Hicks; and these two forms have not, up to the present time, been discovered in strata which underlie or overlie the grey grits. *Agnostus cambrensis* and *Theca antiqua* have also been obtained from these grey beds. These two species also occur in the underlying rocks; but they have not yet been met with in deposits higher than the grey grits. *Discina pileolus*, Hicks, and *Obolella sagittalis*, Salter, are also found in the grey beds. They likewise occur in the underlying purple strata, and they extend upwards through the Menevian group.

Lingulella ferruginea is also found in the grey beds; and this form has the widest range of any of the fossils that have been obtained from the purple and green rocks of the St. David's promontory. It occurs in the lowest fossiliferous zone which has hitherto been discovered, and it extends through the Menevians. *Theca penultima*, Hicks, also occurs in these grey rocks; and this is the lowest horizon from which it has been procured. Its range seems limited, as it has not been met with above the lower portion of the Menevians.

On the N.N.W. side of the axis, on the E. shore of Ramsay

Sound, these grey fossiliferous grits are not seen: a fault having an E.N.E. course has cut through the upper portion of the purple-coloured rocks which support the grey strata. A few beds of these grey grits, however, are seen on the N.N.W. side of this fault, near Ogaf Golhfa, in Whitesand Bay, reposing upon the higher members of the purple flags and sandstones. The order of the rocks from the quartziferous breccias upwards, when not disturbed by faults, is as follows:—

Lower Cambrian.

	feet.
1. Greenish hornstones on the S.E., and earthy greenstones on the N.W., forming the outermost portions of the so-called Syenitic and Greenstone ridges.	
2. Conglomerates composed chiefly of well-rounded masses of quartz imbedded in a purple matrix	60
3. Greenish flaggy sandstones	460
4. Red flaggy or shaly beds, affording the earliest traces of organic remains in the St. David's Promontory—namely, *Lingulella ferruginea*, *Leperditia cambrensis*, a larger *Lingulella*, and a *Discina*	50
5. Purple (sometimes greenish) sandstones	1000
6. Yellowish-grey sandstones, shales, and flags containing the genera *Plutonia*, *Conocoryphe*, *Microdiscus*, *Agnostus*, *Theca*, *Protospongia*, and *Paradoxides*	150
7. Grey, purple, and red flaggy sandstones, containing most of the above-mentioned genera	1500
8. Grey flaggy beds, containing *Paradoxides aurora*	150
9. The true beds of the "Menevian Group," richly fossiliferous, and the probable equivalents of the lowest portions of the Primordial Zone of M. Barrande	550

The discovery of a fauna specially rich in Trilobites among the purple and green rocks and their associated strata of the St. David's promontory affords very important information concerning the earlier forms of life which occur in the old sedimentary deposits of the British Isles. Until the discovery of this fauna, these rocks and their equivalents in North Wales have been looked upon as all but barren in fossils. We have now scattered through about 3000 feet of purple and green strata a *well-marked* series of fossils such as have nowhere else been obtained in the British Isles.

In the Longmynds of Shropshire, consisting of purple and green rocks, which probably represent the rocks having the same colour in the St. David's district, the only evidence of the existence of life during the period of their deposition is in the form of worm-burrows—and in the somewhat indistinct impressions which Mr. Salter regarded as trilobitic, and to which he has given the name *Palæopyge Ramsayi* *.

If we assume the purple and green shales and sandstones with their associated quartz rocks of Bray Head, and the drab shales of Carrick McReily, co. Wicklow, to represent the old rocks of the St. David's promontory, they afford only very meagre evidence of the occurrence of life during the period of their deposition, in the form of worm-burrows and tracks and in the very indeterminate fossils which have been referred to the genus *Oldhamia*.

* Quart. Journ. Geol. Soc. vol. xii. p. 249.

There is one very prominent feature about the palæontology of the ancient rocks of St. David's: this is the occurrence of four distinct species of the genus *Paradoxides*; and this feature contrasts very strongly with the entire absence of the genus *Olenus* from these rocks.

On a comparison of the palæontology of the St. David's rocks with those of the continent of Europe and of America, which seem to occupy nearly the same horizon, we have like features, to a very great extent, presenting themselves.

The lower fossiliferous horizon of Sweden, the Alum-shales, has been divided by Angelin into two groups. The lowest of these, "Regio B," contains forms of *Paradoxides*, among which we learn that Dr. Otto Torell has recognized two species that are St.-David's forms, viz. *P. Davidis* and *P. Hicksii*. The upper portion of the Alum-shales of Sweden, "Regio A" of Angelin, contains several forms of *Oleni*; and from this portion of the series the genus *Paradoxides* seems to be absent.

The deposits upon which the Alum-shales of Sweden rest, the "Fucoidal Sandstones," contain within them purple beds; and from these we have reason to believe that evidence of life has been obtained by Dr. Otto Torell in the form of an *Obolella*. In Sweden the genus *Paradoxides* is found accompanied by *Conocoryphe* (*Conocephalites*); and Trilobites of this genus are also found associated with *Paradoxides* in the St. David's promontory.

Regio B of Angelin is represented by the dark-coloured rocks of Porth-y-Rhaw; and below these are strata which seem to be the equivalents of the Fucoidal Sandstones of Sweden, yielding an extensive series of fossils.

In N. Wales, on the E. and N.E. side of the Merionethshire anticlinal, Regio B is also represented, and is succeeded by the equivalents of Regio A, which, in the form of a thick series of dark-coloured sandstones and shales (Lingula-flags), contain several species of the genus *Olenus*.

In Bohemia, the primordial zone of Barrande, as shown by its fossil contents, is very near to the horizon of the Menevian group as exhibited in Wales. Trilobites appertaining to the genera *Paradoxides*, *Conocoryphe*, *Ellipsocephalus*, *Sao*, and *Agnostus* occur; but no traces of the genus *Olenus* have been obtained from the Bohemian primordial rocks.

In Bavaria, Sir R. I. Murchison states that, in the neighbourhood of Hof, the primordial zone, "which consists of black siliceous slate, above 50 feet thick, contains Trilobites, which have been determined by Barrande to belong to *Conocoryphe* and *Olenus*;" and in a letter from M. Barrande to Sir Roderick it is said that "with these primordial Trilobites are also associated two or three forms which everywhere characterize the second Silurian fauna (Llandeilo and Caradoc), i. e. *Calymene* and *Cheirurus*"*.

With reference to the fauna of the primordial zone of Hof, Barrande has remarked on the absence of the genus *Paradoxides* there-

* Quart. Journ. Geol. Soc. vol. xix. p. 362; Siluria, 4th edit. p. 374.

from. He regards the fossils which occur in these primordial rocks as being of a later age than those found in the primordial zone of Bohemia; and he looks upon them as representing a period between the first and second faunas of Bohemia *.

This fauna of Hof has no analogy with the ancient fauna of the St. David's promontory. It is altogether much higher in position, and connects the upper portion of the Lingula-flags of Wales, not only with the succeeding Tremadoc rocks, but also with higher members of the Silurian series.

The occurrence of rocks which appertain to the primordial zone of Barrande, in Spain, has been referred to by Sir R. I. Murchison †.

The arrangement of these Spanish representatives of the primordial zone has been given in detail by M. Casiano de Prado ‡.

The fauna of the Spanish primordial rocks, which has been obtained from a thin series of red limestones, has been described by Barrande. Among the fossils which it affords are seven Trilobites, referable to the genera *Paradoxides*, *Arionellus*, *Cenocephalites*, and *Agnostus*. The genus *Paradoxides* is represented by *P. pradoanus*, a form which seems to occur only in Spain. The species of *Arionellus* is *A. ceticephalus*, Barr., which is a form found in the primordial rocks of Bohemia. There are three species of *Conocephalites* among the Spanish representatives of the primordial zone, of which two are Bohemian, viz. *C. coronatus* and *C. Sulzeri*; and one form, *C. Ribeiro*, Barr., has not yet been obtained elsewhere. Two species of the genus *Agnostus* are also met with in the Spanish primordial rocks. These several Trilobites have been obtained from deposits which lie north of Scabero, and of Bonar, in the province of Leon.

Sir R. I. Murchison also states that MM. de Verneuil and Louis Lartet have discovered a "primordial" Silurian range with the same species of Trilobites near Daroca. They also found it in various parts of the Silurian strata which extend from Daroca to Moncayo §.

The occurrence of fossils, of a type allied to those which are obtained from the rocks of St. David's, has been recognized in several localities in North America. Mr. Salter has mentioned *Paradoxides Harlani*, Green, as occurring in great quantities in Massachusetts. *P. Bennetti*, Salter, is found in hard, fine-grained, flinty shales at Branch, in the promontory between St. Mary's and Placentia Bays, Newfoundland; and Mr. Salter alludes to the occurrence of *Conocephalites antiquatus*, Salter, as a form which was exhibited at the Great Exhibition, 1851, and which was obtained from a boulder of brown sandstone in Georgia ||.

Dr. Dale Owen has mentioned the occurrence in Wisconsin of several forms of *Dikelocephalus*, with species of *Conocephalites*, *Ari-*

* Faune Silurienne des Environs de Hof, December 1868.

† Siluria, 4th edit. p. 416.

‡ Bull. Soc. Géol. France, 1860, vol. xvii. p. 516 *et seq.*

§ Siluria, 4th edit. p. 416.

|| "Fossils of the Lingula-flags or Primordial Zone," Quart. Journ. Geol. Soc. vol. xv. p. 551 *et seq.*

onellus, and *Lonchocephalus,* in the equivalents of the Potsdam sandstone. The genus *Paradoxides* however, does not, seem to be represented in this fauna *.

A species of *Paradoxides,* which appears to be identical with a form occurring in Bohemia and Thuringia, *P. spinosus,* Boeck, has been met with in altered argillaceous sandstones in a quarry in Quincy, south of Boston, in eastern Massachusetts †.

In Canada, at Point Lévis, on the banks of the St. Lawrence, a fauna, possessing a character nearly allied to that mentioned by Dr. D. Owen as occurring in Wisconsin, is seen. Among the thirty-six forms of Crustacea which this fauna affords are two forms of *Arionellus,* one of *Conocephalites,* and five of *Dikelocephalus.* These are associated with fifty-five species of Mollusca, four of Radiata, and forty-two forms of Graptolites, the latter being generically and, in most instances, specifically identical with those of the Skiddaw slates ‡.

The fossils of Point Lévis occur in limestone conglomerates and in interstratified slates. These rocks appertain to the Quebec group, and represent in this part of North America the calciferous sand-rock §.

In Vermont, as seen at Swanton Falls, the Potsdam sandstones are exhibited in the form of dolomites and red sand-rocks. The lower portion of these afford *Conocephalites Adamsi,* Bill.; and from the higher strata *C. Teneri,* Bill., *Paradoxides Thompsoni,* Hall, *P. vermontiana,* Hall, and three species of brachiopods are obtained ‖. Strata of the same age, and affording the same forms of *Paradoxides,* occur on the coast of Labrador, on the north-west side of the Straits of Belle Isle. Here *Conocephalites,* with two forms of *Bathycirus,* three of *Salteria,* and several brachiopods are found associated ¶.

The Potsdam sandstones are represented in the north-west portion of Newfoundland. The strata here, which have been termed by the late Mr. Jukes the Lower Slate formation, consist of the Signal-hill sandstones and the St. John's slate (Report on the Geology of Newfoundland).

From the slates on the west side of St. Mary's Bay Mr. C. Bennett obtained *Paradoxides Bennetti,* Salter, a form before alluded to.

Dr. Dawson refers to the occurrence of a rich primordial fauna in New Brunswick. It affords fourteen species of *Conocephalites,* two of *Paradoxides,* one of *Microdiscus,* and two of *Agnostus,* associated with six forms of Brachiopoda **.

* Geology of Wisconsin, vol. i. p. 72.

† H. D. Rogers, Geol. of Pennsylvania, vol. ii. pl. 11, p. 816.

‡ Sir W. E. Logan's Report on the Geology of Canada, 1863, p. 232.

§ Professor Dana, in the last edition of the 'Manual of American Geology' (1870), p. 171, unites the Potsdam sandstone and the calciferous sand-rock into one group, placing them at the base of the Silurian, and designating the epoch of their deposition as the "Potsdam or primordial period."

‖ Report, p. 811. ¶ Report, p. 866.

** Acadian Geology, 2nd edit. p. 641.

With reference to the distribution in time of the earlier genera of Trilobites, it would appear that the genus *Olenus* is represented in Britain and Europe by twenty species, which are confined to the horizon of the Lingula-flags, but not occurring so low as the Menevian group, and by two species which, in Wales, are found in the higher horizon of the Tremadoc slates. In America there are four forms of this genus, and these are found in positions higher than any of the Old-World species; and the American forms are distinct from those of Britain and Sweden. Three of these species occur in the Quebec series; and one *O. undulostriatus*, Hall, has been obtained from the Hudson-river group.

Of the genus *Conocoryphe* (*Conocephalites*) there appear to have been found in the Potsdam sandstone of America twenty-six species; and if to them we add the fourteen forms obtained by Dr. Dawson from New Brunswick, forty species of this genus seem to occur in the New World, all being low down in the primordial rocks. There is one form not included in this number, which appears to be common to Britain and Texas, *C. depressa*, Salter; and this, in Wales, makes its appearance in the Tremadoc slates; and in America another form, *C. Zenkeri*, Bill., is found in the Quebec group.

In the Old World eighteen species of the genus *Conocoryphe* occur among the representatives of the Lingula-flags and the underlying deposits, and four forms make their appearance in the Tremadoc slates.

In America this genus does not range so high as the genus *Olenus*; and in the same country it has been met with in a lower horizon than *Olenus*.

Of the genus *Microdiscus* one form is mentioned by Dr. Dawson as occurring in the primordial rocks of New Brunswick, and one form appears also in the Quebec group.

Wales affords two species of this genus, one of which is found in the Menevian series, and the other in the purple rocks of St. David's. This genus also ranges higher in America than in the Old World.

As regards *Arionellus*, four species have been recognized in the Potsdam sandstone of America, and two have been obtained from the Quebec group. In Britain, and on the continent of Europe, three forms occur; and these are found low down among the earlier rocks.

This genus also appears in a higher horizon in America than in the eastern hemisphere.

Of the genus *Dikelocephalus* there are in the Potsdam sandstone of America twelve forms; and in the Quebec group thirteen species occur. In Britain, which seems to be the only country where this genus occurs in the Old World, there are four forms; and these have a limited range, three being confined to the Upper Lingula-flags, and one to the Tremadoc slates.

Here, again, we have a genus which is represented in a higher position in America than in Britain.

Table of the distribution of the fossils in the Cambrian Rocks of the St. David's Promontory, South Wales, by Mr. Hicks.

	Laurentian.	Purple, Grey, and Green Rocks (Longmynd Group).							Dark-grey and black flags, "Menevian."			Lingula-flags.
	Quartziferous rocks.	Conglomerates, 60 feet.	Green flags, 460 feet.	Red shales, 50 feet.	Purple sandstones, 1000 feet.	Yellowish sandstone, 150 feet.	Grey, purple, and red rock, 1500 feet.	Grey rocks. 150 ft.	*Lower* (grey flags), 300 feet.	*Middle* (black flags), 350 feet.	*Upper* (sandstone and shales), 100 feet.	
Protospongia major, *Hicks*	...	...	...	...	...	*						
—— fenestrata, *Salter*...........	...	...	...	...	...	*	...	...	*	*	*	?
—— diffusa ,, ...	...	...	...	...	...	...	...	...	*	*		
—— flabellata, *Hicks*	...	...	...	...	...	...	...	...	...	*	*	
Protocystites menevensis, *Hicks*	...	...	...	...	...	...	...	...	*	*		
Leperditia cambrensis, ,,	...	...	...	*								
—— solvensis, *Jones*	...	...	...	...	...	...	...	...	...	*		
—— vexata, *Hicks*	...	...	...	...	...	...	...	...	*	*		
—— buprestis, *Salter*	...	...	...	...	...	...	...	...	*	*		
Microdiscus sculptus, *Hicks* ...	...	...	...	...	...	*						
—— punctatus, *Salter*	...	...	...	...	...	...	...	...	*	*		
Conocoryphe Lyellii, *Hicks*......	...	...	...	...	...	*						
—— solvensis, ,, ...	...	...	...	...	...	...	*					
—— bufo ,, ...	...	...	...	...	...	...	...	*				
—— perdita, *Salter*..............	...	...	...	...	...	...	...	...	*			
—— applanata, ,, ...	...	...	...	...	...	...	...	...	*			
—— humerosa, ,, ...	...	...	...	...	...	...	...	...	*			
†—— coronata, *Barr.*	...	...	...	...	...	...	...	...	...	*		

†Conocoryphe Homfrayi, *Salter*	...	...	...	...	...	...	...	...	...	*		
—— variolaris, ,,	...	...	...	...	...	...	...	...	...	*		
——, sp. of, ,,	...	...	...	...	...	...	...	...	...	...	*	
Paradoxides Harknessi, *Hicks*	...	...	...	...	...	*	*					
—— aurora, *Salter*	...	...	...	...	...	...	...	*				
—— Hicksii, ,,	...	...	...	...	...	...	...	...	*			
—— Davidis, ,,	...	...	...	...	...	...	...	...	...	*		
Anopolenus Salteri, *Hicks*	...	...	...	...	...	...	...	...	...	*		
—— Henrici, *Salter*	...	...	...	...	...	...	...	...	...	*		
Plutonia Sedgwickii, *Hicks*	...	...	...	...	...	*						
Arionellus longicephalus, *Hicks.*	...	...	...	...	...	...	...	...	*			
Erinnys venulosa, *Salter*	...	...	...	...	...	...	...	...	...	*		
Holocephalina primordialis, *Salt.*	...	...	...	...	...	...	...	...	...	*		
Agnostus cambrensis, *Hicks*	...	...	...	...	...	*	*	*				
—— Davidis, *Salter*	...	...	...	...	...	...	...	...	*	*		
—— Eskriggii, *Hicks*	...	...	...	...	...	...	...	...	...	*		
—— scarabæoides, *Salter*	...	...	...	...	...	...	...	...	...	*		
—— Barrandei ,,	...	...	...	...	...	...	...	...	*			
—— scutalis ,,	...	...	...	...	...	...	...	...	...	*	*	?
Lingulella ferruginea, *Salter*	...	...	...	*	...	*	*	*	*	*	*	?
—— primæva, *Hicks*	...	...	...	*								
Discina pileolus, *Hicks*	...	...	...	?	...	...	*	*	*	*	*	?
Obolella sagittalis, *Salter*	...	...	...	...	...	...	...	*	*	*	*	?
—— maculata, *Hicks*	...	...	...	...	...	...	...	...	...	*	*	
Orthis Hicksii, *Salter*	...	...	...	...	...	...	...	...	...	...	*	
Theca antiqua, *Hicks*	...	...	...	...	...	*	*	...	...			
—— penultima, ,,	...	...	...	...	...	...	...	*	*			
—— corrugata, *Salter*	...	...	...	...	...	...	...	...	...	*	*	
—— stiletto, *Hicks*	...	...	...	...	...	...	...	...	*	*		
Stenotheca cornucopia, *Salter*	...	...	...	...	...	...	...	...	*	*		
Cyrtotheca hamula, *Hicks*	...	...	...	...	...	...	...	...	*	*		

† Found first by D. Homfray, Esq., near Maentwrog, North Wales.

The genus *Paradoxides* is represented in America by six species; and these all appear to occur in the lower portion of the primordial zone. Of these species it seems probable that *P. Thompsoni* and *P. vermontianus,* which Mr. Billings has referred to a new genus, *Olenellus,* occur in a position higher than the forms from Massachusetts; and as regards *P. macrocephalus,* Emmons, its position seems to be doubtful *. The Old World affords, including the new species alluded to in this communication as occurring in the purple and green rocks of St. David's, twenty forms; and these are all very low down in the earliest fossil-bearing rocks of Britain and Europe.

The genus *Anopolenus,* very nearly allied to *Paradoxides,* affords two species only; and these have hitherto only been found in the dark-coloured rocks above the purple and green strata of St. David's; and the same remark applies also to *Erinnys* and *Holocephalina,* a species of each of which occurs in the same rocks.

As regards the thickness of the strata extern to the British isles which afford the earlier forms of Trilobites, this, in Europe, contrasts very strongly with what our own country exhibits.

In Sweden, the strata representing the ancient fossiliferous rocks of St. David's are very thin, if we regard them as included in Angelin's "Regio B." It is, however, by no means improbable that in this country the underlying "fucoid sandstones" represent the lowest series of the fossiliferous rocks of South Wales.

In Bohemia, the primordial zone of Barrande, "Etage C," has a thickness of about 1200 feet.

The thickness of this zone in Spain seems to be very small. There are two bands representing the primordial rocks in that country. One has a thickness of about 40 metres, that of Sabero; and the other seems to have a like thickness. They may, however, be the same band repeated by a fault.

In America the Potsdam sandstones, or their representatives, have very variable thickness. In some spots they are not more than 20 feet in depth, while in other localities they are said to attain to several thousand feet of thickness.

In Wales, if we assume the strata to which the term Lingula-flags has been applied, and those which in South Wales occur in a lower horizon, to represent the Potsdam sandstones, then we attain to a thickness much exceeding even the most extensive development of these sandstones, since the Lingula-flags would afford us about 6000 feet of strata where they are best developed, to which we have to add from 3000 to 4000 feet for the St. David's rocks in which fossils occur, as shown by the labours of Mr. Hicks.

List of Memoirs published since 1862 *on the Rocks of the St. David's Promontory, and on their representatives in North Wales.*

1. Salter, Quart. Journ. Geological Society, Feb. 1863.
2. Hicks, Trans. of the Geol. Soc. of Liverpool, Dec. 1863.
3. Salter, Quart. Journ. Geol. Soc. 1864.

* The form *P. asaphoides,* Emmons, seems to be an *Olenus.*

4. Salter & Hicks, Report Brit. Assoc. 1865.
5. Salter & Hicks, Quart. Journ. Geol. Soc. 1865.
6. Plant, Quart. Journ. Geol. Soc., and Trans. Geol. Soc. Manchester, 1866.
7. Salter & Hicks, Report Brit. Assoc. 1866.
8. Salter & Hicks, Quart. Journ. Geol. Soc. 1867.
9. T. Belt, Geol. Magazine, 1867.
10. Davidson, Geol. Magazine, 1868.
11. Hicks, Report Brit. Assoc. 1868.
12. Salter & Hicks, Quart. Journ. Geol. Soc. 1869.

Descriptions *of* New Species *of* Fossils *from the* Longmynd Rocks *of* St. David's. By Henry Hicks, Esq.

Plutonia Sedgwickii, Hicks. Pl. XV. figs. 1–8.

A large Trilobite having affinities with *Paradoxides* and *Anopolenus* in the form of its glabella, but differing from them in having the whole of its surface covered with coarse tubercles or spines. No perfect specimens have been found, but numerous fragments, including glabella, cheeks, head-spines, and portions of the thorax. These, however, show a form nearly equal to *Parad. Davidis* in size; and it is therefore, next to that species, the largest Trilobite discovered in British Cambrian rocks. The head is semicircular, with a wide margin and tolerably long posterior spines. The glabella is large, strongly convex, wider than the cheeks, and reaches anteriorly to the frontal margin; it has three complete transverse lobes, and one incomplete lobe on either side, and is widest across the anterior lobe. Cheeks triangular. Eyes large, extending from near the anterior furrows of the glabella to about half of the length of the cheeks. The thoracic segments show also a strongly tubercular surface. The axis is wide and slightly convex. Pleuræ long and deeply grooved, and with the spines bent backwards.

Locality.—Headland near Nun's well, St. David's.

Paradoxides Harknessi, Hicks. Pl. XV. figs. 9–11.

Of this species the head and some fragments only have been found; but these show a species entirely distinct from any previously discovered in Britain, although resembling the Bohemian species *P. rugulosus*. The eyes reach the whole length of the cheeks, and are strongly raised at each extremity. The glabella is large, reaches far forwards, and is indented by three complete furrows, and two incomplete ones on either side.

Locality.—Headland near Nun's Well, St. David's, and on roadside between Solva and Whitchurch.

Conocoryphe Lyellii, Hicks. Pl. XVI. figs. 1–7.

An exceedingly well-defined species, and the earliest known of the genus. It occurs tolerably plentifully, and in a well-preserved state. Ovate in form, surface generally raised, and more or less convex. Length from $1\frac{1}{2}$ to 2 inches, breadth from 1 to $1\frac{1}{2}$ inch.

Head strongly marginate, semicircular, and with a smooth surface; angles produced into short spines, directed backwards. Glabella parabolic and convex, and indented by three very distinct lateral furrows which reach about one-third of the distance across. Cheeks wider than the glabella, and raised. Eyes situated at about one-third of the distance across from the glabella, and connected with the glabella by very strongly marked ocular ridges. The facial sutures run outwards and forwards above the eyes, and backwards below the eyes to the posterior margin, a little to the inner side of the spinous angles. Thorax consisting of fourteen segments; the axis is convex and tapers gradually towards the tail. Pleuræ less than half as long again as the rings of the axis, grooved deeply, and bent backwards from the fulcrum, which is situated about midway. Tail semicircular, with a tapering, strongly raised axis of four segments; limb marked with four distinct ribs. This species approaches nearer to *C. applanata* than to any other Cambrian species, but is of larger size, has the eyes placed much nearer the glabella, has shorter pleuræ, and a more strongly ribbed tail.

Locality.—A headland near Nun's Well, St. David's.

Conocoryphe solvensis, Hicks. Pl. XVI. fig. 8.

The head and a few thoracic segments only have been found; but these are sufficient to mark a new species, resembling in some respects the Bohemian species *C. coronata*. The head is semicircular, tubercular all over, and strongly marginate. Glabella small, reaching less than two thirds of the distance forwards, narrow anteriorly, and indented by three lateral furrows. A strongly raised boss occupies the place anterior to the glabella, and reaches from it to the margin, but is separated at the base from the glabella by a deep furrow. Cheeks more strongly convex than the glabella, and about twice as wide; the cheeks are wider than in *C. coronata*; and it seems altogether a wider form.

Locality.—Road-side between Solva and Whitchurch, St. David's.

Microdiscus sculptus, Hicks. Pl. XVI. figs. 9 and 10.

Differs from *Microdiscus punctatus*, the only other species found in Britain, by having the lobes of the tail distinctly ribbed and not punctated; is about equal to it in size.

Locality.—Headland near Nun's Well, St. David's.

Agnostus cambrensis, Hicks. Pl. XVI. figs. 11 and 12.

About one fourth of an inch long, and convex. Head longer than wide, and straight on the sides. Glabella occupying more than a third of the width, and divided at its anterior third by a transverse furrow. Tail nearly of the same shape as the head, with a wide axis centrally raised and indented by three furrows on each side.

Locality.—Headland near Nun's Well, St. David's.

Theca antiqua, Hicks. Pl. XVI. fig. 13.

About $\frac{3}{4}$ of an inch long; surface not corrugated, and extremity rather blunt. Differs from *Theca penultima* and *Theca corrugata* in having a smooth surface, and from *Theca stiletto* in being a larger and wider form, and with a blunt extremity.

LINGULELLA PRIMÆVA, Hicks. Pl. XV. figs. 13, 14.

Half an inch in length and about $\frac{1}{4}$ of an inch in width. Some of the valves show a tolerably convex form, and are marked with concentric lines of growth; most, however, are much compressed and drawn out of form by the cleavage which has affected the beds in which they occur. It is altogether a much larger species than *Lingulella ferruginea*, which also is found in the same beds. It is moderately plentiful in the red beds at the base of the purple sandstones at Caerfai, Nun's Well, and Porth Clais harbour, on the coast to the south of St. David's; but as the beds in each case are much cleaved, good specimens are seldom found.

LEPERDITIA? CAMBRENSIS, Hicks. Pl. XV. figs. 15–17.

Valves about $\frac{1}{4}$ of an inch long, by about $\frac{1}{6}$ of an inch in width. Some of the specimens show a reticulated ornamentation entirely distinct from the ordinary lines of growth in a *Lingulella*, which makes it probable that they belong to the genus *Leperditia*. In other respects the characters are rather indistinct; and though specimens are very plentiful in the red beds along with *Lingulella primæva*, the cleavage has so affected them that it becomes difficult to recognize their true form, or to note any special characters.

PROTOSPONGIA? MAJOR, Hicks. Pl. XVI. figs. 14–18.

The specimens figured under this name I have possibly incorrectly referred to the genus *Protospongia*; but as they approach nearer in character to that genus than to any other yet described from the earlier rocks, I may be pardoned for doing so in preference to making a new genus, where the nature of the fossil is so indistinct. The specimens, however, have very definite characters, and are entirely distinct from those markings so common in the Cambrian rocks, and usually classed together as worm-tracks. In many cases the lines cross each other at sharp angles; at other times a branching appearance is given; nearly all appear as if two flattened fibres were joined together longitudinally, one being wider than the other. At present only a few associated beds, almost immediately below those containing *Plutonia Sedgwickii*, have yielded these fossils; but in them the markings are very plentiful, covering, indeed, almost the whole surface of the beds. One specimen, however (fig. 18), was discovered by me some time since in the "Menevian group." Fig. 19 represents *Protospongia? flabella*, Hicks, a Menevian species, but placed here for comparison; it certainly in some characters resembles *Protospongia? major*, and is most likely connected with it generically. Fig. 20 represents *P. fenestrata*, Salter, also a Menevian species, and the first described of the genus. In this species the fibres do not show the longitudinal lines always present in *Protospongia major,* nor are they flattened; but in this specimen the fibres are much larger than in the one figured by Mr. Salter in Quart. Journ. Geol. Soc. vol. xx. pl. xiii.

EXPLANATION OF PLATES XV. AND XVI.

(*Illustrative of Fossils from the Longmynd Rocks of St. David's.*)

Plate XV.

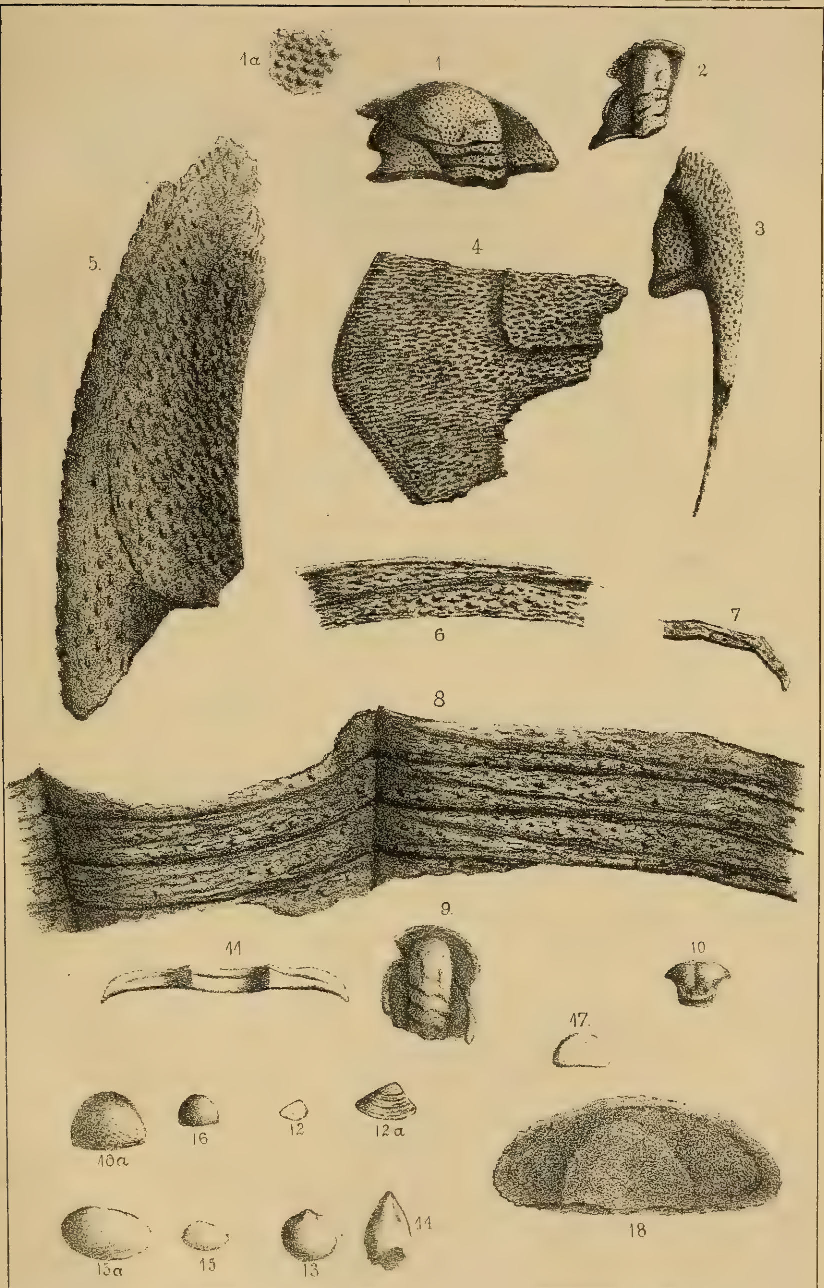
Fig. 1. Head of *Plutonia Sedgwickii,* Hicks.
1 *a.* Portion of the same, magnified.
2. Head (small) of *Plutonia Sedgwickii.*
3. Free cheek of *P. Sedgwickii.*
4. The same, large size.
5. Margin of the head of a large specimen of *P. Sedgwickii.*
6, 7, 8. Pleuræ and part of the axis of *P. Sedgwickii.*
9. *Paradoxides Harknessi,* Hicks, head of.
10. —— ——, labrum.
11. —— ——, a thoracic segment.
12. *Discina pileolus*? Hicks, from the red rocks at the base of the purple sandstones.
12 *a.* —— ——, magnified.
13 and 14. *Lingulella primæva,* Hicks.
15, 16, 17. *Leperditia*? *cambrensis,* Hicks.
15 *a,* 16 *a,* 17 *a.* —— ——, magnified.
18. Part of the head of a Trilobite from a bed at the base of the purple rocks, about 3000 feet below the "Menevian group."

Plate XVI.

Fig. 1–4. *Conocoryphe Lyellii,* Hicks.
5–7. —— ——, narrower form.
8. —— *solvensis,* Hicks, head of.
9. *Microdiscus sculptus,* Hicks.
9 *a.* —— ——, magnified.
10. —— ——, tail of.
10 *a.* —— —— tail of, magnified.
11. *Agnostus cambrensis,* Hicks, head of.
11 *a.* —— ——, head of, magnified.
12. —— ——, tail of.
12 *a.* —— ——, tail of, magnified.
13. *Theca antiqua,* Hicks.
14–17. *Protospongia*? *major,* Hicks, from the Longmynd Rocks, St. David's.
18. —— ——, from the "Menevian Group," St. David's.
19. *Protospongia*? *flabella,* Hicks, from the "Menevian Group," St. David's.
19 *a.* —— ——, portion magnified. St. David's.
20. —— *fenestrata,* Salter, from the "Menevian Group," St. David's.

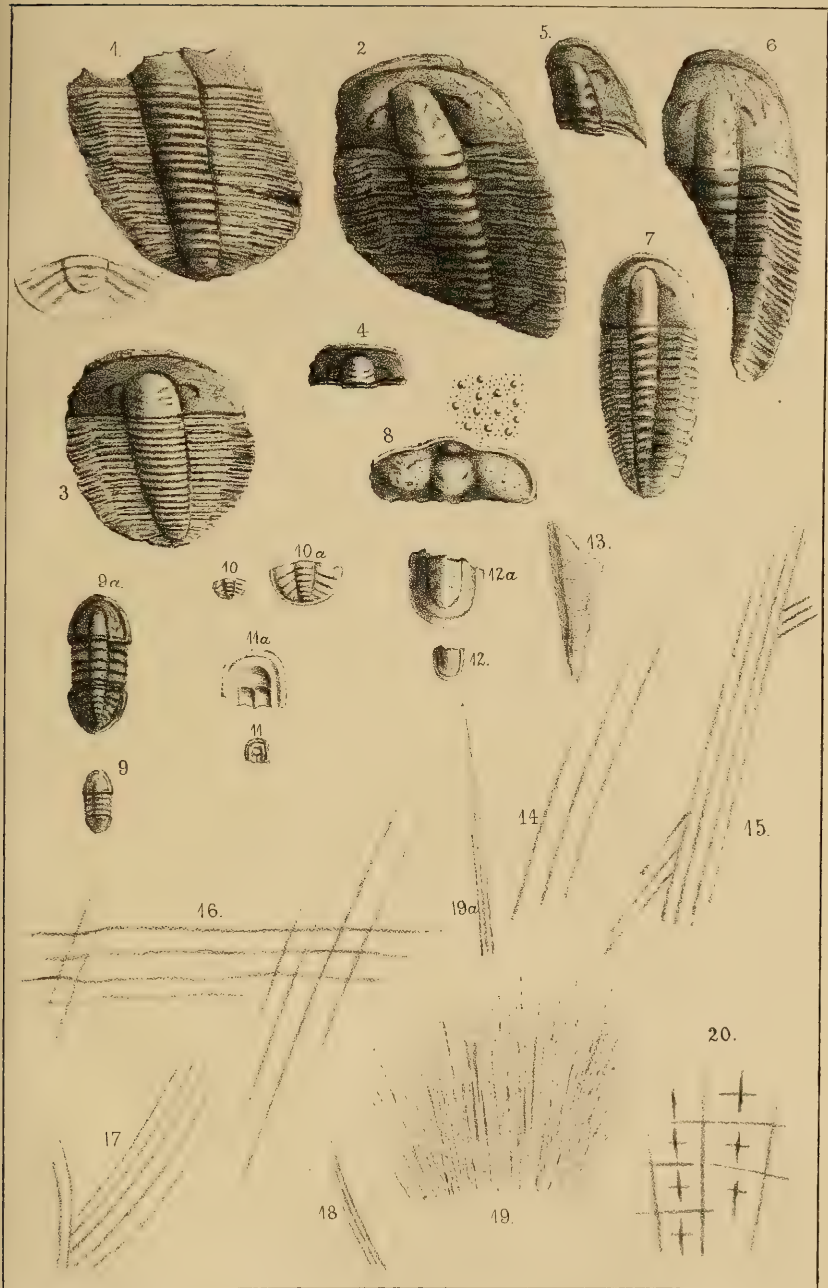
Discussion.

Mr. Hughes bore testimony to the admirable work done by Mr. Hicks, who had, almost unaided, worked out the geology of that district. Allowing that many subdivisions and new specific names had with great advantage been introduced into petrology, he de-



G. R. De Wilde del. et lith. Mintern Bros imp.

LOWER CAMBRIAN FOSSILS FROM St. DAVID'S.



G. R. De Wilde del. et lith.

Mintern Bros imp.

LOWER CAMBRIAN FOSSILS FROM S^t. DAVID'S.

fended the Survey nomenclature by reference to the then received definition of Syenite and Greenstone, terms still imperfectly understood and applicable to the main mass of the rocks in question, though possibly subsequent closer examination and new sections may have rendered some modification of the boundary line desirable. He was prepared to allow the metamorphic origin of all rocks of the classes under consideration, but did not think there was sufficient evidence to show that the divisional planes in the Syenite and Greenstone of St. David's were due to original stratification ; but they might correspond rather to the great joints of most granites. Mr. Hughes pointed out that the conglomerate contained fragments of the hornstone and quartz of this older series, which he considered was probably part of an old ridge or shoal, possibly of Laurentian, but certainly of Pre-Cambrian age, and thought that there were slight differences in the lithological character of the beds on either side, such as might be explained on this supposition. He agreed with Prof. Ramsay in thinking that there was evidence of the proximity of land in early Cambrian times, but was not prepared to refer these red rocks to inland seas or lakes as opposed to open sea ; the whole seemed rather the deposit of an open sea encroaching during submergence. He did not attach very much importance to the restriction of genera to limited horizons in these older rocks of St. David's ; for, as it was reserved for Mr. Hicks to discover these fossils after so many other observers had examined the district, he anticipated that further researches must certainly result in finding links which will connect together more closely beds the stratigraphical relations of which seem to indicate so clearly an unbroken though varying series.

Mr. Gwyn Jeffreys had been struck by the intercalation of non-fossiliferous beds from time to time among the fossiliferous beds described in the paper. Beds now in course of formation contained also very few, if any, organisms, apparently in consequence of the great deposits of mud brought down by rivers and redeposited in certain parts of the sea-bed. That this was the case had been proved by recent dredging-operations both in the Atlantic, off the coast of Spain, and in the Mediterranean.

Mr. Boyd Dawkins called attention to the extension of the Molluscoida, Annulosa, and Mollusca, deep down in the Cambrian rocks, and yet without any trace of their convergence. The origin of life might be as far removed from that period as was the Cambrian from the present time. The difference in the colours of the rocks he was inclined to refer to the different degrees of oxidation of the iron they contained, which might supervene in a comparatively short time.

The Rev. W. S. Symonds had, in visiting the spot, been much struck by the rocks, at that time termed Syenite, which he believed might be an extension of those on the Carnarvonshire peninsula, and which he thought supported the whole series of the Cambrian rocks, so that they might after all be the Laurentian, the same as those of Sutherlandshire and Assynt. If this were the case the nomenclature of the Geological Survey would have to be altered, and the rocks of Pistyl and Holyhead no longer termed metamorphosed Cambrian rocks, but Laurentian.

Mr. Hicks, in reply, stated that the quartziferous breccias forming the central ridge contained so many rolled pebbles, and were, moreover, in places so distinctly bedded, that there could be no doubt of their being sedimentary. Other beds, described as Greenstone in the maps of the Geological Survey, were also distinctly laminated. The non-occurrence of fossils in the more sandy beds he attributed to their having been deposited in very shallow water. The fossils occurred principally in fine-grained beds of a flaggy nature.

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2. *On the* Age *of the* Nubian Sandstone. By Ralph Tate, Esq., Assoc. Linn. Soc., F.G.S.

Mr. Bauerman, in a recent number of the Quarterly Journal of this Society (vol. xxv. p. 27), has discussed at some length the opinions advanced respecting the age of the sandstone strata underlying the Cretaceous limestones, and resting upon the granitic and schistose rocks, in Sinai. These rocks belong to the same series of sandstones described by Russegger as occurring in Egypt, Nubia, and Arabia Petræa, under the name of "Nubian Sandstone."

Though the facts that I have the honour to submit to the Society may be stated in a few words, yet it seems desirable to recapitulate briefly the views that have been advanced as to the period of deposition of the strata in question, the better to explain away those inferences which are so much at variance with my own.

In the first place, it appears, from the circumstance of the Nubian Sandstone being overlain conformably by approximately horizontal strata of Cretaceous age, that this formation has been regarded, in the absence of palæontological evidence to the contrary, as forming part of the Mesozoic group of rocks. Thus Russegger colours and describes it as Lower Cretaceous in his maps; and Bauerman, guided by the lithological similarity of its strata to the Lower New Red Sandstone about Chester, has placed it on the horizon of the Trias; whilst Figari Bey seems to have regarded the tripartite arrangement and lithological features of the series as sufficient tests by which to assign the whole to the Trias, "taking the limestone as representing the Muschelkalk, although the evidence for this determination (other than lithological character) is not very clear"*.

In the second place, the fossils which have been obtained from the limestone separating the sandstone into two great masses are, for the most part, fragmentary, in bad condition, or otherwise undeterminable. Hence the palæontological evidence is of a most con-

* Bauerman, *loc. cit.* p. 27.

tradictory nature; indeed the generic names assigned to the fossils seem to have been given in accordance with their presumed age as determined by the lithological characters and physical conditions presented by the containing rocks, rather than as interpretations of zoological affinities.

Thus the Encrinites which occur in the Nasb-valley limestone are represented by fragments of cylindrical stems, and do not admit of generic determination. The Ammonite, the only fossil mentioned by Figari Bey, is not named specifically; and I have reason to doubt the correctness of its identification, and suspect that it may have been either a *Nautilus* or a Goniatite. Mr. Etheridge and Figari Bey have referred the fossils brought under their notice to Secondary genera, *Encrinus* and *Ammonites*; whilst Mr. Salter assigned the Encrinite stems to the Carboniferous genera *Rhodocrinus* and *Poteriocrinus*, and adds to the list the Gasteropod genera *Murchisonia* and *Eulima* (?), which latter are Triassic as well as Carboniferous.

So that really it has hitherto been difficult to express any very decided opinion on the age of the Nubian Sandstone, owing to the great want of palæontological evidence. Conclusive evidence of the Carboniferous age of the series, however, has been recently brought to light. Captain Wilson and the Rev. F. W. Holland, of the Sinai Ordnance Survey, have placed in my hands a block of limestone from the Nasb-valley section (*vide* Bauerman, *loc. cit.* p. 26) in the hope that it would yield evidence of its age, and so of the associated sandstones.

One fossil only, in a good state of preservation, was contained in the mass; this I at once named *Orthis Michelini*, a well-known fossil of the Carboniferous Limestone; but that the specific determination might be indorsed by the greatest authority on the fossils of the class to which it belongs, and so acceptable as indisputable evidence, I submitted the specimen to Mr. Thomas Davidson, who obligingly writes, that the "inclosed fossil is certainly *Orthis Michelini*, as *you* correctly identify it." With this valuable index to the age of the limestone, the obscure forms associated therewith may be approximately assigned to the genera indicated by Mr. Salter, who thereupon referred these beds to the Carboniferous epoch.

Mr. Salter * has moreover described a *Lepidodendron* from Sinai as a new species, under the name of *L. Mosaicum*; and though neither the locality nor the stratigraphical position of the fossil was known to him, yet, as it is preserved in sandstone, we cannot hesitate in referring it to one or the other of the arenaceous members of the Nubian Sandstone; and the Rev. F. W. Holland was fortunate in obtaining a portion of a Sigillarian stem from the Wady Mokatteb, which, though not collected *in situ*, bears unmistakable evidence of having been enclosed in the sandstone forming its cliffs. The sandstone in this valley is overlain by Cretaceous limestone, and is presumably referable to the Upper Sandstone of the Carboniferous series of this region.

* Quart. Journ. Geol. Soc. vol. xxiv. p. 509.

I append a list of the organic remains from the "Nubian Sandstone" series:—

!	Orthis Michelini	Wady-Nasb Limestone.
!	Streptorhynchus crenistria	" "
!	Spirifera (fragments of)	" "
*	Murchisonia	" "
*	Eulima?	" "
*	Rhodocrinus	" "
!*	Poteriocrinus	" "
*	Lepidodendron Mosaicum	Wady-Nasb Sandstone.
!	Sigillaria, sp.	" "

[The sign ! prefixed to the names of the fossils indicates that the specimens were collected by the Sinai Survey; and the sign * indicates the determination of Mr. Salter.]

In conclusion I venture to suggest that the Adigrat Sandstone in Abyssinia, described and so named by Mr. W. T. Blanford†, is of the same age as the Nubian Sandstone. It appears to have escaped the notice of that author that the Sandstone of Adigrat is similar in character and general appearance to the Nubian Sandstone, and that it, moreover, overlies the schistose rocks in the same manner, and contains iron-ore and psilomelane, as in Sinai. Mr. Blanford surmises, however, that "both the coal-bearing beds of Chelga and the Adigrat Sandstone may belong to a portion of the great series associated with [Triassic] coal in India" (*loc. cit.* p. 175); but the Talcheer and other coals are referred by Messrs. Blanford and Theobald to a Permian age (Mem. Geol. Surv. India, vol. i.).

Note.—My attention has been called since the reading of this paper to Prof. Unger's observations on the Fossil Wood from Assuan and Um-Ombos, in the Nile valley (Quart. Journ. Geol. Soc. vol. xv. Misc. p. 13, 1859). The wood belongs to a coniferous tree of the Araucarian division, and is named *Dadoxylon œgyptiacum*; its habitat is assumed "to be the sandstone, which occurs extensively in Upper Egypt and Nubia, between the granite and Cretaceous beds," in which case *Dadoxylon œgyptiacum* was contemporaneous with *Lepidodendron mosaicum* and *Sigillaria*. Prof. Unger argues, from the presence of this genus, that the sandstone, "hitherto of doubtful rank in the geological series, as no organic remains have been found in it," should be ranked in the Permian, rather than in the Keuper or the Cretaceous formation; but from the palæontological evidence alone he might have argued equally in favour of its Carboniferous age.

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3. *On the* Discovery *of the* Glutton (Gulo luscus) *in* Britain. By W. Boyd Dawkins, Esq., M.A., F.R.S., F.G.S.

The caves in the Mountain Limestone which forms the magnificent gorge of the Elwy, near Cefn, St. Asaph, have furnished from time

† Geology and Zool. of Abyssinia, p. 170.

to time a remarkably complete series of pleistocene mammals. That which opens on the terraced side of the cliff in the grounds of Cefn, first described by the Rev. E. Stanley in 1833, and subsequently by Dr. Falconer, contained abundance of Reindeer, associated with Cave-lion, Cave-bear, Grizzly Bear, Hyæna, *Elephas antiquus*, *Hippopotamus major*, *Rhinoceros tichorhinus*, and *R. hemitœchus*. And nearly all these animals occurred in a second cave, at Cefn, explored by Mr. Williams Wynn in 1869–70. A third cave, at Galtfaenan, explored last winter by Mr. Mainwaring and Mr. Hughes, has furnished the remains of Reindeer and Bear, and the traces of Hyænas; while a fourth, at Plas Heaton, in part dug out by Mr. Hughes and Mr. Heaton, has yielded Wolf, Bison, Reindeer, Horse, and Cave-bear, and a remarkably fine lower jaw which proves that the Glutton inhabited Great Britain during the pleistocene, or quaternary age. Mr. Ayshford Sanford and myself had, indeed, obtained, in 1865, the crowns of three canines from the caves of Banwell, and Bleadon, and of Gower, which belonged to this animal; and we accordingly inserted it, without figure or description, in the list of the British Pleistocene Mammals, published by the Palæontographical Society in 1866. This discovery at Plas Heaton renders any doubt as to its being a true pleistocene British species altogether impossible.

The jaw consists of the left ramus, docked of the angular and articular portions, which are broken off close behind the first true molar. On comparison with the lower jaws of the Glutton in the British Museum, from Norway, and also from the caves of Gailenreuth and Sundwig, I find that the Welsh specimen is slightly larger than the latter, and considerably larger than those of the animal now living in Europe. With this exception, there is not the slightest difference between them. The peculiar ridging and grooving of the inner side of the alveolar border, which at first sight appears as the accidental result of the inflammation of the periosteum, is common to all which I have examined; and, taken in combination with the great alveolar width, affords a means of determining at once a fragment of the jaw from that of any other animal. The premolar and molar series, also, are crowded together in a very short alveolar space, and occupy the upper and outer margin of the jaw, instead of occupying its superior surface, as in the majority of the carnivores. The peculiar wrinkled pattern of the enamel separates the teeth at once from those of any carnivore which are likely to be confounded with them, except the Hyæna, which is put out of court by the larger size and different form of all its teeth except the upper incisor 3, and the first upper premolar. The first of these bears a strong superficial resemblance to the canine of the Glutton, but is differentiated by the enamel surface of the latter being more deeply and irregularly grooved, and by the cingulum passing from the posterior to the anterior ridge being much less prominently developed. The upper premolar 1 of Hyæna can be determined at once from the second lower premolar of the Glutton, which it closely resembles in its single fang and procumbent form, by the crown of the latter being set on the fang much more obliquely, and by the obtusely pointed apex rising abruptly from the anterior border instead of sweeping nearly equally upwards from the posterior and anterior borders. The premolar series of the Glutton may be separated from that of the Canidæ and Felidæ by the great transverse thickness of its teeth, and the absence of the anterior and posterior accessory cusps. The first lower true molar is distinguished at once from that of the Canidæ by the stoutness and obtuseness of the two sectorial blades, and by the non-development of a cusp on the postero-inner edge of the base of the posterior blade. The tubercular portion also of the Glutton is much smaller and more talon-like (consisting of a very obtuse triangular cusp) than in any of the Canidæ. With these exceptions, I do not know of the teeth of any carnivore with which those of the Glutton under consideration can be confounded.

The following Table shows the relation of the lower jaw of the Glutton from Plas Heaton to those found in the caves of Germany, and to a recent specimen preserved in the British Museum. The Welsh fossil in every dimension is larger than any of the rest, and must have belonged to an animal proportionally more robust than any of the others. The measurements are taken in decimals of an inch.

		Plas Heaton Cave.	Gailenreuth Cave.	Sundwig Cave.	Sundwig Cave.	Living, 42.3.13.
Alveolar space occupied by molar series from Pm. 2 to M. 1		1·95	1·9	1·85	1·86	1·72
Depth of ramus beneath Pm. 2		1·1	0·95	0·98	0·95	0·9
Depth of ramus beneath M. 1		0·96	0·88	0·96	0·95	0·85
Length of crown of canine		0·8	0·82			
Pm. 2.	Antero-posterior measurement	0·29	0·24	0·24	0·28	0·25
	Transverse ,,	0·2	0·19	0·18	0·18	0·15
	Height	0·2	0·15	0·16	0·15	0·15
Pm. 3.	Antero-posterior measurement	0·36	0·36	0·35	0·35	0·34
	Transverse ,,	0·24	0·23	0·21	0·2	0·2
	Height	0·24	0·23	0·21	0·22	0·2
Pm. 4.	Antero-posterior measurement	0·5	0·5	0·5	0·45	0·49
	Transverse ,,	0·3	0·29	0·26	0·29	0·25
	Height	0·3	0·29	0·29	0·28	0·26
M. 1.	Antero-posterior measurement	0·95	0·92	0·88	0·9	0·82
	Transverse ,,	0·42	0·4	0·38	0·4	0·34
	Height	0·42	0·4	0·4	0·4	0·36+

I am able to detect no specific difference between the *Gulo spelæus* of Goldfuss, from Germany, and the living form, *Gulo luscus* of Linnæus. The fossil carnivore was larger than the living, probably because in pleistocene times the competition for life was not so keen as it is now among the mammalia. Man in those early times had not increased and multiplied to such a degree as to upset the œconomy of nature, by driving the wild animals away from their feeding-grounds, and robbing the carnivores of a large portion of their food. To this cause I should assign the larger size of nearly all the pleistocene mammalia, as compared with those which are undoubtedly their lineal descendants, such as the Cave-lion, the Cave-hyæna, and the Stag.

The Glutton at the present day inhabits the inclement northern regions of the Old World, to the point where the forests gradually die down into the lonely wastes of the "Tundras," and is to be found in Norway, Sweden, Lapland and as far east as Kamtschatka. In the New World it ranges, under the name of Wolverine, northwards from the latitude of Canada. It was seen by Ross in the 70° parallel in the winter; and its bones have been met with in Melville Island. Its southern limit in Asia is the latitude 50°, where it occurs in the Altai. In Europe its southern limit is not clearly defined; but it has steadily retreated northwards as the vast forests of Germany and Poland gradually fell under the axe of the woodman. According to Eichwald, it once lived in the Lithuanian region along with the Bison, which still lingers there under the protection of an Imperial ukase; and Zimmermann adduces proof of its having been killed as far south as Helmstadt, in Brunswick*. In the pleistocene caves of Germany it is found abundantly, with the Reindeer, Cave-lion, and Hyæna, at least as far south as Gailenreuth, in Bavaria, where it was first discovered by Dr. Goldfuss. It is figured and described from the caves of Belgium by Dr. Buckland's great rival, Dr. Schmerling. We might therefore naturally expect to find the animal ranging over our island at a time when it formed part of the mainland of Europe, and offered free access to the same animals (the Reindeer, the Lemming, and the Horse) as those which still furnish food to the living Glutton in Siberia. The presence in Great Britain of a creature adapted for enduring the severity of an Arctic winter, and not now found in any hot regions, along with the Rein-deer, Lemming, and Musk-Sheep, implies that the pleistocene winters were of an Arctic severity—just as the Hippopotamus, found under precisely the same conditions, and associated with the same group of animals, points to a hot summer like that which obtains on the Lower Volga. The intimate association in one spot of animals now confined respectively to the hottest and coldest regions seems to me to admit of no other explanation.

I have added to this essay a list (see p. 410) of the pleistocene animals found in the various caves hitherto explored in the valley of the Elwy, as supplementing the Table of the Distribution of the British mammals published in the Quarterly Journal, May 1869.

* The authorities consulted for the range of the Glutton are Blasius (Fauna der Wirbelthiere Deutschlands), Zimmermann (Specimen Zoologiæ Geographicæ), and Sir John Richardson (Fauna Boreali-Americana).

	Cefn No. 1.	Cefn No. 2.	Galtfaenan.	Plas Heaton.
Ursus spelæus	*	*	?	*
—— ferox	*	*	?	
Gulo luscus	...	...	...	*
Meles taxus	*	...	...	*
Canis vulpes	*	*	...	*
—— lupus	*	*	...	*
Hyæna spelæa	*	*	*	*
Cervus tarandus	*	*	*	*
—— elaphus	*	*		
Bison priscus	*	*		
Hippopotamus major	*	*		
Equus caballus	*	*		
Rhinoceros hemitœchus	*	*		
—— tichorhinus	*			
Elephas antiquus	*	*		
Arvicola amphibia	*			

From this list all reference to the series of prehistoric mammalia, and to the traces of prehistoric man, has been omitted.

Discussion.

Mr. Hughes indicated the exact position in which the jaw of the Glutton was found, but pointed out that, owing to the excavations of keepers, Badgers, Rabbits, &c., the earth was so much disturbed in that part that it was impossible to be sure of the original relative position of the bones. He showed that the Plas Heaton Cave was on a hill rising from the top of the plateau, while the Cefn, Brysgill, and Galtfaenan Caves were in the gorge cut through that plateau, and therefore that the Plas Heaton Cave was probably formed, and might possibly have been first occupied, at a much earlier period than the others. As it appeared to pass under that part of the hill which is overlapped by heavy drift, he thought it quite possible that this may have been a preglacial cave, and that by-and-by we may find evidence of a preglacial fauna in it.

The Rev. W. S. Symonds mentioned that in some of the pot-holes in the roof of the Cefn cave he had procured silt containing remains of shells determined by Mr. Jeffreys to be marine.

Mr. Hughes explained that these shells had probably been washed in from the superficial marine drift of the district.

Mr. Dawkins, in reply, expressed his belief that though the excavation of the caves in question might have taken place at different periods, yet that their occupation was, geologically speaking, contemporaneous.

TABLE I.

May 24, 1871.

George Mosley, Esq., 7 St. Paul's Square, York; Alexander Colvin, Esq., B.A., of Barham Lodge, Weybridge; Thomas Shepherd Noble, Esq., F.R.A.S., Lendal, York; and Edward Charles Davey, Esq., of Wantage, were elected Fellows of the Society.

The following communications were read:—

1. *On the* Principal Features *of the* Stratigraphical Distribution *of the* British Fossil Lamellibranchiata. By J. Logan Lobley, Esq., F.G.S.

Having been engaged for some years past in investigating the organic contents of British strata, and in the enumeration of the species which have been recorded as occurring in each geological formation, I am enabled to bring before this Society a summary of the stratigraphical distribution of the remains of one of the classes of the Mollusca, the Lamellibranchiata, as far as it is at present known.

The results here presented are submitted with confidence in their reliability as being approximately correct to the present time, since well authenticated species only have been retained in my lists, and extreme care has been taken to exclude those numerous synonyms which are so frequently productive of incorrect conclusions.

The class Lamellibranchiata of De Blainville, or Conchifera of Lamarck, is represented in British strata so abundantly that the genera alone number nearly two hundred. I will not here attempt to give the details of the range and distribution of these very numerous genera, but confine myself at the present time to the consideration of the principal groups of the class.

The classification of the Lamellibranchiata that will be followed is founded on that of Lamarck, and differs little from the one given in the excellent and much used Woodward's 'Manual of the Mollusca.'

In the accompanying Tables the usual geological scale has been adopted. The term *Silurian* is intended to embrace all the rocks included by Murchison in this "System," namely, from the Lingula Flags to the Passage Beds. *Triassic* includes the Rhætic Beds, and *Jurassic* the Lias and the Oolites.

Table I. (opposite) is intended to show the stratigraphical range as well as the increment, decrement, maximum development, and relative numerical importance of the representation, in our area, of each of the *families* of the Lamellibranchiata, remains of which occur in the fossiliferous rocks of the British Islands.

In this Table an asterisk standing alone indicates the occurrence of a number of species not exceeding ten, two asterisks indicate the occurrence of more than ten and less than twenty species, three asterisks more than twenty and less than thirty, and so on, each asterisk after the first representing ten species. The number of

TABLE I.

Families.	Silurian.	Devonian.	Carboniferous.	Permian.	Triassic.	Jurassic.	Cretaceous.	Tertiary.
ARCADÆ (including *Nuculidæ*)	**** 37	** 14	***** 53	* 7	* 4	*********** 107	***** 60	******* 75
CARDIADÆ	* 5	* 2	** 12		* 1	**** 35	** 16	**** 32
ASTARTIDÆ	* 2	* 2	* 10	* 2	* 2	********* 87	*** 28	******* 62
MYTILIDÆ	**** 39	** 11	****** 55	* 1	* 3	******** 76	*** 23	**** 33
AVICULIDÆ	**** 35	** 15	*************** 151	* 4	* 6	*********** 112	****** 70	* 10
CYPRINIDÆ	* 3	* 1	* 7	* 1	* 5	****** 53	** 14	** 13
TRIGONIADÆ	* 5	* 6	** 18	* 1	* 6	**** 39	** 18	* 2
ANATINIDÆ	* 4	* 2	***** 43	* 4	* 4	************* 132	** 22	** 23
TELLINIDÆ	* 1	* 2	* 5	* 2		** 14	* 10	******* 62
UNIONIDÆ		* 1	* 3			* 3	** 12	** 14
MYADÆ		* 1	*** 23		* 2	*** 25	*** 22	***** 48
SOLENIDÆ		* 1	* 1			* 1	* 1	*** 24
VENERIDÆ			* 6		* 1	** 15	*** 24	****** 55
PECTINIDÆ			* 6	* 2	* 9	************** 163	********* 99	**** 38
LUCINIDÆ			* 5			***** 42	** 17	****** 53
OSTREIDÆ (including *Anomiidæ*)			* 1		* 6	******** 79	****** 58	**** 33
MACTRIDÆ			* 3			* 8	* 4	*** 26
PHOLADIDÆ			* 1			* 4	* 8	** 13
GASTROCHÆNIDÆ						* 5	* 8	** 13
CYRENIDÆ						* 8	* 7	*** 28
CHAMIDÆ							* 2	* 5
HIPPURITIDÆ							* 1	

species is also indicated by numerals; but it is not intended that these numbers are to be regarded as other than a record of what has been already arrived at by palæontological investigation. Further research will add much to our knowledge not only of the forms contained in each series of strata, called by the not altogether satisfactory name formation, but also of the generic and family affinities of the species at present recorded.

The names of the families are arranged in the order of their incoming or earliest appearance in British strata. We can thus see at once the relative antiquity of the various families, so far as it is indicated by the results of research confined to the British area.

From this Table it will be seen that all the genera represented in our rocks may be classed under twenty-two heads, or patronymic designations. As no species of the family *Tridacnidæ* has yet been discovered in British strata, that name does not appear in the table. Though not occurring in the strata of these islands, species of *Tridacna* are found in the Miocene deposits of Poland.

The first family mentioned in Table I., the *Arcadæ*, ranges from the Llandeilo rocks to the most recent, and has species living in our present seas. The maximum development of the *Arcadæ* was in the Jurassic epoch, though the species from any one formation of that system of rocks are not equal in number to those from the Carboniferous Limestone. A large number of species of *Arcadæ*, chiefly of the typical genus *Arca*, have been taken from the Cretaceous strata, and a still larger number (upwards of seventy) from Tertiary deposits.

The *Cardiidæ* and *Astartidæ* also commence in the Llandeilo rocks, and have equal ranges with the *Arcadæ*, though not a similar distribution. The former of the two families, *Cardiidæ*, did not attain its greatest development until the Older Pliocene or Crag period, while the Inferior Oolite has hitherto yielded the largest number of species of *Astartidæ*, though the specific forms of this family are almost equally numerous in the Older Pliocene deposits. But though the maximum number of species of *Astartidæ* have been obtained from a Tertiary formation, the Jurassic system gives us a much greater number of species than all the Tertiary formations. With the exception of the Carboniferous Limestone, the Palæozoic rocks have furnished us with few species of either *Astartidæ* or *Cardiadæ*.

Four families, the *Mytilidæ*, *Aviculidæ*, *Cyprinidæ*, and *Trigoniadæ*, commence their ranges in Caradoc strata; and two of the four (*Mytilidæ* and *Aviculidæ*) are represented by a considerable number of species in those rocks. In the Devonian system the *Mytilidæ* are sparingly represented; but when we rise to the Carboniferous Limestone we find this family largely developed. The Jurassic rocks, however, yield the greatest number of species of *Mytilidæ*, upwards of seventy having been described from the Jurassic strata of Britain. A much smaller number have been found in Cretaceous and Tertiary deposits, though the typical genus of the family, *Mytilus*, is abundant at the present day in the form of the common mussel (*Mytilus edulis*).

The distribution of the *Aviculidæ* is very extraordinary, since we find in one formation, the Carboniferous Limestone, a singularly great development of one of the genera of the family, the *Aviculopecten* of M'Coy. The number of species of *Aviculopecten* taken from these rocks amounts to upwards of eighty. These with the species of the other genera of the *Aviculidæ* found in the Carboniferous Limestone make up a total of about 150 species of this family which have been furnished by the Mountain or Carboniferous Limestone of the British Islands. Compared with the enormous development of the *Aviculidæ* in Carboniferous strata, the family is very moderately represented in Jurassic and Cretaceous rocks, while Cainozoic deposits have yielded not more than one or two species. Indeed the representation of the *Aviculidæ* is as remarkably small in the Tertiaries as it is remarkably great in the Carboniferous rocks.

The *Cyprinidæ*, though ranging from Lower Silurian rocks, are not represented by a large number of species in any formation; and the family attains its maximum development in the Jurassic system.

Though the typical genus of the *Trigoniadæ* is characteristic of Mesozoic strata, yet we have a genus, *Lyrodesma* (represented, however, by only one species, and placed by Bronn amongst the *Arcadæ*), carrying the range of this family down to the Caradoc rocks. The greatest number of species of *Trigoniadæ* have been furnished by the Inferior Oolite; and these are all of one genus, and that the typical one of the family, *Trigonia*. Although the genus *Trigonia* has not been found in any other rocks than those of Mesozoic age, yet living *Trigoniæ* inhabit the waters on the coasts of Australia.

One or two species of the family *Anatinidæ* have been found in Silurian rocks, and not more in Devonian strata; but the Carboniferous Limestone has given us upwards of forty species. By far the greatest number of species, however, have been taken from Jurassic rocks, which have yielded upwards of one hundred and thirty species of this family. A great decrement is found in the Cretaceous system, which gives us about an equal number of species of *Anatinidæ* with the Tertiary deposits.

The *Tellinidæ* are very few in the Palæozoic and Mesozoic rocks, and attain their maximum development in Middle Eocene strata, in which the specific forms of the typical genus *Tellina* are very numerous.

The estuarine and fluviatile *Unionidæ*, as might be expected, are not numerous in the stratified rocks of Britain, which are chiefly of marine origin. The estuarine Wealden deposits furnish us with the greatest number; and the fluviatile beds of the Newer Pliocene yield several species of *Unionidæ*.

The *Myadæ* commence with a species of *Corbula* in the Middle Devonian, and have but a moderate number of species in any formation. They attain their greatest development, both of generic and specific forms, in the Tertiary strata.

Of *Solenidæ*, the species in any rocks older than those of Tertiary age are very rare. These later deposits, however, have given us upwards of twenty species of this family.

No fewer than six families, the *Veneridæ*, *Pectinidæ*, *Lucinidæ*, *Os-*

TABLE II.

Orders or Sections.	Silurian.	Devonian.	Carboniferous.	Permian.	Triassic.	Jurassic.	Cretaceous.	Tertiary.
ASIPHONIDA	************	*****	*****************************	**	****	**	**********************************	*********************
	116	47	282	15	34	579	340	205
SIPHONIDA	**	**	************	*	**	***	*******************	**
	15	11	116	9	15	429	184	457

TABLE III.

Class.	Silurian.	Devonian.	Carboniferous.	Permian.	Triassic.	Jurassic.	Cretaceous.	Tertiary.
LAMELLIBRANCHIATA - - -	**************	******	***************************************	***	*****	**	**	**
	131	58	398	24	49	1008	524	662

treidæ, *Mactridæ*, and *Pholadidæ*, commence their ranges in the Carboniferous Limestone. Of these six families, four (*Veneridæ*, *Lucinidæ*, *Mactridæ*, and *Pholadidæ*) attain their maximum development in the Tertiaries, and two (*Pectinidæ* and *Ostreidæ*) in Jurassic strata.

The small family *Gastrochænidæ*, of which but few species have been found in British strata, has its earliest representative in the Lias, and its greatest number of species in Tertiary strata.

The fluviatile *Cyrenidæ* also range from the Lias, and, like the *Gastrochænidæ*, have their maximum development in the Tertiaries.

The remaining two families, *Chamidæ* and *Hippuritidæ*, are numerically unimportant, and yet are structurally perhaps the most remarkable of all the Lamellibranchs, some of the forms of *Chamidæ* strongly resembling Gasteropods, and the *Hippuritidæ* being so abnormal in form and structure as to have been for a long time considered a separate order, the *Rudistes* of Lamarck. The *Hippuritidæ* are also of great interest, as being the only extinct family of the Lamellibranchiata as yet discovered. They are represented in the British Islands by only one species, the *Hippurites*, or *Radiolites Mortoni* of Mantell; and this species is confined to the Upper Greensand and Chalk.

Though we are able somewhat satisfactorily to divide the Lamellibranchiata into families, there are not sufficiently good distinctions for ordinal divisions. The fact of some genera, however, having only one adductor muscle has been seized as a basis on which a division of the class into the orders, groups, or sections *Monomyaria* and *Dimyaria* has been made. This division, though perhaps not a sufficiently scientific or philosophical one, is in some respects convenient, and it has been adopted by several authors.

A better division of the Lamellibranchiata than into *Monomyaria* and *Dimyaria* is perhaps that founded on the possession, by a large number of genera, of respiratory siphons, and some being unprovided with those organs. This great structural difference naturally divides the class into *Asiphonida* and *Siphonida*—the *Siphonida*, or those furnished with respiratory siphons, including by far the greater number of genera. These two great sections of the class have an equally extended range; but the *Asiphonida* have their greatest development in Jurassic rocks, while the greatest number of species of *Siphonida* have been furnished by Tertiary strata. It may be mentioned, however, with respect to the former section, that although the Jurassic *system*, which includes all beds from the Lower Lias to the Purbeck, yields a greater number of species of *Asiphonida* than any other of the great groups or *systems* of rocks, yet when we compare *formations* we find that no single formation equals the Carboniferous Limestone in its yield of species of this division of the Lamellibranchiata. (See Table II.)

The distribution of the entire class now demands our attention; and disregarding generic, family, ordinal, or sectional divisions, and having regard only to species, we find the Lamellibranchiata sparingly represented in the lower division of the Lower Silurian group;

but when we ascend to the upper division and to the Upper Silurian rocks, Lamellibranchs are numerous. In the Devonian system a much smaller number of species than is yielded by Silurian rocks rewards our search. The Carboniferous formations, however, give us a greatly increased number, nearly four hundred species having been described as occurring in these rocks. The numbers of Permian and Triassic species are small; but Jurassic strata have furnished us with upwards of a thousand species of Lamellibranchiata, the Jurassic epoch having witnessed the maximum development of the class. The number falls to about half in the Cretaceous system, and rises again in the Tertiary deposits, strata of the latter age having furnished to science between six and seven hundred species of fossil Lamellibranchs. (See Table III.)

We thus see that the Lamellibranchiata have had a great development in each of the three great epochs of geological time, the *Palæozoic*, the *Mesozoic*, and the *Cainozoic*, and have undergone great modifications of form during the long period required for the deposition of the sedimentary portion of the crust of our globe. As in other classes of the animal kingdom, some genera have lived on through many of the great cosmical changes which our planet has seen, while other generic forms have existed during only a comparatively brief portion of the earth's history.

Many and grave questions are suggested by this fact, a fact well known to students of science, but the elucidation and explanation of which are at the present time sought for by our most earnest thinkers, and form the battle-ground, so to speak, for the contests of the ablest and most richly furnished intellects of our day and generation.

Discussion.

Mr. Etheridge, after noticing the importance of the paper, remarked that possibly the great difference observed in the proportions of the Lamellibranchiata in different formations might to some extent be due to our want of knowledge. Of late years, in the Caradoc and Lower Silurian series, the number of species had been nearly doubled, principally through the persevering industry of one single observer, Lieut. Edgell. The same was to some extent the case with the Carboniferous rocks, owing to the collections of Mr. Carrington. Much was also being done for the Oolitic series, in connexion with which the names of Mr. C. Moore, Mr. Sharp, and Dr. Bowerbank ought to be mentioned. Mr. Griffiths and the Rev. Mr. Wiltshire were doing the same work for the Gault. What the late Dr. S. P. Woodward had done as to the distribution of the different species of mollusks through time, Mr. Lobley was doing on a larger and more extended scale.

Prof. Ramsay was glad to find that Mr. Lobley was, to some extent, doing the same for the Lamellibranchiata that Mr. Davidson had done for the Brachiopoda. He did not know how the case might be with the Silurian and Devonian formations; but in the Carboniferous strata the Lamellibranchiata were obtaining a preponderance over the Brachiopoda. He accounted for their comparative absence in formations of other ages, especially between the Upper Silurian and Rhætic beds, by the best-known areas of those periods having been mainly continental, or containing principally freshwater or inland-sea remains, so that the true marine fauna was absent. In Carboniferous times possibly the true relative proportions of the two forms had been preserved in the deposits.

Mr. Judd was doubtful as to the safety of placing too great reliance upon figures. He questioned whether some of the conclusions as to the great increase of Lamellibranchiata between the Carboniferous and Jurassic periods could be substantiated. Much depended on the amount of the rocks present in different countries, and the study bestowed on each. The conditions also for the preservation of the fossils might be more favourable at one time than another.

Mr. Carruthers considered the tables of the greatest value, as indicating the present state of our knowledge. He called attention to the difference of conditions under which different deposits had accumulated, which must have to some extent affected the proportion of Lamellibranchiata preserved in the different formations.

Mr. Charlesworth remarked on the occurrence of *Trigonia* in the Australian seas, and on there being varieties of form among specimens of existing species so great that if they were found fossil they might be regarded as of several species.

Mr. Hughes considered that the data were too incomplete to justify the generalizations of some of the previous speakers. It had been pointed out that whenever the Tables showed a very large number of Lamellibranchs from any formation, that formation had been carefully worked out by local observers; and therefore he should like to know in each case the proportion the Lamellibranchiata bore to the total number of fossils found. It had been shown also that a larger proportion of Brachiopoda had been found in the older rocks, and of Lamellibranchiata in the newer. But in the older rocks whole genera of Lamellibranchs are confined to horizons and localities which are not cut off by stratigraphical breaks, such as would allow us to think it at all probable that they can be characterized by peculiar genera. He thought the scarceness and irregular occurrence of Lamellibranchs in the older rocks could be best explained on the supposition that those portions of the older deposits which were least favourable to Lamellibranchs happened to be those now chiefly exposed to our search, and that those few portions are only in part worked out.

Mr. Jenkins observed that in thick deposits there was a far greater likelihood of numerous forms being present than in thin; for thickness meant time, and time meant variation.

Prof. Morris dissented from this view, as in thin littoral deposits an enormous number of shells might be present, while in beds formed in deep sea they might be almost entirely absent.

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2. Geological Observations on British Guiana. By James G. Sawkins, Esq., F.G.S.

A detailed geological survey of British Guiana, in the present state of the colony, would be a very difficult and prolonged undertaking, as the only lands not covered by dense forests are the coast alluvium, and the savannas or prairies of the interior; few roads extend beyond the sugar plantations on the former, and few Indian tracks over the latter; therefore it must be understood that my observations were chiefly confined to the rivers.

Along the coast the land is low, at many places (as at Georgetown) below the sea-level, composed entirely of sands, clays, and marine débris brought down by the larger rivers, which have been frequently silted up into lakes by the contra-action of the waves of the Atlantic ocean. The extent of this alluvium varies from ten to forty miles inland, where it terminates in low sand-hills of 10–70 feet elevation above the sea-level. These sand-hills extend inland until they are seen resting on granite. They are somewhat rounded by the action of the water of insignificant streams and rain.

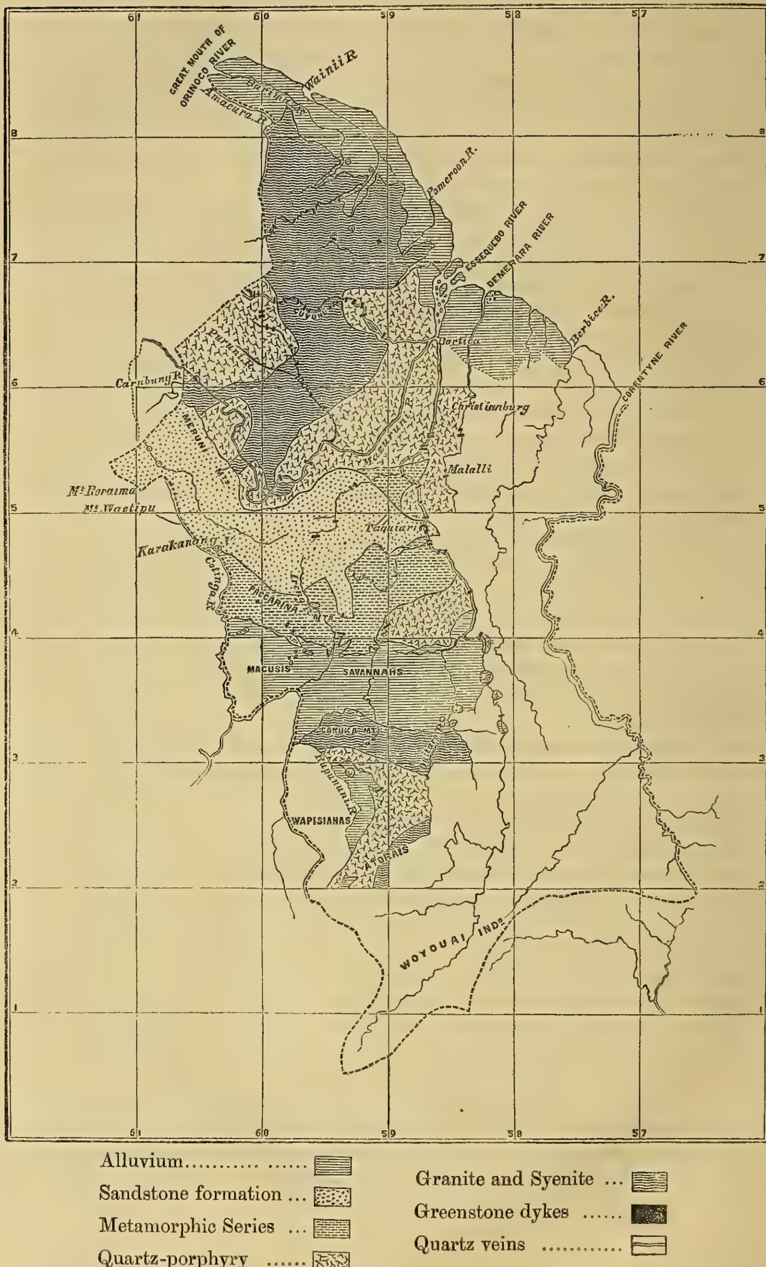
The amount of rain, according to observations by Mr. Sandeman during ten years, shows an annual average of 102·826 in., the minimum being 68·680, and maximum 133·219; these facts will convey an idea of what the denuding influences in this colony are.

My first excursion was limited to what is called the Pomeroon district, comprising the Wainii, Barama, Barima, and Pomeroon rivers. The first granite was observed on the Wainii and Canyaballi, just below the mouth of the Barama, where it is much weathered and worn into deep furrows, particularly under the rain-droppings of large trees; the crystals of quartz, withstanding the effects of exposure longer than either the felspar or mica, protrude on the surface very remarkably.

To the south-west of the junction of the Wainii and Barama there is a depression covered with alluvium or with lakes, ponds or bayous; then rise granite, gneiss, and mica-schist, often friable on the surface from the decomposition of iron pyrites; dykes of greenstone traverse the schistose rocks, and indurate them at their junction. At Dowacima falls, on the Barama river, a green mica-schist occurs containing veins of granite. Chlorite-schist also appears in many places, pierced by grey trap dykes. The same series of rocks occurs on the Barima and Wainii; but those above tide-water are chiefly gneissose, with small veins of quartz, or coarse granite, in which the quartz is in semitransparent crystals an inch in length, and the felspar of the same dimensions and of a milk-white colour, while the mica is an inch and a half in diameter and half an inch thick.

My next excursion was along the western shore of the Essequebo, then up the Cuyuni, to the line of Venezuela, then across the land between the Cuyuni and the Puruni, a tributary of the Mazuruni, and then up the Mazuruni towards the highest lands of the colony.

Fig. 1.—*Sketch Map of the Geology of British Guiana.*
Scale 104 miles to 1 inch.



On reaching the western shore of the Essequebo, my course was nearly south-west to Supinaam Creek, which courses along the base of the sand-hills to the Mission of Indiana, where these hills rise nearly 50 feet and are composed of sand and clay; decomposed granite, or gneiss-quartz, occurs as aggregated pieces of conglomerate cemented by red or white clay. Where the clays are separated from sands, they are mottled or streaked with red lines of oxide of iron. Sand-deposits increase in ascending the creek, and occur in many instances without any argillaceous admixture.

Above the Mission there are rapids, near which the granite is exposed, and numerous small islands formed by deposits accumulated on it.

In proceeding up the Groote Creek, which runs parallel to the Supinaam on the south, the same series of granite rocks is exposed here and there, and likewise along the banks, under deposits of sand and clay.

Saxacalli point is composed of granite and appears to be the remains of a dyke that extended across the Essequebo river. On examination it was found that none of the rocks composing this group presented any sharp edges; all are rounded by attrition or disintegration. The surface of the granite is worn away below the quartz veins that run through it; and although they present no regularity as by deposition, yet there is such an amount of parallelism as we frequently find in false bedding of sand and gravel, while the lines of separation in the granite are more constant in one direction, dividing the quartz veins as well as the granite. At Swarte Point,

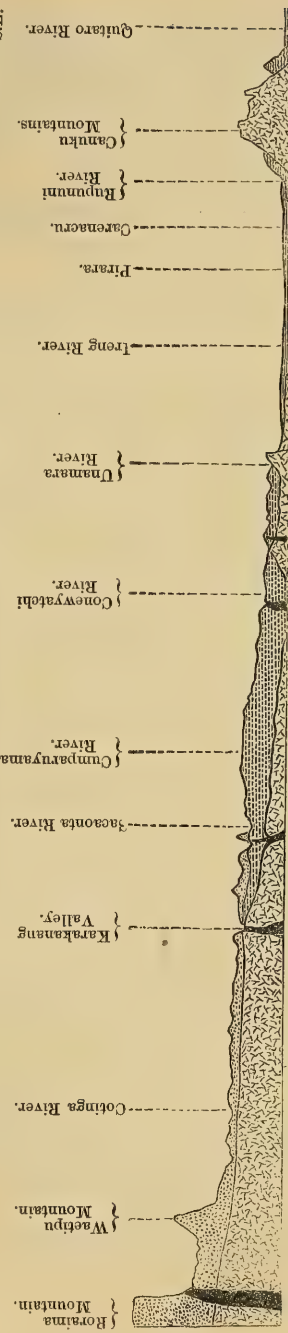


Fig. 2.—Section from the Roraima Mountain to the Quitaro River.

Vertical Scale 10,000 feet to the inch. Horizontal scale 28 miles to the inch. (For explanation see Map.)

a few miles south, the same characteristics appear on a larger scale in the granite, but in place of regular lines of separation a foliaceous structure predominates. At the penal settlement the land rises 56 feet; and this is the highest point on the lower portion of the river Essequebo; it is composed of a grey and red granite much decomposed on the surface. Some quarrying that has been done here presents good sections.

Almost immediately opposite the Commissioner's House, on the opposite side of the river, is an intrusive dyke of greenstone; and at the mouth of the Mazuruni there is a large quarry of granite well worthy of examination.

Proceeding up the Cuyuni, instead of going over the falls of Seregatara, Tivrimi, and Ematubo, I walked across the land. The rocks observed on this path are granite, syenite, and quartz, the latter not in veins, but granulated. The same rocks occur above the cataract of Camaria and on one of the numerous islands between it and Woko Creek and Powis Hill, on which hydro-oxide of iron and hæmatite, with quartz in detached pieces from 2 to 6 inches in diameter, lie on red and variegated clay.

At Arnakanmatabo there is an intrusive hornblendic rock, associated with granite, on the surface of which is ironstone, or hydro-oxide of iron in the form of gravel, or cemented by clay into a stiff conglomerate, a large block of which is lying at the mouth of a small stream at the east end of the Tapore Hills. On the western part of these hills there is a mass of quartz, about 200 feet in length, and 25 in width, containing minute specks of gold, lying on decomposed mica-schist, which has been mined in different directions in the expectation of intersecting it. Had it been a vein, or reef, it would have been intersected; but it does not descend so far below the surface as where the adits are driven.

About one mile and a half up the river, there is a rivulet, where the mica-schist is more compact; and after washing the black sand collected in the rivulet for some time I detected a few minute specks of gold, which may have been derived from the adjoining rocks, but most probably from those of the auriferous country at the head sources of the river Cuyuni, where gold was collected by the natives prior and subsequent to the discoveries of Columbus.

Proceeding up the river Cuyuni, syenite appears again at the rapids on the south of Suwaraima Island, and at the extreme north-west point of it in juxtaposition with an intrusive trap or greenstone; these occur again about four miles further up the river.

Near the Berebisi creek and Tonoma rapids, granite and syenite occupy a considerable part of the river-bed; they also appear at the rapids of Payuca, and up as far as the island between the Quive Kura river and the Zane Kura, at the extreme end of which there is a body of quartz, around which a quantity of black sand is deposited. In this a speck or two of gold was found; but in the quartz at this locality I could see no gold, even by the aid of a strong magnifying power.

After passing decomposed granite, syenite, and quartz, about a mile below the Caruma creek, on the north, and the Wairyarra, on the south, the rocks become decidedly schistose. There is also a small dyke of quartz of a red and white colour in the course of the river; but by microscopic examination no gold could be seen in it.

At the base of one of the hills in the vicinity, gold in very small quantities was soon obtained.

On passing over the rapids of Olupikai a variety of greenstone and talcose-schist occurs, very slaty in structure, particularly at the rapids of Atete, where it is of a greenish colour.

At the cataract of Waicuri there is an extensive development of the red brecciated rock lying on a phonolite, with small crystals of pyrites, and a blackish mineral that, like the pyrites, dissolves out of the rock, leaving square cavities more or less filled with oxide of iron.

At the falls of Wakupany, the rocks are principally greenstone, or coarse schist, on which there is a considerable deposit of white sand. A little up the river the rocks become more slaty and foliaceous by the presence of talcose-schist with quartz veins 2 inches in diameter, and a good deal of iron pyrites.

The granite rocks in the river from this point became more gneissose, with occasional quartz veins; therefore the space between the Copang and the Maruparu creeks may be regarded as the schistose district on the Cuyuni river, within the boundary of British Guiana.

From Maruparu talcose schist occupies a considerable portion of the north bank. On approaching the falls of Duquari, the granite rises in large bosses alternating with syenite, porphyry, greenstone, and hornblendic and talcose schist, which lie on the granite at different angles. Above the Iroma river, these rocks are more decomposed, and assume a red colour, but still preserve their laminated structure.

At Duquari falls there is a better opportunity of observing these various rocks and determining their relative age. It appeared to me evident that the greenstones have displaced the granite, and intruded through lines of weakness, or fissure, without materially altering the granite, by which it also appears that the greenstone was at a low temperature during its ejection, *i. e.* below a white heat, like the lava of the present day at Vesuvius, and at Mouna Loa, in Hawaii.

From the Duquari falls to the Otomong river, granite is general, except where the cataracts of Aroroyamo, Callo, Darra, Corrocororoopung, Icarima, Poinchaima, Tacarric, and Aberiwaika traverse the river by dykes of greenstone, gneiss, &c.

After passing the Paccu falls there is a small creek called Cartuni, along the banks of which there is an Indian path that leads to the Puruni, a tributary of the Mazuruni river, over which I made the transit on foot. I estimated the distance to be twenty-one miles.

The rocks observed on the way were granite, granular quartz, syenite, and trappe. In the creeks black sand occurred very generally; and I consider this part of the Cuyuni valley at least as likely to contain auriferous deposits as any other portion of it that I have seen.

The greatest elevation between the Cuyuni and Puruni rivers was 320 feet, on the south of which a tributary of the Puruni takes its rise. Down this narrow stream, we cut our way through the branches and trunks of trees that were lying across it. After passing the Tapara and the Tariparu creeks, from the south, granite and syenite occur in two places, and after passing the Waini creek, from the north, the river is divided into many branches by numerous islands composed of a red clay, and obstructed by fallen trees, to avoid which the Indians have cut a passage through the clay, large enough for corrials (canoes) to pass. These clay banks are generally low, and lie on some hornblende and schistose rocks near Maruparu and again further down the river.

Granite occurs near Tuvastimpi creek and a little below, associated with gneiss of a blue colour.

On approaching Curaspara creek a soft mica-schist occurs, near which there is a hill of 600 feet elevation. The ascent is rather steep being on the average 30° of inclination; the trend is north-east, and south-west. The surface is covered with hydro-oxide of iron, in the form of pebbles, or in concretionary masses, sometimes conglomerated and hæmatitic.

Near the falls of Marchughi the hydro-oxide of iron occurs forming a soft rock, with blackened surface. Diorite, trap, and greenstone form the barrier across the river, about 15 feet higher than the lower basin. A deposit of iron and manganese occurs on all the rocks in this as in most of the other rivers in the colony. Sometimes I have seen it $\frac{1}{8}$ of an inch thick.

About a quarter of a mile below the junction of the Mapa-aima with the Puruni, are the falls of Payuca, which are divided into three streams. A dyke of greenstone forms the obstruction. The mica-schist dips to the south-east.

Ombaroa Creek enters the Puruni from the north a little below these falls, and the hills of Ruminga and Murupina soon appear, forming the south bank. At the base of these hills are dykes of a dense greenstone. Between these two hills is a small water-course, near which I observed granite, syenite, trap, hornblende-schist and decomposed schist. Near Gasparupa creek there is a curious conglomerate, and also trap with quartz veins. After passing Gangrooma and Langooma creeks greenstone occurs; and below Cabilli and Humaribara creeks quartz, greenstone, and conglomerate; and at Paraani creek red and green schist with quartz veins. These extend down to the vicinity of the Maramara creek, where gneiss and blue clay-slate appear. A short distance lower down the river is a bed of conglomerate.

The river soon after passes through a ridge trending north-east and south-west, and soon after another hill is seen about the same height (600 feet) trending more to the south. Then follows the Uricon, which is the highest in the range.

At the base of these hills a ferruginous conglomerate and red clays are found accumulated on either granite or some hornblende rock.

Near the Tacuparu creek a decomposed granite appears, also at the rapids of Maritote, and others below them, where the granite and syenite are extensively exposed.

After passing several rapids, including that of Alabamaloo, the syenite is more general. A remarkable dyke of porphyry, 4 feet wide, which has passed through the granite, occurs at the falls, which were about 12 feet in height at the time I descended.

The granite series, with trap dykes, are more largely developed. At Huamata they cross the entire river. Most of this granite is very coarse-grained, with green or red felspar.

At the rapids and the island of Taparu, also at the rapids of Presatu, white granite occurs; and near Cubangan, gneiss, which extends down to the Ourasas-sartur rapids.

The land rises here, on each side of the river, to from 150 to 200 feet. At the base granite, syenite, trap, and quartzose rocks spread out over a much larger surface, in comparison with those on the upper part of this river.

After passing the great falls at the junction of the Puruni with the Mazuruni, there is so great an extent of bare granite separated into innumerable islands, and such a large expanse of water within the low and distant confines of the river, that it presents a scene rarely to be met with.

On entering the Mazuruni I found the river unusually low, and consequently many rocks exposed that would not have been seen had the river been in flood; but all are so uniform in their character (granite, syenite, gneiss, and porphyry, with trap dykes) as to render the labours of the geologist very monotonous.

These rocks continue up the river without any important modification as far as the Wanamu and Maribisi rivers, where a fine conglomerate occurs. Above this there is an altered sedimentary rock, forming a mass.

At the falls of Tebuco there are granite, diorite, and very dark porphyry, also veins of dark quartzite, followed by greenstone, and schistose rock with quartz veins, both black and white.

At Carinang Creek the same rocks occur, and continue some distance further up the river. Some of the quartz veins are bold, being several feet across; but no gold could be detected in them with the aid of a strong magnifying power.

About this part of the river I obtained the first view of the Maribiacru cliffs, which form a part of the Meremé range, rising from 1000 to 2000 feet over the forest-trees growing on the banks of the river.

At a point turning south, towards the cliffs, granite underlies 8 and 10 feet of recent conglomerate and sand interstratified; then the granite again rises to the surface.

At this point the heights of Caribisi are seen to rise in a peak about 18 to 20 miles distant; and not far above, conglomerate is again seen lying on white granite with quartz veins. This is followed by greenstone of a greyish hue, forming a dyke in a N.E. and S.W. direction, the rapids of Curanassai and a large gravel beach. Beyond this point were observed gneiss, hornblende, trachytes with iron pyrites, greenstone, a dark grey trap, quartzite followed by greenstone, schist, porphyry, and altered conglomerate.

At the mouth of the Carubung river there is a talcose slate, through which there are small veins of plumbago or graphite; these are followed on the Carubung river by gneiss, greenstone, porphyry, granite, mica-schist, ironstone, conglomerate, sands, and clays. Several precipitous cliffs of stratified rock appear here above the forest, forming the Morokina, Wataparu, and Curumina mountains; and the granite and metamorphic series of rocks are occasionally covered by large blocks of old conglomerate, composed of white quartz pebbles in a very hard siliceous matrix, which lie in the river at different angles of inclination. Soon after, the grey and pink granite disappear under extensive beds of conglomerate, composed entirely of siliceous rocks or quartz pebbles and boulders, coated, as all the rocks are in the rivers I have visited, by hydro-oxide of iron, with or without manganese. The falls of Macrabah are produced by a mass of this rock traversing the river 35 feet between the level of the water above and that below.

The hills on either side of this river, at the Macrabah falls, rise almost perpendicularly to the height of 1300 feet. To gain the summit, I proceeded up the Seronne, a smaller stream, and climbed up over large masses of conglomerate and sand until I attained that altitude.

By a slight divergence to the north of the Indian track a cascade may be seen, reported by Hillhouse to be 400 feet perpendicular; it was dry when I passed.

On reaching the summit of that portion where the land becomes comparatively level, I found it to be, by aneroid barometer, 1500 feet, continuing to rise in a distance of ten miles to 2534 feet above the sea-level.

Nothing but sand (red, yellow, or white), ironstone, conglomerate, quartz-pebbles, as white as milk, and greenstone dykes is to be seen in the course of this transit.

On reaching the southern portion of this range I found it equally precipitous, and was obliged to descend by the aid of ropes tied to the trees that grew scantily out of the mural side of about 700 feet before reaching the level below.

The space between the base of the precipice and the Upper Mazuruni is occupied by rugged sand-hills cut by small streams into deep ravines.

The alluvial banks of this part of the Mazuruni present the same general aspect that they do below the great falls of Piamah, but become narrower on arriving at its junction with the Cako. On this part of the river granite was only observed at three points, under either the old conglomerate or recent alluvium.

From the mouth of the Carubung, during the journey up the Mazuruni, the rocks that appeared above the surface of the water consisted of trap, trachyte with iron pyrites and red decomposed pyrites, a greenish porphyry with quartz-veins, then trap and diorite, mica-schist, quartz, and a very hard purple trap, forming a dyke a little below the great falls of Piamah, which are now cutting away beds of sandstone and conglomerate that present escarpments like masonwork, so regular are the lines of stratification.

This was the extent of my second excursion and examination on the Mazuruni river. I estimated the distance from the coast to be 430 miles.

Examination of the River Demerara.

The lower portion of this river is exceedingly monotonous and uninteresting, being formed of low alluvium from the coast up to the "sandhills." Between these two points there is little else than swamp or low muddy flats covered by caladium, arborescent arums, mangroves, &c., and affording not even a landing-place of sufficient firmness to support a man.

The sand-hills are low and undulating, composed chiefly of a whitish sand with a little clay; they rise a little as they recede from the river, but nowhere exceed the height of 70 feet, until we arrive at Berlin.

At Dalgnin the hills rise higher, but none so much as 200 feet, until near Christianburg, where the country becomes decidedly hilly. About two miles above this the first rock, a coarse-grained trap, is seen near the centre of the river at low tide.

At Akyma one of these hills has been cleared of timber, and gives an opportunity of seeing the configuration of the surrounding country. To the east and south the land is low and swampy, and is often overflowed by the river.

At Seba a boss of granite (common) rises from 15 to 18 feet on the east side of the river, exposing an area of more than fifty yards; and at Tiger's-leap, on a hill about 350 feet high, some large boulders of granite occur.

The sand-hills seldom rise over 300 feet; on one near Manabadin there is a landslip or breakaway, by which the lines of stratification are seen resting on granite.

At the rapids of Mouranicrocaba the granitoid schist constitutes the barrier across the river, forming rapids and falls of 5 or 6 feet perpendicular.

At Labacabra granite appears, and continues up the river as far as Curuwa creek, where a fine-grained hornblende rock occurs; the same appears at Curabelicabra, also at Morocabra, and occasionally as high as Arampa, where sand and clay compose the banks. At the base of a hill near Umpa a white pottery-clay forms a bold bank.

At the north of the next creek, Cornbara, there is an island composed entirely of sand. About two miles further up there is a hill covered chiefly with hydro-oxide of iron, bearing the appearance, in some instances, of cellular lava or scoriæ from a furnace. This same formation crosses the river near Couchman's grant, where the river is very shallow by the accumulation of this ferruginous gravel. At the base of Mecropie hill the same occurs.

Derrire hill is covered with hydro-oxide of iron; and much of it has been brought down, in the form of gravel, into the creek bearing the same name.

At Camoodecabra a trap rock rises, and extends to the Anobaro Creek, forming a dangerous barrier for boats descending the river. Above the Waburicabra another large ferruginous gravel-bank occurs that extends up almost as far as Coomaparo creek.

From Coomaparo there is an Indian path to the Essequebo river, which occupied eight hours' walking. The land rises in undulating swells up to the "burnt grounds," where it attains 200 feet, and, after continuing on that level for a few miles, gradually descends, like steps, until it reaches the low swampy flat of Moraboo, on the east bank of the Essequebo.

In this distance, computed at 18 miles, the only rock to be seen is a quartzite, which decomposes into white sand.

Returning to the Demerara river, the banks continue low until arriving at Acururi Hill, which connects with a ridge that extends to Lucananycabra, chiefly composed of white sand.

By proceeding up the Marbooroo creek about a mile, and then walking south-west a few miles, the Maburu Hill rises to about 800 feet above the sea: one of its sides towards the Essequebo is nearly perpendicular; and from it a fine view of that river is obtained. It is composed of trap, and appears connected with the same range that forms the dyke at the great falls of Malalli.

The falls of Malalli are 35 feet in perpendicular height, and form the greatest barrier to the navigation of the Demerara river.

At the base of the falls may be seen ejections of trap and porphyry between the granite; and on the confines of the basin below the falls, several interesting examples of weathering and decomposition of the granite.

The trap or greenstone, that has passed up the fissures or lines of weakness, appears very dense, and so fine-grained that it might be taken for petrosilex. The curious contortions and the splitting of veins that have forced their way through masses of granite are exceedingly interesting and instructive.

The hornblendic rocks continue over a distance of ten miles up the river, occasionally rising to the surface, but more frequently observed covered by clays and sands, resulting from the decomposition of these and granitic rocks.

Where the clays or sands form the banks of the river the land is low and often swampy for miles around, intersected by numerous bayous, showing a considerable depression of the country.

On approaching Navaroo creek, granite occurs of a very beautiful character, with purplish felspar and green mica.

There are several large boulders near Kanimapoo's Landing. This series of granite continues up the river four or five miles. A very good yellow-ochre appears to be the result of its decomposition, and occurs in thick beds in this vicinity.

Arriving at Uriburoo Hill there is a bold escarpment of trap and schist, with iron pyrites. A stream runs down the cliff, as a cascade, on the west side of the river. On each side of the river, as high as the Ubaroo creek, trap dykes occur traversing the river; and between these is a ferruginous gravel, sand, or clay. The land beyond this is low and swampy, and traversable only during the dry seasons.

Observations made on the Essequebo River, its tributaries, and southern mountain-ranges.

At the junction of the Mazuruni and Cayuni rivers with the Essequebo is the penal settlement, and on the opposite shore the village of Bartica, the only settlements of civilization on these rivers; and as the geology between this point and the sea has been already given, I commence the following observations from Bartica, which is built on a low sandy deposit resting on granite and porphyry. This low land continues to the cataract of Aretaka; but before arriving at Camaka Serima, dikes of greyish trap with iron pyrites and felspathic hornblende occur. At Camaka Serima grey granite, somewhat gneissic, rises, dividing the river by several islands and forming the Aretaka cataract, where the granite appears in large bold masses, sometimes showing lines of scaling or peeling in concentric layers like an onion, at others of decided gneissic structure. The entire area occupied by these falls or cataracts is composed either of granite proper or of members of the granitic family; at the head of them is Gluck Island, and a great extent of still water expanding to lacustrine dimensions, where no rock is seen *in situ*, but large sand-banks render the water very shallow.

A few miles up the river the Arissara hills appear; and near their base granite occurs; and a little up the river a trap dyke crosses it.

From this, for several miles, nothing but sand and clay is seen. At the Cumuka rapids, granite with quartz-veins 2 inches in diameter appears, with detached blocks of hornblendic rocks superposed. At Acuramalli Rapids trap rocks rise a few feet above the river, also at those of Curamucu, where greenstone and hornblendic rocks form obstructions in the river.

A short distance above this are the hills and islands of Buhuri and Banaca, and the Waraputa falls, where the granite extends across the river, some of it being very dark from the quantity of black mica it contains. There are veins of quartz a few inches in diameter, also petrosilex, gneiss, and syenite, diffused much in the same manner as at the Malalli falls on the Demerara river, with which this is in all probability connected. A depression in the land to the south-east also corresponds with that on the Demerara river.

After passing the next rapid there is a collection of granite rocks, all having a scattered and confused position detached from each other, some larger ones on smaller. To one of these the name of Paiwori Cayra is given by the natives, from its resemblance to the vessel in which they preserve their favourite liquor "Paiwori;" it resembles some of the rocking-stones.

After passing the still water in the depression mentioned I came to a succession of rapids rushing and pitching over beds of granite and dykes of trap that traversed the river, until I arrived above the falls of Itamine; soon after the Taquiari mountains came into view, about 800 feet above the river.

This is the first place where I observed sandstone *in situ*; dykes of greenstone pass through it, and rise on the south-east side of the Taquiari. At the termination of the hill, about 600 feet above the river, a column of rock stands out from a somewhat similar one, which makes the final point on the hill. This has weathered into three distinct pieces of rock, resting on a broad base one above the other. At each junction there is a separation; and as at these junctions the weathering of the rock has been greatest, each piece has assumed a spherical or elliptic form; and as the difference in size of the three is proportionate to the form of the large water-vessel used by the natives, the name "Comuti" has been given to it by the Araawak Indians and "Taquiari" by the Caribs, both signifying a large water-jar.

South of these hills there is a great depression or extent of level land towards the south-east, corresponding to that I observed at the upper part of the Demerara river. The banks of this river are low; and, I suppose, by a rise of ten feet above the present level it would overflow its banks. Before reaching the large pond of Tambicabo I observed some altered sandstone in the middle of the river, the granular structure of which is nearly obliterated, making it appear like flint: it decomposes into white sand.

The Tarratara hills are seen in the distance; the land around them is low, extending apparently many miles back from the river.

At the falls of Ouropocari there are some very curiously water-worn rocks; parts of them are porphyritic, and others like an altered conglomerate. They are deeply grooved by weathering; some rest on others of very inferior size, leaving space beneath them to shelter many men.

After passing over a series of rapids and cataracts formed by dykes of trap and porphyritic rocks, the Macari Mountain is seen, with a mural precipitous escarpment of near 1000 feet above the river. The range appears to trend off to the S.E.; the summit is comparatively level, resembling the sandstone mountains on the Mazuruni river; and it appears to have been cut away by the Essequebo river, but resembles more the cliff of a sea-coast. At the base there are dykes of a purple-coloured porphyry.

At the Pishani falls the rocks present the character of altered sandstone. At the upper part of the falls these rocks are of much finer grain.

On the east side of the river, granite rises to the surface and covers a considerable area, particularly at the cataract of Achramucra. From this the river rises but little, as it becomes comparatively still water.

From this no rocks appear above the surface until arriving at "Musara," an abandoned Carib settlement; and from this to King William IV. Falls, a distance of five days from this point, there are no rocks to be seen but granite, syenite, gneiss, a series of dense hornblendic rocks, and in one instance columnar basalt.

The Falls of King William IV. consist of a succession of rapids about 100 yards apart, closely interspersed with rocks.

The Ascent of the Rupununi.

The Rupununi river is one of the largest tributaries of the Essequebo, entering it at nearly 4° N. latitude; there is scarcely any current perceptible at their junction; and high banks of alluvium occupy both sides of the river, which are sometimes broken by large ponds or inlets, conveying the idea of an extensive depression between the Maccari and Paccarima ranges, and again between the Makrapan and the Annai.

The Makrapan Mountain is composed of granite and syenite. From the base of this mountain the great savannas spread to the south and west into Brazil and Venezuela like large inland lakes, a resemblance which is increased by the difference of vegetation growing on them. The alluvial deposits of the lower Essequebo are covered by the largest and highest forests in the world, whereas on approaching these savannas trees begin to decrease in altitude until they become like the stunted growth on a promontory of a sea-coast. This peculiarity is not confined to the river-courses; for the savannas or grassy plains are only here and there dotted by a dwarf tree resembling the coast-grape, *Coccoloba uvifera.*

The geology of these savannas is very clearly defined, as they consist of only three distinct, stratified Tertiary deposits, resulting from the disintegration of the adjacent mountains:—1st, sand, clays, and vegetable mould; 2nd, red sand and ferruginous gravel, often concreted or hæmatitic; 3rd, white clay, resting on gneiss, granite, &c.

On the Annai mountains the savannas, or tracks of land denuded of trees, rise to the summit in a most capricious manner in strips and lines as regular as if laid down by line and compass; but the rocks do not differ in character from those on which forests grow.

To the south of the Paccarima or Annai range are the Cunuku mountains, which extend from the Takutu river on the west to the upper Essequebo. This range is chiefly composed of granite and gneiss, with trap dykes of the same character as those before described. The savanna from the Rupununi to the Ireng and the base of the Paccarima mountains consists of three Tertiary stratified deposits. At the mouth of the Unamara river there is a vein of quartz, and adjoining it are hills of quartz similar to those of Annai. Between the savanna and the Unamara river there is a ridge of granite intersected by greenstone dykes.

The next hill to the northward is composed of a different kind of rock, which continues to the edge of the sandstone escarpment on the Sacaonta river. This rock in its commonest form is composed of white crystals of felspar and clear crystals of quartz in a siliceous base of extreme hardness; it usually contains crystals of hornblende, and occurs in regular layers of great thickness, some of which are massive and break with a conchoidal fracture, while the others are slaty and split vertically. It often occurs in isolated patches in the valley and Unamara river. Although this rock has been called and laid down on the map as quartz-porphyry, I should rather regard it as an altered sandstone or quartzite, as by further investigation I found the lines of stratification sufficiently distinct to justify such an inference.

Large dykes of greenstone occur, similar to those in granite, traversing this formation, which extends to the Marakang river, where it passes under an escarpment from the top of which sandstone like that observed in the Mazuruni and Carubung has rolled down. At the base of the hill a greenish bedded rock, dipping north, with greenstone dykes and quartz veins, lies upon the conglomerate and white quartzose sandstone, occupying in vertical height some hundreds of feet; and upon these are beds of considerable thickness of red and yellowish sandstone; the latter are slightly contorted.

Continuing up the valley of Murapang the stratigraphical arrangement is as follows:

Grey sandstone in thin beds.
Yellow sandstone.
Pinkish sandstone.
White hard sandstone.
Conglomerate, dipping from 5° to 10° N.
Strike of the hill N.W. and S.E.

Not far from the Karakanang river there are low rounded hills of white and pink argillaceous sandstone, on the surface of which quartz crystals occur in such quantity that they are called Crystal Mountains.

The mountain to the north-west of the village presents the following section:—

150 feet of dark green slaty rock resting on granite.
175 „ red shaly sandstone.
175 „ hard white quartzose sandstone.
100 „ coarse pebbly conglomerate.
200 „ pink and grey interbedded argillaceous sandstone.
100 „ red ferruginous sandstone and beds of red jasper.

The hills beyond the Karakanang river are formed of the white argillaceous sandstone with small water-worn pebbles of quartz &c., on which lie beds of hard red jaspideous sandstone.

Beyond the Peepee river to the Cotinga a red thin-bedded sandstone occurs, containing red jasper; and at the falls of Orinedouke, on the Cotinga also; and from that to the pyramidical mountain of Waetipu and Roraima, the sandstone forms the surface-rock.

Waetipu mountain is composed of horizontal beds of sandstone and conglomerate of a light yellowish or grey colour. Height estimated at 5000 feet.

Roraima is a flat-topped mural mountain, rising to the height of 7500 feet above the sea, with perpendicular walls of 1500 to 2000 feet from the summit to the inclined portion surrounding it like a glacis or closely built buttresses, and formed by accumulated débris.

This and the surrounding mountains are composed of sandstone and conglomerate resting on gneiss or granite, with intrusive dykes of greenstone &c. When we consider that not a fossil of any kind has been discovered or limestone in any form, and also the fact already ascertained of the extension of this formation from Venezuela to Brazil, and perhaps to Patagonia, it becomes an object of great interest.

Schomburgk speaks of the sandstone range of Humerida to the south of Roraima and of the sandstone of which Fort Sao Joaquim is built on the Rio Branco, 2° south. Travellers on the Amazons speak of flat sandstone mountains as called by the natives "Guiana Mountains;" and from Darwin's observations on the more recent formations of the valley of St. Crux, in Patagonia, I infer that Roraima represents deposits from the Cordilleras at an earlier date and under similar conditions, and since it was uplifted it has been eroded by the waters of the valleys of the Essequebo and Orinoco.

Returning to the extensive granite and gneiss formations, there is on the Rewa, a tributary of the Rupununi, a ridge of granite which presents several conical or pyramidal hills, one of which, Ataraipu or Devil's Rock, is nearly bare of vegetation, and rises about 900 feet above the river and 550 feet above the forest by which it is surrounded; it is south-east of Roraima, and forms a part of the Cunuku range.

Discussion.

Prof. Ramsay remarked upon the barrenness, from a geological point of view, of the district investigated by Mr. Sawkins, and especially called attention to the absence of fossils in the stratified rocks. He referred briefly to Mr. Sawkins's labours in Trinidad and Jamaica, and to his discovery of metamorphosed Miocene rocks in the latter colony exactly analogous to the metamorphic Eocene rocks of the Alps. He was glad to see that the author had brought forward examples of cross-bedding in metamorphic rocks, and considered that the results adduced were favourable to those views of the metamorphic origin of granite which he had himself so long upheld.

Mr. D. Forbes, on the contrary, considered that the facts brought forward by Mr. Sawkins were confirmatory of the eruptive nature of the granites observed. He added that a structure analogous to the so-called cross-bedding was common in igneous rocks and even in lavas.

Mr. Tate remarked that in the country to the north of the district described in the paper metamorphic rocks abound. He considered that the series of metamorphosed Jurassic rocks extends across the whole north of South America, and perhaps into California. Similar sandstones to those described occur in the basin of the Orinoco, and contain fossils which show them to be of Miocene age. Mr. Tate did not consider these sandstones the equivalent of the Patagonian sandstones, as the latter, from the shells contained in them, would appear to be Pliocene or Pleistocene.

Mr. Sawkins, in reply to a question from Mr. Tate, stated that the only gold found in the country had probably been carried down from the well-known gold-district of Upata. He also entered into a few additional details connected with the chief points in his paper, dwelling especially upon the physical features of the country, in illustration of which several landscape drawings were exhibited.

June 7, 1871.

Henry Collinson, Esq., 7 Devonshire Place, Portland Place, W., and Thomas Milnes Favell, Esq., of Eighton College, Gateshead, were elected Fellows, and Dr. J. J. Kaup, of Darmstadt, was elected a Foreign Member of the Society.

The following communications were read:—

1. *On the* Persistence *of* Caryophyllia cylindracea, *Reuss, sp., a Cretaceous Species of Coral, in the Coral fauna of the Deep Sea.* By P. Martin Duncan, M.B. Lond., F.R.S., F.G.S., Professor of Geology in King's College, London.

The simple stony coral *Caryophyllia cylindracea*, Reuss, sp., is, comparatively speaking, a common fossil in the White Chalk.

Lonsdale described the form, under the name of *Monocarya centralis*, in Dixon's 'Geol. of Sussex,' 1850; but it appears that MM. Milne-Edwards and J. Haime had already named the species *Cyathina lævigata* in their Monographie des Turbinolides, 'Ann. des Sci. Nat.' 3e série, t. ix. p. 290, 1848.

D'Orbigny recognized the species in 1850 as a form which had been described by Reuss in 1846 under the name of *Anthophyllum cylindraceum* ('Kreideformation,' p. 61, pl. 14. figs. 23–30); and after altering the generic title, he created that of *Cyathina cylindracea*.

MM. Milne-Edwards and Jules Haime described the coral in their monograph of the British Fossil Corals (Palæontog. Society, 1850) under the name *Cyathina lævigata*, and, after recognizing the priority of Reuss in their 'Hist. Nat. des Coralliaires,' finally accepted the name of *Caryophyllia cylindracea*, Reuss, sp.

I have referred to the species in the Supplement to the 'British Fossil Corals' (Palæntog. Soc.) and in the Report on the British Fossil Corals to the British Association.

Hitherto *Caryophyllia cylindracea*, Reuss, has been considered a characteristic fossil of the White Chalk; and its horizon does not appear to have reached that of the uppermost beds of that series.

The following diagnosis of the species was published by MM. Milne-Edwards and Jules Haime in their last work, the 'Histoire Naturelle des Coralliaires,' vol. ii. p. 19:—

"The corallum is elongate and subcylindrical, straight or slightly curved; the lower two-thirds of the wall are smooth and glistening, but in the upper third there are small subequal and very slightly prominent costæ. The calice is subcircular. The columella is fasciculate, and is composed of a small number of delicate 'tigelles.' There are four cycles of septa; but in the halves of three systems the septa of the fourth and fifth orders are absent. The septa are thin, but externally they are slightly thickened. The pali are narrow and thick."

An examination of a series of forms referable to this species proves the general correctness of this diagnosis; but still it is not sufficiently exact. Some rather important structural details, which were noticed by these careful naturalists in their 'Monograph of the British Fossil Corals' (Pal. Soc.), are not contained in the above diagnosis, and yet they certainly should have been. For instance, the spreading base of the corallum narrowing rapidly into a more or less cylindrical stem, and the occasional perfection of the fourth cycle in all the six systems, are details which cannot be overlooked.

It is quite true that corals with broad bases may become detached above the base, and that they then possess a pedunculate appearance; but the presence of a broad base is a positive structural peculiarity.

The occasional perfection of the fourth cycle has not been observed by me; but it is consistent with the variability of the septal arrangement in other species in which irregular septal systems prevail.

The distinctive structural peculiarities of *Caryophyllia cylindracea* are the general shape, the condition of the wall, the development of the costæ, and the septal arrangement.

Caryophylliæ with four cycles of septa complete in each of six systems, and with the incomplete arrangement noticed in the species under consideration, were formerly supposed to be extinct, and to have been restricted to the Cretaceous and Tertiary periods. The following are species with four perfect cycles:—

Caryophyllia	*Bowerbanki*,	Ed. & H., found in the Gault.
,,	*Debeyana*,	Ed. & H., from the Chalk of Aix-la-Chapelle,
,,	*Bredai*,	Ed. & H., from the Maestricht Chalk.
,,	*cylindrica*,	Ed. & H.. from the Maestricht Chalk.
,,	*Haimei*,	Ed. & H., from the Maestricht Chalk.
,,	*Sismondai*,	Ed. & H., Turin Miocene, Sicily.
,,	*arcuata*,	Ed. & H., Older and Newer Pliocene.

Seguenza has, moreover, described many species with the four cycles fully developed from the Older Pliocene of Sicily.

A species with the same septal arrangement has been found in the volcanic sands of Guadaloupe.

The following are species with the fourth cycle incomplete :—

*Caryophyllia cylindracea**, Reuss, sp.	Wiltshire, Kent, Norfolk, Chalk, upper beds usually. Nehon (Manche). Bilin and Weiss Kerchlitz.
„ *Lonsdalei*, Duncan	Dunstable.

The progress of research, especially in the investigations concerning the fauna of the deep sea, has shown that there are some remarkable exceptions to this rather hasty generalization.

Pourtales described *Caryophyllia formosa*, Pourt., in the 'Contributions to the Fauna of the Gulf-stream at Great Depths,' No. 6 (Bull. of the Museum of Comp. Zoology, Cambridge, U.S. 1868). This form was dredged up off Havana in 270 fathoms. It has four complete cycles in six systems. Although I have not seen the specimen, still I can but recognize, from the very able description, the decided fossil facies, if such a term may be tolerated, of the species.

During the last expedition of H.M.S. 'Porcupine' †, under the direction of Dr. Carpenter, F.R.S., and Mr. J. Gwyn Jeffreys, F.R.S., many specimens of *Caryophylliæ* belonging to several species were dredged up, some of which presented the perfect and others the imperfect development of the fourth cycle. Some species to which they could be referred had hitherto been recognized as extinct forms; and others were new to science. Thus *Caryophyllia arcuata*, Ed. & H., a well-known Pliocene form, was found not to be an uncommon inhabitant of the deep sea; and *Caryophyllia abyssorum*, Duncan, a new species, was discovered in a dredging from the depth of 1095 fathoms off the coast of Portugal.

The falsity of the generalization which would restrict the *Caryophylliæ* with four cycles to extinct forms having been proved, it became necessary to compare the forms dredged up from great depths, and which had only four complete or incomplete cycles of septa, with the fossil forms possessing similar arrangements.

I was especially led to do this on account of my having detected some instances of remarkable persistence of form during some late examinations of large series of corals from different formations.

Whilst I was impressed with the great variability of the reef-building species of corals, and had obtained proofs of their increase of variation under alterations in the surrounding physical conditions, I became aware of the very persistent character and less variable nature of the corals of the deep-sea fauna.

During the examination of the corals dredged up from the Channel slope in 690 fathoms (No. 9 dredging, see Messrs. Carpen-

* Duchassaing (Anim. Rad. des Antilles, p. 15) described a species with an irregular septal arrangement, but which is associated by MM. Milne-Edwards and Jules Haime with the *Caryophylliæ* having the incomplete fourth cycle; but an examination of the plate (Hist. Nat. des Corall. plate D 1, fig. 1) proves that there are four complete cycles and part of a fifth, or else that the specimen is a monstrous form having seven systems. For a corresponding monstrosity see P. M. Duncan, Ann. & Mag. Nat. Hist. 1865, vol. xv. p. 276, pl. xi. fig. 2, *e*.

† My description of the stony corals dredged up in the expedition of H.M.S. 'Porcupine' is about to be published by the Zoological Society.

ter and Jeffreys's "Deep-sea Researches," Proc. Roy. Soc. Dec. 8, 1870) some *Caryophylliæ* were noticed which possessed four incomplete cycles of septa, large and thick pali, and a columella made up of from two to six processes. They had glistening walls; and the costæ were subequal and principally visible superiorly. They were of course associated by me with the species *cylindracea* as varieties, the variation being in the size of the pali and the number of the columellar tigelles, both being very uncertain anatomical elements.

The dredging in 1095 fathoms off the coast of Portugal which yielded *Pentacrinus Wyville-Thomsoni*, Jeffreys, produced many corals; and the series presented an eminently Cretaceous facies. The genus *Bathycyathus*, whose species *Sowerbyi* is so well known in the Upper Greensand, was represented there by numerous specimens of a species closely allied to that form.

A new species, *Caryophyllia abyssorum*, was also found, which is allied by its structural peculiarities to *Caryophyllia Bowerbanki* of the Gault; and the specimen was discovered which is the subject of this communication.

The characteristics of *Caryophyllia cylindracea*, Reuss, sp., are shown in the specimen in a most unmistakable manner. The type is somewhat variable, and I have delineated some varieties in the "Supplement to the British Fossil Corals" (Pal. Soc.); but the specimen obtained from the greatest depth at which coral-life is as yet known to exist, belongs not to a variety, but to the original specific type.

The interest of this proof of the persistence of a deep-sea coral species is enhanced by its being associated with other corals which possess Cretaceous alliances. The group of forms has a decided Cretaceous facies.

When the discovery of *Caryophyllia formosa*, Pourtales, and that of the variety of *Caryophyllia cylindracea*, Reuss, sp., already alluded to, are considered in relation to the small group from the great depths, the homotaxis of part of the coral fauna of the Atlantic and that of the Cretaceous ocean about the same area becomes very remarkable.

Such Cretaceous genera as *Trochosmilia*, *Parasmilia*, *Synhelia*, and *Diblasus* are extinct; but *Amphihelia ramea*, Müll. sp., represents the *Synheliæ*, and the position of the first two groups is now occupied by species of *Paracyathi* and *Caryophylliæ*, more elaborately constructed types, it is true, but adapted to the same bathymetrical zones and for the same destiny.

Why such species as *Caryophyllia cylindracea* should persist, and others, like *Parasmilia centralis* of the Chalk die out, is inexplicable, unless it is admitted that there is a law regulating the life-duration of species like that which restricts the years of the individual; for the forms apparently throve under the same external conditions; and if these have lasted so that the one species has persisted generation after generation, how upon any other theory can the other have become extinct?

Considering that the generalization respecting the structural distinctions of deep-sea and reef-building corals must be accepted, it follows that deep-sea conditions must have prevailed within the limits of the diffusion of the ova of coral polypes somewhere or other on the Atlantic area ever since the Cretaceous period. The deposits which were formed during the Eocene period in clear deep oceanic water far off from coral-rerfs and muddy rivers have not been discovered; consequently the oceanic corals of the period are still unknown. The muddy sea-deposits and the vast aggregations of reef-corals and Nummulites so almost invariably associated abound; and in the Pyrenees and in the Hala mountains of Sindh there are littoral and shallow sea-corals found with Nummulites. These last-mentioned deposits and those of the London clay and Paris basin present evidences of the existence of neighbouring deep seas as yet unnoticed geologically.

I have already advanced, in former communications, proofs that the reefs of the Miocene age of Europe were continued across the Atlantic, through the Caribbean Sea, and into the great ocean-desert of the eastern Pacific when the Isthmus of Panama and vast tracts of land to the north and south of it were sea-floors. According to the theory which distinguishes between the deep-sea and reef-building corals, the descendants of the Cretaceous oceanic forms could not be found on the remains of that belt of islands which are to be traced in the West Indies, the Faluns and away to the east far past Vienna, and along the Italian peninsula. In fact, they have not been discovered in those deposits.

But with the first evidences of deposits far from reefs and well adapted for the invertebrate life of the deep sea come the proofs of the persistence of deep-sea coral forms. The older Pliocene of Sicily (the Zanclean of Seguenza) yields *Caryophylliæ* with four cycles, and species with shapes like those of the former deep seas, although with important structural distinctions.

At the present time in the deepest known coralliferous depths of the eastern Atlantic the persistent species, its varieties, and the representatives of its former associates are living in consequence of the resumption of the external conditions which favoured their existence before the initiation of the great alterations in the relative level of the land and sea which destroyed the majority of the Cretaceous forms on the European areas before the age of Nummulites. It is unnecessary to enlarge upon this part of the subject, as it has been so ably handled by the President in his last Address; and it therefore remains for me to conclude this communication by reminding the Society that I have attempted to show that deep-sea corals may persist somewhere through the ages when littoral and reef- and muddy deposits were formed in their proper area, and may return upon the resumption of the former physical conditions.

Discussion.

Mr. Gwyn Jeffreys remembered that at the spot where the coral in question was dredged up the sea-bottom was extremely uneven, varying as much as 350 fathoms within a quarter of a mile. It was also not more than forty miles from land. The species of Mollusca also procured in this dredging were extremely remarkable, and many were quite new to him. They were, however, living or recent species; none of them were Eocene or Miocene, much less Cretaceous, like *Terebratula caput-serpentis.* He quoted from Mr. Davidson instances of the persistence of Brachiopoda, especially of the genus *Lingula* from the Silurian formation: The continuance of this species of coral, as well as of certain Foraminifera, from the Cretaceous to the present time was therefore not exceptional; and other cases of survival from even earlier times might eventually be recognized.

Dr. Carpenter, after commenting on the reductions that extended knowledge enabled naturalists to make in the number of presumed species, could not accept the mere identification of species as of the highest importance in connecting the Cretaceous fauna with that of our own day. The identity of genera was, in his opinion, of far more importance. He instanced *Echinothuria* and *Rhizocrinus* as preserving types identically the same as those of a remote period, and as illustrating the continuity of the deep-sea fauna from Cretaceous times. The chemical and organic constitution of the deep-sea bottom of the present day was also singularly analogous to that of the Chalk sea. The low temperature at the bottom of the deep sea, even in equatorial regions, was now becoming universally recognized; and this temperature must have had an important bearing on the animal life at the sea-bottom.

Prof. Ramsay thought that there was some misapprehension abroad as to the views held by geologists as to continuity of conditions. They had, however, always insisted on there having been an average amount of sea and land during all time; and the fact of sea having occupied what is now the middle of the Atlantic since Cretaceous time would create no surprise among them. If, however, the bed of the Atlantic were raised, though probably many Cretaceous genera, and even species, might be found, there would on the whole be a very marked difference between these Atlantic beds and those of the Chalk.

Mr. Seeley had already, in 1862, put forward views which had now been fully borne out by recent investigation. His conviction was that, from the genera having persisted for so long a time, the genera found in any formation afforded no safe guide as to its age, unless there were evidence of their having since those formations become extinct.

Mr. Etheridge maintained that the species in different formations were sufficiently distinct, though the genera might be the same. Recent dredgings had not brought to light any of the characteristic molluscan forms of the Cretaceous time; and it would be of great importance to compare the results of future operations with the old Cretaceous deep-sea fauna.

Prof. Rupert Jones, with reference to the supposed sudden extinction of chambered Cephalopods, remarked that Cretaceous forms had already been discovered in Tertiary beds in North America, and also that cold currents could not have destroyed them, seeing that icebergs came down to the latitude of Croydon in the Chalk sea.

2. *Note on an* Ichthyosaurus (I. enthekiodon) *from* Kimmeridge Bay, Dorset. By J. W. Hulke, Esq., F.R.S., F.G.S.

[Plate XVII.]

On the 22nd December, 1869, I brought under the notice of the Society two fragments of a long, slender snout with sauroid teeth of a peculiar form, obtained in Kimmeridge Bay by J. C. Mansel, Esq., F.G.S., which I was inclined to refer to the genus *Ichthyosaurus*; but the evidence not being quite decisive I was obliged to leave the true position of the Saurian indicated by them to be determined at some future time, whenever new material for the purpose might accrue. Meanwhile I gave it the provisional name *Enthekiodon*, from the thick capsule of cementum surrounding the tooth-fang.

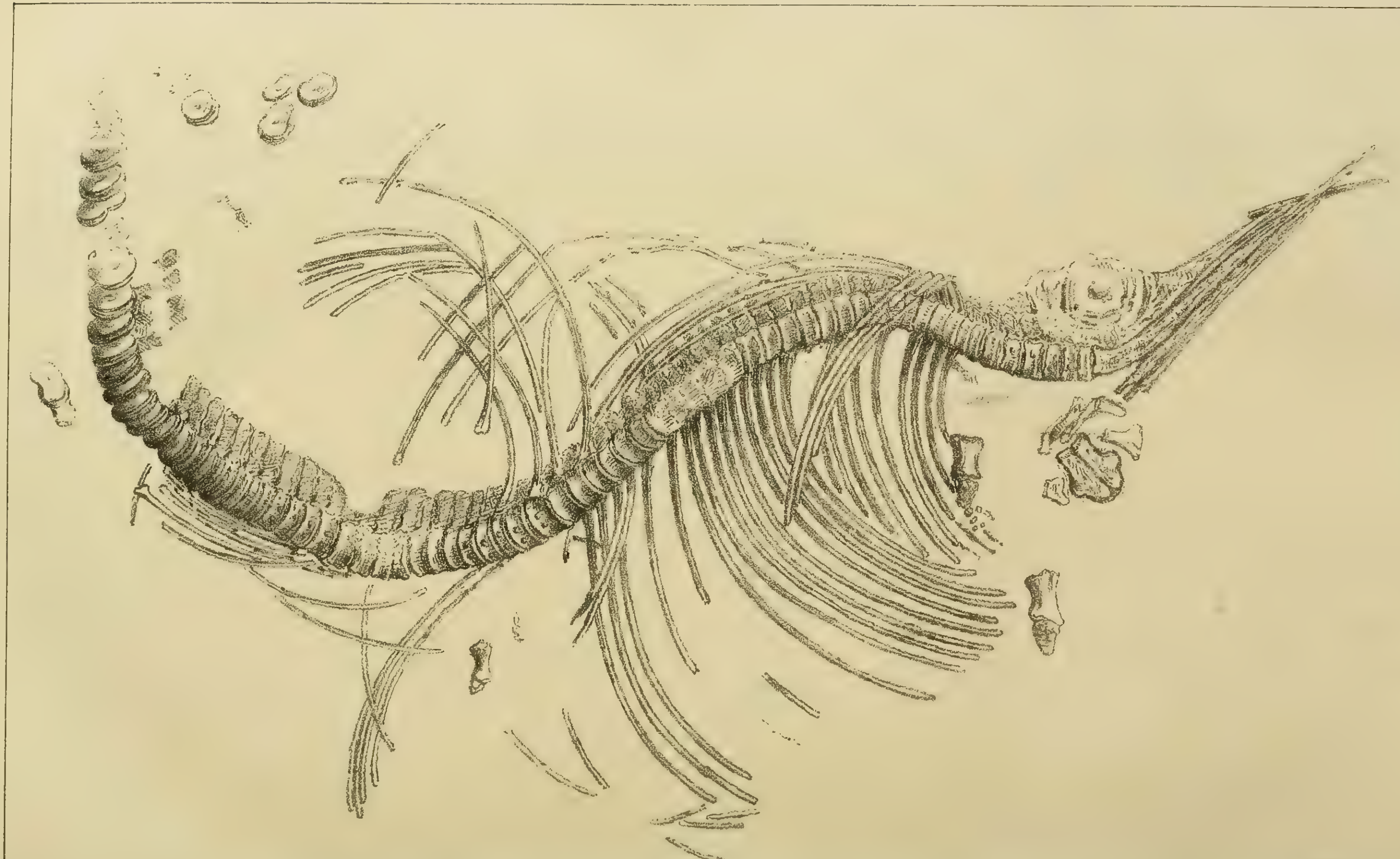
A very few days afterwards, while making a short visit with Mr. Mansel to Kimmeridge Bay, we discovered great part of the skeleton of an indubitable *Ichthyosaurus*, the snout and teeth of which agreed so closely with those of *Enthekiodon* as to leave no reasonable doubt of their identity, Mr. Mansel generously added it to the splendid series of Kimmeridge fossils already presented by him to the British Museum, and it has lately been placed in the Palæontological Gallery.

The skeleton lies (as we found it on the reef) on its left side; the head is bent upwards, the vertebral column makes a double curve, the greater part of the tail is missing, a large number of the ribs on the right side preserve their relations to the vertebral column and to one another nearly undisturbed; beneath them is a black stain (cuttle-ink?), in which are small scales; below the early thoracic ribs lie the bones of the breast-girdle. The least mutilated fore-paddle was inadvertently taken from the situation where I saw it before the skeleton was removed by the quarrymen; and it and the remaining hind paddle have been fixed in the slab below the skeleton.

The anatomical details of the skull are not decipherable; but the orbit is large, and the eyeball has the usual bony ring.

The entire length of the head is 23·5 inches. The jaws are very long and slender. The teeth are smooth, slender, cylindrical, and pointed; they are composed of an internal core of simple tubular dentine, the crown overlaid with enamel, and the root enveloped in a thick smooth sheath of vascular cementum, which gives it a bulbous figure. The basal end of the cylinder of dentine contracts slightly, and it is also slightly and irregularly indented, very faintly shadowing, as it were, the beautiful inflexions of the dentine and cementum of the same part in the tooth of *I. communis*. The apex of the pulp-cavity rises into the crown; it is filled with a brittle cone of spar; and the base of the cavity contains a small plug of osteo-dentine, the vascular canals of which inosculate through the open end of the cavity with those of the external sheath of cement, just as in *I. communis*.

In the spinal column 56 vertebræ, connected in an unbroken series, now occupy 8 feet; but the hinder ones have slipped slightly



De Wilde del. et lith. M. & N. Hanhart imp.

ICHTHYOSAURUS ENTHEKIODON.

on one another. The first forty-five bear a double costal tubercle, and the remaining centra have a single one. The fifth, sixth, and seventh centra are each ·8 inch long; the fifteenth is rather less than ·9 inch. The vertical and transverse horizontal diameter cannot be accurately taken. The length of the hindermost centra is rather under ·8 inch, while their transverse horizontal diameter exceeds that of any of the preceding ones. The ribs do not offer any thing peculiar; towards their vertebral end they are compressed and channelled; in the flank they have a cylindrical form; and their ventral ends are flattened.

A pair of flat bones going below the early thoracic ribs are, I infer, from their position, and from their close association with the scapulæ, the coracoids. Their form is unusual. They are much more elongated in the direction of the trunk's axis than are those of the Liassic *Ichthyosauri* with which I have had an opportunity of comparing them, their axial diameter being to their transverse one as 5·3 : 2·8 inches. With this greater length their anterior border reaches much further forwards in advance of the glenoid cavity than in the Liassic forms; and it, as also the median border, is straight, so that the latter touches its fellow throughout its whole length when the two coracoids remain naturally united, as they do in this instance. The articular end of the scapula is unusually broad.

The paddles, particularly the hind ones, are extremely reduced. Their precise form and composition cannot be learned; for most of the lesser bones are missing. The humerus is 2·7 inches long, its distal end is 2·1 inches broad, and the diameter of its middle is 1·6 inch. The femur is only 2 inches long; its proximal end is 1·4 inch broad, its distal end is 1·1 inch, and the diameter of the middle is ·9 inch.

This, as I believe, new species, which I propose to call *I. enthekiodon*, resembles in the slenderness of its snout the two Liassic species *I. longirostris* and *I. tenuirostris*, but it is readily distinguishable from these by the following characters. Its snout, relatively to the length of the cranium, is not so long as that of *I. longirostris*; its smaller tooth-root is smooth, and not distinctly fluted as in *I. tenuirostris*; the shape of its coracoid is quite different from that of the coracoid of *tenuirostris*; and its spinal column is much stouter than that of either of these species. It resembles both *I. tenuirostris* and *I. longirostris* in the preponderence of its fore paddles over its hind ones; but its fore and hind paddles, so far as I can judge of their size by that of their proximal bones, are very much smaller; indeed the paddles, relatively to the whole skeleton, are smaller than in any other species known to me.

EXPLANATION OF PLATE XVII.

Skeleton of *Ichthyosaurus enthekiodon* from Kimmeridge Bay, one twelfth natural size.

3. *Note on a* Fragment *of a* Teleosaurian Snout *from* Kimmeridge Bay, Dorset. By J. W. Hulke, Esq., F.R.S., F.G.S.

[Plate XVIII.]

This piece of a Teleosaurian snout, which fell last winter from the cliff in Kimmeridge Bay, and was lately entrusted to me by J. C. Mansel, Esq., F.G.S., seems to me worthy of a short notice, as it is the first indication of this genus which, within Mr. Mansel's knowledge, has been discovered at Kimmeridge; and I do not find in the British Museum any Teleosaurian fossils from this locality, nor are any mentioned in Mr. Seeley's recent catalogue of the fossil Reptilia in the Woodwardian Museum, although in both these collections there are Teleosaurian remains from other Kimmeridge-clay localities.

The fragment, 17 inches long, represents a very long and slender snout tapering gradually and slightly (its breadth decreases only 0·5 in. through a distance of 15·5 in.) to behind the external nostril, where the præmaxillæ suddenly and largely expand. The nostril, wholly inclosed in these bones, is dilated, strictly terminal, and directed obliquely forwards; its lower margin is interrupted by a prominent median tubercle formed of the swollen præmaxillary suture; and a shallow convex lobe projects from the middle of the upper margin. The præmaxillæ ascend 2·5 in. above the nostril, and end in an acute point, the maxillæ composing all the remainder of the fragment. The upper surface of the snout is convex transversely, more so in front than posteriorly, where it becomes depressed; but its transverse section nowhere approaches the semicircular form of the stouter-snouted *Steneosaurus Manselii*, which I described last session. The lateral margins are slightly crenated by the prominent alveoli of the sixteen foremost maxillary teeth, the openings of which slant outwards and downwards, while the hinder ones look directly downwards. The palatal surface between the alveoli is convex transversely in front, and it becomes gradually flatter posteriorly. Throughout its whole length it descends below the level of the alveoli. No trace of the front ends of the palate-bones are discernible.

Most of the teeth have fallen out; but a few, broken short off, remain in the sockets. The transverse section of the best-preserved of these teeth, at the neck, is nearly circular. Each præmaxilla contains five alveoli; judged of by the size of these, the third and fourth teeth were larger than the others, and the first and fifth were the smallest. Each maxilla in the space of 15·5 in. has a series of twenty-five alveoli, of which the three front ones are smaller than the others.

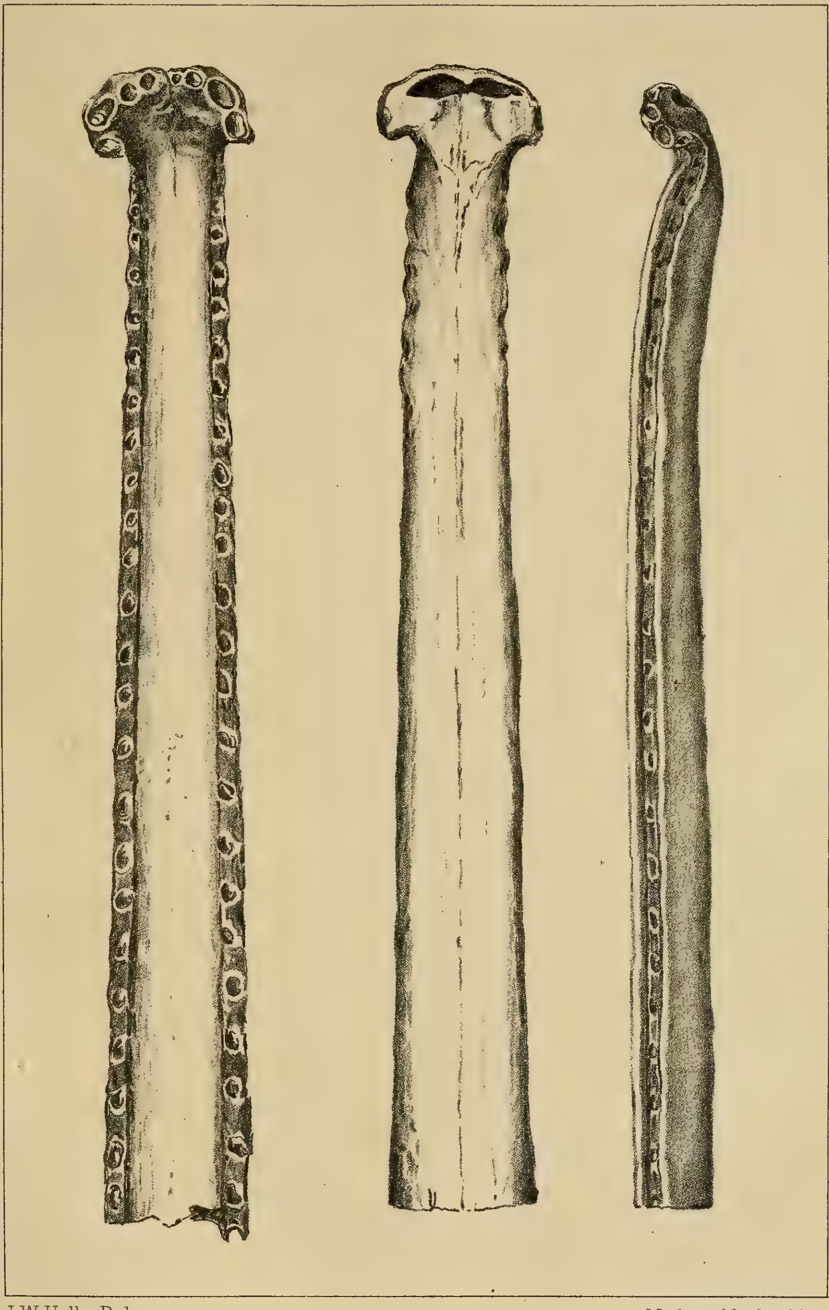
The dilatation of the terminal nostril is much greater than in any other *Teleosaurus* known to me. I believe the fossil represents a new species, and I propose for it the specific designation *megarhinus*.

EXPLANATION OF PLATE XVIII.

Fig. 1. Snout of *Teleosaurus megarhinus* from Kimmeridge, seen from beneath, reduced.

2. The same, from above.

3. The same, from the left side.



J. W. Hulke, Del:

Maclure & Macdonald imp:

TELEOSAURUS MEGARHINUS.

Discussion.

Mr. Seeley thought it likely that Mr. Hulke would eventually be led to reestablish his genus *Enthekiodon.* He remarked on the peculiar characters presented by the specimen, and referred especially to the coracoids, which were unlike those of *Ichthyosaurus,* but presented a close resemblance to those of *Plesiosaurus.* He considered that there were indications of its having been connected with a cartilaginous sternum. The scapula furnished an important difference in its widening, which formed a distinct acromion process. Mr. Seeley remarked that double-headed ribs similarly attached occur only in animals with a four-chambered heart, and that, considering this and other characters, there was no reason for placing *Ichthyosaurus* lower than among the highest Saurians*. He considered that the Teleosaurian snout differed from all known types.

Dr. Macdonald believed that what is called the coracoid has nothing to do with the shoulder-girdle, and thought it might be a part of the palate.

Mr. Mansel stated, in answer to the President, that the fossils were obtained from about the middle of the Kimmeridge Clay.

Mr. Etheridge suggested that it would be desirable to ascertain whether the horizon of the *Ichthyosaurus* described was the same as that of the specimens from Ely.

Mr. Gwyn Jeffreys inquired as to the food and habits of the *Ichthyosaurus.*

Mr. Hulke, in reply, stated that, from the presence of a stain and of numerous small scales under the ribs, the food of the *Ichthyosaurus* probably consisted of Squids and small fishes. He showed that the so-called coracoid was clearly a part of the shoulder-girdle.

June 21, 1871.

Robert John Watson, Esq., B.A., Assistant Master at Dulwich College; W. T. Scarth, Esq., Raby Castle, near Darlington; Gen. A. C. Bentinck, of East Court, Wokingham, and John Brooke, Esq., of the Collegiate School, Newark, were elected Fellows of the Society.

The following communications were read:—

1. *On* some supposed Vegetable Fossils. By William Carruthers.

[Plate XIX.]

The baneful influence of the imagination in science is seldom more clearly seen than in the way in which fossil botany has been too often pursued. The determination of the name of a recognizable

* Having since seen the specimen, Mr. Seeley believes that the truncated margin was *anterior,* and abutted against the interclavicle (episternum); so that the posterior margins of these coracoid bones are similar to the same margins in *Ichthyosaurus,* and there is no evidence of the animal having had a sternum.

fragment can of course be made by any one who can intelligently compare a specimen with a drawing or a description; but the interpretation of the affinities of a fossil or the restoration of a plant from the few fragments known, can be accomplished only by one who has some acquaintance with living organisms, and with the essential and non-essential characters which combine or separate them. When this knowledge is wanting, a lively imagination supplies its place to the complete satisfaction of the investigator, but to the great injury of science. From its very nature, moreover, an imaginative interpretation is more tenaciously adhered to by its author than if it were the legitimate deduction from known facts; and it is more satisfactory, because it does not present the difficulties that are always encountered in *real life*. It is quite in keeping with this that a considerable contributor to the subject of fossil-botany has declared that a knowledge of recent plants is a serious hindrance to the investigation of fossil vegetables—and that another has recently expounded in a science-lecture his important determination of the affinities of *Lepidodendron* and *Calamites* to *Lycopodium* and *Equisetum*, although his descriptions make it evident that he never has examined, and probably never has seen a single specimen of either a club-moss or a mare's-tail in his life.

I propose in this paper to call attention to some of the specimens which I have either met with in collections, or have had sent to me as fossil plants, but which have no connexion with the vegetable kingdom. Instead of setting them aside as non-vegetable, I have taken advantage of the opportunities afforded by my connexion with the British Museum, and especially of the important assistance of my friend Mr. Thomas Davies, to determine what they are.

It would be curious to trace such errors in scientific works, and show how frequently careful observers have thought that they had the most perfect foliage in dendritic crystals, and beautiful wood-structure in stalagmites. But I have encountered errors more remarkable than these, now happily exploded. Among others I may mention:—a curious form of calamite from a particular bed in the South Wales coal-field which turned out to be the fragment of the handle of a Wedgewood basalt tea-pot; a branching part of the root of a great tree, the remainder of which was yet *in situ* and could be obtained, converted into metallic lead; and a fragment of exogenous wood showing the openings of the medullary rays, which was a singularly altered piece of shale or slate from the wall of a vitrified fort.

The first specimen to which I would ask special attention is a supposed fruit figured and described by Sternberg in his 'Flora der Vorwelt,' tab. ix. fig. 2, as *Carpolites umbonatus*. These are round, flattened bodies, with a glazy polished surface and a central nucleus (Pl. XIX. figs. 12–17); they sometimes separate from the matrix enveloping them, and then appear to be fruits, with their pericarp converted into a thin shining layer of coal, like the Trigonocarpons that are found in similar beds. On careful examination, however, it is seen that the glazy surface is not produced by a foreign substance, but is the material of the bed polished in some way—and, further, that the detached fruit-like body has many layers of such glazed surfaces, subparallel to each other, and all separated by the ordinary substance of the bed, which thus makes up the body of the so-called fruit. The glazed laminæ originate from the somewhat granular nucleus. There frequently occur on the same hand-specimen small patches of similarly glazed surfaces with irregular outlines (Pl. XIX. fig. 12), to which the name *Slickenside* has been incorrectly applied; this term is properly employed and should be restricted to designate the smooth and polished appearance produced by enormous friction on the contiguous surfaces of a fault. The structures, however, in shale, to which the name is applied are confined to the stratum in which they occur, and never pass from one surface to the other; they occupy all positions in the bed, and are isolated or sometimes united at angles more or less acute; the polished surfaces are frequently crumpled and waved. All these points in their structure show that they are not due to a force external to the bed, and that the polishing has not been produced by the sliding backwards and forwards of the one surface on the other. Dr. Fleming carefully investigated these appearances, and proposed what appears to be a very satisfactory explanation of their origin. He believed them to have been produced in cavities in a comparatively soft plastic matter by the presence of water or gas contained in the cavities, and that the specular aspect was the casting or impression of the fluid substance*. These limited slickensides, or as I would prefer to call them *fluid-casts*, occur in rocks which have been at one time or other in a more or less viscous or tenacious condition; they are found in argillaceous rocks of all ages. So also are the fruit-like bodies which I have described; I have obtained them from the shale-beds of the Coal-measures in England, Wales, Scotland, and North America, and from the Newer Tertiary clays of Ulm, Württemberg; they have been figured from the Coal-measures of Germany, and from the Permian rocks of Saxony. The granular nucleus which is found in the centre of these fruit-like bodies, was, I believe, the source of the gaseous substance which has left its impress on the glazed surface. This nucleus appears to me to have been a crystalline concretion, which subsequently decomposed; and the gas then given off spread outwards as it was produced in the planes of stratification, this being the direction of least resistance.

These fluid-casts were figured by Rhode in his 'Beiträge zur Pflanzenkunde der Vorwelt' (1820) pls. vi., vii., ix., and x. The first two plates give a faithful representation of the objects; but a little play is given to the imagination in plate ix.; and its unfettered operation is seen in the tenth plate, where the different polished surfaces are converted into the petals of flowers, and the whole are associated with foliage for which a species of *Veronica* has apparently supplied the design.

The two following species have been based on these fluid-casts:—

* "Dr. Fleming on the structural characters of Rocks," Proc. Roy. Soc. Edin. vol. iii. p. 170.

1. Carpolites umbonatus, Sternb. Flora d. Vorwelt: Tent. p. xli, tab. ix. fig. 2.

Cardiocarpum umbonatum, Bronn, Leth. Geogn. vol. i. p. 37, tab. viii. fig. 3.

Guilielmites umbonatus, Gein. Leitpflanzen d. perm. Form. p. 19.

Quercites palæococcus, Unger, *fide* specimen in the Bruckmann collection, British Museum.

2. Guilielmites permianus, Gein. Die Leitpflanzen der permischen Formation, p. 19, tab. ii. fig. 6–9.

Carpolithes permianus, Schimper, Traité Pal. Vég. vol. ii. p. 226.

Geinitz established the genus *Guilielmites* for the reception of these supposed fruits, because of their resemblance to the fruit of *Guilielma speciosa*, Martius, a palm from Brazil. Schimper places *Guilielmites permianus* among the fruits which he considers to be related to the seeds of *Cycadeæ*; while *G. umbonatus* is not noticed by him; it may be either rejected as a spurious fossil, unintentionally overlooked, or referred to a place in the vegetable kingdom which his valuable work has not yet overtaken.

There occur not unfrequently in the Stonesfield slate roundish flattened bodies (Pl. XIX. figs. 4–7), most frequently exhibiting only the amorphous cast of the organism in which they were originally moulded, and lying loose in the cavity of the matrix, but occasionally inclosed in a dark-coloured polished covering. These have been considered to be fruits; and they so closely resemble the aspect of the ripe seed of a chestnut that it is not to be wondered that they are always placed amongst vegetable fossils in museums. Some time ago the Rev. P. B. Brodie, F.G.S., was so good as to send me his large collection of Stonesfield-slate remains for investigation. I have already described from them an interesting Araucarian cone. There were in his collection several specimens of these round bodies, one with the dark covering entire, and another with it partially removed. Besides these I have examined a large series in the Oxford Museum, and several in the British Museum. The continuous nature of the covering, without any indications of a base or apex, which would have been indicated had it been a fruit, or of the hilum, had it been a seed, made me doubt its vegetable nature; and the uniform thickness and continuity of the covering suggested that these bodies might be eggs. Fortunately the surface yet exhibited sufficient markings to assist in determining whether this was the case or not. After the examination of a considerable series of eggs in the zoological collections of the Museum, I discovered that the sculpturing on the surface agreed very closely with that on the eggs of reptiles, and especially those of turtles. This determination was confirmed when I subsequently ascertained that the bony plates of Chelonians were not uncommon in the Stonesfield slate. Besides turtles, however, there occur also in this deposit the remains of Pterodactyles; and it is not improbable that they may be, as suggested by Mr. Seeley, the eggs of these flying lizards ('Ornithosauria,' p. 106). That they are reptilian eggs there cannot be any doubt; and as they add somewhat to the knowledge of the Reptilia of the Secondary rocks, and are likely to be quoted by writers, I venture to give them a specific name.

Mr. Buckman has already, in the Quarterly Journal of this Society, described some eggs which he discovered in the Great Oolite of Cirencester. From their form he determined them to be reptilian; and on examining the sculpturing on the surface of the egg, I find his determination is confirmed. He proposed for them the generic name *Oolithes*; and, employing this, I now add to the oblong form described by him the round Stonesfield eggs as a second species, with the designation *Oolithes sphæricus*.

The Rev. Thomas Fox, of Brixton, Isle of Wight, has supplied me with another and much smaller egg, which he obtained from the Wealden in that locality, and which he also believed to be a fruit.

The three species may be thus characterized:—

Oolithes, Buckman, Quart. Journ. Geol. Soc. vol. xv. p. 107.

O. bathonicæ, Buckman, Quart. Journ. Geol. Soc. vol. xvi. p. 107. (Pl. XIX. figs. 8 & 11.)

Eggs ovate, twice as long as broad.
Locality. Great Oolite of Cirencester.

O. sphæricus, sp. nov. (Pl. XIX. figs. 4–7, 10.)

Eggs globular, about three quarters of an inch in diameter.
Locality. Stonesfield Slate, Stonesfield.

O. obtusatus, sp. nov. (Pl. XIX. figs. 1–3.)

Egg small, subglobular, obtuse on one side, about three eighths of an inch in diameter.
Locality. Wealden of Brixton, Isle of Wight.

Count Sternberg, in his great work on fossil plants, describes a supposed Alga from Solenhofen under the name of *Cystoseirites nutans* ('Flora der Vorwelt,' fasc. v. & vi. p. 35, 1833), having a frond with linear branches bearing opposite, linear-lanceolate, acuminate, falcate, and spreading leaves with a single midrib; and the figure (*l. c.* pl. viii. fig. 1) agrees with the description, and without doubt accurately represents the specimen. It has been since ascertained that the drawing was made from an imperfect specimen of a cuttle-fish, in which the body is wanting and the fleshy arms have perished, leaving only their horny hooks somewhat in the position they occupied in the animal. These Sternberg mistook for the opposite leaves of an Alga. Münster figured a more perfect specimen, and gave to it the name of *Acanthoteuthis speciosa* (Beiträge, fasc. i. p. 105, pl. ix. 1843).

Among the specimens for the examination of which I am indebted to the Rev. P. B. Brodie there is a delicate cuttle-bone, which so closely resembles a leaf that it is not to be wondered that it was placed among the vegetable fossils. It belongs to the genus *Teudopsis*, Deslongchamps, which is distinguished from *Loligo* only by the different form of its horny pen. In the recent genus the pen is lanceolate, with a long and slender shaft in front, while in *Teudopsis* it is spatuliform, with a short and somewhat broad shaft in front. Specimens found at Calvados show the ink-bag still preserved and in its proper position.

To this I propose to give the name of *Teudopsis Brodiei*. This interesting fossil was obtained by the Rev. P. B. Brodie from the insect-bed of the Purbeck series of Dorsetshire, in which he has done such important service to geology by his patient and persevering investigation of the fragmentary remains of insects buried in it.

The species hitherto known are all from the Upper Lias of France or Württemberg; this species, therefore, carries the form somewhat higher in the geological series. The following diagnosis will be sufficient to distinguish it:—

Teudopsis Brodiei, sp. nov.

The horny bone anteriorly elongated and tapering to the (broadish) apex. The boundary lines of the anterior portion subconcave, extending two-thirds down the bone, where it reaches its greatest width; the posterior portion oval, with a blunt termination. The whole surface is marked by faint longitudinal striæ, which diverge outwards on the expanded portion of the bone.

Teudopsis Brodiei.

EXPLANATION OF PLATE XIX.

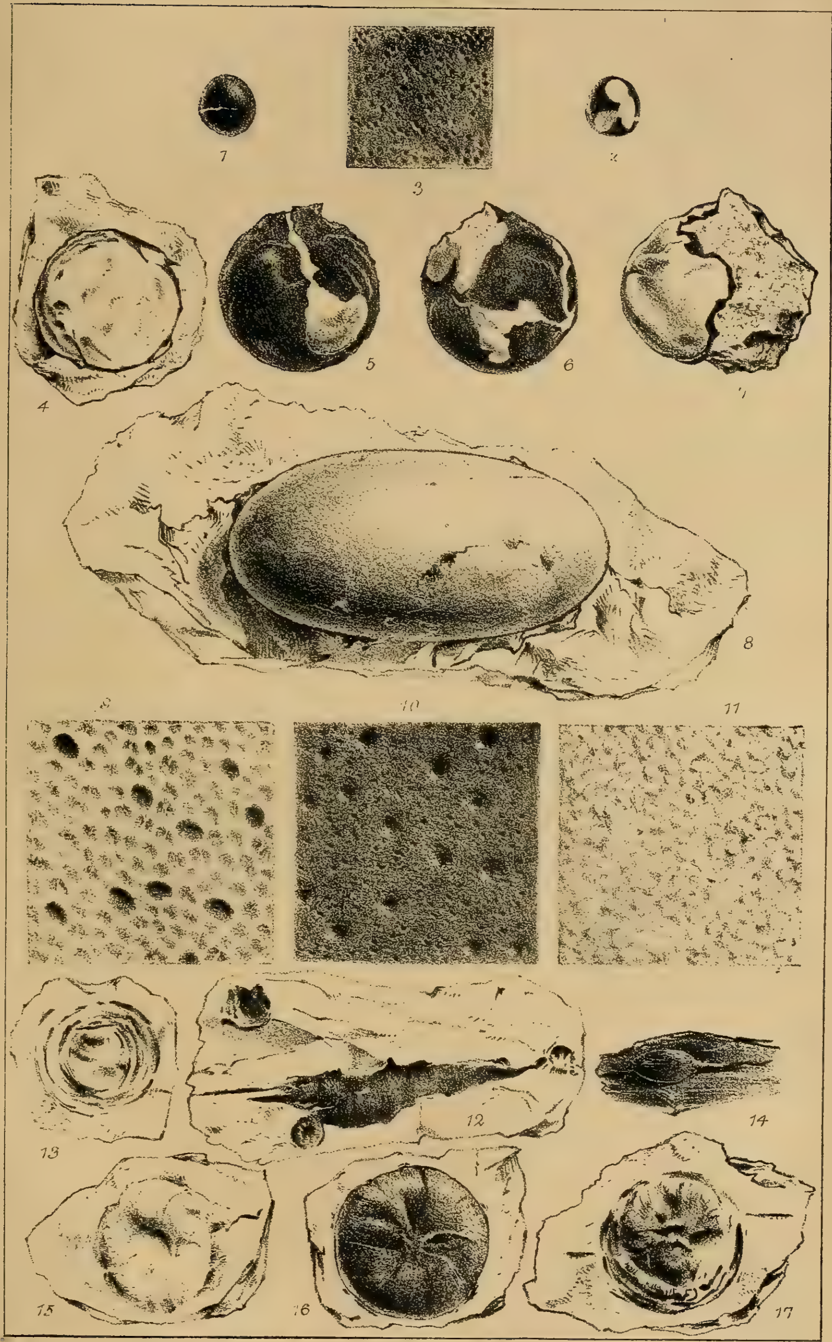
Figs. 1–3. *Oolithes obtusatus*, Carr.
Figs. 1 & 2, natural size. The ruptured opening, through which the clay filling the interior obtained access to it, is shown in fig. 2. Fig. 3. Fragment of the shell, magnified, to show the markings on the surface.

Figs. 4–7, 10. *Oolithes sphæricus*, Carr.
Fig. 4. Specimen in which the amorphous material filling the cavity of the egg remains. Figs. 5, 6. Two views of the same egg nearly covered with its shell. Fig. 7. The internal cast of another, showing, around the edge where it is still inclosed in the matrix, portions of the shell still remaining. These figures are the size of nature. Fig. 10. Fragment of the shell, magnified, to show the markings on the surface.

Figs. 8, 11. *Oolithes bathonicæ*, Buckman.
Fig. 8. Natural size. Fig. 11. Fragment of the cast of the shell, showing the markings of the surface.

Fig. 9. Fragment of the shell of a recent Turtle.

Figs. 12–17. Fluid-casts in shale from Carboniferous rocks.
Fig. 12. Exhibiting three small fruit-like casts, and a flat irregular-shaped cast. From South Wales. Figs. 13, 15. Specimens from Cape Breton, N. America. Figs. 14, 17. Specimens from South Wales. Fig. 16. Specimen from Old Cumnock, Ayrshire. All natural size.



W.G. Smith, F.L.S. fec.

W. West & Co. imp.

Supposed Vegetable Fossils.

Discussion.

Mr. Seeley remarked, as to the compressed spheroids found in so many rocks, that there was a difficulty in accepting the view of their originating in fluid vesicles, though he was unable to suggest any other theory by which to account for them. He observed that the eggs from the Stonesfield Slate closely resemble those of some birds in the pitting of the egg-shell, which differed from the pitting on such reptile-eggs as he had examined—and that it was of the highest interest to find such eggs in strata containing so many remains of ornithosaurian forms, such as *Rhamphorhynchus* and *Pterodactylus*, of which latter genus these were probably the eggs.

Prof. Rupert Jones fully recognized the ingenious explanation of the bubble-formed limited slickensides that looked so much like possible fossil fruits, and Mr. Carruthers's masterly treatment of the other specimens; but he wished that the author would take up the subject exhaustively, and define the nature of other supposed vegetable fossils, such as the so-called fucoids, *Palæochorda*, *Palæophyton*, *Oldhamia*, &c., many, if not all, of which Prof. Jones thought to be due to galleries and other tracks made by Crustaceans.

Prof. Ramsay had known many instances of such blunders as those pointed out, made, not by experienced geologists, but by those unacquainted with the science. Though he had never regarded the flattened spheroids as fossils, he was unable to account for their presence in the clay-beds of different ages.

Mr. Hulke inquired whether Mr. Carruthers regarded the limited slickensides common in the Kimmeridge shales as due to gaseous origin. He remarked on the rarity of Pterodactylian remains as compared with those of other Saurians in the Wealden beds, in which the presumed eggs of Pterodactyle were found.

Mr. Seeley did not regard the Wealden egg as that of a Pterodactyle.

Mr. Carruthers, in reply, remarked that the local slickensides mentioned by Mr. Hulke differed in character from those to which he had referred.

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2. Notes *on the* Geology *of* part *of the* County *of* Donegal. By A. H. Green, Esq., F.G.S.

[Abstract.]

In this paper the author described the geological structure of the country in the neighbourhood of the Errigal Mountain, with the view of demonstrating the occurrence in this district of an interstratification with mica-schist of beds of rock which can hardly be distinguished from granite, the very gradual passage from alternations of granitic gneiss and mica-schist into granite alone, and the marked traces of bedding and other signs of stratification that appear in the granite, to which the author ascribed a metamorphic origin. He also noticed the marks of ice-action observed by him in this region, and referred especially to some remarkable fluted bosses of quartzite, and to the formation of some small lakes by the scooping action of ice.

Discussion.

Mr. Forbes stated that none of the facts of this communication were new; but he dissented altogether from the conclusions arrived at by the author in regarding these rocks as originally of sedimentary origin, and for the following reasons:—(1) That this district had been studied in detail by Mr. Scott and Prof. Haughton, who declare the rock to be undoubtedly intrusive, as it not only sends out veins into the neighbouring strata, but also encloses fragments of the rocks through which it has broken. (2) Because the author starts from the idea that if such rocks are found to lie conformably on beds of undoubted sedimentary origin, it is a proof of their being themselves sedimentary or stratified,—a conclusion which is totally unwarranted, since there are innumerable instances, not only of beds of lava or other igneous rocks being conformable to fossiliferous strata, but of their also being found intercalated with such beds even for considerable distances. (3) The strata, so far from being proved by him to be of truly sedimentary origin, are of a most questionable origin, since they are neither in themselves fossiliferous, nor can they be correlated with any containing fossils as proofs of true sedimentary deposition; and the description of his section is sufficient to show this; for although it looks well on paper on a scale of 3 feet to the mile, the author has so little confidence in it that he is not even certain as to which is the top or bottom of the section on which so much generalization is based. (4) That a parallel structure equally, if not better, developed than any occurring in the gneiss of Donegal is common to many volcanic rocks, as in a specimen laid before the meeting, in which this parallel foliated structure due to crystallization-layers is so well developed as to make it appear exactly like a stratified rock, and even split along these lines; and this, although the product of volcanoes still active, is found for great distances both overlying conformably and intercalated between beds of the Cretaceous and Oolite formations.

Mr. Scott was unwilling to accept the section given by the author as satisfactory, but stated that Mr. Green had, without knowing of the existence of his papers on Donegal, confirmed many of his observations. He agreed with him as to the bedded appearance of the granite, and to the masses lying in general conformably with the lines of stratification of the country. The nearest spot at which fossiliferous rocks occurred was separated from the beds described by the whole width of the county of Tyrone, though some presumed Eozoonal forms had been found at a less distance. He was not prepared to believe in the original absolutely fused condition of granite, nor in there being two distinct types of granite, one metamorphic and the other purely igneous.

3. MEMORANDA *on the most recent* GEOLOGICAL CHANGES *of the* RIVERS *and* PLAINS *of* NORTHERN INDIA, *founded on* ACCURATE SURVEYS *and the* ARTESIAN WELL-BORING *at* UMBALLA, *to show the practical application of* MR. LOGIN'S THEORY *of the abrading and transporting power of water to effect such changes.* By T. LOGIN, Esq., F.R.S.E.

(Communicated by Alfred Tylor, Esq., F.G.S.)

[The publication of this paper is deferred.]

(Abstract.)

THE author commenced by referring to the general conditions of the surface of the country under consideration, and to the evidence afforded by it of a great decrease in the amount of rainfall, and a great change in the nature of the rivers. His object was to show that the superficial deposits of the plains of India were formed by the action of mountain-streams, the deposits being irregular transversely, but exhibiting a uniform section longitudinally, in a curve which the author believed to be a true parabola, as indicated by Mr. Tylor. The connexion of this with the author's theory as to the transporting power of water was indicated. The author also showed that the beds of the large Indian rivers are rising rather than being lowered, and pointed out that this was in accordance with his theory.

PROCEEDINGS

OF

THE GEOLOGICAL SOCIETY.

POSTPONED PAPERS.

1. *On the* Structure *of the* Crag-beds *of* Suffolk *and* Norfolk, *with some* Observations *on their* Organic Remains. By Joseph Prestwich, Esq., F.R.S., &c., President. Part III.—The Norwich Crag and Westleton Beds.

(Read January 26, 1870*.)

[Plate XX.]

In the first and second parts of this paper † I described the structure of the Coralline and Red Crags, and discussed the conditions under which they were formed. It now remains to describe the structure of the Crag series in Norfolk, and determine the correlation of the two geographical series.

The order of succession in the Suffolk area is clear and defined; but the relation which the Crag-beds of that area bear to those of the same series in Norfolk does not admit of the same ready determination. The Norfolk beds themselves, in their several localities, have been described by Mr. R. C. Taylor ‡, Mr. S. Woodward §, Mr. Charlesworth ||, Sir Charles Lyell ¶, and Mr. Trimmer **; and more recently a good brief account of them has been given by the Rev. J. Gunn††; whilst various papers, by Mr. Searles Wood §§, Mr. S.

* For the discussion on this paper see Quart. Journ. Geol. Soc. vol. xxvi. p. 282.

† *Antè* pp. 115 & 325.

‡ "On the Crag-strata at Bramerton," Trans. Geol. Soc. 2nd series, vol. i. p. 371, 1826.

§ Outlines of the Geology of Norfolk, 1833.

|| "On the Crag," Lond. & Edinb. Phil. Mag. 1835–36; and Ann. Nat. Hist. vol. ix.

¶ "On the Relative Ages of the Crags of Norfolk and Suffolk," Mag. Nat. Hist. vol. iii. 1839; and "On the Tertiary Strata of Belgium" &c., Quart. Journ. Geol. Soc. vol. viii. p. 277.

** "On the Cliffs of Norfolk," Quart. Journ. Geol. Soc. vol. i. p. 218, and vol. vii. p. 19.

†† Sketch of the Geology of Norfolk, 1864.

§§ "On the Extraneous Fossils of the Red Crag," Quart. Journ. Geol. Soc. vol. xv. p. 32; and "On the Structure of the Red Crag," Quart. Journ. Geol. Soc. vol. xxii. p. 538.

Wood, jun.*, Mr. J. E. Taylor †, Mr. Harmer ‡, and Mr. Maw §, the Rev. O. Fisher ‖, Mr. Ray Lankester ¶, and others, have since contributed largely to our knowledge of it. With respect to these papers, many of which (those especially of Mr. Wood and his colleagues) are marked by much research and original opinions, I feel rather at a loss how to proceed. Were I to give the views of each author and discuss the points of difference between us, I fear I should have to lengthen this paper to an extent which might be wearisome to the Society. If I do not therefore always notice all the points wherein I may agree or differ from other observers, I beg they will not consider it arises from oversight, or from want of due estimation of their researches, but from the mere necessity of avoiding the long details which a discussion of the controverted points would entail. I may be further justified in this course by the circumstance that my own researches are in great part anterior to most of the papers in question. It may be observed that where the several conclusions arrived at thus independently prove to be concordant, they must be entitled to greater weight. One object of this paper is also to give more fully than has been hitherto done the stratigraphical details of the several pits and particular coast-sections in which the relation of the several beds can be determined, following their range from the Red-Crag district and proceeding northwards through the Norwich-Crag district.

I described the Chillesford beds in 1849; and I then expressed an opinion that they were probably of the age of the Mammaliferous Crag of Norfolk, or possibly one degree more recent, an opinion shared by Mr. Searles Wood after an examination of the fossils **. My own observations, continued since that period, and the active researches of many of the geologists just named, have confirmed that suggestion. It has further been shown that the Norwich Crag may be divided into an upper and lower division, the former corresponding with the Chillesford Sands and possessing a deeper-water fauna of a more northern character than the other,—conclusions which I accept with, possibly, a few modifications. Another interesting question raised by Mr. S. Wood, jun., and his colleagues relates to the position of the Weybourne Crag; and on this we do not altogether agree.

In my last paper it was shown :—that the Chillesford Clay was probably the upper and deeper-sea portion of the second or higher

* "On the Red and Fluvio-marine Crags" &c., Ann. & Mag. Nat. Hist. March 1864; 'On the Upper Tertiaries of the Eastern Counties,' 1865; Geol. Mag. vol. v. p. 452; Quart. Journ. Geol. Soc. vol. xxii. p. 546.

† Geol. Mag. vol. iii. p. 273, vol. iv. p. 331, and vol. vi. p. 231.

‡ *Ibid.* vol. vi. p. 231. § *Ibid.* vol. iv. p. 560.

‖ "On the Relation of the Norwich Crag to the Chillesford Clay," Quart. Journ. Geol. Soc. vol. xxii. p. 19.

¶ Quart. Journ. Geol. Soc. vol. xxi. p. 221; and Geol. Mag. vol. iv. p. 91. vol. v. p. 254, and vol. vi. p. 47.

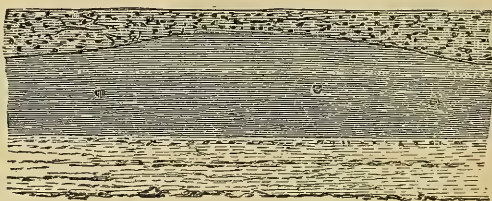
** Instead, however, of their overlying both the Red and Coralline Crag unconformably, I afterwards found that, while they were unconformable to the latter, they succeeded to and passed transgressively off the former.

division of the Red Crag; that the Chillesford series filled up and levelled the irregular surface of the Red and Coralline Crags, over the highest portion of both of which it extends; that reefs of the Coralline Crag divided the Red-Crag sea into different areas, with local variations in the distribution of the Molluscan fauna; and that the area north of Aldborough was not only separated from the more open sea to the south, but was also more subject to the influence of fresh water, the beds at once being more littoral and containing a larger number of freshwater Testacea. The Chillesford Clay was traced to Southwold, where it holds the same relation to the shelly sand-beds as it does in the Chillesford and Sudbourne districts.

Beyond the few pits in the neighbourhood of Southwold and Wangford there are no sections of the crag in north Suffolk. On the borders of Norfolk, however, we reach a section of great interest, which was discovered a few years since by Mr. Rose, of Yarmouth. It is in a brick-pit in the parish of Aldeby, at a distance, by road, of four miles from Beccles.

The section is as under:—

Fig. 27.—*Pit at Aldeby.*



		feet.
a.	Valley-gravel	2 to 4
3.	Chillesford clay	5 to 7
3′.	Light-coloured sands, with seams of fine gravel and of shells	6

A boring has been carried through sands 10 feet deeper, when the tool was stopped by a bed of gravel.

The Chillesford Clay is well developed, with its usual characters of a laminated grey micaceous clay; but no shells have been found in it here. Large flints, little worn, and fragments of wood are occasionally met with; and Mr. Dowson informs me that he found in the upper part of the clay the condyle of the femur of *Elephant.* The marked feature of the section is the occurrence of the Crag shells, not, as usual, with the larger portion in a comminuted state, but entire and with a number of double shells, many in the same position as when living. Occasionally large masses of flint are found in the sand. I saw one which weighed ¾ cwt.; and adhering to it were numerous basal plates of the *Balanus porcatus.* The undisturbed condition of the beds offers an unusually favourable opportunity of investigating the fauna of this part of the series free from the introduction of any foreign element,—an opportunity of which Mr. W. M. Crowfoot, and Mr. E. T. Dowson, of Beccles, have taken excellent advantage. The collections of these gentlemen now contain above seventy species from this bed; and I am indebted to them for the following list* :—

List of Shells found at Aldeby by Mr. W. M. Crowfoot and Mr. E. T. Dowson.

c. common. r. rare. fr. fragments. v c. very common. v r. very rare. n c. not common. For one or two specimens numerals are given.

Bivalves.

Abra alba?	v r
—— prismatica	r
Anomia aculeata	r
—— ephippium	r
—— striata	r
Astarte borealis	r
—— compressa, 2 vars.	v c
—— sulcata	v c
Cardium edule	c
—— grœnlandicum	v r
—— nodosum	r
—— strigilliferum?	v r
Cochlodesma complanatum	r
Corbula striata	v c
Cryptodon sinuosum	v r
Cultellus pellucidus	r
Cyprina islandica	v c
Donax vittatus	c
Kellia ambigua	1
Leda limatula	c
—— pygmæa (*Bell*)	1
Lepton nitidum	r
Loripes divaricatus	v r
Lucina borealis	v c
Lucinopsis undata	v r
Mactra ovalis	v c
—— solida	r
—— subtruncata	v r
Modiola modiolus	v r
Montacuta bidentata	r
—— ferruginosa	r
—— substriata	v r
Mya arenaria	v c
—— truncata	r
Mytilus edulis	c
Nucula Cobboldiæ	c
—— tenuis	n c
Pecten tigrinus	n c
—— opercularis	n c
Pectunculus glycymeris?, worn	1
Saxicava rugosa and var.	c
Solen siliqua?, fragment	v r
Tellina fabula	1
—— lata	v c
—— obliqua	v c
—— prætenuis	c
Thracia phaseolina	n c
Venus ovata	v c

Univalves.

Actæon tornatilis	r
Bulla regulbiensis	v r
—— truncata	v r
Calyptræa chinensis	r
Capulus ungaricus, var.	1
Cerithium tricinctum	1
Chemnitzia —?, fragment	1
Clavatula linearis	v r
—— turricula	c
Hydrobia ulvæ?	v r
Littorina littorea	r
Natica clausa	v c
—— helicoides	r
Purpura lapillus	r
Ringicula buccinea	v r
—— ventricosa	v r
Scalaria grœnlandica	r
—— Trevelyana	r
Trochus tumidus	c
Trophon antiquum	r
Turritella communis	v r

Balanus crenatus	
—— porcatus	

As the pit is a small one, and the sands are only occasionally excavated, it is easy to see how rich and promising the locality is. In the shell-bed a few Mammalian remains have been found, including tooth and part of antler of Deer, teeth and bones of small Rodent, vertebræ of Whale, together with bones and vertebræ of Fish, otolites, spines of Echini, Foraminifera and Bryozoa.

There are no Crag-pits between Aldeby and the neighbourhood of Norwich, where we have the well-known sections of Thorpe,

* In this list, as well as in that of Mr. Reeve, the greater part of the species have been, I understand, determined by Mr. Searles Wood.

Postwick, and Bramerton, each pit presenting certain distinctive palæontological characters. In future collections from these beds it would be very desirable to keep the fossils of each pit and each bed separate, as has been so well done by Mr. Reeve for Bramerton.

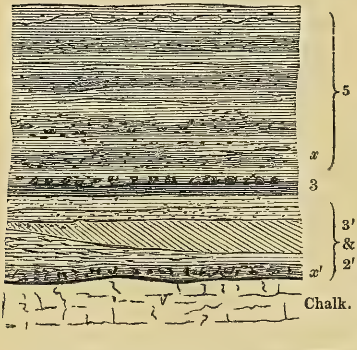
The pit near the Asylum at Thorpe exhibits the best-known and most interesting section of the Norwich Crag. Mr. R. Fitch, F.G.S., of Norwich, has made a very fine collection from this pit, including a large series of Mammalian and Molluscan remains. The former, which are common chiefly amongst or immediately upon the basement bed of worn flints (*x′*, fig. 28), consist of teeth and bones of the following species *:—

Mastodon arvernensis.
Elephas meridionalis.
Ursus.
Equus plicidens?
Bos.
Felis pardoides.
Hyæna antiqua.
Cervus Falconeri.
—— ardeus.
Lutra.

Trogontherium Cuvieri.
Arvicola.
Bones of birds.
Platax Woodwardii.
Raia antiqua.
Vertebræ and otolites of fishes.
Teeth of Shark.
Crab (claws of, notch in edge as in *Carcinus*).

The shells are found in a bed of white sand with seams of small flint-shingle, lying immediately over the basement-flints. The more common shells are, *Tellina obliqua*, *T. lata*, *T. prætenuis*, *Mytilus edulis*, *Lucina borealis*, *Cardium edule*, *Mactra subtruncata*, *Mya arenaria*, *Buccinum undatum*, *Purpura lapillus*, *Natica catena*?, *Cerithium tricinctum*, *Littorina littorea*, and *L. rudis*. Many species are very rare; and doubt attaches to some unique specimens in the older collections. Mr. Fitch's collection, which contains a typical and distinct one from the Norwich district, consists of about 72 species of marine shells. They are included in the list of the Norwich-Crag Testacea appended to this paper, which is taken chiefly from the list drawn out by the late Dr. Woodward for Mr. Gunn, supplemented from my own and other collections.

Fig. 28.—*Thorpe pit, Norwich.*



feet.
5. Ochreous and ferruginous sands and flint-shingle, with a layer of iron-sandstone, full of casts of shells at *x*... 20
3. Grey clay (Chillesford), with a few large worn flints ...1 to 1½
3′&2′. White sands, with seams of gravel and patches of shells and comminuted shells, with a layer of large flints at base ......from 5 to 12

At this pit the line of separation between 3′ and 2′ is not well marked. At Bramerton 3′ & 2′ are much thicker (nearly 30 feet), and the division into separate beds more apparent.

* In the revision of the mammalian remains I have been kindly aided by Mr. Boyd Dawkins.

This pit shows also the relation of the Crag-beds to the overlying series. I give the section (fig. 28) I took in 1856, as at that time a thin seam of clay, which is probably the equivalent of the Chillesford Clay, and a layer of pebbly iron-sandstone, with casts and impressions of shells, were well exposed at the east end of the pit*. On that occasion also I found a fragment of Deer's horn immediately upon the Chillesford Clay in the ferruginous gravel.

Mr. R. Taylor, so early as 1826, showed in his section of Bramerton pit that the fossils were grouped differently in the several beds, and that some of the shells were peculiar to certain beds. Mr. J. E. Taylor has recently † shown the differences to be still more marked. He found that the upper beds of the Norwich pits were characterized more especially by the much greater abundance of deeper-water and more northern shells, and the lower beds by a more littoral and freshwater group. Mr. Taylor and Mr. S. Wood, jun., refer this upper division to the zone of the Chillesford series. This, as they justly notice, is an important elimination, as it places the lower division of the Norwich Crag on terms which admit of a juster comparison with the Red Crag of Suffolk, to which they refer the lower beds. On general grounds I had long held these two crags to be synchronous; but the correlation of the molluscan fauna still presented some difficulties, which this determination of Mr. Taylor may help to remove. Owing to the absence of sections in Mr. Taylor's paper, I am uncertain how far I agree with him in correlating these divisions at Bramerton with others at a distance from Norwich and on the coast. The Chillesford Clay is not visible in the Bramerton pit; but I have found traces of it in the road leading up the hill at the back of the pit.

I am indebted to Mr. James Reeve, Curator of the Norwich Museum, for the following carefully worked out list of the shells from Bramerton, showing, I believe, more completely than has hitherto been done, the species proper to the upper and lower divisions. For a further list, comprising all the species recorded from the Norfolk Crag, I beg to refer to the general list at the end of this paper, where, in column VI. the different localities at which the several species have been found are given:—

List of Shells in the Norwich Museum from the Sand-pit on the Common at Bramerton, collected by Mr. Reeve.

Univalves.	Upper Beds.	Lower Beds.	*Univalves.*	Upper Beds.	Lower Beds.
Admete viridula		1	Clavatula turricula	v r	r
Buccinum undatum......	c	c	Conovulus pyramidalis..		r
Bulla obtusa...............	v r	r	Hydrobia ulvæ............		v r
Calyptræa chinensis		r	Lacuna crassior ?..........		1
Cerithium tricinctum ...	c	c	Littorina littorea	c	v c
Chemnitzia internodula.		v r	—— rudis..................	n c	n c

* On visiting this pit again last summer (1870) I found the same beds still better exposed at the west end of the pit. The clay there varies from 1 to 2 feet in thickness, and the iron sandstone is about 1 foot thick. The former contains some large subangular flints, but no shells; the latter is full of well-preserved shells (see Geol. Mag. vol. vii. p. 539.)

† Geol. Mag. vol. iii. p. 273, vol. iv. p. 331.

List of Shells (continued).

Univalves.	Upper Beds.	Lower Beds.
Nassa —?, sp. n.	......	*
—— incrassata............	v r	r
—— propinqua	......	2
Natica catena	c	c
—— clausa	......	v r
—— grœnlandica	......	v r
—— helicoïdes............	v r	v r
Odostomia conoidea......	......	*
Patella vulgata............	......	v r
Purpura lapillus	c	v c
Ringicula ventricosa ...	v r	r
Rissoa semicostata	......	r
Scalaria grœnlandica ...	r	n c
—— Trevelyana	......	v r
Tornatella tornatilis ...	......	r
Trochus tumidus	r	r
Trophon antiquum	r	c
—— scalariforme	......	†
Turritella communis ...	n c	c
—— incrassata	n c	c
Velutina lævigata.........	......	v r
Bivalves.		
Anomia ephippium	c	r
—— patelliformis	r	r
Astarte borealis	c	r
—— compressa	v c	r
Cardium edule	v c	v c
—— grœnlandicum ...	v r	v r
Corbula striata............	c	r
Cyprina islandica	c	v c

Bivalves.	Upper Beds.	Lower Beds.
Diplodonta astartea......		†
Leda lanceolata	......	fr
—— limatula	c	r
Lepton nitidum	......	†
Loripes divaricatus	......	r
Lucina borealis............	n c	r
Mactra ovalis	r	v r
—— solida	c	v c
—— stultorum............	......	r
—— subtruncata	c	v c
Mya arenaria	c	v c
—— truncata	......	c
Mytilus edulis	v c	v c
Nucula Cobboldiæ	v r	r
—— tenuis	v r	v r
Pectunculus glycymeris.	......	v r
Pecten opercularis	r	v r
Saxicava rugosa	r	r
Solen siliqua...............	......	r
Tapes texturata	......	†
—— virginea	......	†
Tellina fabula	......	†
—— lata	c	v c
—— obliqua...............	v c	v c
—— prætenuis............	c	v c
Thracia phaseolina	r	v r
Trigonella plana	v r	1 or 2
Venus fasciata	......	r r
Brachiopod.		
Rhynchonella psittacea..	......	v r

Land and Freshwater Shells.

Bythinia tentaculata ...	......	v r
Carychium minimum ...	......	†
Helix hispida	......	r
—— pulchella	......	†
Limnæa peregra	......	v r
—— palustris	......	r
Paludestrina subumbilicata	v r	v c
Paludina lenta............	......	r
Planorbis complanatus ..	......	†
—— spirorbis	......	v r
Pupa marginata	......	†
Succinea putris	......	†
Valvata cristata	......	v r
—— piscinalis	v r	v r

Cyclas cornea	......	v r
Pisidium amnicum	......	v r
Foraminifera.		
Polystomella	c	c
Rotalia	c	c

Fragments of *Balanus* are common in both beds. Spines of *Spatangus* and small claws of Crab are scarce. Vertebræ and other small bones of fishes are common in the lower bed and rare in the upper one. Remains of *Arvicola* very rare in either. Remains of Elephant and Mastodon have been quoted from Bramerton, but they are very rare.

In addition to these, Mr. Harmer has found the *Panopæa norvegica* and *Trochus zizyphinus* in the lower bed, *Astarte sulcata*, *Abra alba*, and *Nucula nucleus* in the upper bed.

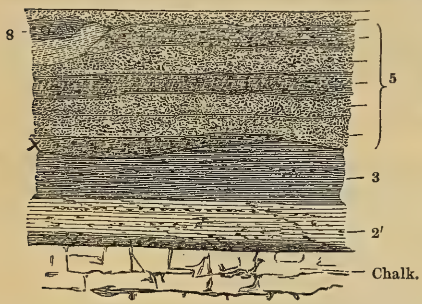
Postwick pit has long been noted for the occurrence of *Rhynchonella psittacea* and for the annelid-drilled surface of the chalk at the base of the crag.

* From a bank in a lane leading to Bramerton.

† These are from a small adjacent pit in Mr. Blake's grounds, in which *Scrobicularia piperata* (*Trigonella plana*) occurs in abundance.

At Coltishall, 8 miles N. of Norwich, the relation of the Crag to the Chillesford Clay is again clearly shown in the pit at the lime-kiln (fig. 29).

Fig. 29.—*Chalk-pit, Coltishall.*



	feet.
8. Boulder-clay (traces of).	
5. Ochreous and ferruginous sand and shingle	12 to 15
3. Grey clay, with a few fragments of wood and a seam of pebbles (Chillesford Clay)	6 to 8
2′. White sand and fine gravel, with patches of shells and large flints at base (Norwich Crag)	4 to 6

The shells collected by Mr. Reeve* and by myself in bed 2′ are:—

Astarte borealis.
—— compressa.
Cardium edule.
Corbula nucleus.
Cyprina islandica.
Mactra —— ?
Mya arenaria.
Mytilus edulis.
Pecten opercularis.
Tellina obliqua.
—— prætenuis.

Littorina littorea.
—— rudis.
Purpura lapillus.
Scalaria grœnlandica.
Turritella incrassata.
Natica catena.

Helix hispida.
Limnæa palustris.
Planorbis complanatus.

Teeth and bones of the Mastodon are occasionally found at the base of the same bed. One of the workmen informed me that he had also found bones above the clay (3).

In the closely adjacent pits at Horstead the Chillesford Clay may be seen holding the same position. But in one pit (the old water-channel) the sand bed (2′) under the clay is not fossiliferous, whereas the one above it (5) is; whilst at the farmyard-pit, close by, the lower bed (2′) is fossiliferous and 5 is not. An entire skeleton of Mastodon is said to have been discovered in 2′ some years since.

Thence we pass to the coast at Cromer without meeting any more Crag-pits †. At Cromer traces of the Crag were found lying on the chalk in digging the foundations of the jetty; but no section of it is seen until we reach Runton Cliff. At a short distance west of the Gap a ferruginous pebbly mass of crag, 2 feet thick,

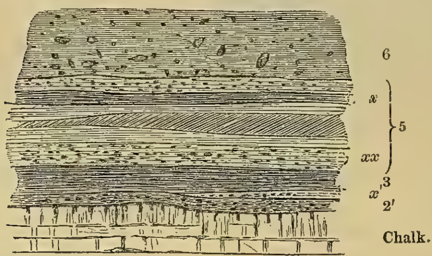
* In addition to these, Mr. Reeve has found in the same bed at Wroxham, two and a half miles S.S.E. of Coltishall pit, *Nucula Cobboldiæ*, *N. tenuis*, *Leda limatula*, *Lucina borealis*, *Mactra subtruncata*, *M. solida*, *Tellina lata*, *Anomia ephippium*, *Trophon antiquum*, and *Pecten tigrinus*, but no freshwater shells, no *Turritella*, and no *Astarte borealis*.

† My friend the Rev. J. Gunn has this summer been with me to the pits at Burgh, between Coltishall and Weybourne. The Chillesford Clay is again well exposed there, and overlies a foot or two of pebbly sand, which contains in places a few Norwich-Crag shells.

rises at the base of the cliff, and is overlain by 3 feet of laminated clays with imperfect impressions of plants and traces of shells.

The crag may be traced more or less well at the base of the cliff thence to Sherringham. Here it assumes larger proportions. On one occasion (in 1856) I found several undeterminable bones in the iron pan (crag) lying on the chalk, but no shells; forty yards further west the crag becomes more sandy, and contains shells. The following is a section taken at the base of this cliff:—

Fig. 30.—*Lower part of Cliff west of Sherringham.*



6. Boulder-clay (base of).		feet.
5. White sand and flint-shingle, with a subordinate bed of laminated clay (x) and a few shells in lower bed (xx)		12 to 14
3. Grey clay, with fragments of wood (Chillesford Clay)		3 to 4
2′. Iron sandstone (pan) with a few shells, overlain at x' by 6 inches of sand with numerous shells, including *Tellina balthica*		1 to 1½

The pebbly sands (5) continue more or less shelly all the way to Weybourne; and in places near Weybourne the surface of the chalk under the crag has been pierced by Annelids and by the *Pholas crispata*, whilst pebbles of chalk bored by *Saxicava rugosa* are met with in the overlying craggy beds. These lower beds, which Mr. Jeffreys has examined with me, contain the following shells collected on the occasion of several visits:—

Cardium edule.
—— grœnlandicum?
Cyprina islandica.
Astarte compressa.
—— borealis.
Mya arenaria.
Leda lanceolata.
Mactra subtruncata.
Nucula Cobboldiæ.
Tellina balthica.
—— lata.
—— obliqua.

Pholas crispata.
Saxicava rugosa.
Venus fasciata.

Buccinum undatum.
Helix hispida.
Littorina rudis.
—— littorea.
Natica helicoïdes.
Purpura lapillus.

Balanus crenatus.
Bones and vertebræ of fish.

Above these shelly sands the bed of clay (3), which I would refer to the Chillesford Clay, can be traced with few interruptions. It is not fossiliferous. Sometimes (as just west of Sherringham) the sand and shingle (5) have worn down and denuded this clay, and then in its place we often find a reconstructed bed, consisting of a base of sand, and iron-sand, with fragments of wood, and flint-pebbles, together with *clay-pebbles* of the destroyed bed, which latter are in places so numerous as almost to hide its reconstructed character.

Immediately over this clay-bed is another series of sands and shingle "5," which are often fossiliferous; and when the clay-bed is wanting, it is difficult to draw a line of demarcation between the two series, especially as the fossils themselves, with the exception chiefly that the *Tellina balthica* is far more abundant, do not show any very marked difference. The shells I have found are:—

Cardium edule.	Mytilus edulis.
Cyprina islandica.	
Leda lanceolata.	Purpura lapillus.
Mya arenaria.	Littorina littorea.
Tellina balthica.	—— rudis.
—— obliqua.	

These, however, are, I believe, far from representing the fauna of this bed, which is undergoing, I understand, in the hands of the Messrs. Searles Wood, a thorough examination. The importance to be attached to these beds does not arise so much from their exhibition here, as from the circumstance that they will serve to determine the position and age of beds of sand and gravel, generally without fossils, which have a wide range in the south-east of England, and the exact position of which it is important to know in consequence of their bearing on many interesting problems connected with the denudation of the country. These beds, which overlie the Chillesford Clay and the Forest-bed, and are succeeded by the lower division of the Boulder-clay, I propose to designate the "Westleton Sands and Shingle."

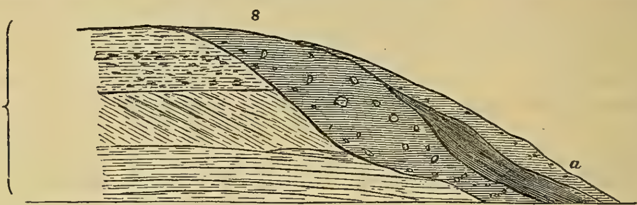
As, however, some uncertainty may be considered to attach to the clay which we have referred in Norfolk to the Chillesford beds, on account of the absence of fossils and the presence also of laminated clays in the overlying beds, we prefer to commence our observations in a district where both the Chillesford Clay and the Crag-sands are distinctly developed, and where the relation of the several groups to one another is more clearly determined.

The Westleton Sands and Shingle.

Between Yoxford and Dunwich there rises, just above the village of Westleton, a ridge of low hills largely excavated at that spot for sand and gravel. Nowhere, except on the north-west of Henham Park, are these shingle-beds so largely developed. They attain a thickness of from 30 to 40 feet, and consist of a series of stratified beds of well-rounded flint-pebbles imbedded in white sand, and with two or three subordinate beds of light-coloured clay. They look more like the pebble-beds of Blackheath than any other beds in the eastern counties. Mixed with the flint-pebbles are a few small pebbles of old rocks, with a considerable number of white quartz-pebbles, the presence of which constitutes a distinctive feature of these beds throughout their range. No fossils are found here, and no other beds are exposed. Elsewhere this series is generally not more than from 20 to 25 feet thick; and sands predominate, the shingle being subordinate.

In the neighbourhood of Reydon, near Southwold, the same beds, usually light-coloured, are seen underlying the Boulder-clay in some of the clay-pits; but they are better exposed in the pits along their line of outcrop on the north side of the valley of the Blyth, nearer Southwold. In a pit close on the north-east edge of Reydon marshes, I found in these sands, last autumn, a seam of the same pebbly sand concreted by oxide of iron. This seam was full of the casts and impressions of *Mytilus edulis* in all stages of growth, and many of the shells double. Southwold* stands on these beds; and their relation to the Boulder-clay and to the valley-beds was well exposed before the removal of the brick-pit, just north of the town, further from the shore. The section was as follows:—

Fig. 31.—*North end of Southwold Cliff* (see also coast sect. Pl. XX.).



		feet.
a.	Brick-earth and gravel, with the remains of *Elephas primigenius* ...	5 to 10
8.	Boulder-clay (upper division)	8 to 12
5.	White and yellow sand and shingle, with a few ferruginous bands	20

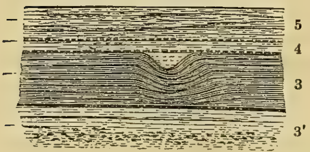
In the next cliff, at Easton Bavent, we find the same sand and shingle, with seams of the ferruginous bed. In the latter, casts of shells are numerous, but difficult of determination. I found

Cardium, Mytilus (edulis?), Littorina, Natica,

and numbers of small Foraminifera.

The Chillesford Clay here rises from beneath these shingle-beds (5); and under the clay is the well-known Southwold crag (*antè*, fig. 26, p. 345). This section clearly shows not only the relation of these divisions, but in the same cliff, a short distance further north (fig. 32), may be seen the setting-in of the Forest-bed and its relation to the same series.

Fig. 32.—*Section near the north end of Easton-Bavent Cliff.*

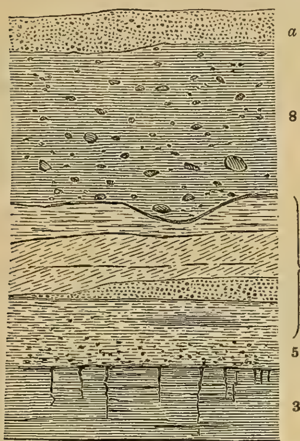


		feet.
5.	White and yellow sand and shingle	5
4.	Traces of wood and carbonaceous matter.	
3.	Laminated grey clay with double shells in the position of life (Chillesford Clay)	6
3'.	Shelly sands (Chillesford Sands).	

* But for the existing sands and shingle of Southwold strand, I should have preferred "Southwold" to "Westleton" to designate these beds.

In the next range of cliffs the further relation of the same beds to the Elephant-bed of Norfolk is shown. The higher part of the cliff at Kessingland is formed by the upper division of the Boulder-clay. Beneath are beds of sand with subordinate seams of small flint-gravel, which may be referred to the Boulder-clay series, though the lower part may belong to the Westleton beds. Beneath these sands, and just on the same level as in the cliffs at Cove and Easton Bavent (two and four miles south), the Chillesford Clay crops out and ranges to near Pakefield.

Fig. 33.—*Cliff between Kessingland and Pakefield, about one mile north of the former place.*



feet.

a. Loamy sand and gravel ....4 to 6

8. Boulder-clay (upper division) 15 to 20

7. Light-coloured sands, with some seams of fine gravel and a few fragments of shells ....20 to 25

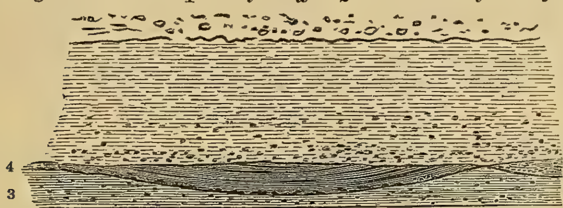
5 & 4 (traces of). Flints and iron-sand, with rootlets running down into 3 ....0 to 1

3. Greenish clay (Chillesford Clay) 5

The clay is here more compact, and in places contains a number of worn fragments of flint. No shells are found in it *.

The Forest-bed, together with the associated freshwater bed, now becomes sufficiently well marked, as the following section shows :—

Fig. 34.—*Lower part of Cliff $1\frac{1}{2}$ mile south of Pakefield.*



7. As in fig. 33.
5. Elephant-bed, 1 foot.
4. Forest-bed, 0 to 6 feet.
3. Chillesford Clay.

At this place a depression in the Chillesford Clay has been filled by a local freshwater deposit (4) consisting of a dark carbonaceous and

* Mr. Crowfoot informs me that he found a deer's bone in this clay.

laminated sandy clay, at the base of which freshwater shells are found. The shells are only in occasional patches, and consist of *Unio pictorum*, *Cyclas cornea*, and *Bythinia tentaculata**.

As we approach Pakefield the bed of shingle, which rests on the clay (3) becomes ferruginous, and contains pebbles of clay derived from the Chillesford Clay. A considerable number of mammalian remains (Elephant?, Rhinoceros, Deer, Ox, and Horse, the same apparently as in the Forest-bed of Norfolk) have been found in this bed.

Besides the common occurrence in this cliff of rootlets passing from the base of the shingle into the underlying clay to a depth of 4 or 5 feet, the trunk of a tree, 20 feet long, was found some years since on the surface of the clay-bed (3), and nearer to Pakefield the stool of a large tree was found *in situ*, as at Hasborough.

Nearer to Pakefield the Chillesford Clay is entirely broken up, and a bed composed of sand, flint-pebbles, and pebbles of Chillesford clay takes its place, while the "Westleton sand and shingle" is immediately overlain by the upper division of the Boulder-clay.

At Corton, to the north of Lowestoft, the Forest-bed appears again for a short distance at the foot of the cliff, with the Lower Boulder-clay immediately above it, whilst the Westleton beds are wanting. They are largely developed inland, however, and are worked on the west side of the Somerleyton brick-pit, and at several pits N.W. of Lowestoft.

From the cliffs at Corton, where we lose the Forest-bed, to the cliffs at Hasborough, where it again crops out at the foot of the cliff, is a distance of 24 miles. The Crag-beds beneath it there (if they exist) are not exposed; but in the series above it we find the same order of succession as at Southwold and Kessingland. The Forest-bed along this coast appears to exist, as between Pakefield and Kessingland, under two forms:—the one a local freshwater deposit of grey and carbonaceous clay, containing the remains of mammalia, insects, plants, and freshwater shells; and the other of trees, rooted sometimes in this bed and sometimes in the Chillesford Clay beneath it. It is not often the latter is seen. It appears, however, on the shore at low tide at Pauling. The Forest-bed itself has been bored into at Hasborough by Mr. Gunn to the depth of 14 feet, without reaching its base. From this point to Trimlingham none of the beds under this level are visible; but the Westleton beds are well exhibited at various places, as, for example, at the cliff north of Bacton Gap (fig. 35; see also coast-section, Pl. XX.).

Fig. 35.—*Cliff near Bacton.*

6. Boulder-clay (lower division) with fragments of shells.
5. Sandy flint-shingle with seams of laminated clay (x) and fragments of wood; shells at places in lower part of the shingle, 10 to 12 feet.
5′. Elephant-bed............½ to 1 foot.
4. Top of Forest-bed.

* Mr. Crowfoot's Collection.

The Westleton beds here exhibit the characters we have noticed further south, consisting essentially of flint-pebbles with numerous white quartz-pebbles and a small admixture of pebbles of some peculiar varieties of siliceous sandstone, chert, and slate rocks; mixed with them is a considerable quantity of drift-wood, both in large pieces and in matted small branches. Further, the basement bed of this series again often contains at places clay-pebbles derived from the Chillesford Clay *.

At this part of the coast the Westleton beds become more argillaceous, containing several subordinate beds of laminated grey clays without fossils. These clays sometimes replace, in great part, the sands and shingle, whence Mr. Gunn has applied to this series on the Norfolk coast the term of "the laminated clays," which often well expresses their character †. In this area the Westleton beds rarely exceed 25 feet in thickness; and where the Forest-bed rises higher, as at Paston Cliff (fig. 36), or where the underlying beds have been denuded before the deposition of the Boulder-clay, they are sometimes wanting.

Fig. 36.—*Section in Paston Cliff.*

7. Sands, gravels, and laminated loams (base of 7).
6. Boulder-clay (lower division).
5. Sandy shingle.
5′. Elephant-bed.
4. Forest-bed.

As we proceed further northwards these beds assume a fluvio-marine character. Just south of Mundesley a thin seam of clay with freshwater shells, consisting of

Anodonta cygnea,	Pisidium amnicum,
Unio pictorum,	Bythinia tentaculata,
Sphærium corneum,	Valvata piscinalis,

which I have already described ‡, appears at their base; whilst on the north of Mundesley marine shells are intercalated with seams

* I had not found any shells on this part of the coast; but Mr. Gunn pointed out to me this summer a spot about half a mile north of Bacton Gap, where we procured from the lower bed of the Westleton shingle the following shells:—*Purpura lapillus*, *Littorina rudis* and *L. littorea*, *Mytilus edulis*, and a species of *Scalaria*, all much decayed. Some years since, Mr. Green, of Bacton, stated that the Crag was found in Bacton cliff; but his statement remained discredited. This was no doubt the bed to which he referred.

† I hesitate to adopt this term, as the character is again repeated in the beds above the Lower Boulder-clay in the same cliffs, as well as in the Chillesford beds below. Nor in any case is a mineral designation convenient, especially for such variable beds. (See also my paper on the Mundesley Section, in the 'Geologist' for 1861, p. 68.)

‡ 'The Geologist' for 1861, p. 68.

of freshwater shells throughout the series †. It is the ferruginous "pan" lying at the base of this series, which is so rich in mammalian remains, and is known as the Elephant-bed. It is, however, clear that the Westleton beds often repose upon a much denuded surface of the underlying beds, the débris of which they then contain. Therefore how far the bones found in the Elephant-bed may be proper to it, or how many have been derived from the Forest-bed, is uncertain, as it has not always been possible to keep the fossils of the two beds distinct, nor is it always practicable to distinguish the proper from the extraneous fossils ‡.

A large number of these mammalian remains were collected by Miss Gurney; and Mr. Gunn's magnificent collection, which he has also lately presented to the Norwich Museum, is known to all geologists. Dr. Falconer, who studied them with so much zeal, has left a number of interesting notices respecting the more important specimens, in those memoirs in which he investigates the characters of the Proboscidia §.

Mr. Gunn, in his excellent concise account of the Forest-bed, in which he includes the Elephant-bed as an upper division, gives the following list of mammalian remains ||, chiefly on the authority of Dr. Falconer, to which Mr. Boyd Dawkins has obligingly added the species marked with an asterisk.

Elephas antiquus.	Cervus megaceros.
—— ——, var. priscus.	—— elaphus.
—— meridionalis.	—— Sedgwickii.
Rhinoceros megarhinus.	—— Poligniacus.
—— etruscus.	—— capreolus?
Hippopotamus major.	*—— ardeus.
Equus (*caballus).	Trogontherium Cuvieri.
Machairodus?	Mygale moschata.
Bison priscus?	Sorex fodiens.
Bos (*primigenius).	—— remifer.
Sus (*arvernensis).	Arvicola amphibia.
Ursus arvernensis.	Castor europæus.
*—— spelæus?	Two species of whale.
*—— etruscus?	[Vertebræ of fish.]

† Mr. Gunn has also pointed out to me a spot, just under Mundesley, where a pebble bed, with *Littorina*, *Mytilus*, &c., just as at Bacton, occurs, and a little to the north the *Pinna pectinata* is found.

‡ A large proportion of the fossils have been collected from the shore after storms, when they had been washed out of the cliffs; and many have been dredged out at sea. Those which are derived from the elephant-bed frequently have a portion of the gravel cemented to them, which may show that they are not derived (directly, at all events) from the forest-bed; but I would observe that the "pan" at the base of the Crag, and immediately lying on the Chalk, presents lithological characters not to be distinguished in detached portions from the other; and as I have found bones in this crag-bed at Sherringham, this bed may, although not so rich as at Norwich, have supplied a portion of the remains found on the shore.

§ 'Palæontological Memoirs and Notes,' edited by Charles Murchison, M.D., 1868, vol. ii.

|| Mr. Gunn considers that there is evidence of several other species of Deer, and two more varieties of Elephant, in the Forest-bed.

Sir Charles Lyell, in his 'Antiquity of Man,' gives a list of the plants from the Forest-bed, determined by Dr. Heer, they are:—

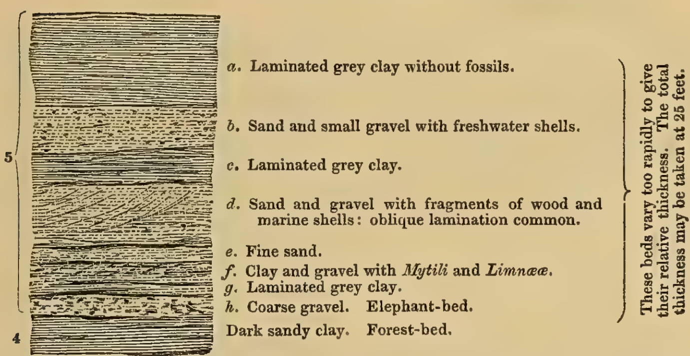
Pinus sylvestris.	Nuphar lutea.
Abies excelsa.	Ceratophyllum demersum.
Taxus baccata.	Potamogeton.
Prunus spinosa.	Alnus.
Menyanthes trifoliata.	Quercus.
Nymphæa alba.	

To these Mr. Gunn adds rhizomes and fronds of Ferns.

The insects have not yet been fully described. They include several species of *Donacia*.

The following affords a good general section of this series, lying beneath the Boulder-clay, in this part of the coast.

Fig. 37.—*Section of the Westleton Beds near Mundesley.*

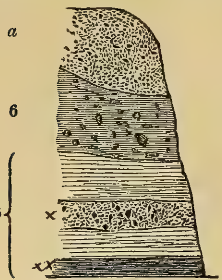


These beds may be followed, with few interruptions, to Trimlingham and Cromer. Mr. Gunn states that it is from these beds at Bacton that the remains of two Whales were obtained; and it is probable that, as the Forest-bed is not exposed at Cromer, the Narwhal tusk and the remains of a Walrus found by Mr. King near Cromer were also from the sand-and-shingle beds.

The next point of interest is near Runton Gap, where we again find at the base of the series a bed of peaty clay full of the following species of freshwater shells:—*Bythinia tentaculata, Valvata piscinalis, V. spirorbis, Planorbis marginatus, P. fontanus, Limnæa palustris, Paludina achatina, Pisidium amnicum, P. nitidum, Sphærium corneum, Anodonta cygnea, Unio pictorum, U. margaritifer.* Some years ago Mr. Trimmer discovered in the sand and shingle between this peaty bed and the Lower Boulder-clay, at Runton Gap, a bed containing numerous *Mya truncata* and *Leda myalis* in their natural vertical position, with both valves perfect. The section is as shown in fig. 38.

This brings us back to the part of the cliffs described (*ante*, p. 460) in the section on the Norwich Crag. The beds now lose their subordinate fluviatile seams, and, in proceeding westward, instead of an occasional seam of *Mytili* or *Myæ* or a few *Littorinæ*, we get fossiliferous beds so like the Norwich Crag that they were always referred

Fig. 38.—*Section of the Westleton Beds on the side of Runton Gap.*



	feet. feet.
a. Valley-gravel.	
6. Boulder-clay	8 to 10
5. Beds of light-coloured sand and flint-shingle, with shells at ×, and a freshwater peaty bed at ××	12 to 15

to that series. But Mr. Searles Wood, jun., on palæontological evidence, places them on a higher zone. The difference between Mr. Wood and myself is, that I think the lowest beds "2′" from Runton to Weybourne should be referred to the true Norwich Crag, whilst I would refer the upper shell-beds "5" to the Westleton series, instead of putting them all together, as I believe Mr. Wood does, into one zone, higher than either of these*. At this part of their range there is, with the exception of the presence of the more numerous fossils, little difference in their character from that of the same beds in the neighbourhood of Southwold, where the fossils are rare and, with few exceptions, in the state of casts and impressions only†.

Taking a line from Weybourne to Norwich, the Westleton beds are scantily exhibited over the Chillesford Clay at Burgh and Oxmead. At Coltishall they are more fully developed and contain a subordinate bed of iron-sandstone and clay-ochre, $1\frac{1}{2}$ ft. thick, which reposes upon a slightly denuded surface of the Chillesford Clay. At Horstead the Westleton shingle with crag-shells overlies the Chillesford Clay (*ante*, p. 459). This is the shelly bed to which Mr. S. Wood, jun., has applied the name of "Bure-Valley Crag." It is seen again at Belaugh‡, and still better at Wroxham. At the latter place there are two pits, in one of which a thin bed of Norwich crag, with numerous single valves of the *Cyprina islandica*, overlies the Chalk, and underlies a thin bed of clay, representing, probably, the Chillesford Clay, and in the other the same clay is overlain by a sandy crag characterized by the presence of numerous *Tellina balthica*.

I have already (*ante*, p. 456) shown the relation of the typical

* Quart. Journ. Geol. Soc. vol. xxii. pp. 547–549. The only other alternative that I could admit is, that they all belong to the Westleton series.

† I have one perfect valve of *Tellina balthica* from near Pakefield.

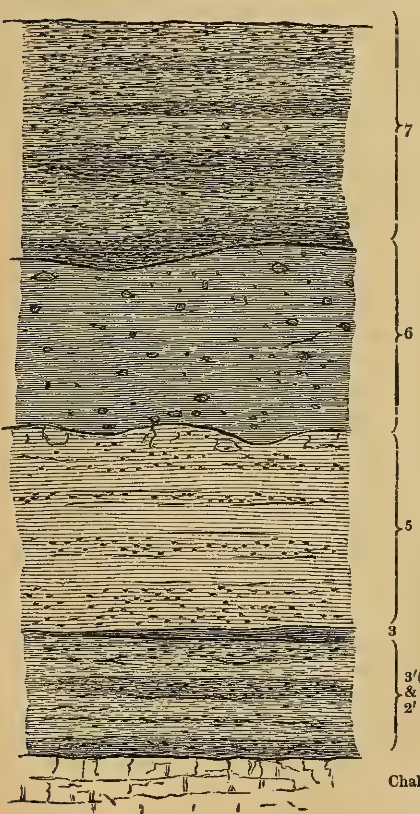
‡ Freshwater shells again appear in these beds. I found, this autumn, in a pit near the Anchor Inn, Coltishall, *Limnæa palustris* associated with *Tellina balthica, Mya arenaria, Cardium edule, Littorina littorea,* and *Cyprina islandica.*

Norwich Crag to the Westleton beds at the Thorpe pit. The latter there put on the character of a coarse ferruginous shingle passing under the Boulder-clay series higher up the hill; but that is not seen in this pit. The shells of this ferruginous bed (x 5) consist, as far as they have been determined by Mr. Reeve, of:—

Cardium edule.	Modiola (large sp.).
Mytilus edulis.	Littorina littorea.
Mya arenaria.	Purpura lapillus.
Tellina obliqua.	

There is, however, nearer Norwich, a section which, although wanting in the confirmation afforded by organic remains, shows in a very interesting manner the superposition of the whole series, and the relation of different members of the Crag and glacial beds in this district (fig. 39).

Fig. 39.—*Pit at Bishopford Bridge, Norwich.*



feet.

7. Coarse ochreous loamy roughly stratified flint-gravel 25

6. Brown Boulder-clay (lower division)........................... 15

5. White sands and flint-shingle (Westleton beds) 20

3. An irregular seam of grey clay (Chillesford Clay?).........0 to 1

3′ (?) & 2′. White and ochreous sands, and flint-shingle and gravel. Small patches of shells (Norwich Crag) found occasionally in the lower part, and large flints at the base 12

Conclusion.

Nothing can be clearer than the relation of the Red to the Coralline Crag; but the Norwich Crag occupying a different area, and each area presenting a crag-series of its own type, without superposition or passage, their relation to one another must necessarily be established on other grounds. We have to see what other beds there may be common to the two districts, whether in each they bear a like relation to those Crag beds which are the object of inquiry, and whether the differences known to exist in the latter may not be owing to geographical distribution.

In this case we have the one common bed in the Chillesford Clay, which forms a zone limiting in ascending order the position both of the Red and of the Norwich Crags, both of which it overlies and with both of which it shows a close relation. But although we can follow the Chillesford Clay (retaining its usual characters and fossils) into the southern part of the Norwich-Crag area at Southwold, north of that district it is not fossiliferous and we can only identify it by position and mineral characters. Nevertheless we can follow this argillaceous zone, although a character of uncertain value, with sufficient clearness to Bacton and Weybourne, and also inland to Norwich and Coltishall. In Norfolk, however, as the sands and shingle overlying the Chillesford Clay become interstratified with beds of laminated clay very similar in appearance to the Chillesford Clay, it might be a question whether the bed which I have referred to that deposit in Norfolk belongs to it, or whether the Chillesford Clay is represented by the Laminated Clays of Mr. Gunn. Mr. Gunn contends that such is the case. Although I am ready to admit that, on lithological characters alone, the evidence would be almost as good for one as for the other, still I think that the clear superposition of the Chillesford Clay to the Crag, and its infraposition to the Westleton shingle, at Easton Bavent, with the commencing indications of the Forest-bed at the same place, and its clearer exhibition at Kessingland, accompanied by the setting in, in the same cliff, of the Elephant-bed—taken in conjunction with the presence of the Mastodon in the Norwich Crag and its absence in the Forest-bed, and the difference in the species of Elephant, Rhinoceros, Deer, &c. in the two series—sufficiently prove their relative position and age. Mr. Gunn's Laminated Clays constitute a subordinate lithological character of the Westleton series in Norfolk, and are occasionally present in Suffolk.

The Forest-bed, of which we get indications at Easton Bavent, is more fully developed at Kessingland and Corton, at which latter place it passes under the lower division of the Boulder-clay, the Westleton shingle having been denuded as it occasionally has been even in the Hasborough and Mundesley district (see fig. 36, p. 465). At Hasborough and Bacton the base of the Westleton shingle is usually cemented into a hard "pan" by oxide of iron, and constitutes the well-known Elephant-bed. This reposes upon the Forest-bed, which, in its turn, rests on the Chillesford Clay when that is not denuded. Between Hasborough and Sherringham, the latter usually lies at too low a level to be exposed. When it does appear, the relations to the Norwich Crag and to the Westleton beds remain constant, in the same way as at Coltishall, Wroxham, and Thorpe.

I have, in my last paper, noticed that the rich fossiliferous beds of the Red Crag of Walton, Sutton, and Butley become poorer after passing beyond that area, that at Chillesford the number of species is much less, and that the same poverty characterizes the few pits on the west flank of the Coralline ridge of Sudbourne.

North of this ridge the Crag at Aldborough is still poorer; but still the fossils are all Red-Crag species. At Thorpe the facies of the fauna seems different; but this is chiefly due to the difference in the relative proportion of the species. There is not a single new species of Mollusca; but such species as are found on the beach of a sandy bay abound. The *Littorina littorea*, scarce at Chillesford, Butley, and Aldborough, is here abundant, as are also the *Mya arenaria*, *Mactra ovalis*, and *Cardium edule*, whilst *Natica*, *Cerithium*, and *Turritella* become much more common. At the same time some fragmentary mammalian remains, vertebræ and teeth of fish, and fragments of Crustacea are also more numerous. At Sizewell the *Conovulus pyramidalis* is a common shell. At Bulchamp and at Easton Bavent freshwater shells increase in number, and the *Corbicula fluminalis** and the *Astarte borealis* make their first appearance. But of 43 other species of marine shells I have collected at Thorpe, Sizewell, Bulchamp, and the neighbourhood of Southwold, there is not a single species which is not found also in the Red Crag. In both also some species, such as the *Tellina obliqua*, *T. lata*, and *Purpura lapillus*, continue to be very abundant, and the *Cyprina islandica* is common. In lithological character the only difference is the greater extent of gravelly (flint) beds and the absence of the ferruginous colouring, though that exists at Sizewell and Bulchamp. Neither of these characters is of any importance.

Probably Thorpe, Wangford, and Bulchamp (in part) may be regarded as the equivalents of the lower division of the Red Crag, whilst Sizewell and Easton Bavent should be referred to the upper division or Chillesford sands.

This upper division is better exposed at Aldeby, where a large addition is made to the number of species; several new forms appear, while some old forms of the Red and Coralline Crags reappear. In the neighbourhood of Norwich the *Rhynchonella psittacea* † comes in, and on the coast at Sherringham the *Tellina balthica* is added to the fauna. In the upper bed of the Norwich Crag at Bramerton and Thorpe many of the species found in the lower bed are wanting, but, with the exception of the accurate lists of fossils from the Bramerton pits made by Mr. Reeve, we are yet without fully sufficient separate lists of the two divisions of the Crag, whether in Norfolk or in

* Mr. Bell has lately found this shell in the Red Crag at Waldringfield.
† Also lately found by Mr. Bell in the Red Crag at Shottisham.

Suffolk, although we have good lists of special localities. That such a division exists in Suffolk, both lithologically and palæontologically, there can be no doubt; and that it is to some extent maintained in Norfolk is probable. But in Norfolk it is not always easy to show the line of separation, and it becomes a question whether the differences in the Molluscan fauna are not differences produced in the fauna of one period by local conditions of sea-bed, depth, and fresh waters. There is no doubt that the lower beds, both in Suffolk and Norfolk, are more-shallow-water deposits, and that, in the latter county especially, they contain a large freshwater element; while the upper beds, with greater depth of water, show the Mollusca less drifted, more *in situ*, and as having been under the influence of colder currents.

Not only, however, do the upper and lower beds differ, as at Bramerton, but the same division shows marked differences in different pits. Thus the lower bed in the pit east of the one on the common has been named by Mr. Reeve the *Scrobicularia*-bed, from the abundance of that shell, of which only one or two fragments have been found on the same level in the adjacent pit, while *Trophon clathratus*, *Diplodonta astartea*, and *Tapes aureus* have been found by Mr. Reeve in the former pit and not in the pit on the common. So *Cardium edule* and *Littorina littorea* are rare at Aldeby, but are very common at Beccles (section of town well), while of the *Cerithium tricinctum*, also common at Beccles, only one specimen has been found at Aldeby. In the same way the fossils from the same beds at Thorpe, Bramerton, Postwick, Coltishall, and Horstead present marked differences of grouping and in relative numbers. So, as is well known on our own coasts at present, the distribution of the Mollusca presents rapid variation. Amongst other instances, Mr. Jeffreys states that the *Tellina balthica* abounds in Swansea Bay, but that not a single specimen is to be found at Oxwich Bay, only nine miles distant. It is possible, therefore, that the differences found to exist throughout the Norfolk and Suffolk areas are more or less dependent on these causes—that Thorpe (Suffolk), Wangford, Thorpe (Norwich), may represent old lines of coast or shingle-banks in the old sea, while Sizewell, Southwold, Beccles, Aldeby, and Bramerton may represent synchronous deeper-water deposits. Difference of depth is also probably the cause why the fauna of Aldeby is so much richer than that of the upper division at Bramerton, and why so many of the older Coralline-Crag species reappear. I have therefore, for the present, taken the two divisions together; and this gives the following result:—

Total number of species recorded in the Norwich Crag		179
Deduct land and freshwater species	24	
——— doubtful and varieties	16	
	—	40
		139

The relation which these species (155, including the varieties) show to the Red and Coralline Crags of Suffolk is as follows:—

	Bi-valves.		Uni-valves.		Total.
Common to the Red Crag	69	...	68	=	137 or 88 per cent.
Common to the Coralline Crag	54	...	33	=	87 or 56 „

We have before (*ante*, p. 352) seen that the number of species of the Red Crag found in the Coralline Crag was 62 per cent.

With regard to the proportion, in the Norfolk-Crag period, of existing species to those not known as living, the following is the result, after excluding the 16 varieties and doubtful species:—

Total.	Living.	Extinct.	Proportion of extinct species.
139	130	9	6·5 per cent.

Comparing the three Crags, the respective proportions of extinct and living species of Mollusca in each is as under:—

	Extinct.	Living.
In the Norfolk Crag	6·5	93·5 per cent.
In the Red Crag of Suffolk	7·7	92·3 „
In the Coralline Crag	16·0	84·0 „

showing so close a relation between the Norwich and Red Crags as to afford good reason for considering them to be both of the same age*.

With respect to the geographical range of the 216 living species (exclusive of varieties and extraneous species) of the Red Crag, and of the 130 species of the Norwich Crag, some marked differences are noticeable, as shown in the following Table.

Table of Geographical Distribution of the Mollusca of the Red and Norwich Crags.

	Red Crag.					Norwich Crag.				
	Bi-valves.		Uni-valves.		Total.	Bi-valves.		Uni-valves.		Total.
Arctic	21	...	19	=	40	18	...	18	=	36
North American	7	...	10	=	17	7	...	7	=	14
Scandinavian	63	...	72	=	135	42	...	44	=	86
British	77	...	80	=	157	42	...	45	=	87
West European	80	...	76	=	156	37	...	36	=	73
Mediterranean	79	...	88	=	167	33	...	34	=	67
Atlantic	35	...	49	=	84	18	...	20	=	38

Special localities.—Africa, 1; South Africa, 1; West Indies, 1; Gulf of Mexico, 1; Japan, 3.

* Taking Aldeby to represent the upper division (or the Chillesford Sands) and the lower beds at Bramerton the lower division (or the equivalent of the Red Crag of Sutton, Waldringfield, &c.) of the Norwich Crag, we have the following results:—

	Total species.	Proportion of extinct to living species. per cent.	Numbers common to the Red Crag.	Numbers common to the Coralline Crag.
Aldeby	71	5·6	53	38
Bramerton	64	6	58	24

This gives a slight increase in the proportion of northern species in the Norwich Crag, while the proportion of southern species shows a greater decrease, but not more than might be dependent on local coast conditions. The relative proportion of total British species in the Red and Norwich Crags respectively is as close as 67 : 69, while the total northern forms show as 80 : 105, and southern forms 150 : 104. Or, taking the species not now found living in the British seas, their relative distribution in the three Crags is as under :—

	Total living species.	Species now restricted to Northern seas.	Southern seas.
Norwich Crag	130	19	11
Red Crag	216	23	32
Coralline Crag	264	14	65

So that while the relative number of British species, as well as of the extinct species, remains nearly uniform, there is a considerable decrease of southern and some increase of northern species in the Norfolk area.

The relation of the two crags as shown by the Mammalian remains is less conclusive; but the differences are no greater than we might expect from the evidently different relations of the land to the water in the two areas. The same Mastodon*, Horse, Hyæna, and *Felis* occur in both; and there is strong reason to believe that the Elephant (*meridionalis* ?) is likewise found in the Red Crag. A Bear (*arvernensis*), and a Deer (*megaceros*), though not found in the Norwich area, are found in the Suffolk Red Crag, and pass into the Forest-bed, and must therefore have existed in the Norwich-Crag period.

After carefully weighing all these considerations, I must confess that, as I see no sufficient reason for regarding any of the Norwich-Crag Mammalia as extraneous fossils, I now cannot but look upon all species common to the two Crag areas, together with those species which, though not found in both Crag areas, are still found in one, and occur again in the later-deposited Forest-bed, as really contemporaneous fossils proper to the Red and Norwich-Crag series. This view is in the main in accordance with that arrived at by Dr. Falconer, upon the evidence of the contemporaneous continental Pliocene fauna.

The Forest- and Elephant-bed inaugurate a condition of things materially different from that prevailing during the Crag period. A number of new Mammalia make their appearance, including the *Elephas antiquus* and var. *priscus* in numbers, two new species of Rhinoceros, a Hippopotamus, two Bears, together with species of Horse and Ox, and some small rodents of existing species. But the marked feature of the period consists in the number and variety of the Deer, no fewer than six species, several of them of very peculiar

* As the occurrence of the nearly entire skeleton of the Mastodon at Horstead shows that it lived in the Norfolk Crag area, I do not think that it can be looked upon as extraneous to the Red Crag.

types, having then flourished in considerable numbers. In the Crag, all the Mammalia, except possibly the *Arvicola*, belong to extinct species. In the Forest- and Elephant-bed, three species pass in from the Crag, associated with thirteen other extinct species, and with six living species of Mammalia. On the other hand, the shells, whether freshwater or marine, so far as we can judge from the limited number yet known, are of existing British species; and all these, with possibly one or two exceptions, are species which are continued up from the underlying Norwich Crag. The break in time, therefore, between the Crag and the Westleton Sands and Shingle is probably not inconsiderable.

These conclusions, whilst they agree in part with those of Prof. E. Forbes, Sir Charles Lyell, Dr. Woodward, and Mr. Searles Wood, with regard to the gradual lowering of the temperature from the period of the Coralline Crag to that of the Forest-bed, differ from previous results in the proportion of recent to extinct species, showing a much closer approach to the existing fauna than before was estimated to exist. In arriving at this conclusion I have had the valuable assistance of Mr. Gwyn Jeffreys, whose researches in the seas of Europe have done so much to make us acquainted with Crag-species supposed to have been extinct, and with the variations produced by geographical distribution, nature of ground, and depth of water. As an instance of the geological bearing of these considerations, I will quote some remarks of Mr. Jeffreys * in speaking of *Mactra solida*:—"I regard *Mactra truncata* as the littoral or shallow-water and southern variety, and *M. elliptica* as the deeper-water and northern variety of one and the same species." "Every conceivable gradation of shape and solidity may be seen in a recent state; and the union of *M. solida* and *M. elliptica* is cemented by palæontological evidence." "I may also observe that when *M. solida* gradually finds its way into deeper water than it had been accustomed to, the shell becomes more slender and glossy although nearly of the usual size. It has then all the appearance of *M. elliptica*." He also alludes to the still greater difference in *Buccinum undatum* taken at low water and at depths of from 70 to 80 fathoms, as well as to the case of *Venus gallina* and other bivalves. It is upon evidence such as this that Mr. Jeffreys has arrived at the conclusion that so many of the Coralline and Red-Crag species are to be regarded merely as varieties.

In my former papers the conditions under which the Coralline and Red Crags were formed, together with the mode of distribution and relations of the fauna, were investigated. It was shown that at the very commencement of the Crag-period a degree of cold prevailed severe enough to give rise to the transport by ice into the Coralline-Crag sea, not only of flints from the neighbouring chalk shores, but

* British Conchology, vol. ii. p. 418. This work is full of remarks interesting to the geologist on the range and habits of most of our Pliocene and Post-pliocene shells.

of boulders from a great distance, and that, during the formation of the lower Coralline Crag, movements of subsidence prevailed, succeeded in the upper division by an elevation of the sea-bed, which brought the Coralline Crag partly above the sea-level, where it became exposed to the action of the tides, currents, and breakers of the Red-Crag sea. In consequence of this action, a very large portion of the Coralline Crag has been destroyed, and its débris incorporated in the mass of the Red Crag; and the beds of phosphatic nodules (or the Coprolite-beds) of the Red Crag are probably derived in whole or in greater part from the Coralline Crag. Floes laden with large unworn flints from the neighbouring chalk coast were stranded on the Sutton Coralline-Crag islets, whilst shore-ice floating off from the same islets strewed the sea-bed around them with large blocks and boulders of the Coralline Crag.

The Norwich Crag, which occupies the contiguous area, and lies on the same level, seems to have been divided from the more open sea of the Red Crag by a barrier of Coralline Crag, behind which were sandy bays, into which flowed a river or rivers bringing down land and freshwater shells, and probably mammalian remains from land to the north-west and west. There is evidence of these streams coming from that direction in the circumstance that in the Crag at Norwich, Lias Ammonites, Mountain-Limestone corals, besides the many fossils from the Chalk, are found. I have found also, at the base of the Crag at Weybourne, a fragment of fossiliferous Kimmeridge Clay, and in the Norwich Crag an encrinital column similar to some I have seen in the Red Crag of Suffolk, in which latter also occur Belemnites, Ammonites, *Ostreæ*, and *Terebratulæ* from various Secondary rocks, together with fragments of chert from the Lower Greensand, while the occurrence of the fragments of red granite points to transport from still more distant localities*.

After a time a general subsidence of the whole area took place, followed by the deposit of the Chillesford sands over the irregular surface of the Coralline Crag, Red Crag, and Norwich Crag, and at the same time colder currents from the north introduced new and more Arctic species of Mollusca. Still notwithstanding the greater depth of water and the greater cold, there is an absence of all foreign boulders, with the exception, if they may be so termed, of large blocks of subangular chalk-flints.

The sea-bed was then raised and a land surface formed in eastern Norfolk, and over some adjacent part of the German Ocean. On this freshwater deposits were formed, and a forest of Scotch firs, Norway spruce and other trees of a temperate character grew. The forest was frequented by herds of deer, whose shed antlers are found in abundance (Woodward), as well as by troops of *Elephas antiquus*.

Another subsidence then took place submerging the whole forest,

* For considerations on the subject of the old Crag-area, and on the causes modifying the Crag-fauna, see Godwin-Austen "On the Kainozoic Formations of Belgium" (Quart. Journ. Geol. Soc. vol. xxii. p. 228).

but still leaving land in the near vicinity. From this land wood and freshwater testacea, and some mammalian remains were carried down into the great beds of shingle forming off the coast in a sea in which still lingered some of the Crag Mollusca. At the same time a portion of the old forest land as well as of the marine clays which preceded it were denuded. These sands and shingle are of much greater extent than the forest-area, and spread over all East Norfolk, Suffolk, Essex, and beyond. The main feature of this deposit is the presence of flint pebbles with a considerable proportion of white and pink quartz pebbles and a few pebbles of slate, together with some rolled fragments of Greensand chert. On the table-land above the Meuse, in Belgium, there is a gravel of a very similar character; and I think it not improbable that some old river traversing the Ardennes may then have brought down into this Crag-sea area the old slate, quartz, and quartzite pebbles found so abundantly in the Westleton shingle, while other streams from the south or south-west may have drifted in the chert from the Lower Greensand and the mass of flint pebbles from the Chalk *.

The relation of the Crag sea of Belgium with that of the south-east of England has been the subject of frequent inquiry. Taking the revised lists of M. Dewalque and those at the end of this paper, the following results are arrived at respecting the species common to the several deposits.

Numerical Distribution.

	Total.	Sables gris.	Sables jaunes.	Sables noirs.
Norwich Crag	155	60	68	24
Suffolk or Red Crag	273	122	138	61
Coralline Crag	316	133	135	98

Proportional Distribution.

	Sables jaunes.	Sables gris.	Sables noirs.
Norwich Crag......	43·9	38·7	15·5 per cent.
Suffolk or Red Crag	50·5	44·7	22·3 „ „
Coralline Crag	42·7	42·4	31·0 „ „

This shows a more marked connexion between the upper or Red and Norwich Crags and the *Sables jaunes* and *gris*, forming the *Système Scaldisien* of Dumont, than was before noted; whilst the lower or Coralline Crag seems to hold a place intermediate between these beds and the *Sables noirs*, or the *Système Diestien* of Dumont.

Such, then, are some of the changes which mark the epoch of the

* I have also met with rolled fragments of silicified wood, like that which I have found *in situ* in the Woolwich and Reading Eocene series of Kent.

Crag. Of the first great change produced by the emergence of land to the south previous to the formation of the Red Crag we have scanty evidence. Traces of a Crag of the age probably either of our Coralline Crag or of the *Crag noir* exists in Touraine; so that until that period there had been communication with southern seas and an interchange of species*. The elevation of the Wealden dome brought to the surface beds of early Crag or of Diestien age, portions of which still exist in our North Downs at an elevation of from 500 to 600 feet†; and a like elevated tract, capped by beds of the same age, is prolonged into France and Belgium. This formed a barrier separating the southern and northern sea areas, and so isolating the fauna of the Coralline Crag, that, with the lower temperature of the sea resulting from the exclusion of currents from the south and the setting in of others from the north, a great part of that fauna died out. It is a case of extinction by change of conditions, and not by time.

This accounts for the disappearance in the Red Crag, noticed long since by Mr. Searles Wood, of so large a number of the southern genera of shells which characterize the Coralline Crag; while the descent of the more northern genera continues, with little loss, accompanied by the introduction from time to time of new species of northern forms.

A considerable number of the species which disappeared from our area at the period of the Crag continued to exist further south in the Atlantic and Mediterranean. Other species, under favourable conditions of the low temperature at great depths, survived in the mid-Atlantic, where their existence remained unknown until they were recovered by the deep-sea dredging so successfully carried on of late years. As many as 93 species of the Coralline Crag have been found at greater or less depths in the southern seas; and of these, 17 met with at depths of from 1000 to 7000 feet had not been before met with living‡. In the same way there are 65 species of the Red and Norwich Crags now found ranging to great depths; but of these, 39 lived at the time of the Coralline Crag; and of 4 of these not before known, 2 are Coralline-Crag species.

The presence of northern and arctic species does not, however, necessitate a severe climate; for cold currents may give a northern facies to the sea-fauna, while the land may retain the mean temperature due to geographical position. Beyond the introduction of more northern forms of shells in the Red and Norwich Crags, there is nothing to indicate a great increase of cold. None of the blocks of the Coralline Crag have been found drifted far from the Sutton islet. The porphyry boulder at the base of the Coralline Crag exceeds in dimensions any other foreign block either in the Red or the Norwich Crag. In the Chillesford Clay itself nothing but large

* Only a few shells of the Faluns of Touraine passed into our Crag area; but many of the Bryozoa are common to the Coralline Crag and Douay beds.

† Quart. Journ. Geol. Soc. vol. xiv. pp. 322 *et seqq.*

‡ Quart. Journ. Geol. Soc. vol. xxvii. p. liv.

chalk-flints from neighbouring shores shows transport by ice. The many fragments of secondary rocks and of mountain-limestone in the Red and Norwich Crags were probably brought down by river-action or river-ice. Nor is the increase in the northern species of shells very great in ascending through the Norwich Crag, though the number of individuals increases considerably, and a number of southern species become extinct. At the same time it is singular that so many Coralline-Crag species, mostly of British and Mediterranean forms, should reappear in the last or uppermost stage of the Crag at Aldeby.

This conclusion is in accordance with the land-fauna and flora we find flourishing subsequent to the Norwich Crag. The winter cold may have been greater; but otherwise the climate seems to have been a moderately temperate one. In the Forest-bed the vegetation, whether as regards the species or the size of the trees, is far from indicating a severe climate. Nor do we find any of the Mammalia which indicate extreme cold. The Mastodon no longer appears; but an Elephant, a Bear, and two Deer of the Crag period survive. With these, however, some of the animals of the postglacial period appear, showing probably the setting in of colder conditions there or further north. In the Westleton shingle we get the drifted remains of the same vegetation, and the same land and freshwater shells; but these latter are of a character common to all northern and temperate Europe. The marine Molluscan fauna now becomes poorer, but still without any decidedly marked northern characters; nor are any foreign boulders found—nothing but drifted pebbles carried possibly along a shore-line. Nevertheless we have in this series the nearest known approach to the glacial period, which set in immediately afterwards with a rigour and intensity denoting, I apprehend, causes of an entirely different order from those, the effects of which, up to this time, may be attributed to the known and assignable influence of land configuration and oceanic currents.

Lists of the Mollusca found in the Red and Norwich Crags.

This list is compiled like that of the Coralline Crag, with the exception of the Norwich-Crag species, which are largely supplemented from the late Dr. Woodward's list in the Rev. J. Gunn's 'Geology of Norfolk,' and from the lists furnished me by Mr. Reeve and Mr. Crowfoot (see pp. 455 & 457). The new species introduced in the Red Crag by Mr. Jeffreys, with the assistance of Mr. Bell, are marked J in column I. The names to which a † is prefixed denote species which Mr. Jeffreys identifies with those now living, in addition to those recognized by Mr. Wood. A form regarded by Mr. Jeffreys as a variety ranges through all the columns in italics. In column III. are his critical remarks, with the name first given to the species; while other names adopted by Nyst for the Belgian species are in brackets. The names to which a ¶ is prefixed denote recent or living species; but these species having been originally named from fossil specimens before they were known as living, the original names are retained. The species supposed to be derived from the Coralline Crag have Cor. Cr. marked in column III. Column VI. gives the chief localities where the species occurs in the Red and Norwich Crags. Column VII. shows the species which occur in the Coralline Crag, column VIII. those which occur in the Belgian Crags, and column IX. those which are found at Monte Mario. For columns IV., V., and IX. I am indebted to Mr. Jeffreys. The letter *d* prefixed to species in column II. denotes those bivalves which Mr. Bell informs me he has found perfect or having the valves united in the Red Crag (*ante*, pp. 330 & 351).

Localities in Red Crag:—A, Alderton; B, Bawdsey; Bw, Brightwell; Bt, Butley; F, Felixstow; Fh, Foxhall; H, Hollesley; R, Ramsholt; S, Sutton; W, Walton-on-the-Naze; Wd, Waldringfield.

Localities in Norwich Crag and Chillesford Sands:—Ad, Aldeby; Bl, Bulchamp; Br, Bramerton; C, Chillesford; N, Norwich (pits not particularized); P, Postwick; E, Easton Bavent (Southwold); T, Thorpe (Norwich); Th, Thorpe (near Aldborough); W, Weybourne Cliffs.

Geographical Distribution:—A, Arctic; Am, North American; At, Atlantic; B, British; M, Mediterranean; S, Scandinavian; W, West European.

Depth:—Lt, Littoral; L, Laminarian; C, Coralline; D, Deep-sea; **D**, depths exceeding 1200 feet.

Class I. Brachiopoda.

I.	II.	III.	IV.	V.	VI.		VII.	VIII.		IX.
Page of Monograph.	Names of Species.	Synonyms and critical remarks.	Zones of depth.	Geographical distribution.	Localities.		Coralline Crag.	Belgium.		Monte Mario, Italy.
					Red Crag.	Norwich Crag.		Sables gris.	Sables jaunes.	
16.	*d*Terebratula grandis.	Cor.Cr.(T. Sowerbyana).	......	....	Wd S R	......	*	o? *	*	*
21.	*d*Rhynchonella psittacea.	....	L–D	B S A	S	P T Br	......	......	......	

Class II. Conchifera.

I. Page of Monograph.	II. Names of Species.	III. Synonyms and critical remarks.	IV. Zones of depth.	V. Geographical distribution.	VI. Localities. Red Crag.	VI. Localities. Norwich Crag.	VII. Coralline Crag.	VIII. Belgium. Sables gris.	VIII. Belgium. Sables jaunes.	IX. Monte Mario, Italy.
237.	Abra alba	Genus Scrobicularia.	Lt–D	B S M	S B W Bt	Br Ad C	*	o *	*	*
238.	—— *fabalis* ...	*S. alba, var.* ...	......	....	W	......	......	......	......	
240.	—— obovalis...	Erycina ovata, *Philippi.*	Lt–C	M	S	N E Th	......	......	......	
239.	—— prismatica	....	L–D	B S M W	......	Ad	*	*	*	*
9.	Anomia *aculeata*	*A. ephippium, var.*	......	....	......	*Ad*	*	*	*	*
8.	—— ephippium, *L.*	....	L–D	B S M W At	S Bt	Br Ad	*	o *	*	*
10.	—— patelliformis.	....	L–C	B S M W	S B W Bt	Br	*	......	......	*
9.	—— *striata* ...	*A. patelliformis, var.*	......	....	......	*Ad*	*	......	......	*
77.	Arca lactea......	....	L–C	B M W At	S W Bt	......	*	o	......	*
76.	—— tetragona	A. imbricata	Lt–D	B S M W At	S Bt	......	*	o	......	*
215.	*d*Artemis lentiformis.	Venus exoleta, *Linné*, var. (Dosinia exoleta).	Lt-C	B S M W	S W Bt	......	*	*	*	*
216.	*d*—— lincta......	G. Venus (D. lincta).	Lt–D	B S M W	W	N ?	*	*	*	*
177.	*d*Astarte *Basterotii.*	*A. sulcata, var.*; *Cor. Cr.*	......	....	*S B F W ? Bt Wd*	......	*	*	*	*
175.	—— borealis ...	....	L–C	S A	......	P Br T Ad	......	......	......	
188.	*d*—— Burtinii...	Cor. Cr. ?	......	....	S Bt	Br. ?	*	*	*	
183.	*d*—— compressa	Not Venus compressa, *L.*	L–D	B S A W	S A B W Bt Fh Wd	Br T Ad E	......	......	......	
184.	—— crebrilirata	Crassina depressa, *Brown*	L-C	S A	S W	......	......	......	*	
190.	—— digitaria .	G. Woodia......	C–D	B M W	S W Bt	......	*	*	*	
181.	—— *elliptica*...	*A. sulcata, var.*	*L–C*	*B S A*	......	*Br*	......	......	......	
185.	*d*—— *gracilis* ...	*A. compressa, var.* (A. Galeotti).	......	....	*S B Wd*	*T Th*	*	*	*	
178.	—— *incrassata*?	*R. sulcata, var.*	......	....	*S*	......	*	......	*	
179.	—— mutabilis .	Cor. Cr.; Italy (A. planata).	......	....	S A B	......	*	o *	*	
189.	*d*—— *obliquata* .	*A. Burtinii, var.*	......	....	*S W B Wd*	......	......	*	*	
180.	†*d*— Omalii ...	¶A. undata, *Gld.*	C	Am	S Wd	Br	*	*	*	
182.	—— sulcata ...	....	C–D	B S A M W At	S	Br T Ad	......	......	......	*
173.	—— triangularis.	A. minuta	L–D	B M W At	W	......	*	o	......	
167.	Cardita *chamæformis.*	*C. scalaris, var.*	......	....	*S W*	......	*	*	*	
168.	*d*—— corbis ...	....	C	M W At	W Bt	N	*	o	......	*
167.	—— orbicularis	....	......	....	S W	......	*	o ?	*	
166.	†—— scalaris ...	C. borealis, *Con.*	C	Am	S W	N C	*	*	*	
165.	†*d*— senilis ...	C. sulcata, *Brug.* Cor. Cr.	C	M W	S B F Bt	......	*	......	......	*
157.	*d Cardium angustatum.*	*C. edule, monstr.?*	......	....	*S B R A Bt*	*Th*	......	......	......	

CONCHIFERA (*continued*).

I. Page of Monograph.	II. Names of Species.	III. Synonyms and critical remarks.	IV. Zones of depth.	V. Geographical distribution.	VI. Localities. Red Crag.	VI. Localities. Norwich Crag.	VII. Coralline Crag.	VIII. Belgium. Sables gris.	VIII. Belgium. Sables jaunes.	IX. Monte Mario, Italy.
159.	*Cardium decorticatum.*	*C. norvegicum, var., Spengler; Cor. Cr.*	......	....	*Bt*	......	*	......	......	*
152.	—— echinatum	....	L–D	B S M W At	S	......	......	○	....	*
165.	*d*—— edule......	....	Lt–L	B S M W	Passim	Passim	*	*	*	*
160.	—— grœnlandicum.	....	C	A	S B Bt	P Br C Ad	......	......	......	
159.	†—— interruptum.	C. norvegicum, (C. oblongum).	L–D	B S M W At	S Bt	......	......	*	*	*
153.	—— nodosum, *S. Wood.*	C. fasciatum, *Montagu.*	L–D	B S M W At	S A B	Ad	*	○	......	
J	—— nodosum, *Turton.*	....	L–C	B S M W	Bt	......	......	......	......	
154.	*d—— nodosulum*	*C. Parkinsoni, jun.*	......	....	*S*	.....	......	......	......	
158.	†*d*—Parkinsoni	C. Nuttalii, *Conrad.*	......	Am	S F W	T ?	......	*	*	
154.	—— strigilliferum.	....	C	A	......	Ad ?	*	......	......	
160.	—— *venustum*	*C. norvegicum, var. rotunda.*	......	....	*S W*	*T*?	......	......	......	
162.	Chama gryphoides.	Cor. Cr.	Lt–C	M W	S W	......	*	......	......	*
198.	Circe minima...	Cytherea trigona	L–D	B S M W At	S	E	*	*	*	*
263.	†Cochlodesma complanatum.	Thracia prætenuis, *Pulteney*, var.	Lt–D	B S M W	W	Ad	......	......	......	
275.	Corbula complanata.	G. Corbulomya	......	....	S W Bt	.. ...	......	*	*	*
274.	*d*—— striata ...	C. gibba, *Olivi* (C. planulata)	Lt–D	B S M W At	S B W Wd Bt	Br N Ad Th	*	○ *	*	*
258.	—— tenuis ...	....	......	....	W	....	*	....	*	*
134.	Cryptodon sinuosum.	....	Lt–D	B S A M W At	......	Ad	*	*	......	*
	Cultellus pellucidus.	Solen pellucidus, *Penn.*	L–C	B S M W	......	Ad	......	......	......	
196.	Cyprina islandica.	....	Lt–D	B S W	S B A F Bt	Passim	*	○ ? *	*	*
197.	—— rustica ...	Cor. Cr.	......	....	S Wd	......	*	○ *	*	
208.	Cytherea rudis	G. Venus (V. cycladiformis).	C	M W	S W Bt	N	*	○ *	*	*
146.	†Diplodonta ? astartea.	D. trigonula, *Bronn.*	C–D	M At	S Bt	Br	*	*	*	
145.	—— *dilatata*...	*D. rotundata, var. Cor. Cr.* (*D. Woodi*).	......	....	*S*	*T*	*	*	......	
144.	—— rotundata	Cor. Cr.	L–C	B M W At	S Bt	......	*	......	......	*
J	Donax politus, *Poli.*	(D. vinacea) Cor. Cr.	Lt–C	B M W	S W	......	*	......	*	
220.										
219.	—— trunculus	....	Lt–L	B M W	S	Th ?	......	......	......	*

CONCHIFERA (*continued*).

I. Page of Monograph.	II. Names of Species.	III. Synonyms and critical remarks.	IV. Zones of depth.	V. Geographical distribution.	VI. Localities. Red Crag.	VI. Localities. Norwich Crag.	VII. Coralline Crag.	VIII. Belgium. Sables gris.	VIII. Belgium. Sables jaunes.	IX. Monte Mario, Italy.
219.	Donax vittatus .	....	Lt–L	B S M W	S	Br P Bl Ad	......	......	......	*
J 171.	Erycinella ovalis, *Conrad*?	A doubtful identification; Cor. Cr.	......	....	W	......	*	o	......	
217.	†*d*Gastrana laminosa.	G. guinaica, *Chemnitz* (Fragilia laminosa).	......	South Africa	S A B W Wd	......	*	*	*	
292.	*d*Gastrochæna dubia.	Cor. Cr.	L–D	B M W At	S Wd	......	*	*	......	*
291.	Glycimeris angusta.	G. siliqua, *Ch*...	L–C	A	S	N	*	*	*	
19.	†*d*Hinnites Cortesyi, *Defrance*?	H. giganteus, *P. Carpenter*; Cor. Cr.?	......	Am	Trimley	T?	*	......	......	*
193.	*d*Isocardia cor	....	L–D	B S M W At	S	......	*	*	*	*
120.	†*d*Kellia ambigua, *Nyst*.	Scintilla parisiensis, *Conti*, non *Desh*.	C	B M W	S W Bt	C Ad	*	o *	*	*
118.	*d*—— suborbicularis.	....	Lt–D	B S M W At	W Wd	......	*	o	......	*
92.	Leda caudata...	L. minuta, *Müller*	C–D	B S A W	S	......	......	......	......	
J	——hyperborea, *Lovén*.	....	C	S A	Bt	......	......	......	......	
88.	—— lanceolata	Nucula arctica, *Broderip & Sowerby*, not *Gray*.	......	A	B Bt	Br C	......	......	......	
90.	—— myalis . .	(L. depressa)...	......	Am	S Bt	P Br Bl C Ad	......	*	*	
J 95	—— pygmæa, *v. Münster*.	(L. Phillipiana)	C–D	B S A M W At	W	Ad	*	o	......	
115.	†Lepton deltoideum.	Erycina Geoffroyi, *Payraudeau*.	C	M W	S	......	*	o *	*	*
116.	—— nitidum...	L. squamosum, jun.	L–C	B S W	......	Ad	*	......	......	*
43.	†Lima exilis ...	L. inflata, *Lamarck*.	C	M	W	......	*	*	......	
45.	—— Loscombii	....	L–D	B S M W	W	......	*	*	......	*
70.	†Limopsis aurita	(L. sublævigata) Cor. Cr.	D–D	B A M W At	Wd	......	*	o *	......	*
J 71	†—— pygmæa, *Ph*.	(L. anomala)...	C–D	M W	W F Wd	......	*	o	......	*
137.	Loripes divaricata.	L. divaricatus...	L–C	B M W At	S Bt	Br T Ad	......	......	......	
139.	*d*Lucina borealis	(L. flandrica)...	Lt–D	B S M W At	Passim	Passim	*	o *	*	*
148.	Lucinopsis Lajonkairii.	¶Venerupis decussata, *Ph*.; Cor. Cr.	C	M	S	......	*	......	*	

CONCHIFERA (*continued*).

I.	II.	III.	IV.	V.	VI. Localities.		VII.	VIII. Belgium.		IX.
Page of Monograph.	Names of Species.	Synonyms and critical remarks.	Zones of depth.	Geographical distribution.	Red Crag.	Norwich Crag.	Coralline Crag.	Sables gris.	Sables jaunes.	Monte Mario, Italy.
	Lucinopsis undata.		L–C	B S M W	......	Ad	......	......	......	
251.	Lutraria elliptica.	....	Lt–L	B S M W	S	......	*	*	*	*
243.	Mactra *arcuata*	*M. glauca, var.*	......	....	*S B W*	*P E Ad*	*	*	*	*
249.	—— *constricta*	*M. solida, monstr.*	......	....	*S Bt*	......	......	......	......	
249.	—— *deaurata* .	*M. solida, monstr.*	......	....	*S W*	......	......	*	*	
241.	*d*—— glauca ...	....	L	B M W	N Wd	......	......	......	......	*
248.	—— *obtruncata*	*M. subtruncata, var.*	......	....	*S*	......	*	......	......	*
246.	*d*—— *ovalis*......	*M. solida, var. elliptica.*	Lt–D	....	*B S Wd Bt W*	*Br C Ad N Th*	*	*	*	
244.	—— procrassa .	M. solidissima, *Ch.*; M. ponderosa, *Ph.*	Lt–L	S A	F Wd	......	......	......	......	
245.	—— solida......	....	Lt–L	B S M	S	Br T Ad	......	......	*	
242.	—— stultorum	....	Lt–C	B S M W At	S	Br P	*	......	......	*
247.	—— subtruncata.	....	Lt–D	B S M W	S ? Bt	Br Bl Ad	......	......	......	*
245.	*d*—— *truncata* .	*M. solida, var*...	......	....	*S W*	......	......	......	......	
58.	Modiola barbata	G. Mytilus	Lt–L	B M W	W	......	......	......	......	*
60.	*d*—— costulata .	G. Modiolaria...	Lt	B M W At	W Wd	......	*	o	......	*
62.	——marmorata	G. Modiolaria...	L–D	B S M W At	W	C	*	o	......	*
57.	—— modiolus..	G. Mytilus	Lt–D	B S W	S	P Ad	*	o *	*	*
J	*d*Modiolaria Petagnæ, *Scacchi*	....	L–C	M W	Wd	......	......	......	......	
126.	*d*Montacuta bidentata.	(Erycina faba)	L–D	B S M W	W	Ad	*	*	*	*
129.	——ferruginosa	....	L–D	B S M W	......	Ad	*	o *	......	*
128.	—— substriata	....	L–D	B S M W	......	Ad	*	o	*	*
279.	Mya arenaria ...	....	Lt–L	B S A W	S B F Bt	Passim	......	......	*	
277.	*d*—— truncata...	....	Lt–D	B S A W	S B Wd Bt	BrBlCAd	*	*	*	
52.	*d*Mytilus edulis and var. hesperiana.	....	Lt–L	B S A M W	S B Wd R H Bt	Passim	*	*	*	*
82.	†*d*Nucula Cobboldiæ.	¶ N. insignis, *Gould.*	L–C	Japan........	S B T F Wd Bt	Passim	......	......	......	
81.	*d*—— lævigata...	....	......	....	W Wd Bt	......	*	o *	*	
85.	—— nucleus ...	....	L–D	B S M W	S B Wd Bt	......	*	*	*	
84.	*d*—— tenuis ...	....	C–D	B S A M W At	B Wd W	Br C E Ad	*	*	*	*
13.	*d*Ostrea edulis	....	Lt–D	B S M W	Passim	N		o *		*
17.	——princeps...	Cor. Cr. (O. undulata).	......	....	S N B	......	* *	*	* *	
270.	Pandora pinna	P. inæquivalvis, *L.*, var.	Lt–D	B S A M W At	W	......	......	......	.....	
283.	*d*Panopæa Faujasii.	Cor. Cr.	......	....	S A Wd	......	*	*	*	*
281.	—— norvegica	G. Saxicava ...	C–D	B S A	S Bt	Br C	......	......	......	

CONCHIFERA (*continued*).

I.	II.	III.	IV.	V.	VI.		VII.	VIII.		IX.
					Localities.			Belgium.		
Page of Monograph.	Names of Species.	Synonyms and critical remarks.	Zones of depth.	Geographical distribution.	Red Crag.	Norwich Crag.	Coralline Crag.	Sables gris.	Sables jaunes.	Monte Mario, Italy.
J	Panopæa plicata, *Mont.*	¶ (Saxicava? fragilis) Cor. Cr.	L–C	B S W	......	......	......	......	*	
38.	Pecten dubius...	(P. radians) Cor. Cr.	......	....	S N B Bt	......	*	*	*	*
37.	—— *gracilis* ...	*P. opercularis, var.*	......	....	*S H B W Bt*	......	......	......	......	
22 & 323.	*d*—— maximus	(P. grandis) ...	L–D	B S M W At	S B Wd	......	*	o *	*	*
35.	*d*—— opercularis	....	L–D	B S M W At	Passim	Passim	*	*	*	*
31.	—— princeps ..	P. islandicus, *Ch.*	L–C	S A Am	Wd	T Yarn	*	*	*	
33.	*d*—— pusio	....	Lt–D	B S M W At	S B W Wd	N	*	o *	*	*
J	—— septemradiatus, *Müll.*	(P. danicus) ...	C–D	B S M W	Fh	......	......	o *	......	
27.	*d*—— tigrinus ...	....	L–D	B S W	S B W Bt	Br Ad	*	o *	*	
66.	*d*Pectunculus glycymeris.	....	L–D	B S M W At	Passim	T Br Th	*	......	*	*
J	—— pilosus, *L.*	....	C	M	Wd	......	......	......	......	
J 293.	Pholadidea papyracea, *Turton.*	Cor. Cr.	Lt–D	B W	......	......	*	o	......	
296.	*d*Pholas crispata	....	Lt	B S W	S W Wd Bt	P W	*	......	......	
295.	*d*—— cylindrica	....	......	....	S W	......	*	......	......	
J	—— dactylus, *L.*	....	Lt	B S M W	W	......	......	......	......	
J	*d*—— parva, *Pennant.*	....	Lt–L	B M W	W Wd	......	......	......	*	
J	Pinna rudis, *L.*	....	Lt–D	B M W At	W	......	......	......	......	
287.	Saxicava *arctica*	*S. rugosa, var.*...	......	....	*S Bt*	......	*	o *	*	*
285.	*d*—— rugosa ...	....	Lt–D	B S A M W At	S W Wd Bt	Br T Ad	*	o *	......	*
J 121.	†Scacchia elliptica, *Sc.*	....	C	M	Bt	......	......	......	......	
256.	*d*Solen ensis ...	....	L–C	B S M W	S W Wd Bt	......	*	o *	*	*
254.	*d*—— *gladiolus*..	*S. siliqua, var.*...	......	....	*S W Bt*	......	......	*	*	
255.	*d*—— siliqua ...	....	Lt–L	B S A W At	S Wd	BrTAdTh	......	*	*	*
204.	*d*Tapes pullastra	....	Lt–L	B S M W	Wd	......	......	......	......	
204.	*d*—— texturata?	T. aureus, *Gm.*	L–C	B S M W	W Wd	Br	......	......	......	*
201.	*d*—— virginea...	T. virgineus ...	Lt–D	B S M W	S W	Br	*	......	*	*
230.	Tellina *Benedenii.*	*T. calcaria, var.*	......	....	*S*	......	......	*	*	
231.	—— balthica, *L.*	....	Lt	B S A W At	.....	P (?) W	......	......	......	
226.	*d*—— crassa......	....	Lt–D	B S M W	S W Bt	T P C	*	*	*	*
232.	—— fabula ...	....	Lt–L	B S M	......	EBlBrAd	......	......	......	*
228.	—— lata	T. calcaria, *Ch.*	L–D	B? S A Am At	S	Br C Bl Ad Th	......	......	......	
228.	*d*—— *obliqua* ...	*T. calcaria, var.* (*T. ovata*).	......	....	*S B F T Wd Bt*	*Br P Bl C Ad Th*	*	*	*	

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230.	*d*Tellina *prætenuis.*	*T. calcaria, var.*	......	....	*S W Wd B*	*Br Bl C Ad Th*	......	*	*	
300.	Teredo norvegica.	....	Lt	B S M W	S Bt	......	*	*	*	
261.	Thracia inflata..	T. Conradi, *Couth.*? (T. corbuloïdes, *Desh.*).	C	Am	Bw ?	......	*	......	*	
260.	—— phaseolina	T. papyracea, *Poli.*	Lt–D	B S M W At	......	Ad	*	*	*	
235.	Trigonella plana	Scrobicularia piperata, *Belon.*	Lt–L	B S M W	S ?	Br C	......	......	......	
205.	Venerupis irus..	....	L–C	B M W At	W	......	......	......	......	
210.	*d*Venus casina	(V. sulcata) ...	L–D	B S M W At	S B F A Wd Bt	......	*	*	*	
J 207.	*d*—— chione, *L*	(Cytherea chionoïdes).	L–C	B M W At	Wd	......	......	o *	*	*
211.	—— fasciata ...	....	Lt–D	BSMWJapan	S W Bt	Br	......	......	......	*
212.	*d*—— *imbricata*..	*V. fasciata, var.*.	......	....	*S W*	......	*	......	......	*
213.	—— ovata	Cor. Cr.	L–**D**	B S M W At	S Bt	Ad	*	*	*	*

Class III. Solenoconchia.

I.	II.	III.	IV.	V.	VI. Red Crag.	Norwich Crag.	VII.	VIII. Sables gris.	Sables jaunes.	IX.
188.	Dentalium costatum.	D. dentalis, *L.*, var.; Cor. Cr.	L–C	M W	S Bt	......	*	o *	......	*
J	—— abyssorum, *Sars.*	....	C–**D**	B S A M W At	......	......	......	......	......	

Class IV. Gastropoda.

I.	II.	III.	IV.	V.	VI. Red Crag.	Norwich Crag.	VII.	VIII. Sables gris.	Sables jaunes.	IX.
J	Actæon exilis, *J.*	....	**D**	M At	W	......	......	......	......	
169.	—— Noæ	¶A. pusillus, *Forbes.*	**D**	M At	Bw W	B	......	......	*	
170.	—— *subulatus*..	*A. tornatilis, var.*	......	....	*S Bt*	*Br*	......	......	......	
170.	—— tornatilis..	....	Lt–**D**	B S M W	S Bt	Br P Bl E Ad	*	o *	......	*
139.	Adeorbis subcarinatus.	(Trochus trigonostomus).	Lt–C	B M W	S	......	*	*	*	
J	Amaura candida, *Möller*	....	C	A Am	Bt	......	......	......	......	
25.	Aporrhaïs pespelecani.	(Chenopus) ...	L–D	B S M W	S N Bw B Bt	Th	*	o ?	*	*
34.	Buccinum Dalei	G. Buccinopsis	C–D	B S	S W Bt	E C P	*	*	*	
J	—— glaciale, *L.*	....	......	A	W	......	......	......	......	
J	—— grœnlandicum, *Ch.*	....	Lt–L	A	Bt	N E C	......	......	......	
35.	—— undatum..	(B. tenerum) ...	Lt–D	B S W	S Bt N W	N E C Th	*	*	*	
175.	Bulla cylindracea.	G. Cylichna ...	L–**D**	B S M W At	S Bt	Br	*	o *	*	*
173.	—— lignaria...	G. Scaphander..	Lt–**D**	B S M W	S Wd	......	*	o *	*	*

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177.	Bulla regulbiensis.	Utriculus obtusus, *Mont.*	Lt–D	B S A M W	......	Br P Ad	......	......	......	
176.	—— truncata ..	....	C	B S M W At	......	Ad	*	......	......	
116.	†Cæcum mammillatum.	Cor. Cr.	C	Japan	S	......	*	......	......	*
159.	Calyptræa chinensis.	....	Lt–D	B M W At	Passim	Br P Ad Th	*	○ *	*	*
64.	Cancellaria coronata.	C. varicosa, *Brc.*	......	....	W Wd	......	......	○ *	*	
66.	—— costellifera	Admete viridula, *Fabricius.*	C–D	B S A At	S Bt Wd	Br	*	*	*	
65.	†—— mitræformis (?)	Cor. Cr.	C–D	W	S	......	*	○	......	
156.	Capulus *militaris.*	*C. ungaricus, jun.*	......	....	*S N W*	......	*	*	*	
156.	—— *obliquus* ...	*C. ungaricus, var.*	......	....	......	......	*	*	*	
155.	—— ungaricus	C. ungaricus....	Lt–D	B S M W	S W N B Bt Wd	Br Ad	*	*	*	*
27.	†? *Cassidaria bicatenata.*	*C. tyrrhena, Ch., var.* ?	*C*	*M*?	*S B F*	*T*	*	*	*	
J 71.	Cerithiopsis Metaxa, *Delle Chiaje.*	....	L–D	B M At	W	......	*	......	......	
70.	—— tubercularis	....	Lt–D	B S M W At	S	Br	*	......	......	*
72.	Cerithium adversum.	G. Triforis; T. perversa, *L.*	Lt–D	B S M W At	W	......	*	......	*	*
73.	†—— granosum	....	D–D	B S	W	......	*	......	......	
	—— reticulatum, *Da Costa.*	....	Lt–D	B S M W At	Bt W	N	......	......	......	
69.	—— tricinctum	(C. Woodwardi)	......	....	Passim	Br T Ad Th	......	......	*	
70.	—— trilineatum, *Ph.*	(var. inversum)	C	M	W	......	*	○	......	
69.	—— *variculosum.*	*C. reticulatum, var.*	......	....	*W*	......	......	......	*	
80.	†Chemnitzia costaria.	G. Odostomia; Cor. Cr.	C	M	Bt	......	*	......	......	
J 82.	—— densecostata.	O. rufa, var. ...	C	M	W	......	*	......	......	*
81.	—— elegantissima.	O. lactea, *L.* ...	Lt–C	B S M W At	W Bt	N	*	......	......	*
J 81.	—— internodula.	¶C. corbis, *Conti*	C–D	M W	S Bt	Br Ad	*	......	*	*
63.	Clavatula Boothii.	Defrancia Leufroyi, *Michaud.*	Lt–D	B S M W At	S W	......	......	......	*	
61.	†—— cancellata	D. reticulata, *Renier*, var.	L–D	B S M W	W	......	*	......	......	*
61.	†—— concinnata	Pleurotoma decussata, *Ph.*	C–D	M W At	S	......	*	......	......	

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58.	Clavatula costata (?)	G. Pleurotoma	Lt–D	B S M W	S W Bt	......	*	......	*	*
62.	—— lævigata (?)	,, ,,	Lt–L	B M W At	W Bt	......	*	......	......	*
56.	—— linearis ...	G. Defrancia ...	L–D	B S M W At	S W Bt	Br Ad	*	......	......	*
59.	—— *mitrula* ...	*P. costata, var.*	......	....	*S W Bt*	*N*	*	......	......	
60.	—— nebula ...	G. Pleurotoma	Lt–D	B S M W	S	......	......	......	......	
64.	—— plicifera...	P. elegans, *Möller?*	C–D	B S	S	......	......	......	......	
63.	—— *Trevelliana*	*P. turricula, worn*	......	....	*S*	*Br*	......	......	......	
62.	—— turricula...	G. Pleurotoma	L–D	B S A W	S W Bt Fh	Br Th Ad	......	......	......	
J	Columbella scripta.	....	L–C	M W	S W Wd	......	......	o *	*	
23.	—— sulcata ...	....	......	....	W	Br	*	......	*	
J	†Conopleura Maravignæ, *Bivona.*	¶Pleurotoma incrassata, *Dujardin*; Cor. Cr.	C–D	M W	S	......	*	......	......	
12.	Conovulus myosotis (?).	G. Melampus...	Lt	B M W	S	Br P	......	......	......	
11.	—— pyramidalis	,, ,,	......	....	S Bt	Br E Th	......	*	*	
16.	Cypræa *angliæ.*	*C. retusa, var...*	......	....	*S*	......	......	......	......	
15.	—— avellana...	....	......	....	S W	Bl	*	......	......	
17.	—— europæa	....	Lt–D	B S M W	Passim	T	*	o *	*	*
16.	—— retusa ...	....	......	....	S	......	*	......	......	
J	†Defrancia hystrix (*Jan*), *Bellardi.*	....	D–D	M At	W	......	*	*	......	
165.	Emarginula crassa.	(E. fissura)	Lt–D	B S At	S N	......	*	*	*	
164.	—— fissura ...	....	Lt–D	B S M W At	Passim	......	*	o ? *	*	
18.	Erato lævis......	G. Marginella	L–D	B M W	S	N	*	o	......	*
19.	—— Maugeriæ	Cor. Cr.	C	West Indies	S	......	*	......	......	
J	†Eulima distorta	....	C–D	B S M W At	W	......	......	......	......	*
J	—— intermedia, *Cantraine.*	....	C	B S M W At	W	......	......	......	......	*
96.	—— polita......	....	L–D	B S M W	W	Br	*	......	......	*
J	Fissurella costaria, *Basterot.*	¶F. neglecta, *Desh.*	C	M	Wd	......	*	......	......	*
168.	—— græca ...	....	Lt–D	B M W At	S B W Bt	......	*	*	*	*
J	Fusus despectus, *L.*	....	C–D	A B S	S	Br Th	......	......	......	
J	†—— Sarsi, *J.*...	....	......	B S At	Bt Wd	......	......	......	......	
109.	Hydrobia ulvæ, *Penn.*	....	Lt–C	B S M W Am	W	Br T Ad	......	......	......	
	Lacuna crassior	....	Lt–C	B S A	......	Br	......	......	......	
316.	—— divaricata, *Fabr.*	....	Lt–L	B S A Am	......	Br	......	......	......	
J	Lepeta cæca, *Müll.*	....	C	B S A	W	......	......	......	......	*

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118.	Littorina littorea	....	Lt	B S A W	S B Bt	Passim	......	......	......	*
	—— rudis, *Maton.*	....	Lt	B S A W	......	Br T W	......	......	......	
120.	—(?)*suboperta*	*L. littorea, var.*	......	....	*S W B*	......	......	*	*	
J	Mitra cornicula, *L.*	M. ebenus, *Lam.*	C	M At	Wd	......	......	......	......	
J	Menestho albula, *Fabr.*	....	C	A	W	......	......	......	......	
40.	†Murex tortuosus.	M. erinaceus, *L.*, var.	Lt–C	B S M W At	S W Bt	Br	*	......	*	
32.	Nassa conglobata.	Desmoulea abbreviata, *Ch.*	......	Africa	W	......	......	......	......	
31.	—— *consociata*	*N. elegans, var.*	......	....	*S*	......	*	......	*	
J	—— Cuvieri, *Payr.*	....	C	M W	Bt	......	......	......	......	*
30.	†—— elegans ...	....	C–D	W At	W Bt	......	......	*?	*	
29.	†—— granulata	....	C	W	Passim	......	*	......	*	
29.	—— incrassata	....	Lt–D	B S M W At	S Bt Wd	Br	*	o ? *	*	*
28.	†—— labiosa ...	N. semistriata, *Brc.*; Cor. Cr.	C–D	M W	S Bt	......	*	o ? *	*	*
31 & 315.	—— *monensis*	*N. incrassata, var.*	...	....	*S Bt*	......	......	......	......	
32.	—— prismatica	Not N. prismatica, *Br.*, but N. lima seu limata, *Ch.*, = N. scalariformis, *Kiener*; Cor. Cr.	C–D	M W	S	......	*	o *	*	*
30.	†—— propinqua	N. trivittata, *Say*	Lt–L	Am	S W Bt	Br E	......	*	*	*
J 315.	—— pygmæa, *Lam.*	....	C	B S M W	Bt	......	*	......	*	
33.	—— reticosa ...	(B. elongatum)	......	....	Passim	T E	......	*	*	
J	Natica Alderi, *Forb.*	....	C–D	B S M W	S Bt	......	......	......	......	
142.	—— catena ...	(N. Sowerbyi)	Lt–C	B S M W	S Bt	Br Bl C	......	*	*	*
141.	†—— catenoïdes	N. heros, *Say*?	L	Am?	S W	E Bl	*	......	......	
145.	†—— cirriformis	N. sordida, *Swainson.*	L–D	B M W At	S Wd	......	*	*	*	*
147.	—— clausa ...	N. affinis, *Gm.*	C–D	B S A At	S Bt	Br C Ad	......	......	......	
146.	—— grœnlandica, *Beck.*	....	C–D	B S A	S Bt	Br T W	......	......	......	
142.	—— *Guillemini* (?)	*N. catena, jun.*	......	......	*S*	*Yarn*	......	......	......	
145.	—— helicoïdes	N. islandica, *Gm.*	C–D	B S A	S Bt	Br E Ad	......	......	......	
144.	—— hemiclausa	....	......	....	S W	N Bl	......	o ? *	*	*
148.	—— multipunctata.	N. millepuncta-ta, *Lam.*, var.	C	M	W Bt	......	*	o *	*	*
143.	—— *varians* ...	*N. cirriformis, var.; Cor. Cr.*	......	....	*S*	......	*	......	......	

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J	Odostomia acicula, *Ph.*	....	C–**D**	B S M W At	W	......	.....	......	......	
J	—— acuta, *J.*..	....	L–C	B S M W At	W	......	*	......	......	
J 317.	—— conoïdea, *Br.*	....	L–**D**	B S M W At	W	Br	.....	......	......	
J	—— interstincta, *Mont.*	....	Lt–D	B S M W	Wd	......	.....	......	......	
J 85.	—— plicata, *Mont.*	(Tornatella conoidea) Cor. Cr.	L	B S M W	W	......	*	○	*	*
J	†—— plicatula, *Brc.*	....	D–**D**	M W	W Bt	......	.....	......	......	
317.	—— unidentata	....	C–D	B S M W At	W	......	.....	*	*	*
14.	†Ovula Leathesii	Bulla spelta, *L.*	C	M	W Bt	Br ?	*	......	*	*
183.	Patella vulgata	....	Lt–L	B S M W At	S Bt	Br	.....	......	......	
J	Pleurotoma bicarinata, *Couth.*	....	C–**D**	S At Am	Bt	......	.....	......	......	
54.	†—— carinata...	Cor. Cr. (P. modiola)	D–**D**	B S M W At	S	......	*	*?	......	
J	—— harpularia, *Couth.*	....	C–**D**	S At Am	Bt	......	.....	*	......	
53.	—— intorta ...	....	......	....	S Bt Wd	......	.....	○ *	*	
J	—— pyramidalis, *Ström.*	....	C–D	S Am	Fh	Th	.....	......	......	
61.	—— rufa, *Mont.*	....	Lt–C	B S M W	Bt	T	.....	......	......	
54.	—— semicolon (?).	P. galerita, *Ph.*? Cor. Cr.	**D** ?	B At ?	S	... ..	*	......	......	*
J	—— striolata, *Sc.*	....	C	B S M W	S	......	*	......	......	
53.	—— turricula	Not P. turricula. *Mont.* (P. turrifera).	......	....	S B Bt	Br T	.. ...	○ *	*	
J	—— violacea, *Mighels & Adams.*	....	C	S A Am	Bt Wd	Th	.....	......	......	
36.	Purpura lapillus	....	Lt–L	B S A W At	Passim	Passim	.....	*	*	
38.	—— *tetragona*	*P. lapillus, var.*	......	....	*S W Bt*	*N*	.....	*	*	
J	†Pyramidella uniplicata, *Duj.*	(P. plicosa) Cor. Cr.	D–**D**	M W	W	......	*	○	......	*
42 & 311.	Pyrula acclinis.	P. subintermedia, *Bronn*; Cor. Cr. (P. reticulata).	...	....	W Wd Fh	......	*	○ *	*	
22.	Ringicula buccinea.	R. auriculata, *Menard.*	C–D	M W At	S Bt	Yarn Ad	*	○ *	*	*
22.	†—— ventricosa	....	**D**	M At	S Bt	Br T Ad	*	......	......	*
104.	Rissoa confinis	....	......	....	......	Br	*	......	......	
104.	—— pulchella(?)	Not Philippi's sp.; R. curticostata, *S. W.*	......	....	S R Bt	......	......	......	...	

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J	†Rissoa Stefanisi, *J.*	R. costulata, *S. W.*, not *Alder*; Cor. Cr.	C–D	M	W	......	*	....	......	
J 100.	—— striata, *Adams.*	....	Lt–D	B S A W At	......	......	*	......	......	
J 101.	—— zetlandica, *Mont.*	....	L–D	B S M W At	W Wd	......	*	......	.....	
94.	†Scalaria clathratula, *Ad.*	....	L–D	B S M W	......	N?	*	......	*	*
J	†—— communis, *Lam.*	....	C–D	B S M W	Wd	......	......	......	......	
J 91.	†—— fimbriosa	Turbo lamellosus, *Brocchi*, var.; Cor. Cr.	Lt–C	B S M W At	Woodbridge Wd	......	*	o * ?	......	
93.	—— foliacea ...	Cor. Cr.	......	....	S	N?	*	......	*	*
90.	—— grœnlandica.	....	C–D	B S A	S	Br E Bl Ad Th	......	......	*	
J	—— pseudoscalaris, *Br.*	....	C	M	Sudb	......	......	......	......	
94.	—— Trevelyana	....	C–D	B S M	S	N Br Bl Ad	......	......	*	
J	—— Turtonæ, *Turt.*	....	L–C	B S M W At	Sudb	Th	......	......	......	
J 90.	—— varicosa...	Not Turbo varicosus, *Br.*, nor S. varicosa, *Lam.*; Cor. Cr.	......	....	W Wd S	......	*	......	......	
161.	Tectura virginea	....	Lt–D	B S A M W At	S B Bw Bt	Br	......	*	*	
26.	Terebra *canalis*	*T. inversa, var.; Cor. Cr.*	......	....	*Wd*	......	*	......	......	
26.	—— inversa ...	Columbella minor, *Scacchi*?; Cor. Cr.	......	....	S	......	*	*	*	
129.	Trochus Adansoni.	A doubtful identification.	Lt	M	S	......	*	*	*	
131.	—— cinerarius	....	Lt–D	B S M W	S W Bt	......	......	......	......	
131.	—— *cineroïdes*	*T. cinerarius, var. (T. solarium).*	......	....	*S W Bt*	......	......	*	*	
125.	—— formosus	T. occidentalis, *Migh.*	C–D	B S	S Bt	......	*	......	*	
127.	—— granulatus *Born.*	....	C–D	B M W At	W Wd Bt	Br T	......	......	......	*
J	—— grœnlandicus, *Ch.*	....	Lt–L	B S A	......	N	......	......	......	
130.	—— *Kicksii* ...	*T. Adansoni, var.; Cor. Cr.*	......	*M*	*S*	......	*	*	......	
J 127.	—— millegranus, *Ph.*	....	C–D	B S M W	W	......	*	o	......	
129.	—— Montacuti	A doubtful identification.	L–D	B M W At	S	......	*	......	......	*

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					Localities.			Belgium.		
Page of Monograph.	Names of Species.	Synonyms and critical remarks.	Zones of depth.	Geographical distribution.	Red Crag.	Norwich Crag.	Coralline Crag.	Sables gris.	Sables jaunes.	Monte Mario, Italy.
127.	Trochus multigranus.	(T. Dekini)......	D–D	At	S	......	......	*	......	
126.	—— papillosus (?).	Not T. papillosus, *Da Costa.*	......	....	S N B W Bt	......	......	......	......	
126.	—— *subexcavatus.*	*Var. of last species.*	......	....	*S N W*	......	......	*		
130.	—— tumidus...	....	L–D	B S M W	S Bt	Br T Ad	......	......	......	
128.	—— *villicus* (?)	*T. Adansoni, var.; Cor. Cr.*	......	....	*S Bt*	......	*	......	......	
124.	—— zizyphinus	....	Lt–D	B S M W At	S	Br	*	*	......	*
47.	Trophon altum	T. altus	C	Am	Bt	......	......	......	......	
44.	—— antiquum	G. Fusus.........	C–D	B S W	Passim	Br T C Ad Th	......	*	*	
49.	—— alveolatum	T. alveolatus; Cor. Cr.	......	....	S Bw	......	*	*	*	
J	—— barvicensis, *Johnston.*	....	L–D	B S M W At	W S	......	......	......	......	
49.	—— *consociale*	*T. alveolatus,* var.; Cor. Cr.	......	....	*S*	......	*	......	......	
48.	—— costiferum	T. costifer	D–D	At	S W Bt	......	*	......	......	
	—— *Gunneri*	*T. clathratus, L., var.*	......	....	......	*N*	......	......	......	
46.	—— *elegans* ...	*F. antiquus, var.*	......	....	*F Bt*	......	......	*	*	
46.	—— gracile ...	Fusus curtus, *J.*; not Buccinum gracile, *Da C.*	C	Am	Passim	N	*	*	*	
50.	—— muricatum	T. muricatus ...	L–D	B M W	W Bt	......	*	*	*	
312.	—— norvegicum	G. Fusus	D	B S A	S F	N	......	......	......	
48.	—— scalariforme	T. clathratus, *L.*	L–C	S A	B Bt	Br T	......	*	*	
312.	—— Turtoni ...	G. Fusus	C–D	B S	R	......	......	......	......	
74.	Turritella communis.	T. terebra, *L.*...	L–D	B S M W At	S	BrCBlAd Th	......	......	......	*
75.	—— incrassata	T. triplicata, *Brc.*	C–D	M W	Passim	T Br Th	*	o ? *	*	*
J	†—— subangulata, *Brc.*	....	C–D	M	Wd	......	......	......	......	
113.	Vermetus intortus.	V. subcancellatus, *Biv.* Cor. Cr.	Lt–C	M	S Bromswell Bw	......	*	o	......	*
J	—— glomeratus, *Biv.*	....	C	M	Wd	......	......	......	......	*
J	—— triqueter, *Biv.*	....	C	M	Fh Wd	......	......	......	......	
20.	† ? Voluta Lamberti.	V. Junonia, ... *Ch.* ?	D	Gulf of Mexico.	Passim	N	*	*	*	

LAND AND FRESHWATER SHELLS.

Page of Monograph.	Names of Species.	Synonyms and critical remarks.	Geographical Distribution.	Localities in Red Crag.	Localities in Norwich Crag.
107.	Cyclas cornea	Sphærium corneum	Europe, Asia ...	....	Br T Bl E
104.	Cyrena consobrina	Corbicula fluminalis, *Müll.*	Asia	Wd.........	Br Bl E
108.	Pisidium amnicum	....	Europe, Asia, N. Africa, N. America.	....	Br T E Bl
	Carychium minimum	....	Europe, Asia, N. Africa.	....	Br
3.	Helix arbustorum...	....	Europe, Madeira	....	E N
2.	—— hispida	....	Europe, Asia ...	Bt	Br T Bl
3.	—— *plebeium*	*H. hispida, var.*	N. America......	....	N Bl.
4.	—— pulchella	....	Europe, Asia, N. Africa.	B	Br
7.	—— rysa	H. rufescens, var.?...	Europe, Asia, N. Africa, Madeira	W Wd ...	....
7.	Limnæa palustris	....	Europe, Asia, N. America.	Bt	Br Bl
8.	—— peregra	....	Europe, Asia ...	Bt	Br E
109.	Paludestrina (?) *pendula* ...	*P. terebellata, var.* ...	....	*W*	
108.	—— subumbilicata	Hydrobia ventrosa, *Mont.*	Europe, Asia ...	....	Br
109.	—— (?) terebellata	....	....	S W Bt ...	
9.	Paludina lenta	....	Asia	Wd	Br T Bl Th
111.	—— tentaculata	G. Bythinia	Europe	....	Br Bl
10.	Planorbis complanatus......	....	Europe, Asia ...	Bt	Br Bl
9.	—— corneus	....	Europe, Asia, N. Africa.	....	Bl
6.	—— spirorbis	....	Europe, Asia, Iceland.	....	Br Bl
5.	Pupa marginata, *Draparnaud.*	....	Europe, Asia, N. America.	Bt	Br
6.	Succinea oblonga	....	Europe, Asia, N. America.	....	Bl
5.	—— putris	....	Europe, Asia, N. & S. America.	....	Br
112.	Valvata piscinalis	....	Europe, Asia ...	....	Br
	—— cristata	....	Europe, Asia ...	....	Br

Since the preparation of the Lists of Mollusca appended to my papers on the Coralline and Red Crags, Mr. Alfred Bell has published, in the 'Annals and Magazine of Natural History' for September 1870 and May 1871, considerable additions to the Crag-fauna. As regards the Mollusca, several had been previously communicated by him to Mr. Jeffreys, who examined the specimens; these are incorporated in the above lists. Others have not undergone the same revision. The names of all the species described by Mr. Bell as new are here subjoined, with the critical remarks of Mr. Jeffreys as to those of which he has examined specimens.

Coralline Crag.

GASTROPODA.

Admete Reedii.
Buccinopsis pseudo-Dalei (*S. Wood*).
Conopleura crassa. C. Maravignæ, *Bivona*, = Pleurotoma incrassata, *Dujardin*.
Menestho britannica. Not known to me as recent; but query as to the genus.
Nassa pulchella.
Pleurotoma curtistoma.
—— elegantula.
—— gracilior.
—— notata.
—— volvula.
(All these are P. attenuata, var. tenuicosta, *Brugnone*; and they are one and the same species.)

Red and Norwich Crag.

GASTROPODA.

Actæon? Etheridgii. A. exilis, *J.*
Capulus incertus.
Melampus fusiformis (*S. Wood*).
Menestho Jeffreysi. Previously known to me as an undescribed Greenlandic species.
Nassa pulchella (also Cor. Cr.).
Ranella anglica. Young; perhaps R. gigantea, *Lamarck*.

Crag not mentioned.

GASTROPODA.

Fusus cordatus.
Nassa densicostata.
Terebra exilis. T. canalis, *S. Wood*, var.

Besides the above, Mr. Bell has given the names of other species as found by him and his brother in the Crag; but Mr. Jeffreys has not had an opportunity of examining the specimens. These species are as follows:—

Coralline Crag.

CONCHIFERA.

Pectunculus insubricus, *Brocchi*.

GASTROPODA.

Cancellaria Bonellii, var. dertonensis, *Bellardi*.
Cancellaria contorta, *Basterot*.
Nassa granifera, *Duj.*

Red and Norwich Crag.

CONCHIFERA.

Nucula nucleus, var. radiata, *Hanley*.
Pecten Westendorpianus, *Nyst*.

SOLENOCONCHIA.

Dentalium incertum, *Gmelin*.

GASTROPODA.

Buccinum ciliatum, *Fabricius*.
Columbella avara, *Say*.
Cypræa dertonensis, *Michelotti*.
Defrancia Philberti, *Michaud*.
Fusus Jeffreysianus, *Fischer*.
—— Largillierti, *Petit*.
Nassa variabilis, *Philippi*.
Pleurotoma Bertrandi, *Payraudeau*.
—— gracilis, *Ph.*
—— pygmæa, *Ph.*
Scalaria communis?, *Lam.*

In consequence also of Mr. Bell's papers in the 'Annals,' and of Mr. Jeffreys having lately had an opportunity of examining the Mollusca procured by deep-sea dredging in the Swedish expedition of 1869 on the Josephine Bank and off the Azores, I am enabled to add a few more species and localities to the list of the Coralline-Crag Mollusca, as well as the zones of depth and geographical distribution for some species hitherto considered extinct. Two or three errata in that list will also be noticed.

Conchifera.

Cardita scalaris; C. borealis, Conrad: C; Am.

Kellia ambigua is not *Erycina pusilla* of Philippi, but *Scintilla parisiensis* of Conti (not Deshayes); the first of these names must therefore stand. In the column of "Geographical distribution" add "At."

Lima ovata (*L. nivea*, Brocchi) occurred in the Swedish expedition at a depth of 790 fathoms.

L. plicatula (*L. squamosa*, Lamarck), add Gedgrave.

Montacuta truncata is a variety of *M. bidentata*; but the shell figured by Mr. S. Wood as *M. bidentata* is a distinct species, which Mr. Jeffreys dredged in the last 'Porcupine' expedition, and proposes to name *M. ovata*.

Pandora inæquivalvis, var. *pinna*, add Gedgrave.

Thracia inflata is probably *T. Conradi* of Couthouy (a North-American species), and not *T. corbuloïdes*.

Gastropoda.

Adeorbis pulchralis: Swedish expedition, 320–600 fathoms. *Margarita trochoidea* of S. Wood is the same species.

Cancellaria scalaroïdes (*C. varicosa*, Brc.), add Gedgrave.

Cassidaria bicatenata (*C. tyrrhena*, Ch., var.?), add Sutton.

Cerithium adversum (*Triforis perversa*, L.): 'Porcupine' expedition, 364 fathoms.

64. *Clavatula plicifera*; ¶*Pleurotoma elegans*, Möller: C–D; B S A; S. Also Red Crag.

J. †*Conopleura Maravignæ*, Bivona; ¶*Pleurotoma incrassata*, Dujardin: C–D; M W; G.

Emarginula elongata, add Gedgrave.

Fossarus sulcatus = *F. costatus*, Brc. S. Wood figured two different forms as *F. sulcatus* and var. *lineolatus*; the latter appears to be *F. japonicus* of A. Adams.

Odostomia plicata, Montagu. This species must also be added from Gedgrave and Sutton. It inhabits the laminarian zone on the coasts of Great Britain, Denmark, France, Italy, and Algeria; and it occurs in a fossil state at Monte Mario and in the Red Crag.

Pleurotoma gracilior, A. Bell: Sicilian Pliocene; Gedgrave. See list of Mr. Bell's new species.

Pleurotoma Renieri, Ph., add "**D**" and "At."

P. striolata, Sc., is from the Red Crag, and not the Coralline Crag, at Sutton.

Scalaria subulata is not a variety of *S. foliacea*, but is a distinct species. Mr. McAndrew dredged it off Teneriffe, in from 40 to 60 fathoms.

S. varicosa is not a variety of *S. fimbriosa*, but is a distinct species. It is not the *Turbo varicosus* of Brocchi, nor *S. varicosa* of Lamarck.

Trochus millegranus, add "**D**."

127. †*T. multigranus*: D–**D**; At; S. Also Red Crag.

T. tricariniferus (recte *tricarinifer*): Swedish expedition, 340–430 fathoms.

Trophon costiferum (recte *costifer*): Swedish expedition, 110–300 fathoms.

Add *Vermetus arenarius*, L.: C; M; Orford.

The above will somewhat increase the percentage of recent species, but will not, in other respects, materially alter the tabulated results given in my paper on the "Coralline Crag."

EXPLANATION OF PLATE XX.

This gives a diagram-section passing through the centre of the Crag district from near Manningtree, by Ipswich, across the hills near Buckenham and Newbourne, passing through Sutton, Butley, Chillesford, Aldborough, Sizewell, to the coast at Dunwich, thence along the coast by Southwold, Lowestoft and Yarmouth to Hasborough and Bacton. A branch from the section is prolonged inland from Easton Bavent across the hills near Beccles to Thorpe, near Norwich. The names of the towns and villages are given approximately.

The relation of the Coralline, Red, and Norwich Crags, of the Westleton series, and of the Boulder-clay series is given generally, and in accordance with observed sections referred to in the text and given in detail in the woodcuts.

CORRECTIONS TO PARTS I. AND II.

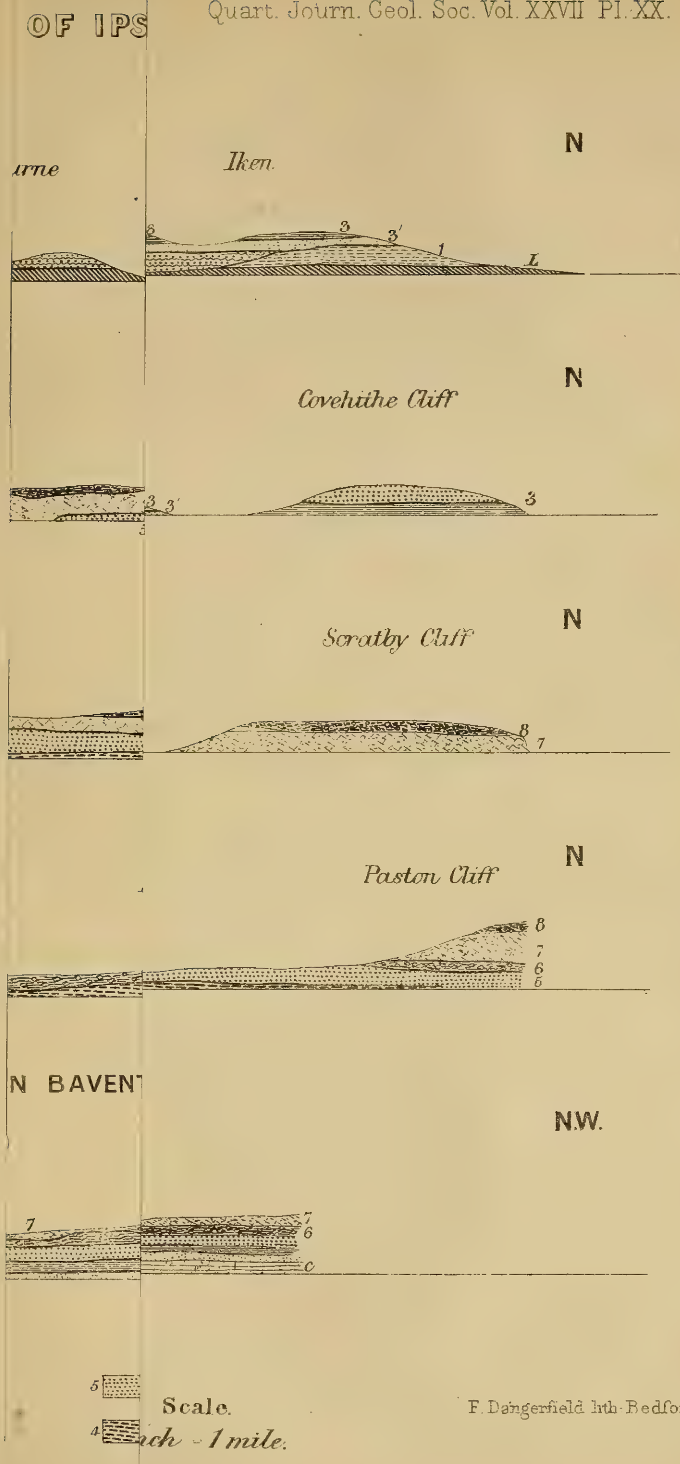
Page 121. It is possible that the estimate for bed "*e*," may be 2 feet, and for bed "*d*" 5 feet, too thick, which would make the thickness of the lower division of the Coralline Crag about 40 instead of 47 feet.

„ 330. Add *Pectunculus glycymeris* to the list of Butley shells.

„ 343. Add *Mastodon* (tooth) to list of fossils found at Sizewell.

„ 344. For the freshwater shells found at Bulchamp and Easton Bavent, see General List at the end of the third paper.

„ 346. From some memoranda left by Capt. Alexander, it seems that a portion of the jaw was attached to the Mastodon tooth found at Easton Bavent, and that it was taken out of a spot 5 feet above the base of cliff, and apparently in the clay and not in the sands.



F. Dangerfield lith. Bedford St. Covent Garden

GENERAL SECTION FROM THE NEIGHBOURHOOD OF IPSWICH TO NEAR MUNDESLEY ON THE NORFOLK COAST.

F Dangerfield lith Bedford St Covent Garden

2. *On some* Points *in* South-African Geology. By George William Stow, Esq., of Queenstown, South Africa.—Part I.

(Communicated, with Notes, by Professor T. Rupert Jones, F.G.S.)

[Read Nov. 23, 1870*.]

Part I.—§ 1. The Jurassic Formations.

Introduction.—Whatever advances geology has made during the last twenty-five years in South Africa (with which the names of Bain, Atherstone, and Rubidge will be ever connected), it must be confessed that we are but mere students in the elementary portion of this part of the great "stone book of nature;" and it may be expected that every new investigation will bring to light facts, and lead to conclusions, of which at present we have but a feeble and imperfect notion.

To the present time geological knowledge in South Africa has progressed but slowly. The great broad outlines of the geology of the country have been traced by those whose names have been mentioned; but the minutiæ have yet to be filled up. The South-African explorer labours under many serious disadvantages, not only from the horizontal position of many of the strata, but from the want (with the exception of a few mountain-passes) of great road-cuttings, and from the absence of mining operations, so that he has to depend upon the escarpments found along the river-valleys and mountain-sides, leaving large intervening tracts that must still remain in some degree of uncertainty until opportunities shall arise for their more definite examination.

With regard to the fossiliferous strata in the neighbourhood of Port Elizabeth, and of the Zwartkops and Sundays Rivers, for a long time I had felt that too much had been done in the way of curiosity-hunting, by *mixing* and generalizing all the fossils of what has been termed the "Uitenhage Formation," from whatever part of it they may have come; thus shells from the upper and lower parts of the Zwartkops River have been massed together, as well as those from the Upper and Lower Sundays River, although many miles intervene between the different localities—a plan that can only lead to a confused idea of the different strata; and I felt certain that this was one of the causes that prevented just conclusions being arrived at with regard to the formation in question.

As a commencement towards getting more perfect results, I sepa-

* For the other papers read at this meeting see pp. 29–33.

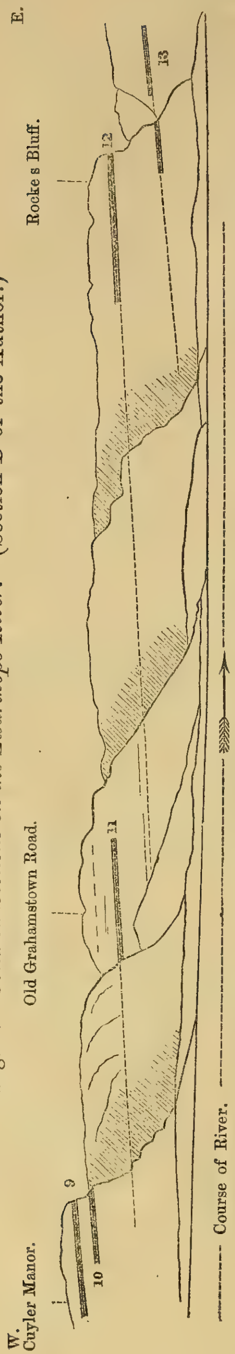


Fig. 1.—*Collated Sections on the Zwartkops River.* (Section D of the Author.)

No. 9. *Trigonia*-bed. No. 10. Ammonite- and *Trigonia-Herzogii*-bed. No. 11. *Cucullæa-Kraussii*-bed. No. 12. *Exogyra-imbricata*-bed. No. 13. *Astarte-Bronnii*-bed.

rated the various fossils I obtained; and the longer I continued the examination the more I was convinced that not much practical good would be effected until not only the fossils from each locality, but also from *each particular stratum*, had been separately arranged. In this paper I record the results of these observations, imperfect as of necessity they are, doubting not that future investigators, with more lengthened opportunities than I have had myself, will most probably modify some of my conclusions.

A. *Trigonia-beds of the Uitenhage Formation.*—In following up this subject I shall first treat of the fossiliferous strata of the Zwartkops River, and then of those of the Sundays River. After that I shall proceed to describe the more recent deposits in the neighbourhood of the former river and Port Elizabeth.

Lower Zwartkops River. Section at Rocke's Bluff.—The portion of the Lower Zwartkops River that has been most frequently examined is a part of the heights not far from the mouth of the river, named by the geologists visiting it "Rocke's Bluff," after our friend and fellow-labourer Colonel R. H. Rocke. It is situated about a mile above Rawson's Bridge, on the east bank of the river. Here the lowest fossiliferous band is found in an old road, and is marked No. 13 in Section A* and fig. 1 (see also fig. 3). From it *Isastræa Richardsoni* † was obtained. The most characteristic fossil of this stratum is *Astarte Bronnii*. *Pleuromya lutraria* and *Astarte*

* The sections mentioned but not figured in this memoir are preserved in MS. in the Society's archives.

† Quart. Journ. Geol. Soc. xxiii. p. 162.

Herzogii are rather frequent. The other shells are *Gervillia dentata*, *Pholadomya dominicalis*, *Exogyra imbricata*, *Arca Jonesii*, and an *Ostrea*. In the bed, marked No. 12, near the upper part of the bluff (figs. 1 & 3) we find *Exogyra imbricata* very abundant; *Astarte Herzogii* and *Pleuromya lutraria* are numerous; but of *Astarte Longlandsiana* only one specimen has been found, and one of *Trigonia Cassiope*. The other fossils known to occur, in bed No. 13, are:—*Arca Jonesii*, *Cucullæa Kraussii*, *Pinna Atherstonei*, *Placunopsis subjurensis*, *Trigonia ventricosa*, *T. conocardiformis*, *Ostrea*, *Pecten*?, *Ammonites*. No. 13 is about 50 feet above the level of the river, and No. 12 about 200 feet. The rocks in this section dip 2°–4° from the river inwards, and are surmounted by Pliocene (?) limestone.

Upper Zwartkops River. Section on the Old Road.*—Some miles further up the river, on the old Grahamstown Road (fig. 1), above the drift (ford), another fossiliferous bed (No. 11) is exposed along the hill-side and across the road, as shown in Section B (fig. 3), some hundred feet above the river. The dip of the strata here, said by Dr. Atherstone to be about 8°, is inwards from the banks of the river. It is here that *Cucullæa Kraussii* is found more frequently than in any other of the fossiliferous bands, together with *Trigonia Herzogii*, *Astarte Herzogii*, and *Pleuromya lutraria*, all of which are very numerous, and may be looked upon as the characteristic shells of this stratum. The *Cucullæa*, especially, seems to have flourished at the time of the formation of this bed, and must have grown to a large size, as its fragments show. The other fossils are:—*Pleuromya lutraria*, *Ceromya papyracea*, *Trigonia Herzogii*, var., *T. conocardiformis*, *T. vau*, *Exogyra imbricata*, *Pecten*, *Pinna*, *Patella*.

Section at Cuyler Manor.—Still further up the stream, near Cuyler Manor (fig. 1), is another exposed portion of this formation. I have not visited this locality myself; but Mr. Longlands, who examined it in 1867, very kindly furnished me with the section shown in Section C (fig. 3).

In the stratum of friable sandstone, marked 10, he found Ammonites, and very numerous specimens of *Trigonia Herzogii*; in fact the latter abounds so much that it may be looked upon as the most characteristic fossil of this section. He also found a few specimens of *Exogyra imbricata*, and a few fragments of *Trigonia conocardiformis* and *Pleuromya lutraria*.

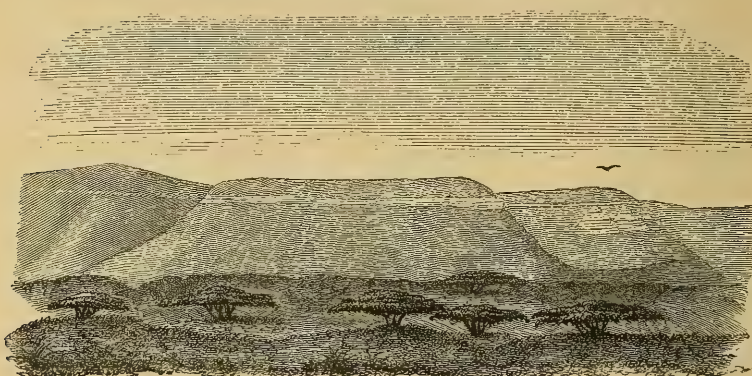
Remarks.—As the whole of the Zwartkops strata dip inland, and along the course of the river, which has a somewhat rapid fall towards the sea, I think these circumstances tend to prove that these fossiliferous bands, as shown in Sections A, B, & C (fig. 3), are not one and the same stratum, but form a *parallel series*, as is shown (in an exaggerated form) in fig. 1. Thus the stratum No. 13, in which *Astarte Bronnii* abounds, must be the lowest; the bed, No. 12 at Rocke's Bluff follows, with its multitudes of *Exogyra*; the *Cucullæa*-bed on the old Grahamstown road is the next in succession; and,

* The word "upper" here used in reference to the Zwartkops and Sundays Rivers does not indicate the highest parts of those rivers, but some portions towards the furthermost range of the Trigonia-beds traversed by them.—T. R. J.

finally, the *Ammonites*- and *Trigonia*-zones of Cuyler Manor succeed; and these positions, I believe, will be fully proved upon more mature investigation.

Lower Sundays River. McLoughlin's Bluff, or Prince Alfred's Rest.—I will now describe the Sundays-River strata, commencing with those nearest the mouth of the river, and following up our examination along the course of the stream. The first section is that of a bluff, about a couple of miles from the mouth, which has been named by some of my geological friends "McLoughlin's Bluff," after "mine host" of a small inn*, now called "Prince Alfred's Rest,"

Fig. 2.—*Range of Hills near the mouth of Sundays River.* McLoughlin's Bluff on the right (⌣).



in the plain below. This Section, E (see fig. 3 and Sketch, fig. 2), is the most marked of any I have seen of *the upper portion* of the "Uitenhage Formation." The rocks of this series appear to be *superior* to those exposed along the lower banks of the Zwartkops, shown in Sections A & B. Unfortunately, the lower part of the bluff is so thickly covered with brushwood that no definite conclusion could be arrived at with regard to the underlying strata; but in the watercourse of a somewhat precipitous kloof, at a little distance from the bluff (see Section F) was found a lower fossiliferous stratum containing *Astarte Herzogii*, *Trigonia Herzogii*, and *Pleuromya lutraria*. This bed seems to be nearly similar to the stratum No. 11 (fig. 1) on the lower part of the Zwartkops River. Intervening between this and the fossiliferous band marked 5 in this section (F), which bed is evidently the same as that indicated by a similar number in Section E (fig. 3), were sandstones some 250 feet in thickness; but here, as at the bluff, the brushwood and débris prevented an accurate examination

* Formerly referred to as "McLoughlin's Inn" in the papers by Atherstone and Rubidge. The fossils from Sundays-River mouth and those from "Prince Alfred's Rest" (or McLoughlin's Bluff) were unnecessarily separated in the paper in Quart. Journ. Geol. Soc. vol. xxiii. p. 170.—T. R. J.

[*To face* p. 500.

Fi[?]ns A, B, C, E & F, and G.)

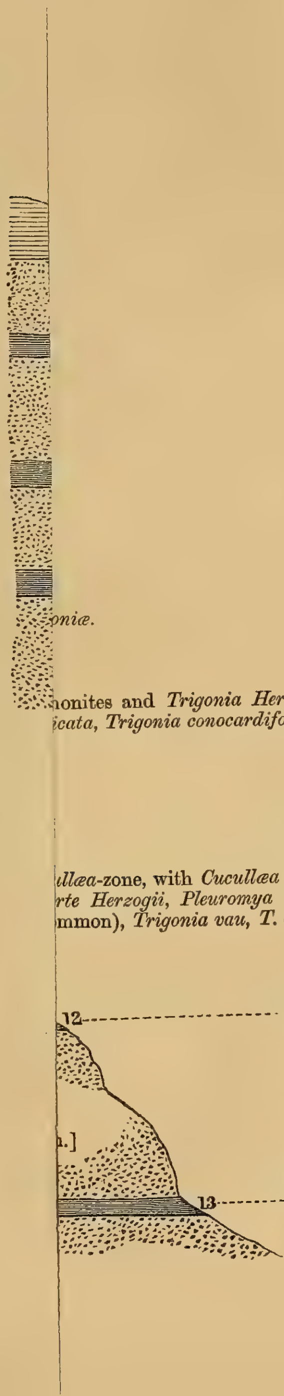
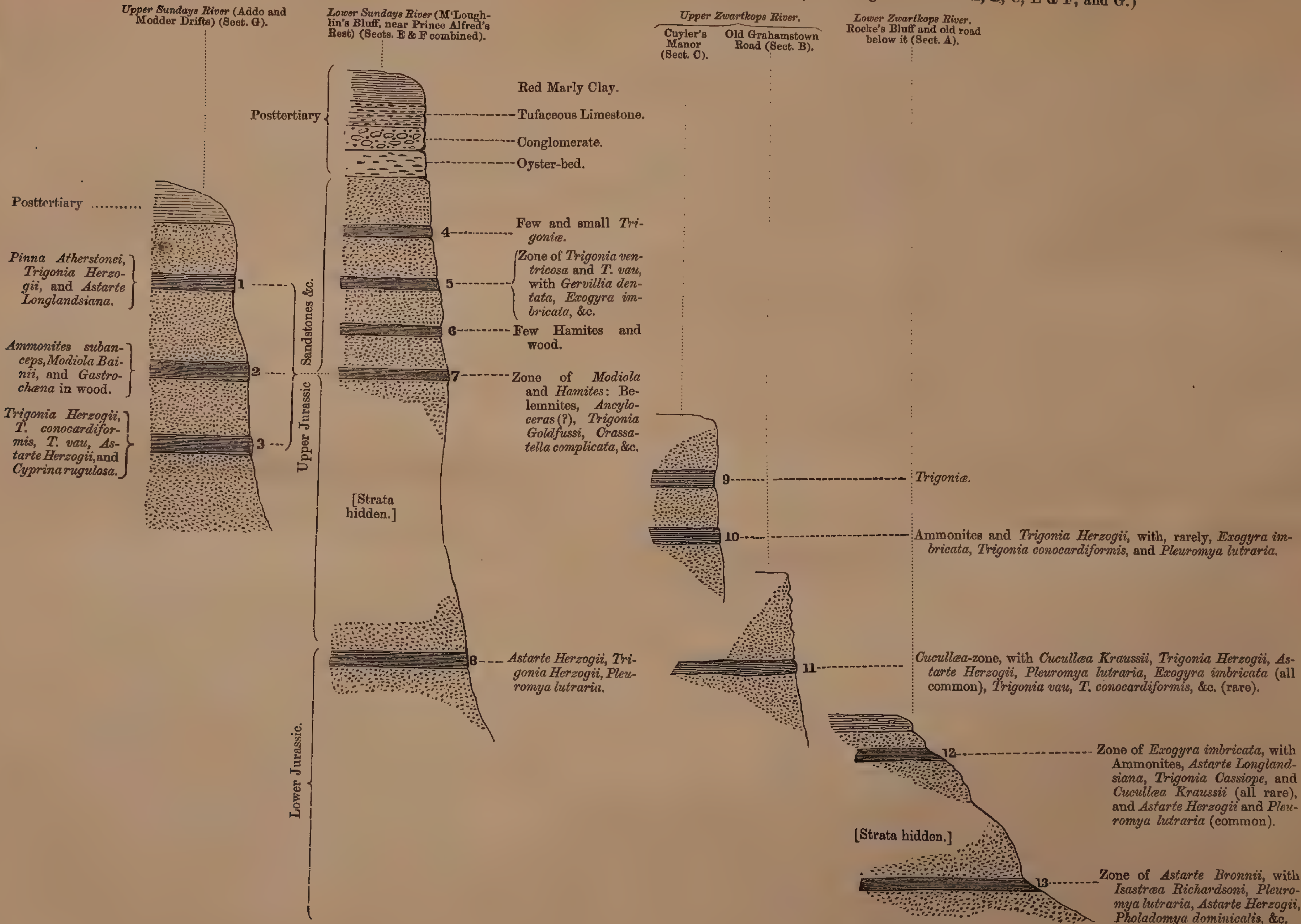


Fig. 3.—*Collated Sections of the "Uitenhage formation" (Jurassic).* (Section H of Author, including his Sections A, B, C, E & F, and G.)

[*To face* p. 500.



being made. The existence of this *Astarte-* and *Trigonia*-band seems to point out that the position I have given to the sections (on the Zwartkops) is the most probable one.

The fossiliferous strata Nos. 6 & 7, in Section E (fig. 3), were evidently deposited under very different circumstances from any of the others; and wherever the one I have styled the *Modiola-* and *Hamites*-zone (No. 7) makes its appearance, it possesses the same lithological character. I have given this name to it on account of the numerous specimens of *Modiola Bainii* and fragments of the *Hamites africanus* found in it. In this locality (McLoughlin's Bluff) this stratum is full of *small* fragments of carbonized wood, which rub down to black powder under the finger. These minute fragments seem to indicate that the sedimentary matter of which this particular portion of the bed is composed, must have been the deposit of some current of water laden with innumerable small pieces of vegetable drift, such as we see washed up in the present day on the seashore, after rains, near the mouths of small rivers.

Some miles further up Sundays River, where this bed is again exposed, and where its thickness is much greater, these specks of carbonized matter are wanting—an indication that this latter portion was most probably deposited further off shore, or from a different direction; but I shall have again to allude to this in my observations on the Upper Sundays River. The shells also of this stratum are, with few exceptions, of a very different character from those of the *Astarte-* and *Trigonia*-beds, the shells of the latter being, for the most part, strong massive shells, fit to live along the coasts of an open sea, whilst those found in the zones of which I am now speaking are, most of them, thin and fragile. The rock itself is of a much looser texture than the associated non-fossiliferous sandstones—while these latter, which intervene between this bed and the uppermost layer, increase in friability as they ascend, and show a considerable difference from the compact sandstones of the Lower Zwartkops. The rock composing the *Hamites*-zone is patchy in colour, appearing in some places of a reddish sandy tint, but more frequently grey. This was the bed (No. 7) in which the large, coiled, broken fossil, thought to have been an *Ancyloceras* (?), was discovered by Major (now Lieut.-Col.) Rocke. In no other, that I am aware of, have *Hamites africanus* and *Belemnites africanus* been found: fragments of the former are here exceedingly abundant; but the latter is rare. *Modiola Bainii* seems almost exclusively confined to this stratum. Fragments of either *Hamites* or *Modiola*, found in the débris of the neighbouring cliffs, are always a sure indication of the close proximity of this band. The principal shells characteristic of this zone, are:—*Hamites africanus* (very numerous), *Ancyloceras* (?) (two specimens), *Trigonia Goldfussi*, *Tr. conocardiformis* (young), *Crassatella complicata*, *Modiola Bainii* (numerous), *Mytilus Stowianus*, *Mytilus Rubidgei*, *Belemnites africanus* (rather scarce); also, I believe, *Alaria coronata*, and small specimens of *Astarte*, *Cyprina* (?), *Psammobia* (?), and *Ostrea* (narrow, curved).

There cannot be the slightest doubt that, if future explorers will arrange the fossils they obtain from these different strata according to *the particular band* from which they are derived, the scanty lists here given will be greatly enlarged.

There is another somewhat remarkable feature in the shells of this (No. 7) and the stratum (No. 6) immediately above it—namely, that the large *Trigoniæ* are wanting, although there are numbers of the smaller kind, and young individuals. Future investigations will perhaps modify these conclusions. The *Hamites* and *Modiola*, from which I have named the zone, may be found to extend into others in reduced numbers; but in this particular zone they have a great numerical superiority.

In the bed marked 6, the same type of shells appears as in No. 7. The rock is also apparently of the same kind. But only a few small fragments of *Hamites* are found; and in the bed above, marked 5, the *Hamites* seems to have disappeared entirely, and apparently all the peculiar shells that accompanied it—their places being supplied by others of a different character. Amongst these the principal is the beautiful *Trigonia ventricosa*. It abounds here, and is, in fact, the characteristic fossil of the bed in this particular locality. A few isolated specimens have been found in the Zwartkops strata; but here they are, in some places, massed together in thousands, outnumbering every other shell. *Trigonia vau* is also very abundant; and hence, in the general Section (fig. 3), I have called this (No. 5) the *Trigonia-ventricosa-* and *T.-vau-*zone. Fine specimens of *Gervillia dentata* also have been obtained from it, together with *Exogyra imbricata*, *Pecten Rubidgeanus*, and *Turbo Stowianus*.

In bed No. 4 the *Trigoniæ*, compared with those in No. 5, are not only very much fewer and smaller, but, from some alteration of circumstances, apparently were disappearing from this part of the ancient ocean. The remains of other shells are also far less abundant than in the lower zones. The sandstone above No. 4 is much altered in character compared with those underlying it, being, as I have before remarked, less compact, and far more coarse and friable than those below. This difference of texture increases the nearer we approach the upper portion of the section, where the sandstone seems to assimilate in lithological character more to the upper sandstones of the Koega, and *to those interlaminated with the clays at the Bethelsdorp Saltpan* (see further on), than to any others.

Immediately above these, as shown in Section E (fig. 3), is a shell-bed, from 3 to 5 feet thick, composed of small fragments of shells, thickly interspersed with a species of *Ostrea*. This stratum seems to be of Pliocene or Postpliocene age, and to be the equivalent of the upper shell-limestone on the Zwartkops and the Koega. Above this, again, is a conglomerate, varying from 3 to 6 feet in thickness. This is capped with tufaceous limestone, from 2 to 3 feet thick; and above the limestone is a red, sandy, marly clay, varying, according to the inequalities of the surface, from 4 to 6 feet. I send a sketch of the bluff (fig. 2), the better to show the formation.

Above the Modder Drift (*Ford*).—The country for a distance of some 10 miles in a straight line between McLoughlin's and Modder Drift, on the Sundays River, I have not been able to examine; but from the Modder Drift, for several miles, to the krantzes (precipices) below the Addo Drift, at Tunbridge's, three distinct fossiliferous bands make their appearance at intervals—that is to say, wherever the rocks are sufficiently exposed on the slopes of the hills that bound the S.W. side of the river.

Unfortunately, it is here the same as lower down the river, and the hill-sides are too much covered with débris and brushwood to enable any one to make a very accurate survey of the intervening strata. The belts vary from 2 to upwards of 3 feet in thickness. The lowermost, No 3 (see Section G, fig. 3), contains large numbers of *Trigonia Herzogii*, young and adult); but *Trigonia conocardiformis* is more abundant, and appears to be the characteristic shell here. *Trigonia vau* is often found, but it is far scarcer than those just mentioned; also *Cyprina rugulosa*, *Astarte Herzogii*, and *Ostrea*.

The middle band, No. 2, Section G, is composed of a fossiliferous rock that appears to be, as before alluded to, the equivalent of the "*Modiola*- and *Hamites*-zone" at McLoughlin's. At present, however, I am not aware that any fragments of *Hamites africanus* have yet been found in this locality. Only in this bed, and in Nos. 6 & 7, at McLoughlin's, is *Modiola Bainii* found, as far as I have been able to learn; and the accompanying shells, much like those found in the corresponding zone shown as No. 7, Section E, are *Ammonites subanceps*, *Gastrochæna dominicalis* (in fossil wood), *Alaria coronata* ?, *Cardita nuculoides* ?, *Astarte Pinchiniana* ?, and small specimens of *Astarte*, *Cyprina* ?, *Psammobia* ?, *Ostrea*.

The differences are that, above the Modder Drift, this stratum, No. 2, is much thicker than No. 7 at McLoughlin's Bluff, as it here attains, in some parts, a thickness of 3 feet; the rock also is of a closer and harder texture, and of a more uniform grey colour, whilst the black specks of carbonized matter which characterize the "*Hamites*-zone" at McLoughlin's are, as far as I could observe, entirely wanting, owing most probably to the sediment of which this rock is composed having been deposited in deeper water. This stratum makes its appearance, as I have said, at intervals, wherever the mountain-side is sufficiently denuded of the superincumbent soil: thus it is exposed a little above Modder Drift, again in a kloof (gully) called by Drs. Rubidge & Atherstone, from the number of *Ammonites* they found there, "Ammonite Kloof," and again some six miles above the Addo Drift, and beyond Commando Kraal on the Sundays River. These indications therefore enable us to trace this "*Modiola*-zone" from the bluff, in Section E, to the last-named spot, a distance of upwards of fifteen or sixteen miles. Other indications of this same bed may most probably be found between these different and widely separated points; but the difficulties of making a thorough examination, as I have previously explained, are very great, covered as many of the hills are with dense entangled brushwood, while at the same time there are few either natural or artifical cuttings through these strata anywhere.

In the uppermost stratum, No. 1, Section G, I found a number of *Astarte Longlandsiana*. In one small mass of rock I obtained upwards of twenty specimens of different sizes. In a small kloof near the top of one of the hills, near the Modder Drift, Col. Rocke and I discovered a place where this fossiliferous bed was exposed, containing innumerable remains of *Pinna Atherstonei*. I have never seen such a collection of these shells at any other spot. From this circumstance we named it "Pinna Kloof." *Trigonia Herzogii* is also numerous here. If these rocks prove to be, as I suppose, the equivalents of those at McLoughlin's, there is to be noticed that, whereas at the latter place the whole series occupies a space of but some 40 or 50 feet in thickness, here, above the Modder Drift, the fossiliferous beds are not only thicker themselves, but are separated by wider spaces of non-fossiliferous rock, it being a height of some 200 or 250 feet from the lowest stratum to the top of "Pinna Kloof."

I was not able to make any satisfactory observation of the dip of these lower rocks during my visit; but some four or five miles to the west, on the plateau over which the road passes from the Bay to Tunbridge's, I found that the dip of the upper sandstones was at an angle of 9°, with an apparent direction of 32° E. of S., taking a slope from the higher portions of Grass-ridge towards the coast. These latter rocks, where I obtained this observation, are at a higher elevation than those examined along the banks of the Sundays River; but whether the dip here taken is likely to indicate the true dip of the lower rocks under notice I am not at present able to say. A quantity of fossil wood was strewed among the débris of these strata, although I did not find any *in situ*; and Dr. Rubidge informed me that he had found Ammonites in the same locality.

As a recapitulation of the foregoing, I would observe that the facts here stated, imperfect as they are, and modified as the conclusions here arrived at no doubt may be with increased information, show that most of the fossiliferous bands in the different localities of the "Uitenhage Formation" form portions of *a series*, and are *not continuations of the same zone*, as was once thought. This, I believe, will be proved to be the case, very convincingly, as soon as their fossils are more accurately tabulated. Thus, in No. 13, at the old road near Rocke's Bluff, *Astarte Bronnii* is in very large numbers, both valves of most of these shells beautifully perfect. This is the only band from which this *Astarte*, as far as I can learn, has been obtained, while I am not aware that a single *Trigonia* has ever been found there. In No. 12, *Exogyra imbricata* is exceedingly numerous; but not one specimen of *Astarte Bronnii* has been discovered in it. Here one or two *Trigoniæ* make their appearance, but are very scarce; while in No. 11, near the drift, on the old road to Grahamstown, *Trigonia Herzogii* becomes one of the characteristic shells. In No. 11 also, *Cucullæa Kraussii*, *Astarte Her-*

zogii, and *Pleuromya lutraria* are very numerous, these, in fact, being the predominant forms of this zone. Whether No. 8, in the kloof near McLoughlin's Bluff, is a continuation of this (No. 11), as seems probable, will require further proof. Again, in No. 10, near Cuyler Manor, are numerous Ammonites and *Trigoniæ*, and the *Exogyra* of the lower strata has very considerably diminished in numbers; while in No. 9 we find a perfect "*Trigonia*-zone" very similar to that marked No. 3 in Section G, of the Upper Sundays River *.

Again, in Section E at McLoughlin's Bluff, we find No. 7, a zone containing numerous Hamites and *Modiolæ* associated with a large *Ancyloceras* (?). This bed seems to have its equivalent in No. 3, Section G, of the Upper Sundays-River strata; and, lastly, we have No. 5, in Sections E and F, with multitudes of *Trigonia ventricosa* and its accompanying *Trigonia vau*. To show my meaning better, I have massed the foregoing Sections A, B, C, E, F & G into one general one (fig. 3).

B. *Saliferous beds of the Uitenhage Formation.*—I will now proceed to notice some sections I have made at the Government and Bethelsdorp Saltpans, the Koega River, and the Salt Vlei near Port Elizabeth. These sections represent the stratified clays and sandstones of the "Saliferous deposits" of the "Uitenhage formation," which have been placed by some investigators † as underlying the Zwartkops fossiliferous sandstones of which we have been speaking.

Government Saltpan between the Zwartkops and Koega Rivers.—The first locality I shall mention is that of the Government Saltpan between the Zwartkops and Koega Rivers (see fig. 6, 7, and 7). This section (Section I) has been figured and described by Dr. Atherstone ‡. 1, 2, & 3 are, as he says, thin bands of hard, highly fossiliferous, dark ferruginous sandstone, about 3 or 4 inches thick, containing broken shells (*Trigonia*, *Ostrea*, *Turritella*) and spines of *Cidarites*. These hard bands alternate with saliferous shales and sandstones, with a dip of 8° towards the north-east §; the hard band (1), overlying porous sandstone, forms the bed of the salt-pan; and marls (without salt) and soil cap the uppermost band. It is very difficult to obtain specimens of the numerous fossils, as they are very perishable. Both Mr. Longlands and myself failed, during a somewhat hurried visit to the locality, to obtain any.

Sandstones on the Koega River.—The sandstones on the banks of

* Mr. G. W. Stow has sent to England specimens of *Trigonia Herzogii* and fossil wood with *Gastrochænæ*, from the Zambesi, that perfectly resemble in zoological and lithological characters these fossils from the Sundays River; and they have their associated Selenite, as at Geelhoutboom.—T. R. J., Oct. 19, 1871.

† See Dr. Atherstone's "Lectures on the Geology of Uitenhage," Eastern Province Monthly Magazine, vol. i. 1857, pp. 581, 584, &c., and Quart. Journ. Geol. Soc. vol. xxiii. pp. 149 & 167.—T. R. J.

‡ See Dr. Atherstone's sketch section, East. Prov. Mag. *loc. cit.*—T. R. J.

§ The beds up the Sundays River (near Geelhoutboom), which Dr. Atherstone considers to be equivalent to those of the Saltpan, have a dip, he says (*loc. cit.* p. 581), of 8° to the south-west.—T. R. J.

the Koega seem to be very similar in character to those of the Government Saltpan—so much so that one is almost led to believe that they must be a continuation of them. Section K (see fig. 6, 6) was made by me near this river, not far from the old road to Grahamstown. In this section, No. 1 (at the top) is a marly clay, interspersed with very numerous, small, calcareous seams. This is comparatively recent, and rests on a conglomerate of quartzite pebbles (No. 2). Immediately beneath this is clay (No. 3), resting upon a coarse loose sandstone (No. 4), and this upon a hardened clay.

Two or three miles lower down the Koega, where I obtained another section, the sandstones appear to be very similar, in their lithological character, to those shown in the section (Section L) of the upper rocks at the Bethelsdorp Saltpan (see fig. 6, 4). I have not found any fossils in them, nor have I heard of any being found; we must therefore look for some further proofs before a positive opinion of their identity can be formed. This last-mentioned section on the Koega is capped with the same Posttertiary shell-limestone as at the Zwartkops.

Bethelsdorp Saltpan.—On the west side of the Bethelsdorp Saltpan is a very good section of the saliferous clays and sandstones. Commencing from the lowest in Section M 1 & M 2 (see fig. 6, 5), No. 22 is a coarse, gritty, rather loose sandstone, the thickness of which is at present unknown, as is also the thickness of the belt of clay (No. 21) resting upon it. It is highly probable, however, that the latter, if properly exposed, would prove to be banded clay and sandstone, some 2 or 3 feet thick, similar to Nos. 15*a*, 17, and 19. No. 20 is a hard, compact, fossiliferous sandstone, not more than 1 foot thick. In this the characteristic fossils of the locality are found, namely the remains of *Cidaris pustulifera.* Its plates and spines are obtained here in large quantities. Judging from the numerous remains, one is led to the belief that it was during the period of the deposition of this particular zone that it most flourished, while at the Government Saltpan these fossils appear scarce. *Ostrea Jonesiana* is also frequent in this belt, whilst other small *Ostreæ* are scarce. Dr. Rubidge found *Crassatella complicata* here. Above this fossiliferous bed we find fifteen alternate bands (altogether 10 feet 9 inches) of a reddish clay and sandstone (stratum 19), each bed being very distinctly marked. These bands seem to be non-fossiliferous, as well as the other strata from No. 19 to 14 in Section M 1 & 2, and from No. 11 to 8 in Section L. More diligent search, however, may discover traces of life not only in these rocks, but also in the upper strata before alluded to, on the banks of the Koega (Sect. K, fig. 6, 6). Above No. 19 in Section M 1 & 2, is a coarse non-fossiliferous sandstone (No. 18), 8 feet thick; then follow banded clays and sandstones (No. 17) 3 feet 6 inches; and above these, 4 feet 8 inches of sandstone (No. 16); again alternate bands of clay and sandstone (No. 15*a*), 5 feet 3 inches thick; then 2 feet of a light-coloured friable sandstone (No. 15*b*), on this a band of 8 inches of clay (No. 15*c*), and above that 4 feet 4 inches of a light-coloured and very friable sandstone (No. 14). On the top of all these lies an irregular deposit of a sandy calcareous tufa, covered with a reddish sandy clay. The remarkably uniform thickness of the several clays and sandstones in these sections is worthy of notice.

From another Section, marked L (see fig. 6), that I was able to obtain in a higher bank about 300 or 400 yards to the N.N.E. of Section M 1, No. 14 does not appear to be the uppermost in this series. This higher section shows nearly the same dip as the lower one; and in it we find a broad band of sandy clay (No. 11) 8 feet in thickness, interspersed with a great number of calcareous stripes near the top. Above this is 2 feet of clay (No. 10) of a pale-greyish stone-colour, (No. 9) six inches of a sandy yellow and brownish striped clay; and above that, (No. 8) two feet more of the same clay as No. 10, with a superficial loam. In the foregoing sections, we therefore obtain (if the uppermost bands belong to the series) a combined thickness of more than 52 feet of these stratified clays. The latter section is capped with the same reddish sandy clay as the former; and I have not been able to find in these two places any trace of a deposit that might be considered the equivalent of the Zwartkops and Koega Posttertiary shell-limestone.

The Salt Vlei near Port Elizabeth.—About five miles nearer to Port Elizabeth, in the clay-pits, at a place called Salt Vlei, we find another excellent section of the stratified clays. This is shown in Section N (fig. 6, 2). In these pits the lowest uncovered rock is that marked No. 18 in the section—namely, a marly, gritty sandstone. It is exposed for a depth of 14 feet; the remainder of it (whatever the entire thickness may be) is covered up with the débris of the excavation. It appears, as far as can yet be seen, to be non-fossiliferous. Immediately above this is a belt of clay (No. 17), and on the clay a band of nodular concretions (No. 16) fourteen inches thick. These nodules are irregular in shape, and of various sizes, some of them being upwards of 2 feet in length; when broken they all display the same fracture as that shown in specimen No. 16*, with a powdery nucleus as in specimen No. 16*a*†. *In situ*, they lie as if they had been regularly packed, their greatest length being in the direction of the dip.

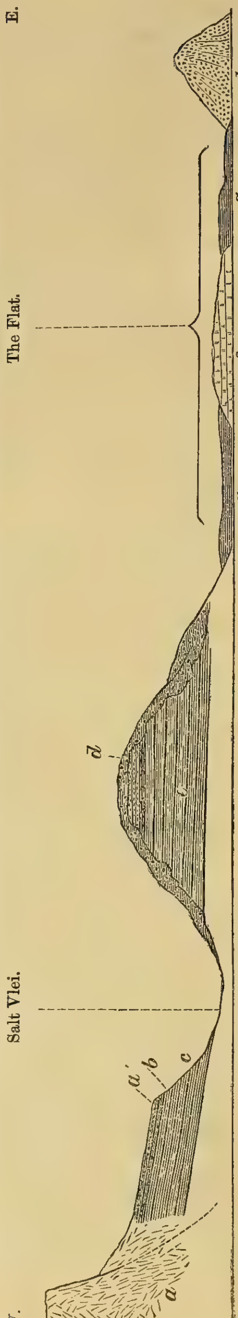
Above this noduliferous band is a sandy clay, No. 15, 2 feet thick, of a yellow-ochre colour. Upon this follows a dark slate-coloured clay, No. 14, also 2 feet thick. The strata Nos. 14, 12, and 10 are clays to all appearance exactly alike, as regards colour and texture, and must have been deposited under similar circumstances. No. 13, 1 foot thick, is the first zone (in this section) in which were found traces of fossils. It is full of small marine shells [*Astarte* (?) and *Natica* or *Phasianella* (?), T. R. J.]: some are very beautiful; and all were so delicate in structure as to be very difficult to remove.

No. 12 is a clay, 3 feet thick; then comes a single line of nodules, No. 11. These nodules are placed either singly or in groups, as shown in the section, all in the same line of bedding. No. 10 is

* No. 16. Ferruginous sandy nodule, with ochreous centre.—T. R. J.

† No. 16*a*. Dark red-purple earthy hæmatite.—T. R. J.

Fig. 4.—*Section of the Salt Vlei and Flat, on the South Side of the Creek or Ferreira's River.* (Section O of Author.)



a. Quartzite hills of Port Elizabeth. *a'.* Loose shingle in soil. *b.* Calcareous tufa. *c.* Stratified clays. *d.* Limestone and sandstone (see fig. 5). *e.* Clays and sandstone*. *f.* Posttertiary limestone or shell-bank. *g.* Red clay (superficial). *h.* Æolian sandhills.

a clay, 7½ feet thick. No. 9 is an indurated shell-band, 3 inches thick; its shells are different from those found in No. 13. Some of the species that make their first appearance here go on increasing in numbers in the deposits marked 8 and 7. Specimens 9, 9*a*, 9*b*, contain numerous fragments and casts of shells, obscure gregarious bivalves [possibly *Cyrena*, T. R. J.].

No. 8 is a clay, from 18 inches to 2 feet where thickest, interspersed with streaky patches of shells [*Cerithium* ?, T. R. J.], the intervening clay being devoid of them.

No. 7 is a deep-red clay, with yellow stripes running through it. This, like the preceding, has bands of shells (small bivalves and univalves).

It is remarkable of these three last-mentioned strata, Nos. 7, 8, and 9 [which may be of estuarine origin, T. R. J.], that they gradually thin out.

The deposit No. 6 is a light slate-coloured clay, 9 feet 2 inches thick. No. 5 is a narrow band of clay, varying in width from 1 to 3 inches, full of fragments of shells, with a small *Ostrea* in abundance. Above this is a deposit of a similar light slate-coloured clay, No. 4, 8 feet 6 inches thick; and upon this a stripe of a yellowish sandy clay (No. 3) or, rather, a loam, pulverizing between the fingers; and above it is a clay similar to Nos. 4 & 6, two feet thick. This is capped with a sandy kind of marl, No. 1, varying from 2 to 4 feet

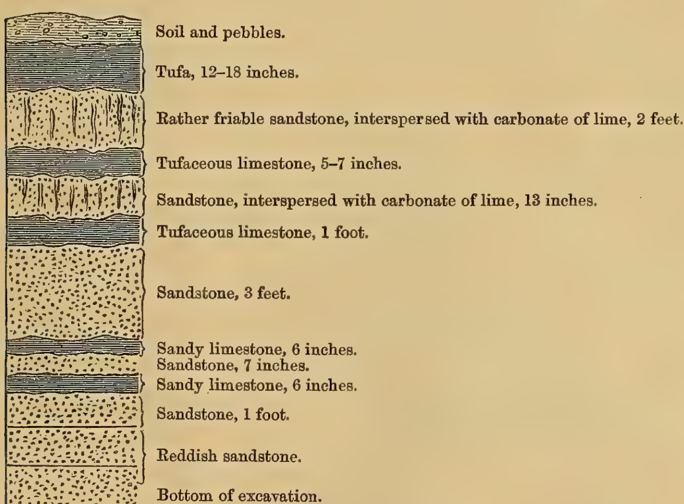
* The sides of this outlier were too thickly covered with débris for me to obtain a good section; but I imagine that it must be similar to the stratified clays at the Bethelsdorp Saltpan, as the spines of *Cidaris pustulifera* are found in the débris.

thick, interspersed with calcareous stripes. From this stratum (No. 1) small burrows or pipes have been sunk through the strata Nos. 2 & 3, and form cavities in No. 4, as delineated in Section N. Some of these curious excavations are several feet in depth; and in some instances the lower part is 18 inches wide, while the pipes leading to them are only a few inches in width; they appear to be the work of some of the old inhabitants of that ancient sea. They are now all filled with the sandy marl of No. 1, with which are mixed small nodules, and, in some of the pipes, fragments of shells, evidently all washed in from above, when the apertures leading to them were open.

These clays dip E. by S. at an angle of 20°, and have been denuded, as shown in the Section. The sandy marl and the outcrop of the clays are covered with surface-soil, the lower part of which is interspersed with beds of well-worn quartzite pebbles, in some parts to a thickness of from 1 to 3 feet. In some places there is a small deposit of calcareous tufa between the underlying clays and the surface-soil.

In another excavation, near the same spot, I obtained a rather different section of these stratified clays exposed for about 39 feet, as seen at *c*, in Section O (fig. 4). The dip here varied from 10° to 20°. Whether the clays of these two last-mentioned Sections (N

Fig. 5.—*Section of the beds marked* d *in Fig.* 4*. (Section P of Author.) From an excavation made for a large tank.



and O) are continued across the Salt Vlei to the opposite outlier *d* in Section O (fig. 4), I am not able to say, as the sides of this hill are

* Possibly this section includes some Posttertiary deposits.

too thickly covered with soil &c. to obtain a trustworthy section; nor can I, of course, say whether its strata assimilate rather to the clays and sandstones of the Bethelsdorp Saltpan; but Dr. Rubidge told me that he picked up a number of the spines and plates of *Cidaris pustulifera* among the débris of this outlier. All I can speak of with certainty is from Section P (fig. 5), which I was able to make during the excavation of a large tank on the top of this outlier. In this section the surface-soil was interspersed with shingle (as in Section N). Below this was a band of tufa, from 12 to 18 inches in depth; then 2 feet of friable sandstone, interspersed with carbonate of lime, as shown in the section; again tufaceous limestone, from 5 to 7 inches; beneath that, 13 inches of sandstone, interspersed with carbonate of lime in the same manner as the sandstone above; again 1 foot of limestone, then sandstone 3 feet; below this, three uneven belts of sandy limestone and sandstone, respectively 6, 7, & 6 inches thick; these were followed by 1 foot of sandstone, of the same character as the thick band above; and beneath them all, at the bottom of the excavation, was a reddish sandstone, the thickness of which is at present unknown.

Very little is accurately known of the fossil contents of the strata shown in the last three sections. They evidently require attentive examination, and promise a rich harvest to future explorers. Since my departure from Port Elizabeth, Messrs. Kemsley & Burness have found fossil Ferns in some of these clays, but have not been able to identify them with any of those from Geelhoutboom, on the Sundays River*. The clay in which they were found "rested upon sandstone containing immense fragments of leaflets and petioles of *Zamiæ*, mixed with pieces of wood." To this discovery I shall have to allude again (p. 513).

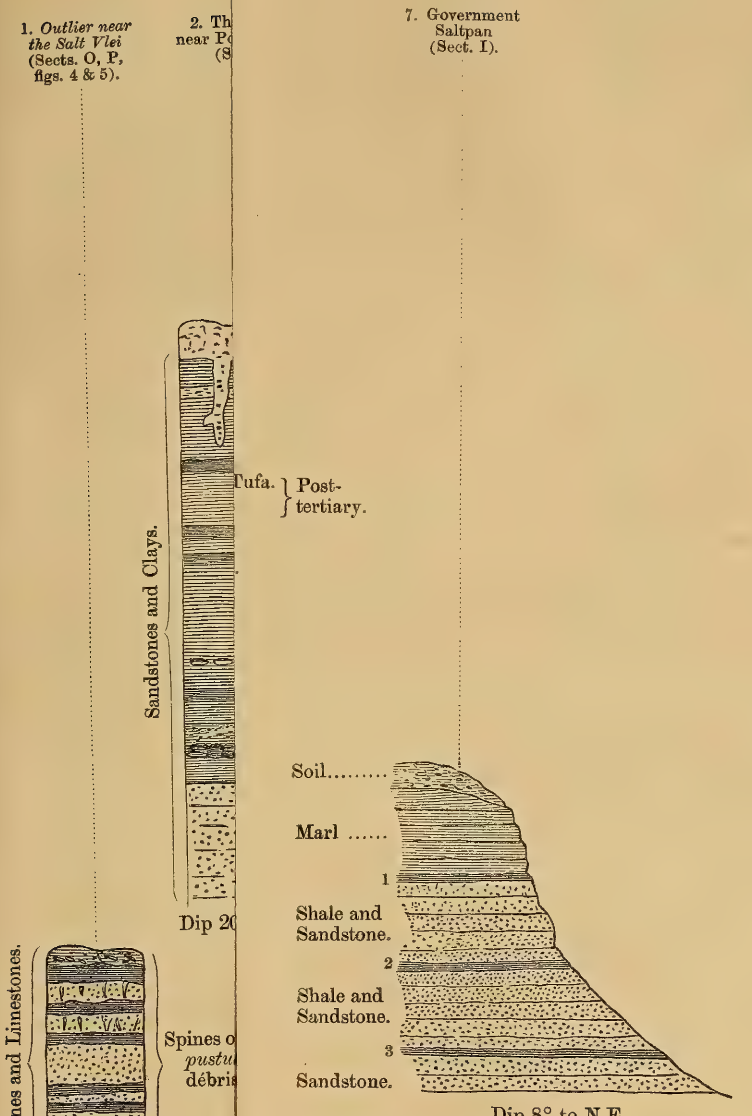
Résumé of the Strata of the Saliferous Group.—None of these sandstones that I have examined possess the close, compact nature of those found among the rocks of the Lower Zwartkops in Section A (fig. 3); but they are all of a coarse gritty texture, very like those I have spoken of as being found on the Koega (p. 506).

In looking over the various sections of these stratified clays and saliferous sandstones (namely I—P), one cannot help being impressed with their diversified aspect, each section differing widely from the others; and they seem to indicate that we are not examining a single wide-spread deposit, but a partially consecutive *series*, something similar to, but of more limited extent than, those of the Uitenhage formation before considered. This becomes more apparent by looking at the diagram (fig. 6), in which the foregoing sections are collated and compared.

Here the section near the Salt Vlei, noticed by Messrs. Kemsley and Burness (fig. 6, 3), becomes an important addition, as by it we find that *Trigoniæ*, *Turritellæ* and a *Gervillia* were obtained from the *lowest stratum* of sandstone in this formation, while the clays with *Ostrea* and *Tellina* (?) are above. This sandstone deposit appears to be one of the oldest, if not the most ancient, of this Saliferous formation.

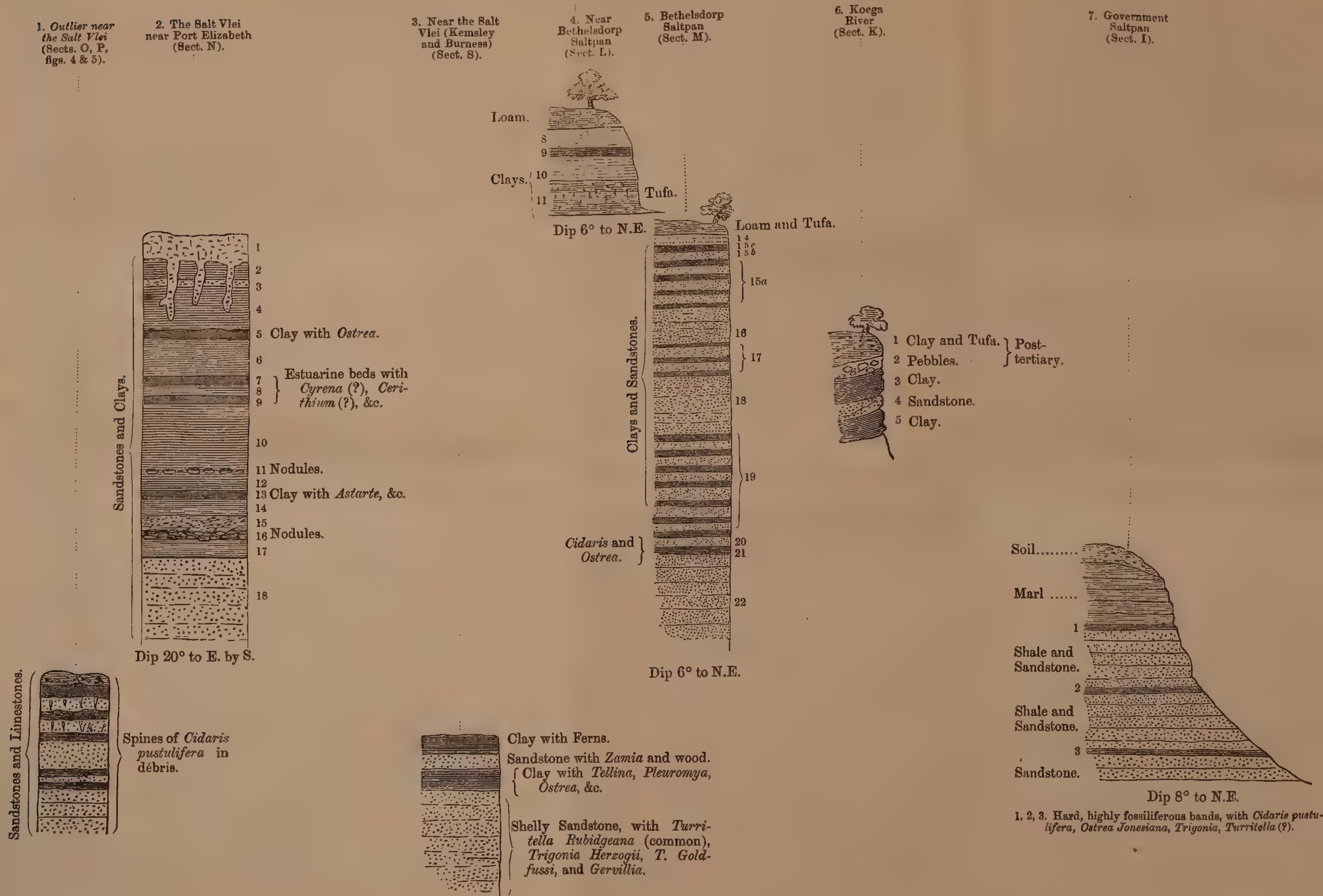
* Quart. Journ. Geol. Soc. vol. xxiii. p. 145 &c.

liferous Group.



1, 2, 3. Hard, highly fossiliferous bands, with *Cidaris pustulifera*, *Ostrea Jonesiana*, *Trigonia*, *Turritella* (?).

Fig. 6.—*Collated Sections, showing the probable succession of the Clays and Sandstones of the Saliferous Group.*
(Section Q of Author, embracing his Sections I, K, L, M, N, O, and S.)



The strata of the Government Saltpan seem to follow, with (according to Dr. Atherstone) *Trigonia*, *Turritella*, *Ostrea*, and *Cidaris pustulifera*. At the Bethelsdorp pan *C. pustulifera* is found in the greatest abundance; and spines and plates of the same *Cidaris*, found scattered on the sides of the outlier at the Salt Vlei, near Port Elizabeth, indicate the position of the associated clays on the opposite side of the Vlei (Section O, fig. 4), with their innumerable specimens of small *Ostrea* unmixed, as it seems at present, with the remains of *Cidaris*. As I have already said, so little is yet accurately known of the fossil contents of all these different strata that nothing can be done to decide the question of position with any degree of certainty until the fossils shall have been more fully studied and classified.

On looking at these collated sections (fig. 6) we at once see how much they differ from the apparent uniformity of the sandstones of the Zwartkops and Sundays Rivers (Sctions A–G, fig. 3). These latter exhibit the features of an extended and uniform deposit, while the former display local differences of a very diversified character. Further, the more I have studied them the more I have been impressed with the idea that the position at present assigned to them * is not correct.

The following reasons may be given to explain this opinion. It is said that these strata are an earlier formation than those of the Zwartkops and Sundays Rivers series; but has this been convincingly proved? As far as I could obtain information, no good section has yet been pointed out (that is, anywhere between the quartzite hills of Port Elizabeth and the Grass-ridge) where these clays &c. are so situated as to demonstrate distinctly that they are really below, and the Zwartkops *Trigonia*-beds above. Even should we find them in a depression *apparently* lower, still this would prove nothing without a satisfactory junction in which the *Trigonia*-beds could be shown to be placed above the stratified clays; whereas sections have been found the reverse of this. It might as well be argued that the red clay (*g*, *g*, in Section O, fig. 4) spread over the surface in different parts of the Oliphants-Hoek and Port-Elizabeth Divisions, instead of one of the most recent clays, is a very ancient one, because in the former locality it has been found (in sinking wells) to be upwards of 100 feet in depth, and in the latter, near the New Prison, about 70 feet—lower levels than either the sandstones or stratified clays have been found at. This clay has evidently been deposited in hollows, eroded out of the more ancient rocks; and in the same way, I cannot help thinking, these "Saliferous Strata" have been deposited in positions where denudation had removed some of the earlier formations. This was especially the case where I examined the strata of the Government Saltpan; for there *these rocks*, as far as I could judge, when the dip of the *Trigonia*-sandstones is taken into consideration, must be placed above those of the Zwart-

* That is, *below* the great *Trigonia*- and *Ammonites*-series of the Uitenhage formation. See Atherstone, *loc. cit.*, and Quart. Journ. Geol. Soc. vol. xxiii. p. 149.—T. R. J.

kops. Again, as a proof that their position is below the Zwartkops *Trigonia*-beds, it has been stated that these saliferous rocks are found resting unconformably on the quartzite and clay-slate, in the direction of Bethelsdorp and Chatty. But, again, this of itself is no proof; for near the Shark's River one of the most recent shell-deposits also rests directly on the quartzite.

Dip.—We will therefore first enter into the question of dip, especially that of the Government Saltpan—in the first place, however, premising that *between* this Pan and the saliferous deposits of Bethelsdorp and the neighbourhood of Port Elizabeth the strata of the Zwartkops, as shown in sections B & C intervene. The Pan itself is in a denuded depression; but this hollow is not very deep, as is indicated by the rising ground that surrounds it, and from the top of which a plateau stretches on the same level as the upper edge of the Zwartkops Heights—in fact, is continuous with them, as is seen at *d'* in Section R (fig. 7).

Dr. Atherstone * says that the strata at Geelhoutboom dip S.W., towards the centre of the ancient estuary, at an agle of 8°, and those of the Zwartkops conversely N.E.; and he gives the dip of the Saltpan rocks at the same angle to the north-east, that is, in the same direction as those of the Zwartkops. Now it is certain that for a number of miles together the dip of the Zwartkops strata continues with great uniformity at nearly the same angle. But an angle of 8° gives a depression of about 1 foot in 15; and if continued two miles (about the distance of the Government Saltpan from the top of the Zwartkops Heights), there would be a total fall of some 1500 feet. The highest hills anywhere in the neighbourhood are the Koega Kopjes; and they are only 480 feet above the level of the sea. The depression of the Saltpan is certainly not 300 feet below the level ef the Amsterdam Flats, the plateau from which these Kopjes rise, as that would place it below the level of the sea, which it decidedly is not; but, even allowing it to be so, the angle given would place the Zwartkops sandstones, if they extended as far as the saliferous strata of the Saltpan (which I think is not doubted), 1200 feet below them. A dip of 4° (the same as at Rocke's Bluff) would allow rather more than 700, or some 400 feet below: and even the small angle of 2° would still leave the *Trigonia*-beds between 70 and 80 feet lower than the deposits of which I am speaking.

Fossils.—At the Government Saltpan (p. 505) Dr. Atherstone has found *Trigoniæ* and *Turritellæ* associated with *Ostreæ* and *Cidaris pustulifera.* I cannot help thinking that this is the oldest portion of the saliferous strata that has been yet examined. The stratified clays of the Bethelsdorp Pan and those at the Salt Vlei are, I believe, more recent. At the former of these *Cidaris* and *Ostrea* are abundant; but *no Trigoniæ* are yet known there; while at the latter spot no specimens of either the one or the other have been obtained, although *Cidaris* has been found on the sides of the outlier (Section O, fig. 4) on the east of the Vlei. This outlier, I believe,

* *Loc. cit.* p. 581, and woodcut, no. 1.

will prove to be older than the clays of the Salt-Vlei section, and probably equivalent to those of Bethelsdorp.

At one of the meetings of the Natural-History Society of Port Elizabeth, Dr. Rubidge published a section (Section S, fig. 6, 3), near the Salt Vlei (see a notice of their Proceedings in the 'Port-Elizabeth Telegraph'), at the top of which is a bed of clay, "No. 1, apparently about one foot." This is the stratum in which Messrs. Kemsley and Burness discovered the Ferns (see above, p. 510). "The stratum of clay which contained the Ferns rested on a sandstone containing immense fragments of leaflets and petioles of *Zamiæ*, mixed with pieces of wood, and that on a clay with shells (*Tellina*, *Orbicula* [?], *Myacites* [*Pleuromya*], *Ostrea*, &c.); no 2, some three feet thick. *Below this* was a shelly sandstone, containing *Turritella Rubidgeana* (Tate), with imperfect specimens of *Trigonia Goldfussi*, and a new species of *Gervillia*. The discovery of these shells, which are on the opposite hill (near Mr. Graham's house) associated with *Cidaris pustulifera* (Tate), at the Bethelsdorp Saltpan with the same and with *Crassatella complicata* (Tate), *Ostrea Jonesii* (Tate), and at the Zwartkops Heights with *Trigoniæ*, *Astarte*, &c., is of great interest, as showing clearly the relation of the whole series of the beds of the ancient Mesozoic bay to each other."

I wrote to the late Dr. Rubidge upon this subject immediately after the publication of the report, to ask him his opinion whether this did not confirm the conclusion I had already arrived at from the study of the dip. Unfortunately I did not receive an answer.

Distribution of Fossils in the several members of the Uitenhage Formation, according to the corrected lists of named species.—T. R. J.

		Species yielded.		Species peculiar.	Community of species between
I.	1. Near the mouth of Sundays River	62?	28	12	1 & 2 =12?
	2. Higher up Sundays River		46	29	I. & II.=16
II.	Zwartkops River		28	9	I. with II. & III. = 6?
III.	"Lowest strata of the Zwartkops Crag (cliff)"		15	9	I. & IV. = 2?
IV.	Saliferous strata		9?	3	II. & III. = 0
					II. & IV. = 0
					III. & IV. = 1?

C. *Conclusion.*—Let us now take a retrospect of the various fossiliferous beds I have mentioned. In the lowest Zwartkops stratum *no Trigoniæ*, as far as I can learn, have been discovered, and certainly not the *Crassatella complicata*, *Hamites*, and some other shells. As we proceed upwards *Trigoniæ* become abundant, and increase in number of species. Ammonites also become frequent in some strata. At M'Loughlin's Bluff on the Sundays River *Hamites africanus*, *Crassatella complicata*, and *Trigonia Goldfussi* make their appearance. These rocks, it will be remembered, I have looked upon as the uppermost of the Zwartkops- and Sundays-River strata. At the Government Saltpan, *Trigoniæ* and *Turritellæ* are mixed with the remains of *Cidaris*—while in the section near the Salt Vlei (Sect. S, fig. 6, 3) we find *Crassatella complicata* and *T. Goldfussi*, together with a *Gervillia* (shells found in the *uppermost* Sundays-River strata), imbedded in a sandstone, *immediately above which* are found stratified clays containing shells which, together with *Crassatella complicata*, are associated with *Cidaris pustulifera*, the characteristic shell of the fossiliferous zones of the Saliferous Strata, and, apparently, the *Trigoniæ*, Ammonites, and their associates are absent. This explanation proves, I think, the regular sequence of the shells.

Mr. Tate, in his paper "On some Secondary Fossils from South Africa," says*:—"Species of this type (*Cidaris pustulifera*) exist at the present time, and are found in the Tertiary and Cretaceous rocks; species of the type with crenulated bosses characterize Oolitic deposits. There are, however, some exceptions to these rules, and for the present the African species may be regarded as another exceptional example." If I understand this rightly, some species of *Cidaris* (this fossil, remember, is associated with *Crassatella complicata*) are indicative of Cretaceous rocks; but this is an "exceptional case." If, then, these same deposits are placed in the position which I believe is their true one, the exceptional condition vanishes; they take their right place, and prove that the law which regulated, with regard to periods, the development of particular races was the same in the southern as in the northern hemisphere.

Origin of the Salt.—The author thinks that the *Trigonia*-series, having been deposited in open sea, would be less likely to contain salt than shallow-water beds succeeding them and formed in narrowing creeks and lagoons. The saliferous series he believes to have thus succeeded the *Trigonia*-beds, and to have become impregnated with salt. At the present time the same causes are at work on a smaller scale, in the mouths of some of the minor rivers of South Africa, where the entrances are blocked up with sand and thus communication with the ocean is cut off, except when broken through occasionally by a freshet after heavy rains. During the time that these mouths are thus land-locked the evaporation is more rapid than the supply; and as a natural consequence, the water in the enclosed basins becomes more intensely salt than that of the neighbouring sea. The deposits formed within them are saturated with this extra-saline fluid, so that when a flood bursts through the opposing barrier, and the water of the imprisoned river falls with the tide, banks of brackish mud are exposed in many places; and these soon prove themselves to be saliferous deposits; for, as they dry in the sun, they become covered with a white saline efflorescence. Such, one cannot help believing, is the explanation of the mode of formation, although on a grander scale, of the saliferous strata we have been considering.

* Quart. Journ. Geol. Soc. vol. xxiii. p. 163.

Part I. § 2. Tertiary or Posttertiary Strata.

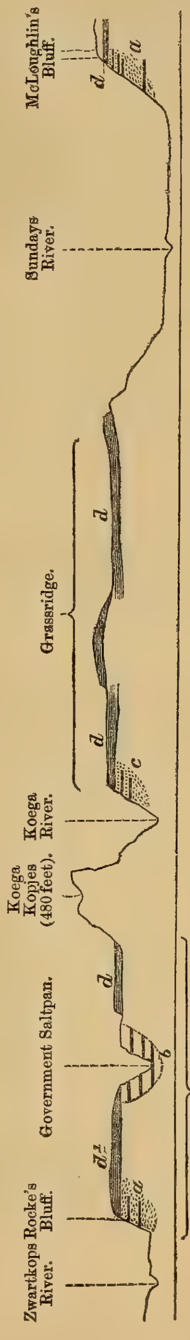
[Abridged*.]

1. *Pliocene or Postpliocene Strata of the Interior.*—Having thus noticed the older rocks, I will now proceed to make a few remarks on the so-called "Tertiary Limestone"†, which covers in many places the rocks we have been describing. This series caps the top of the Zwartkops Cliffs, extending from Rocke's Bluff (see Section R, fig. 7), along the top of the hills towards Uitenhage, and resting upon the Jurassic sandstones. The greatest accumulation appears to be on the Amsterdam Flats and the Grassridge. At the Koega it is found upon the friable nonfossiliferous sandstones of that locality (see above, p. 506). At the Sundays River it is seen on McLoughlin's Bluff as a narrow belt. These positions are shown in Sections E and R (see fig. 7). From the Zwartkops to the quartzite ridges of Port Elizabeth, I am not aware that any traces of it have been found. Mr. Pinchin, who has paid much attention to this formation, states (in a letter) that "it covers the upper part of the plain (Amsterdam Flats), extending westward to Hitzeroth's (the Old Government) Saltpan, and along the tops of the hills to within a mile of Uitenhage; it covers the whole of the Grassridge

* The sections and sketches sent by the Author for this portion of his Memoir are deposited with the others in the Society's Archives; and the large collection of recent and fossil shells &c. sent by Mr. Stow, in illustration of his views as given in this paper, awaits examination by Mr. W. S. Dallas, who kindly promises a full report.—T. R. J.

† This is the limestone termed "Tertiary" in Mr. Bain's Geological Map of the Cape Colony, Geol. Trans. 2 ser. vol. vii. pl. 20.—T. R. J.

Fig. 7.—*Section showing the relative positions of the Trigonia-beds, the Saliferous group, and Posttertiary Shell-Limestone.* (Section R of Author.) Length about 25 miles.



a, a. Zwartkops- and Sundays-River Sandstones. *b.* Saliferous beds. *c.* Soft friable Sandstones. *d, d'.* Posttertiary Shell-beds.

to within three miles of Prentice Kraal, and nearly in the same meridian as Blaaw Krantz. This latter place, however, is some three or four miles off the limestone. It is seen upon Landman's Kop, a hill lying just eastward of the Sundays River's mouth, and at Deep Kloof and Groof Water, in Oliphant's Hoek, twenty miles south of the Sundays River. To the southward of Port Elizabeth the limestone hills of Buffel's Vontein, Chelsea, and Van Staden's River, are probably of the same formation."

Mr. Pinchin's professional duties have given him opportunities of visiting every part of the district. The places which I have examined are:—Rocke's Bluff; a quarry on the flat between the Government Saltpan and the Zwartkops Heights; on the banks of that river, to a deep kloof, a little below the drift (ford) on the old Grahamstown Road; the old waggon-track on the north bank of the Koega, near the Kopjes; different spots on the Grassridge; and at McLoughlin's Bluff. It seems to be a single deposit, and not a series like the others (see p. 519). It varies very little in all the localities that I visited, being from 4 to 6 feet thick, except at McLoughlin's Bluff, where it is much thinner. It is highly fossiliferous, and abounds with fragments of shells, and now and then with some that are nearly perfect. Of the bivalves only single valves are found, and the majority have been broken by the action of the waves. In some localities there are immense deposits of a large species of *Ostrea*. Out of 22 different species of shells, nine are not at present found on the neighbouring coast, five are still doubtful, leaving only eight of the number that are positively recognized as being inhabitants of the present sea.

2. *Pliocene or Postpliocene Strata on the Coast.*—Following this limestone, and with an evidently wide interval, is a series of deposits which are spread out from Port Elizabeth to the mouth of the creek (or Ferreira's River), and thence, in detached spots, to the Zwartkops. The oldest deposit appears to be a sandy tufaceous (?) limestone, interspersed with many patches of conglomerate, formed of small quartzite pebbles. It is very fossiliferous. Out of twenty-five species of shells that I collected from this bed, twelve have not been found in the adjoining sea. The greater portion of these are fragments. This deposit was certainly laid down under widely different circumstances from those of which I shall have to speak presently, and in which the shells, however fragile and delicate, are in a beautifully perfect state.

As far as I could judge from an excavation I had made at the foot of the cliff, I found this stratum to be from four to eight feet thick; but I found great difficulty in obtaining a good section, as, at the lowest level arrived at, the water flowed in so rapidly that we could not proceed. The bed extended from a quarter to half a mile inland, where it was hidden under the æolian sandhills. It was covered by a non-fossiliferous limestone, a few inches thick; and above that was spread a layer of loose pebbles of the same kind as those in the pebbly limestone itself.

In two other diggings, instead of the loose shingle, occurs a clayey sand, mixed with small pebbles and numerous shells (*Cerithium* &c.), out of twelve species of which, seven have not yet been found on the present beach. Most of the shells are broken and worn, owing no doubt to their having been rolled in shallow water with the sand and small shingle in which they are imbedded.

Further south, after digging in a bed representing that last described for about eighteen inches, the influx of spring water prevented the examination being carried further. Above it was a hard limestone without fossils, and above this a band of pale slate-coloured sand from 9 to 18 inches thick, equivalent to the pebbly clayey sand above mentioned. It is mixed with grit and small pebbles, and contains numerous specimens of the straight *Cerithium* which occurs in the equivalent bed; but all the shells found in it are broken and waterworn. Near the Creek there is a bluish sand; and the shells in it are more perfect than in the beds previously mentioned. I had no opportunity of obtaining a measurement of its greatest thickness. From this particular band I have collected forty species of shells, of which there are eighteen that have no living representatives on the present sea-beach. I imagine that their descendants will have to be looked for further to the eastward along the coast.

There are two strata in the southern part of the section whose equivalents I have not been able to trace further north. One is a bright yellow sand, from 1 to 2 feet thick, containing numerous perfect specimens of *Loripes edentula* (Chenu) and *Mactra*, with both valves complete. The other is a pale slate-coloured sand, slightly clayey, varying from 2 to 5 feet in thickness, and containing numerous beautifully perfect shells. From the immense numbers of the *Akeræ* found in it, I have termed it the *Akera-stratum*. This deposit is in some places worn away, and divided in detached portions, as represented at *a*, *a*, *a* in Section T. It is at many places capped with a layer of waterworn fragments of shell-limestone, pieces of shell-grit containing small pebbles, and also waterworn shells of the present ocean. These last were, of course, left in the position in which they are found during the retreat of the sea to its present level. The number of species of shells that I have already obtained from this stratum is 71; of these, 27 have not been found on the present coast, and of 10 others it is doubtful whether they are still living in the neighbouring bay. The straight *Cerithium*, the *Pectunculus*, and others have sometimes been picked up by shell-collectors on the beach, mixed with recent shells; but, possessing none of the fresh appearance of more recent shells, they have always borne evidence of having been disinterred.

§ 3. *Pliocene or Postpliocene Strata* (*Raised Beaches*) *on the Coast and Inland.*—The next deposits, so far as at present known, in succession to these, are shell-banks that are not only found along the coast, forming a raised sea-beach, as on the south side of the Zwartkops River's mouth, but also extending inland as raised banks nearly as far as Cradocktown. They are evidently far more extensive than those we have just been considering. The principal parts that I have examined are:—the raised beach just mentioned, which is about half a mile from the river's mouth, and 40 or 50 feet above the present sea-level; on the south bank of the Zwartkops, near Rawson's Bridge; and along the banks of the creek and Ferreira's River, towards Cradocktown. No trace of these shell-beds is found on the surrounding highlands.

This formation is also found protruding through the red clay that forms a portion of the flat, between the outlier marked No. 1 in the section (fig. 4) near the Salt Vlei and the sandstone on the coast near Port Elizabeth. See *f* and *g g* in that section (p. 508).

In each locality mentioned this deposit extends a considerable distance. Thus it can be traced from a spot where it is exposed by a cutting through the north bank of the creek, on the Grahamstown Road, across the raised flat over which the road passes towards the Zwartkops, until you reach the wide alluvial flats that extend from the south side of the river. Again it stretches from the road mentioned to the sand-hills along the coast. This portion, however, is covered with soil, thickly interspersed with shingle, mainly composed of pebbles of quartzite, from the distant hills. Wherever any wild animal has burrowed through the soil and shingle, or where any excavation has been made, the shells of this deposit are almost invariably exposed to view. In like manner it evidently extends towards Port Elizabeth—as it there again makes its appearance, as indicated in the section alluded to (fig. 4). We must note that we have here the shingly beds with the red clay superposed; I shall have again to refer to the last-named deposit.

I have found the shells from these ancient shell-banks on the coast near the mouth of the creek, evidently washed out and spread over the surface.

Returning to our first point of departure, we can trace the shell-bed, exposed at intervals, along the banks of the creek and Ferreira's River, towards Cradocktown, as before mentioned; and, after passing the mud-flats on the south side of the Zwartkops River, we find it again, extending along the banks of the same for more than half a mile. In this locality it was evidently at one time of much greater extent than at present, and must have occupied the very course of the present river; but it is being rapidly worn away by the action of the stream.

In some parts (at the bridge) this deposit is nearly 30 feet thick. It is composed principally of sand, the upper portion being interlaminated with bands of limestone. This is especially the case at the western (or what was its inland and most sheltered) extremity. In these bands are imbedded large quantities of shells. At this spot a large and characteristic *Panopæa* is found. It is generally buried in the lower part of the stratum, and rather frequently with both valves entire. This is the only bank in which I have found this shell, with the exception of a solitary specimen in the raised beach before mentioned. At the creek and the banks of Ferreira's River, I have not found any indications of it. At this place (Rawson's Bridge) a large *Solen* is also very plentiful, as well as a *Mactra* and a *Tapes*; these shells are perfect; but, although they are so numerous, many of the shells found in the banks at the creek and Ferreira's River are wanting. It is worth considering whether or not this indicates a *series* of these deposits. All the shells in the lowest part of the stratum at this spot have both valves perfect, some of the *Mactræ* still retaining a portion of their colour; those imbedded in the limestone, nearer the surface, are in a more fragmentary condition.

The section I have called "*the raised-beach*" is, as above stated, some 40 or 50 feet above the level of the sea; but unfortunately the upper portion is the only part sufficiently exposed for examination. From the indications on the beach below, it most probably rests on a sandstone there shown. Almost every shell in the remains of this ancient beach is broken, in the same manner as those now found on the present sea-shore where exposed to the full action of the waves rolling in from the ocean.

At the creek on the Grahamstown Road this deposit has been cut through for some 12 feet in depth. Here, again, most of the shells are perfect, and do not seem to have been exposed to the action of rough water. This is eminently the case with the contents of the shell-bank further up Ferreira's River, and near Cradocktown. At this place the deposit rests upon a bank of drift, with bands of large angular pieces of quartzite; this drift overlies a loose gritty sandstone. In the drift there are scarcely any indications of fossils; but in the deposit above there are strata of innumerable shells in a sandy calcareous matrix. This shell-bed, capped with a red clay, several feet thick, is the most prolific portion of the deposit we are now treating of. The shells are all perfect, with the most delicate ornaments preserved.

With the exception of a *Psammobia*, none of the shells found here have, up to the present time, been found on the shores of the bay. Still, in the whole series of shells collected, there is a nearer approach to those of the present ocean, while there is a marked difference in character between these fossils and those obtained from the *Akera*-stratum.

These shell-deposits at Ferreira's River &c., must have been laid down in the waters of a bay, stretching from the Zwartkops to the Port-Elizabeth hills, and extending some miles inland. On the intervening ridges no signs of them are to be traced. In fact, it seems almost certain that the ridges must have stood out of the surrounding waters as islands. This is remarkably the case at the creek, where the high ridges alluded to will be seen. When standing on the shell-bank at Ferreira's River, one cannot help being strongly impressed with this idea, and that the sea must have been as calm there as in a land-locked bay, protected as it evidently was from the roll of the open ocean. The appearance of the shells themselves strengthens this view of the case, from the beautifully perfect state in which almost all of them are found—with all their most delicate outlines preserved, and the bivalves almost invariably having both valves uninjured and closed. These indications must surely prove that here they must have been deposited in still water, below or beyond the influence of the tidal and other waves; while, on the other hand, the shells of the "raised beach" appear to have been deposited on a kind of outer reef, exposed to the full force and constant action of the sea, which broke them into fragments, and rounded off their fractured edges.

§ 4. *The Red Clay.*—The deposit which seems to follow these is the red clay, as shown at *g g*, in Section O (fig. 4). The exact position of this clay, to which I have before alluded (p. 518), requires more careful examination than has yet been given to it. There appears to be little doubt, from the section just referred to, that it must be more recent than the shell-deposits we have been describing; for upon the flat, at a little distance from the north end of Port Elizabeth, they are found cropping up through it. These shell-beds, judging from their fossils, are identical with those of Ferreira's River. However, as I have said, little is at present known of this clay, except that it varies considerably in thickness in different localities: thus it may form merely a superficial covering to the shell-banks mentioned; while the late Dr. Rubidge informed me that at the New Prison it is some 60 or 80 feet thick; and, at Oliphants Hoek, Dr. Atherstone states it to be 100 feet. Whatever may be its thickness, it must have been deposited under totally different circumstances from any thing preceding it. The transition from the one to the other is so sudden that, with the limited information we have about it, it will have to be left to future investigation before its history can be written, as well as to discover (what is probably the case) deposits on other parts of the coast that may intervene between the shell-banks and the clay, and others between the clay and the formation which follows, thus more clearly explaining the changes that led to its deposition.

§ 5. *Latest Shell-beds.*—The next known deposit of the ancient sea is that marked C, C, in section T No. 1, and C in T No. 2. This is evidently the most recent, previous to the existing order of things. In the Bight, as shown in the section, it is found in detached mounds of drift-sand, with a thick horizontal bed of shells on the top. These, however, from their position and structure, are merely the isolated remains of what, at one time, was a continuous and wide-spread deposit. It is found on different parts of the coast, and is especially remarkable on the south side of Port Elizabeth, towards a small indentation called the Shark's-River Mouth. In this locality the quartzite rocks (near the top of the ridge, and at an elevation of 180 feet above the sea) have been worn away to a long slope by the action of the waves &c. About one-third up the ascent, and resting upon the quartzite, is a mass of conglomerate composed almost entirely of quartzite fragments imbedded in limestone, with fragments of shells. There is another accumulation of conglomerate at the same place, at a lower level, composed of waterworn pebbles. These conglomerates have been found at other parts of the coast. Upon this conglomerate, or, where it is wanting, upon the quartzite itself, are high mounds of sand, such as those before alluded to, with immense masses of shells imbedded in their upper portions.

Some of the shells, although identical with those now living on different parts of the coast, are not now as numerous on this particular part of the coast as they were when the shell-mounds now under consideration were deposited; they are, however, still very numerous in other, but somewhat distant, bays.

Some have supposed that these accumulations, at such elevations, are somewhat similar to the "kitchen-middens" of Denmark; and they wish to account for this immense accumulation of shells by imagining that they are the remains of the feastings of some ancient races who at some time inhabited the sea-coast. But, after a careful study of the locality, I cannot arrive at the same conclusion. These shells, judging from their appearance, must have been deposited by the sea where they are now found. The quartzite has been (as before mentioned) worn away until it forms a long steep slope of some two or three hundred yards. The rush of the tidal waves over the surface of this rock (and they have left evidence of their action) would sweep every thing off it; and their recoil, carrying the shells and sand to the lower levels, would deposit them there in comparatively quiet water, and thus form the stratum we now find.

Between this spot and Port Elizabeth, there are a number of places where this same band of shells is exposed; but in these instances there is a deposit of sand many feet thick above it. At the spot to which I am now confining my remarks, however, this upper deposit has been denuded, or blown away, leaving the large masses of shells I have described exposed on the surface. Here and there they look, at first sight, as if they had been placed in piles; hence, no doubt, the mistaken opinion about them; but on examining these detached heaps, they are found to be parts of the original deposit, the surrounding and intermediate portions having been worn away, and the shells having become broken and pulverized by atmospheric influences. There can be little doubt that at one time the exposed portions of this shell-deposit were covered, as before suggested, with a thick layer of sand; for in many parts very large quantities of fossilized roots, stems, and branches are spread over the shells. Specimens of these must, from their perfect state of preservation, have grown on the spot, and could not have been washed from a distance. In some instances, where the sand is left, they are still partially enveloped in it. The probable cause of the change they have undergone has been that the water which permeated through the sandy and shelly soil in which they grew, became so charged with lime that, when the roots &c. decayed, the carbonate of lime itself was deposited, as in a mould, in the spaces left; and these casts, when the sandy matrix was removed, either by strong winds, which so often prevail along the coast, or by other causes, have been laid bare. I have found the same on the coast to the east of the Great Fish River.

Numbers of teeth and bones are frequently discovered imbedded in this shell-deposit near the Shark's River. The position in which these are found would also tend to prove that they and the shells were entombed together by aqueous agency, and that they were not the refuse of the repasts of a primitive race. Thus the bones were perfect, and, in some instances, large portions of the skeleton were together in the proper positions, not scattered and broken, as they would have been had some savage been feeding on them. Unfortunately these relics would not bear removing, but broke up into small fragments as soon as they were dug out and handled.

The facts here stated must, I think, satisfactorily prove that these shells have been accumulated in the position they are now found in by the cause and in the manner here assigned. This deposit is one of the latest, if not the very latest, prior to the last elevation of this part of the South-African coast, and must have immediately preceded the present order of things. Since that time a gradual emergence of at least 150 feet must have taken place—since the ocean-waves broke upon and wore away the sloping quartzite rocks before mentioned.

Table of Postpliocene and Recent Deposits between Port Elizabeth and the Zwartkops.

Feet.	Name.	Remarks.
20 to 30	Shell-deposits with bones and fossil wood.	Raised 60 or 70 feet above the present level of the sea. All the shells are the same as those now found on the South-African coast.
30 to 100	Red clay.	
About 25	Shell-bank at Zwartkops Bridge.	*Panopæa, Tapes, Solen, Mactra*, &c.
Exposed 6	Raised beach near the Zwartkops mouth.	All the shells broken.
15 to 18	Shell-bank at Ferreira's River.	All the shells perfect. *Loripes, Tapes, Cardium, Cerithium*, &c.
18 to 20	Drift and gravel upon which one portion of the last shell-bank rests.	Angular pieces of quartzite, intermixed.
18	Strata at the Bight, Port Elizabeth.	*Akera, Cerithium*, &c. &c.

3. *On some* Points *in* South-African Geology.—Parts II. and III. *On the* Dicynodon *or* Karoo Formation—*its Forest-zones, as shown by Sections in the Winterberg and the Stormberg (Dordrecht, Upper Kei River, and Klaas Smit's River), and its Denudation by Ice-action; with Remarks on the Climatal changes in South Africa.* By G. W. Stow, Esq., of Queenstown, South Africa.

(Communicated, with Notes, by Prof. T. Rupert Jones, F.G.S.)

[Read December 7, 1870 *.]

Part II.—The Forest-zones and other Strata of the Dicynodon Formation.

In the Dicynodon (Karoo) formation † we find two or more distinct forest-zones in this eastern part of the colony. At Dordrecht (Albert), in the Upper Stormberg range, on the south of the Kaga Mountain (an offshoot of the Winterberg, in East Somerset), in the Kroome range, and in the Amatola Mountains (British Kaffraria) a thick and gritty sandstone frequently makes its appearance on the slopes of minor valleys, and on the flats at the same line of elevation; and wherever it is exposed there is almost invariably an abundance of fossil wood. Near Greytown and the Kabousie nearly entire trunks of trees have been discovered. Near the Kom-Kom, a branch of the Kaga River, I have collected numerous specimens‡.

Section at Dordrecht.—In the section (fig. 8) the portions marked *a, a, a* are covered with *débris*. No. 1 protrudes in enormous masses of greenstone or basalt ("ironstone" of the colonists), which, judging from the line of exposure, must be conformable with the strata on which they seem to rest §. About 50 feet below, a rather compact sandstone is exposed, resting upon a claystone (No. 2) ||, about two feet thick; this, again, upon No. 3, a coarse-grained greyish sandstone ¶, twelve or fourteen feet; and immediately beneath this is No. 4, grey indurated shale. Below this is a coarse friable brownish sandstone (No. 5), resting on No. 6, which is very similar, but full of ferruginous patches and nodules, specimens of which are sent**. Many of these nodules are filled with ochres, fine im-

* For the remainder of the papers read at this Meeting, see pp. 49–73.

† For Mr. Stow's description of a section of the Karoo beds of the Rhenosterberg, an offshoot of the Sneewbergen, see Quart. Journ. Geol. Soc. vol. xv. p. 194.—T. R. J.

‡ Several segments of probably coniferous trunks were sent by the author.—T. R. J.

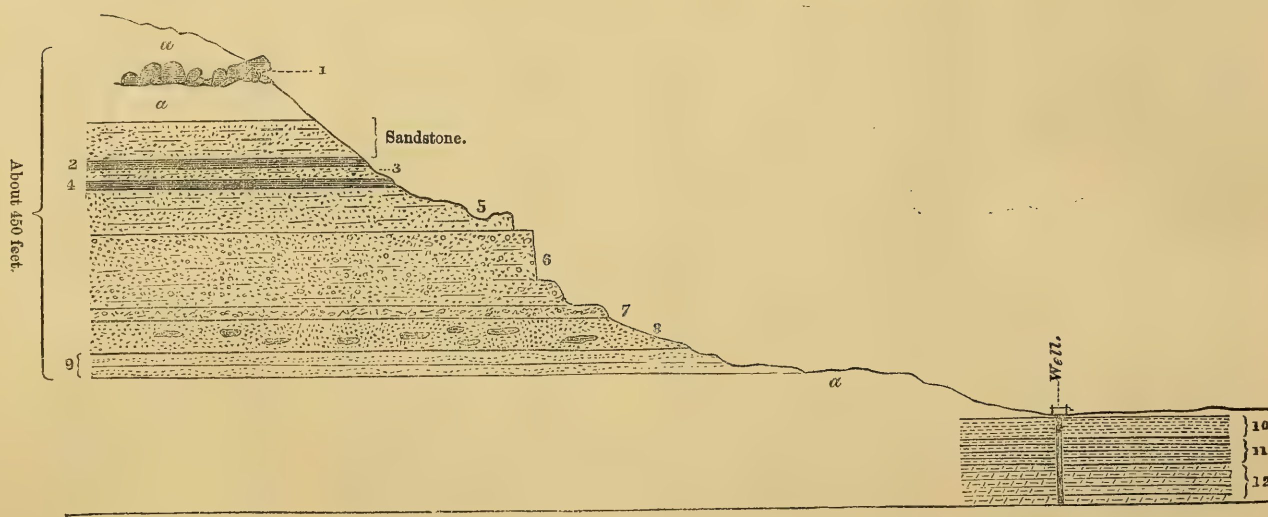
§ The specimen of No. 1 sent is a small exfoliating nodule of greenstone. —T. R. J.

|| The specimen of No. 2 sent is a piece of felspathic trap (claystone).—T. R. J.

¶ With felspathic cement.—T. R. J.

** "D. S. 2." Nodules of quartz grit, with some felspar, cemented with iron-oxide, showing transverse lines of stratificatiou externally, and containing ochre. —T. R. J.

Fig. 8.—*Section at Dordrecht, on the Upper Stormberg, 5000 feet above the sea-level.*



1. Greenstone or basalt.
2. Claystone.
3. Coarse-grained greyish sandstone.
4. Hard grey shale.
5. Coarse, gritty, brownish sandstone.
6. Similar sandstone, with ferruginous patches and nodules.
7. Quartzose grit, sometimes approaching a fine conglomerate.
8. Sandstone, with silicified trees.
9. Close-grained sandstone, with fossil roots &c.

10, 11, 12. Stratified clays :—10 yellowish, and 11 light grey, with abundance of Ferns, *Palæozamia*, &c.; 12 dark blue, with fewer Ferns &c.

a, a, a. Strata unknown.

palpable powders of different colours, from which the ancient Bushman race (now rapidly becoming extinct) obtained many of the pigments they used in their cave-paintings. This noduliferous sandstone lies on the quartzose grit (D. S. 1 *, in some places almost a conglomerate), No. 7, ten feet thick, and composed of quartz, which could only have come from the Washbank. Below this is the coarse sandstone of the "Forest-zone," No. 8, with "silicified" trees, probably coniferous, at least thirty feet long. No. 9 is a much finer-grained sandstone, and of a darker colour. Great numbers of what appear to be casts of roots †, are obtained from this deposit. Sometimes they are soft and easily pulverized; and when found in that state they were ground down and used by the Bushmen as a fine dark chocolate paint, frequently used by them in delineating the human figure in their caves. The height from the lowest exposed stratum to the basaltic blocks is about 450 feet.

The discovery of stratified clays below these beds was made in sinking a well in the village of Dordrecht; and although no intervening section has yet been obtained, it seems very probable that they are conformable. For six or eight feet the upper clays are of a bright-yellowish colour, No. 10, with abundance of *Pecopteris* (?) and other plants. I secured a large case of them; but, unfortunately, during its transit it was saturated with rain, and these beautiful specimens were destroyed ‡. Below, the clays (from seven to eight feet thick) are of a light-grey colour, No. 11; here the Ferns &c. are not so abundant. Below this there is a dark bluish-grey clay, No. 12, much more compact than those above, and from ten to twelve feet thick; in this the leaf-impressions are far less numerous. I am not aware whether or not these clays appear at the surface at a lower level.

The dip of the strata in the section just described is 6° or 7° S.E., and they are probably some of the most recent on the northern portion of this great basin of deposit.

Section on the Upper Zwart Kei.—The section, fig. 9, is from the

* "D. S. 1." Round lump of coarse quartzose grit (some of the grains rounded), with some felspar and a little mica, feebly cemented with iron-oxide and some clay.—T. R. J.

† The specimen sent represents, in fragments, a long subcylindrical concretion (?) of amorphous chocolate-brown hæmatite, striated longitudinally outside, and here and there showing traces of concentric structure within. Specimens of the enclosing rock, sent with the above, consist of ferruginous sandstone, with indeterminable casts and markings.—T. R. J.

‡ Mr. Carruthers, F.R.S., of the British Museum, having examined the specimens here referred to, has kindly supplied the following note:—

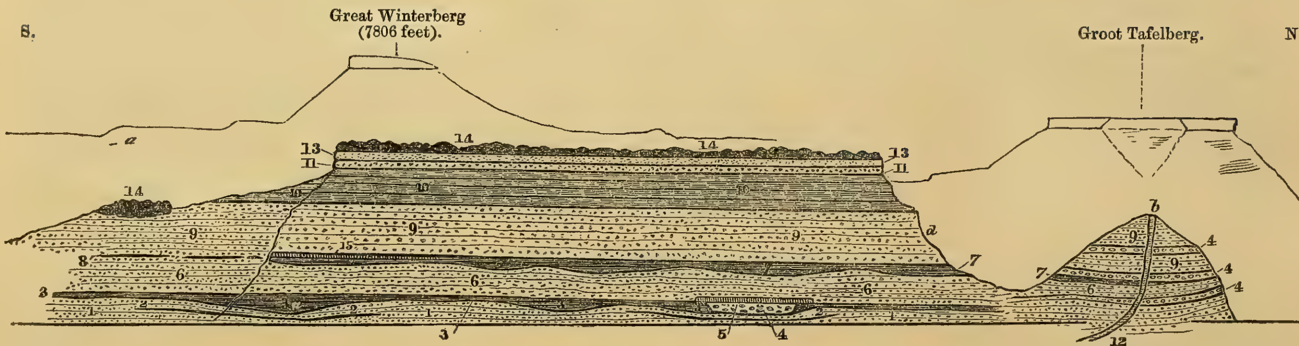
"The specimens from Dordrecht are not satisfactory. Among them are three species of Ferns, which, I believe, are new. One seems to be a species of *Danæopsis*, a second a *Sphenopteris*; and I know not what fossil genus I could refer the third to. With these are associated what appear to be fragments of a monocotyledonous plant, which are undeterminable.

"It is not improbable that a set of these Ferns would comprise specimens with fructification; and this would be very important. The fragments before me have been so much injured by the water which had access to them that they are little more than determinable as Ferns.

"The woods are all, I believe, Coniferous.—W. C., April 10, 1871."

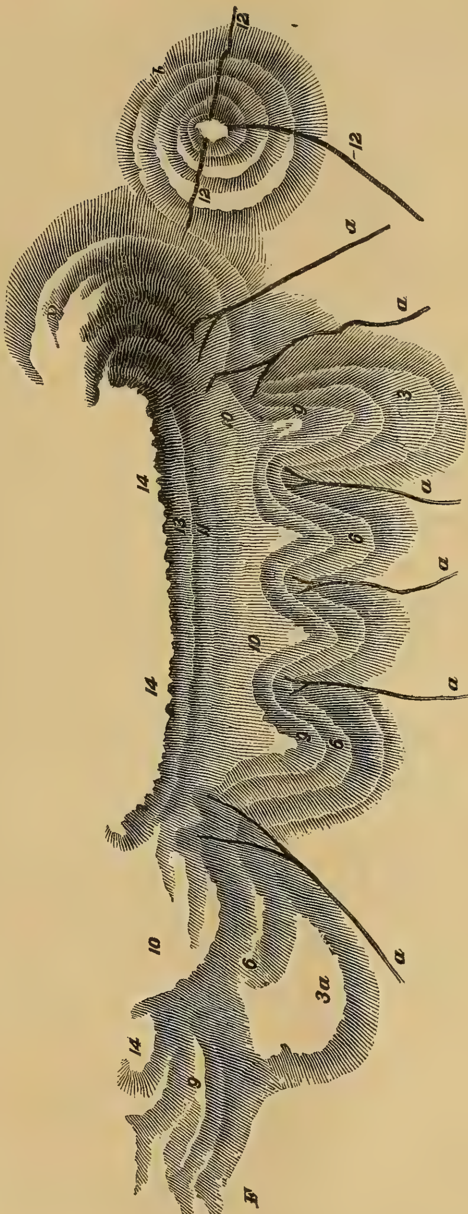
Fig. 9.—*Section on the Upper Zwart Kei, between the Great Winterberg and Groot Tafelberg.*

Distance about 25 miles. Dip of rocks about N.W.



a. Ridge joining the Katberg.
b. Outlier intersected by dykes (12).
1, 1, 1. Fine-grained yellowish sandstone (thickness unknown).
2, 2, 2. Fine-grained purplish-grey sandstone.
3, 3, 3. Reddish shale. 3 *a.* Skulls found.
4, 4, 4. Conglomerate or breccia (?).
5. Plant-bed.
6, 6, 6. Gritty sandstone, very coarse-grained near the top.
7, 7, 7. Shale, about 20 feet, interlaminated by thin streaks of bluish clay.
8, 8. Thin lines of shale, intervening between sandstone.
9, 9, 9. Coarse-grained sandstone (thickness unknown).
10, 10. Dark shale (above 200 feet thick).
11, 11. Coarse-grained sandstone.
12. Dykes in outlier.
13, 13. Very hard compact sandstone (about 30 feet).
14, 14, 14. Basalt blocks.
15, 15. Beds of sandy shale, which thin out.

Fig. 10.—*Contour-plan, showing successive exposures of Strata in the Upper Zwart Kei.* (Section, fig. 9.)



a, a. Valleys and lines of drainage towards the river. *b.* Outlier. Numbers as in fig. 9.

opposite side of the same basin—namely, from the Upper Zwart Kei, north of the Winterberg, and 60 or 70 miles S.S.W. of Dordrecht. The sketch map (fig. 10) is to explain how the sides of this range of hills are worn away, rising from the more level ground to the top of the ridge. In the section the outlines of the Great Winterberg and the Groot Tafelberg are shown in the distance, to mark the relative positions in which they are seen from this point.

On the top of this ridge is found at 14, 14, a mass of enormous blocks of disintegrated basalt capping its edge. Similar blocks are found at a lower portion of the ridge resting on No. 9. No. 13 is a very hard compact sandstone, weathered into vertical lines until it has assumed an almost columnar or basaltic appearance; but on being broken, it displays distinct lines of horizontal stratification. It forms a precipice some 30 feet high along the face of the hills. Below this is a coarse-grained sandstone (No. 11, 11), sloping away to the bed of shale (No. 10) immediately underlying it. This shale is upwards of 200 feet thick, and of a much darker colour than the shales below; no fossils have yet been found in it. It forms a sloping shoulder all along the hills, as shown on the left of the section; and its position in the map is at 10, 10, 10. It rests upon a coarse-grained sandstone (No. 9), the exact thickness of which is unknown. This covers a sandy shale (15), about eight feet in its thickest part, and gradually thinning out. In this shale (15) Mr. Donald White discovered the fragment of bone D. S. 39*, and the fossil D. S. 40*. Below this is a shale (7, 7, 7), varying in thickness, and about 20 feet where thickest, interlaminated with thin streaks of bluish clay, and near the top discoloured with innumerable specks of carbonized matter. No. 6 is a gritty greyish sandstone (specimen D. S. 45*), about 200 feet thick. This becomes exceedingly coarse-grained in the uppermost beds. In its lower portion were found the reptilian skull (D. S. 35*) and the fragments of bone (D. S. 36 and 37*); at the spot marked "5" the lowest band is quite a plant-bed, of which D. S. 38 and D. S. 43 and 44 are specimens*.

No. 4, beneath this, is a concretionary sandstone (see specimen D. S. 46*), containing fragments of shale and quartz, together with nodules, such as those sent† (Nos. D. S. 29 to D. S. 34). Three beds of similar rock occur in the outlier *b*. At one spot, as in stratum 3, it appears as if the shale had been cut through by some stream or current down to the sandstone beneath, and the nodular sandstone (4) deposited in the space thus denuded. If this supposition be correct, the banks of this ancient stream must have been at

* D. S. 35. Small skull in sandstone, with calcareous cement. 36. Bone in similar sandstone. 37. Bone in concretionary calcareous sandstone. 38. Fine-grained concretionary calcareous sandstone as above, with *Calamites* (?). 39. Sandstone, with calcareous cement, containing bone. 40. Tooth in calcareous sandstone, as 39; the other part of the specimen is greenstone. 43 and 44. Fine-grained sandstone, with highly calcareous cement, and containing *Pecopteris* (?). 45. Fine-grained sandstone. 46. Concretionary, fine-grained, calcareous sandstone, with some films of shale.—T. R. J.

† Sandy, chatoyant, radiating calcite.—T. R. J.

least 25 feet high. But whatever may have occasioned this deposit, the other beds (4, 4, 4) have had a similar origin.

It was in the lowest bed of shale (3, 3, 3), especially at 3*a*, where it is 25 feet thick, and of a reddish colour*, that the greatest quantity of reptilian remains were found. Some of them appear to belong to undescribed animals; others, from a cursory view, seem as if allied to *Micropholis* †. Nos. 26 and 27 are remarkably beautiful and perfect, showing rows of exceedingly minute teeth. No. 24 seems almost identical with another little skull that was obtained from the rocks near Whittlesea, most probably a continuation of the same strata. The portions of the reptilian skeleton (D. S. 10 to D. S. 16) are also exceedingly interesting, on account of the perfect preservation of the bones of one of the legs. When first got out of the rock, a few of the bones of the foot were attached; but these were unfortunately lost in removing them: even those that are left seem to characterize an animal of more terrestrial habits than many of those already known.

It is to the energetic zeal of Mr. Donald White that I am indebted for the valuable specimens marked respectively D. S. 10 to 40 and 43–47, and also for much valuable information with regard to this locality ‡. At the spot marked 3 *a* he obtained nine skulls in the course of one day's search.

The denudation of the lower part of this range of hills is very different from that of the higher part occupied by the shale "10." The sandstones, interbedded with the shales, are cut into along the range by numerous kloofs or ravines—the strata forming projecting shoulders between them (as shown in the map, fig. 10), and rising in steps from the more level ground to the slopes of stratum 10, thus forming a marked contrast to the latter.

Below the fossiliferous shale (3), and just below where it is the thickest, the sandstone, a few feet in depth, has a purplish-grey tint (No. 2, 2), as if a portion of the colouring-matter of the shale above had permeated the sandstone to that depth; below and continuously with this the sandstone is fine-grained and yellowish, and is the lowest exposed rock of the series.

The outlier *b* is somewhat different in character from the range of hills. In it the shales are wanting, except at the point 7; and they are replaced in a great measure by the sandstone (4, 4, 4) before described, and which we may imagine to be the deposit of a current deflected from time to time from one part of the area to the other.

On the opposite side of *b*, and also round the shoulder of the mountain at D, the shales are much more largely developed than on this side; but no section has yet been made of them.

Further, three dykes (12) traverse the outlier, converging towards a

* Very fine-grained, purplish-red, nodular, argillaceous sandstone, calcareous near the bones.—T. R. J.

† Quart. Journ. Geol. Soc. vol. xv. p. 642.

‡ The specimen marked D. S. 41 (large skull, in two fragments of rock) was given to me by Mr. Powell. The specimen D. S. 42 was found by myself at the Queenstone Quarries; it is of hard grey sandstone, with a large plume-like plant on it.

central point at the top (see map, fig. 10). There is no displacement or alteration in the composition of the strata where they come into contact with the dykes. Dr. Rubidge thought that such dykes were formed by cracks due to the shrinking of the strata, and filled up in the same manner as deposits are supposed to take place in some mineral veins.

The combined thickness of strata in the two sections (figs. 8 and 9) amounts to about 1200 feet for this portion of the Dicynodon or Karoo formation; but this is evidently but a very small part of their entire thickness; for, taking the dip from the Zwart Kei to the Stormberg, at angles varying from 4 to 7 degrees towards the N.W., and on the Dordrecht side of these mountains, dipping at the same angles towards the S.E., it is highly probable that the central thickness of this portion must be enormous. Very little will be known of their true history until the sections of every intervening mountain-side are fully described. Some time, however, must elapse before this can be accomplished, as many parts of the country are still occupied by the native tribes.

Dr. Livingstone's discoveries seem to throw some light on the origin of this formation, viz. an elevated plateau, with successive chains of lakes and marshes, that have been silted up, and subsequently the basins we find in the present day denuded out of the strata thus formed.

Accompanying the fossils mentioned in this paper, I have sent a packet given to me by Mr. C. W. J. Powell, and collected by him near the Upper Zwart Kei*. The large skull, so remarkable for its peculiar rows of small teeth (D. S. 41. Probably Labyrinthodont. —T. R. J.), was also found in the same neighbourhood by Mr. Powell; but I am not able to point out the exact strata from which any of these were obtained. I have also enclosed casts of stems from Kneehalter's Neck, given to me by Mr. John M'Donald†.

Section of the Stormberg on the Klaas-Smit's River.—After finishing my account of the Dordrecht and Zwart Kei sections, I obtained much valuable information with regard to a section of part of the south face of the Stormberg from Mr. Charles Evans ‡, who has explored a large portion of the range in search of coal.

This section (fig. 11) illustrates some of the strata between the other two, near the synclinal axis of what I will term "the great Stormberg basin"§.

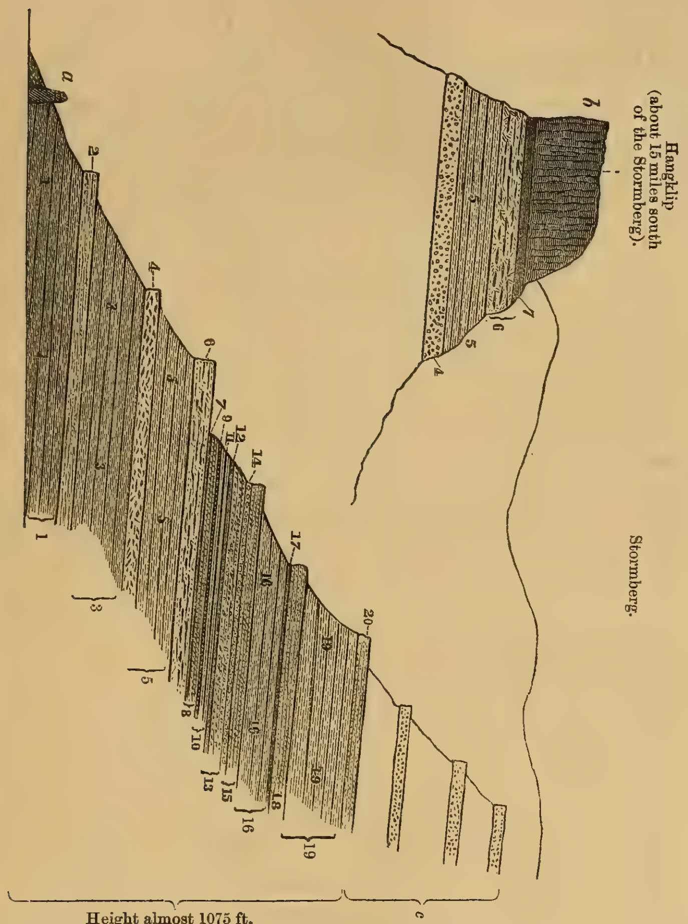
* No. 1. Rippled, fine-grained sandstone. 2. Ferruginous sandstone, with obscure surface-marks. 3. Very fine-grained sandstone, bearing mud-ripples. 4. Sandstone, with cast of *Calamites* or *Equisetites*? 5 and 6. Obscure casts. —T. R. J.

† Nos. 7, 8, and 9. Sandstone casts of small portions of striated stems (*Equisetites* or *Calamites*?).—T. R. J.

‡ For some notes by Mr. Evans of Queenstown, on the Coal of the Stormberg, see the 'Mining Journal,' Jan. 14, 1871.—T. R. J.

§ It is worthy of remark that, as in other instances more numerous than they were once thought to be, the Stormberg range is a synclinal mountain; for, as has been shown at Dordrecht, Buffel Doorns Flat, &c., the strata of the north and south dip towards and into it.

Fig. 11.—*Section on the South Side of the Stormberg, at the source of Klaas-Smit's River.*



a. Trap dyke.
b. Trap capping the Hangklip.
c. Strata not examined.
1. Rather deep brownish-red shale.
2. Sandstone.
3. Light brownish-red shale.
4. Sandstone.
5. Shale, lighter than Nos. 1 and 3.
6. Sandstone, with leaves and wood, coal and black shale.
7. Light-brown hard shale.
8. Alternate layers of light shale and coarse sandstone.
9. Sandstone.
10. Black shale, with seams of coal.
11. Pipe-clay.
12. Bluish-brown clay.
13. Gritty ferruginous sandstone.
14. Ironstone nodules.
15. Rather fine grey sandstone.
16. Dun-coloured shale.
17. Yellow clay.
18. Very fine-grained sandstone.
19. Light-coloured shale.
20. Fine-grained sandstone.

This section is from that part of the mountains where the Klaas-Smit's River (the "Hokili" of Hall's Map) takes its rise. The better to explain its position relatively to the two others previously described, I send a rough sketch-map of the intervening country, (fig. 12).

The lowest exposed stratum (1, 1) is a rather dark brownish-red shale, about 150 feet thick, full of minute specks very much resembling mica. On this is a very fine-grained greyish sandstone. It forms a precipice about 40 feet high; and this is the case with every succeeding sandstone, the shales sloping from the one sandstone to the foot of the other, which rises at once precipitously 40 or 50, and, in the case of stratum No. 6, nearly 75 feet, forms a kind of terrace a few feet wide, or, as on the surface of the last-mentioned stratum (6), one of several yards in width, and then slopes up again to the foot of the next sandstone at the higher level. No. 3 is a shale of about the same thickness as the one below, and very similar in character, except that it is of a lighter colour. Upon this rests a sandstone (4) containing abundant impressions of leaves and very thin layers of fossil wood. The next shale (5) is still lighter in colour than the preceding one. Over this is No. 6, a rather gritty, light-brown sandstone, also containing numerous impressions of leaves, similar to those found in No. 4, as well as fossil wood; also streaks of fine coal and black hardened shale. These small patches of coal appear to have been accumulations of vegetable matter in hollows on the uneven surface of the sandstone beds at the time of deposition. Above this is a bed (7) about one foot thick, composed of thin layers of a light-brown hard shale; a number of thin alternate layers (No. 8) of light-coloured shale and coarse sandstone, containing round nodules and pieces of fossil wood, succeed. These nodules contain the same kind of ochres as some of those found in the Dordrecht section (page 525), the contents of which were made use of by the Bushmen. Next comes a thin sandstone (No. 9), and upon that six feet of black shale (No. 10), containing a number of seams of coal varying from an inch to a foot in thickness. This is the "Stormberg coal deposit." I have seen a spot where this coal-shale is 14 or 15 feet thick. It is found cropping out at intervals for many miles along the face of the mountains; it also reappears on the northern side of the range; but the sections on that face have not yet been examined. In this deposit (at 11) there is a remarkable band of very fine yellow and white pipe-clay, about two or three inches thick, its colour offering a marked contrast to the black shale and its accompanying coal-seams. No. 12 is a stratum of bluish-brown clay, almost shaly. No. 13 is a gritty ferruginous sandstone, containing nodules (very similar to those sent as specimens from Dordrecht) and quartz-pebbles. Upon this lies No. 14, consisting of a thick band of ironstone nodules. It has been thought that the infiltration through these strata, especially No. 13, into the coal-shales below has injured the quality of the coal found in them by impregnating it with mineral matter, from which that found in No. 6, in the small

Fig. 12.—*Sketch-Map showing the relative position of the Sections* 8, 9, *and* 11.

a. Position of Section at Dordrecht (fig. 8). *b.* Position of Section on the Upper Zwart Kei (fig. 9). *c.* Position of Section in the Stormberg (fig. 11).

hollows above described, is free. Above the bed of nodules rises an abrupt precipice (about 40 feet high) of grey sandstone, of rather a fine texture. Above this a dun-coloured shale (16), 140 or 150 feet thick, slopes upwards to No. 17, which is a band of fine yellow clay about a foot thick. From this another precipitous face of about 40 feet (No. 18) of very fine-grained sandstone rises, and above this is a light-coloured shale nearly 200 feet thick. No. 20 is another fine-grained sandstone. The unexplored rocks above this rise some 500 feet, in three successive tiers, as shown in the section. The precipitous portions are sandstones; and it is highly probable that the intervening spaces are occupied by shales. Near the foot of the mountain (at *a*) a dyke makes its appearance, but, as in the other instances mentioned, without causing any change either in the position or character of the rock through which it passes. The rocks here described add another 1000 feet to those before mentioned.

The circumstance that makes this section of the Klaas-Smit's River of great interest is that here are found the *first* indications of connecting links of the strata north and south of the Stormberg range; and thus the equivalents of 4, 5, 6, and 7, near the bottom of that part of the mountain now under examination, are to be found almost at the top of the Hangklip (which is the culminating point of some mountains nearly sixteen miles further south) immediately under the precipice, at a height of 6500 feet above the level of the sea. Further, the yellow clay at "17," the gritty, noduliferous, and ferruginous sandstone "13," and bluish-brown clay "12," remind us of the very similar deposits found at Dordrecht (Section, fig. 8), described at page 523; and it is to be hoped that before long other sections may be obtained that will throw still further light upon this interesting subject.

Part III.—The Climatal changes of South Africa (Eastern Province and the vicinity), as indicated by its Geology and Fossils; and especially the Glacial Denudation of the Karoo Strata.

The consideration of the climatal changes that have taken place in this portion of the ancient world during the deposition of the various formations treated of in the first part of this memoir will lead me to make some remarks upon the probable cause of the denudation of a large portion of the Dicynodon-rocks in the Eastern Province.

Tertiary Climates.—The evidence of the Pliocene shells of the superficial limestone of the Zwartkops heights and elsewhere leads us to believe that the climate of South Africa must have been of a far more tropical character than at present. Take, for instance, the characteristic *Venericardia* of that limestone: this has migrated along the coast some 29 or 30 degrees, and is now found within a few degrees of the equator, near Zanzibar, gradually driven, as I presume it must have been, further and further north by a gradual lowering of the temperature of the more southern parts of this coast since the limestone was deposited.

During the formation of the shell-banks in the Zwartkops estuary, younger than the Pliocene limestone, the immense number of certain species of shells, which have as yet been found living only in latitudes nearer the equator, point to a somewhat similar though a more modified change of temperature.

These, however, do not seem to have been the only periods when this part of the world had a temperature different from that it now possesses. In the Jurassic times the shells of the *Trigonia*-beds indicate a tropical or subtropical climate.

Nor are evidences wanting that there must have been vast intervening periods when the climate approached to something like antarctic severity. A question worth asking is, What can have been the cause of the enormous accumulations of conglomerate at Enon, at the sources of the Zwartkops, at Hankey, and elsewhere? Dr. Atherstone thus writes* of this formation at Wit-water river:—"the whole range of hills was actually formed of these rounded pebbles;" "the further we went the higher the cliffs became;" "a red clay formed the cement which bound them together;" "cliffs 200 or 300 feet high." In the Kloofs at the sources of the Zwartkops this conglomerate is described by him as "piled up 300 or 400 feet high;" at Venster-Hoek, Hankey, it is "740 feet high," "composed entirely of this Enon conglomerate," with a matrix of "soft red sand."

Surely this enormous accumulation of water-worn pebbles† was brought about by no common action of the sea-waves and ocean-tides! but rather by the piling-up of worn fragments of rock on a stormy ice-bound coast under an extreme condition of climate‡.

Configuration and origin of the Karoo Beds.—During the last few years I have had several opportunities of examining portions of the Katberg and Stormberg ranges; and in many places they give (as far as I can judge) strong evidences of having been subjected at a remote period to the force of *ice-action*, and, indeed, that this has been the great denuding agent of the Dicynodon-strata. After a residence of nearly six years, the conviction has been forced upon me that this denudation can be attributed to nothing else than to the action of *glaciers* through an incalculable period of time. It seems almost impossible that ordinary atmospheric agencies could have eroded the surface so deeply and extensively, and carried away vast tracts of strata that not only once occupied the area of the wide plains and valleys now extending between the different branches of

* Eastern Province Magazine, vol. i. (1857), p. 523 &c.

† The "Enon Conglomerate" has also been noticed by Bain and Atherstone as occurring in the George district, Cape of Good Hope.—T. R. J.

‡ The suggestion of Dr. Sutherland that the great breccia-band at the base of the Karoo formation in the Cape Colony and Natal is a boulder-clay of glacial origin (Quart. Journ. Geol. Soc. vol. xxvi. p. 514), is consonant with this view of a severe antarctic climate having again and again obtained in South Africa.—T. R. J.

the mountains, but may have even constituted unknown thicknesses above their present tops.

With regard to the rocks themselves, of which these mountain-ranges are composed, much is yet to be learnt, and to arrive at a satisfactory conclusion about them will yet be the life-study of some future geologist. Many questions of great interest and importance have yet to be answered, thus:—Were these strata really of lacustrine origin? and if so, were these extensive and thick deposits formed during a subsidence? If so, what were the outer barriers of such wide-spread "lacustrine" deposits, effectually cutting off all communication with the ocean during the deposition of sediments, it is said, of some 6000 feet? Or were they laid down when the region was considerably above the level of the sea? The Dicynodon formation is cut across by the oblique sea-coast near the Gualana River, and extends northward thence into Natal; its boundary therefore on the south-east has disappeared in the present ocean.

Proceeding from the sea inland, through Albany, the country rises in a succession of vast steps, as shown in the outline-section, fig. 13.

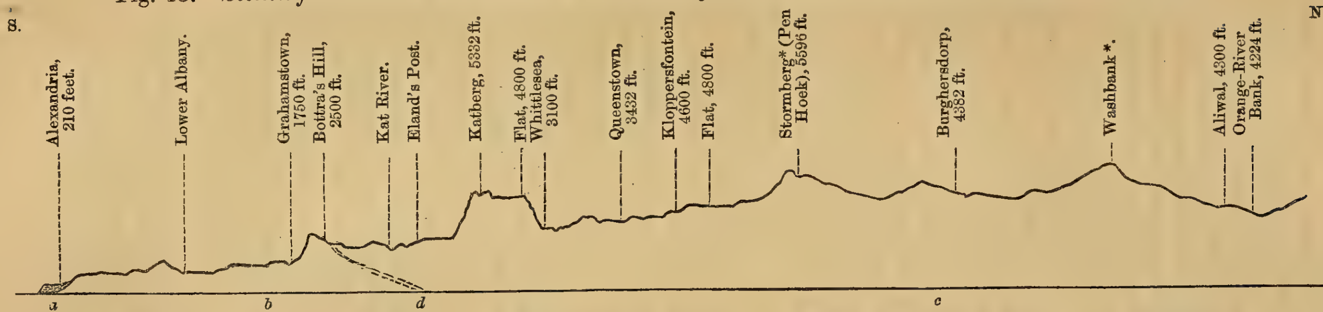
The most recent of the Karoo deposits are to be found in the Stormberg*; and the whole face of this range (as is plainly seen on approaching it) is composed of horizontal strata. Here, again, the question arises, What could have formed the boundary of a formation that shows so little evidence of displacement as the elevated strata of these mountains? Again, Do these constitute one continuous formation? Were they the vast deposits of a single lake, or, rather, of many successive lakes? It is probable that, on a closer examination, the latter will prove to be the case, and that this extensive series of strata may be divisible into several limited and overlapping groups of deposits. To explain this, I have sent a section (fig. 14) of that part of the formation to which this paper principally refers. The synclinal structure indicates that one basin must have extended from the neighbourhood of the Katberg on the south to near the Washbank on the north. Thus the dip of the strata of the Queenstown hills is from 5° to 6°, and at the Bongolo Neck 5° N.N.W.; on an offshoot of the Stormberg, near the Buffel-Doorns Flat, 5° N.N.E.; at the foot of the Stormberg 4° to 5° N.N.E.; while at Dordrecht, on the other side of the mountains, at one spot the dip is 4° to 5° S.E., at another 6° to 7° in the same direction, and some twelve miles nearer the Washbank it is 5° to 6° S.S.E. These dips seem to prove this particular basin to have its synclinal axis somewhere about the centre of the Stormberg range, and that, should the strata be *continuous*, the deposit must be of enormous thickness.

Not only must the period of deposition of such rocks have been of immense duration, but so also must that of their denudation, from the time of the breaking of the original plateau† (of which the

* Quart. Journ. Geol. Soc. vol. xxiii. pp. 143 and 172.—T. R. J.

† Such a plateau must have been similar to that in Dr. Livingstone's ideal section of South Central Africa.

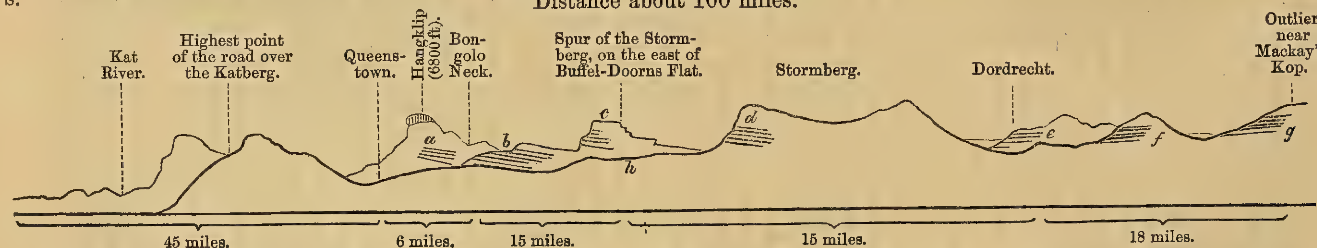
Fig. 13.—*Section from the Sea at Alexandria to the Orange River, about* 200 *miles.* (Section V of Author.)



a, Tertiary, on Jurassic, on Palæozic. *b*. Carboniferous or Devonian. *c*. Karoo or Dicynodon strata. *d*. Great Breccia.

* During the winter months there are constant and severe frosts on the Stormberg range, and the snow frequently remains for weeks together on the Washbank.

Fig. 14.—*Section showing the dip of the Upper Karoo Beds from Beaufort to the Washbank.* (Section W of Author.) Distance about 100 miles.



a. Dip 6° N.N.W. *b*. Dip 5° N.N.W. *c*. Dip 5° N.N.E. *d*. Dip 5° N.N.E. *e*. Dip 5° S.E. *f*. Dip 7° S.E. *g*. Dip 6° S.S.E.

table-tops of such mountains* as the Winterberg, the Groot Tafelberg, the Twee Tafelbergen, Houder Neck, the Mostert Hoek mountains, and Hangklip, near Queenstown, are the evident monuments) to the excavation of the deepest valleys in the existing flats.

Whether or not all these Karoo strata were deposited under a uniform climate it is difficult to prove; but that there was some difference between the climate of the Dicynodon period and the present seems to be indicated by the section (fig. 8) of the Upper Stormberg, exposed near Dordrecht. These strata are now about 5000 feet above the level of the sea. One bed, 10 feet thick, is composed of a fine conglomerate of small fragments of quartz, and can be traced wherever the side of the mountain is sufficiently bare. The only locality, at present known, whence such quantities of quartz could be derived is the Washbank. Immediately above and below this band of conglomerate is a coarse gritty sandstone. The one above is of a yellowish ochre colour, containing coarse nodules, such as Nos. D. S. 2 (D. S. 1 is a specimen of the quartz-grit); in many places it is discoloured with ferruginous patches. The one below is the zone of fossil wood, which is found in abundance, evidently the remains of a primæval forest. In some places there are trunks of trees between 20 and 30 feet long, and great numbers of segments *erect* in the position in which they grew; these latter are often more than 8 or 9 feet in circumference. The fossil wood is found wherever this coarse sandstone makes its appearance. The specimens that have been examined are pronounced to belong to the Coniferæ. These last-mentioned strata are amongst some of the latest of the Stormberg formation; and the wide-spread remains of coniferous forests found there seem to point to climatal conditions different from the present, and still more different from those of the old Carboniferous formations of Europe and elsewhere, the plentiful remains of coniferous trees here most probably indicating that such forests flourished in a more temperate climate. In such a climate and in deposits formed under such circumstances it is not probable that such abundant coal-measures would be found as those accumulated in the northern hemisphere. From the wide extent of this fossil wood it is evident that immense tracts of forest must have existed in those ancient times; but from that time to the present an interval has intervened of incalculable duration, during portions of which agencies (yet to be explained) have been in operation that have not only occasioned the denudation above referred to, but have also rendered the country a treeless region. Trees introduced by human agency thrive well; and it is not, therefore, the present climate that has caused the annihilation of forests: we must look to a remote period for an explanation of this as well as the other peculiar features of the country.

Denudation of the Karoo Beds.—The encroachment and retreat of the sea cannot have effected the vast denudation, either during the subsidence or the upheaval of the land; for there is no evidence that any of the strata, except those on the immediate sea-coast, have

* These are all mountains of denudation and not of elevation.

been subjected to oceanic agency: we must therefore look for other causes to account for the vast alteration that the surface of the country has undergone.

Some of the facts that I have been able to collect as bearing upon the case are as follows:—

Katberg, and its Roches moutonnées and Moraines.—Commencing with the Katberg range, we remark that the face of these mountains on the south side, towards the sea, is generally abrupt and precipitous (this is the case with most of the mountains of the Dicynodon formation), while on the north side, as seen along the road, the rocks are all *dome-shaped*, or rounded and smoothed off, presenting a marked contrast to the opposite side. In the descent of the mountains on the north side, on some of the shoulders and in a number of places at high levels, are found large lateral accumulations of angular fragments of rock, of various sizes, generally imbedded in clay. After following the curvings of the long valley leading to Langfield, we find large transverse mounds of drift and boulders, upwards of 60 or 70 feet high, that have afterwards been cut through where the present watercourses run (see Section X). There are also large deposits of unstratified clays, full of angular boulders of every size, from small gravel and pieces of a few pounds' weight to masses of several tons, turned and tilted into every position. I have not had an opportunity of carefully examining these fragments for striæ or groovings. In several instances I have found transverse mounds, rising like small hills, in far wider valleys, and many miles from the high mountain-ridges whence the boulders have apparently come. At the Bolotwa, in the valley in which the Mission-station is situated, are a number of detached "kopjes," formed of large boulders piled together, and imbedded, as far as can be seen, in a matrix of stiff, black, somewhat loamy clay. Here also the boulders are mixed together indiscriminately; in some parts they are very compact, and numbers are of many tons' weight. The largest of these mounds has the side towards the top of the valley quite abrupt, and it there rises to a height of some 70 or 80 feet. From the foot of this one a bed of clay and boulders stretches for more than a thousand yards through the Mission-station, where it appears to rest upon a loose gritty sandstone (very similar to that at a place called the Bongolo Neck, which I shall presently mention) in which large boulders are imbedded. Again, some 12 miles nearer Queenstown there is a high broken ridge of boulders, which the present watercourse of the Inquobo (a torrent in rainy weather) cuts through at nearly a right angle. A small section of this is exposed by a road-cutting; and in two places the boulders are found resting upon stratified rocks (shale), whilst in another they lie on a bed of the same "whirled" sandstone, with its imbedded boulders, as that at the Bongolo Neck (see above); in some parts this ridge of boulders is from 900 to 1000 yards wide, and from about 90 to 100 feet high.

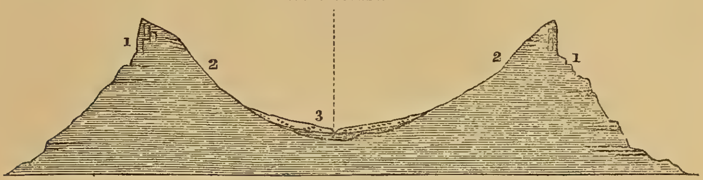
About a mile and a half from this, the whole surface of the precipice along the range of mountains on the south side of the road is smoothed and rounded off in a very remarkable manner. This is just at a bend or shoulder, where a glacier, descending from the northward, would press with the greatest force before turning off to the watershed of the Komani or Inquobo just mentioned. But there are many places where these rounded or dome-shaped rocks are to be found. Thus among these same mountains, near where the Zwart Kei passes through, they are found on both sides of a gorge forming an outlet to an auxiliary branch of that river, near a farm occupied by Mr. Lenard, and through which is an outlet to a basin as large as, although more irregular in shape than, those of Schaap Kraal and the Bongolo (see below). Of this outlet I have sent a sketch (Y). Here the rocks are perfectly rounded off to the height of several hundred feet; it is impossible to imagine how water alone could have produced such an effect. Rocks with similar features occur in another precipitous glen, forming the outlet of a large valley-basin called Schaap-Kraal Hoek (*vide infrà*), near Tarkastad. In this case, on the one side all the rocks are smoothed and rounded, while on the opposite side are beds of unstratified drift intermixed with immense angular boulders. And here, again, we find a portion of this boulder-clay resting upon the same kind of sandstone, with its imbedded boulders and fragments of rock, as at the Bongolo Neck.

Another notable instance of these dome-shaped rocks I noticed on the road from the Rhenosterberg to Cradock. They were outliers, forming small, rounded, bubble-like hills in the middle of a wide flat valley some miles broad.

Basin-like valleys, their moraines, striæ, &c.; *Schaap-Kraal Hoek.*—Another remarkable feature in the denudation consists of so-called flats, but really basins, which seem to have been scooped out of the horizontal strata. It is very difficult to understand how they could have been so excavated by the simple agency of water, or the ordinary atmospheric influences of any climate except an antarctic one. Thus a place before mentioned, Schaap-Kraal Hoek, is an elevated valley some 12 miles long and 6 or 8 broad; it is surrounded on every side by a continuous range of mountains. The outer face of all these mountains is exceedingly abrupt and precipitous, whereas within the basin no precipitous rocks are to be seen; the sides are all smoothed off, gradually sloping from the highest ridge towards the centre, as if the strata that had once filled the intervening space had been scoured out. The inner face of the highest rocks, columnar on the outer precipices, shows lines of stratification. (See section, fig. 15.)

As the elevation of this valley is so near the level of the original plateau, without any inlet through which water could have flowed, one cannot imagine but that the denuding power must have been some such agent as ice that accumulated within the basin itself. Before the eroding of the outlet described above, a far more ancient one existed where the road now passes towards Buissen's Spruit, a branch of the Eland's River, and at the extremity opposite to the present outlet. At both these outlets, where they debouch into the lower country, the mountain-sides are loaded, to the height of several hundred feet, with large mounds of drift, containing angular fragments of rock, intermixed with others more waterworn, impressing one with the idea that they are, in all probability, the remains of *lateral moraines.*

Fig. 15.—*Section showing the denudation of the Schaap-Kraal Hoek.* (Section Z of Author.)



1, 1. Abrupt escarpments of the outer face.
2, 2. Sloping surfaces of the interior.
3. Clay and other alluvium.

Bongolo.—The Bongolo valley, as well as a number of other large valleys around Hangklip, are very similar in regard to the way in which their interiors have been denuded, and also in the precipitous appearance of the outer side of their surrounding mountains. Hangklip, rising 6800 feet above the sea-level, seems to be the culminating height from which these radiate.

Ice-scratches.—The only place where I have distinctly noticed groovings on the surface of these rounded rocks was at a place called Reit-Poort, in the Tarka; and here most of them were so marked. The remote date of the denudation, and the nature of most of the rocks, may explain why so few instances of ice-scratches have yet been noticed.

Buffel-Doorns Flat.—The lines of drainage of the country do not always appear to have been the same as at present, as during the erosion of all these valleys there seems to have been a difference from what obtains now, not only in the level of the interior of these basins themselves, but also in their several outlets; this is seen along the sides of the valley (Buffel-Doorns Flat) represented in section, fig. 16. Here we have three such openings, at three different levels. On the outer side of these outlets there are deep gorges cut through the mountains, leading generally to other wide basins at a lower level; while these, again, are connected, in the same way, with others of a less elevation than those immediately above. The sides of these gorges are frequently covered with heaps of huge boulders of every shape and position, drift, and accumulations of unstratified clay. This succession of outlets is particularly well marked in this basin, on the southern slope of the Stormberg, called Buffel-Doorns Flat. A number of other basins, similar to this, situated among the branches of the same range, have their present drainage through that of Buffel-Doorns. Almost invariably all the *inner faces* of these basins are smoothed off, as has

Fig. 16.—*Section showing the successive outlets on the South and South-east Sides of Buffel-Doorns Flat.* (Section A B of Author.)

a, b, c. Outlets. *d d.* Projecting shoulders, appearing like raised terrace-beaches.

been before mentioned with regard to Schaap-Kraal Hoek, &c., with openings generally tending towards the south or south-east; the outer face of the mountains surrounding them is precipitous and abrupt, as is the case with those previously noticed. If these, under a cold and rigorous climate, were once filled with glaciers, then one is led to believe that the evidence adduced traces their course from the upper valleys of the Stormberg, lower and lower, from one level to another, until they joined at Buffel-Doorns Flat. Here this descending and united force appears first to have broken over the lower barrier at *a* (see section, fig. 16), or it may have made its exit at all three openings, until, either from greater pressure at the point *b* or some other cause, such as the more rapid wearing of the rocks, the débris was carried away to this lower level, until the further erosion of *c*, reducing the level of the drainage still lower, caused it to be diverted finally in that direction. That the level of the strata was at one time the same as that of the respective outlets is clearly proved by remains of them skirting different portions of the plain, looking like the remnants of so many raised beaches at the different levels *d d*.

If the outlets of these different basins were again filled up, the flats would form a series of large lakes, each many miles in extent. In fact they look, even now, more like a number of drained lake-basins than any thing else.

Another thing worthy of notice is, that all the channels of the rivers of this portion of the watershed of the Kei, such as the Klaas Smit's, the Zwart Kei, the Klip Plaats*, the Imvani, &c., cut through the different mountain-ranges at nearly right angles. Along the sides of these openings,

* From the Klip Plaats Mr. Stow has sent specimens,—No. 10, a coarse *Dendrites*, weathered out on the face of a hard ferruginous sandstone (like one sent by Dr. G. Grey: see Quart. Journ. Geol. Soc. No. 106, p. 50), and No. 11, a piece of fine-grained compact sandstone (quartz and felspar), with the cast of a vegetable stem.—T. R. J.

which are outlets such as I have described, extend for miles accumulations of drift and boulders, very different from regular fluviatile deposits; and which seem to indicate that the erosion of the channels in question arose from other causes than those at present in operation in South Africa*.

North of the Stormberg.—On the northern side of the Stormberg, at Dordrecht and the Hot-Spruit (a branch of the Orange River), the same features are equally observable,—the peculiar wearing of the rocks; the large accumulations of unstratified clays, mixed with patches of drift and boulders, both angular and waterworn; and the rounding of the hills that face the *interior* of the valleys. I have not yet visited the district of the Washbank; but Dr. Meintjes informs me that among the mountains there, and which are the highest portions of the Stormberg, there are distinct traces of both lateral and terminal moraines. In a valley near Ladygrey, some 4 or 5 miles wide, he found in the centre a patch of twelve or fourteen enormous angular boulders, standing from 10 to 12 feet out of the ground, and nearly the same in length and breadth. It would have been impossible for water to have moved these masses of rock to such a place†. The evidence in this part of the mountains would refer to far more recent operations than those of which we have before spoken, as the last retreat of the glaciers would be along this range, before the gradual change of climate caused their final disappearance.

British Kaffraria.—Besides the evidence here brought forward, there can be little doubt that an indefinite number of instances of the same description might be collected among these mountains. Not only here, but if we turn to the present coast we there find numerous evidences of the same action that cannot be explained as having occurred through the ordinary agency of water. Within a few miles of Greytown, in British Kaffraria, there is a very remarkable dome-shaped rock, situated on a neck or opening through a high ridge, near the Kabousie. The rock runs across a portion of this neck, and is completely rounded; it is about 350 yards long, and from 60 to 70 feet high. A number of huge boulders are scattered about, as will be seen from the Sketch AC and Plan AE, kindly furnished me by Mr. T. Liefieldt, Resident Government-Agent of the Gaika Tribes. The high ridge on both sides of the neck is perfectly smooth, and no other rocks are visible for miles.

Kaga and Krome Mountains.—On the southern side of the Kaga and Kroome mountains, branches of the Great Winterberg, we also obtain evidence indicating that other agencies have been at work besides those of a purely aqueous nature. Extensive flats are

* See the late R. N. Rubidge's paper on pluvial denudation in South Africa. Geol. Mag. No. 20, Feb. 1866, p. 88.—T. R. J.

† I have frequently seen large angular boulders, 10–12 feet in diameter, with the uncovered part 9 or 10 feet out of the surrounding clay, in the centre of a wide valley, where it would be impossible to explain how such ponderous masses could have been transported by the force of water.

covered for many miles with clay, and innumerable angular fragments of rock are thickly strewn over the surface. At Beaufort this unstratified clay is from 30 to 40 feet thick. In Lower Albany, again, similar angular pieces of rock are spread over a large extent of country; some of the latter fragments I have found with one or more polished surfaces. Some of the Dutch farmers offered to explain the circumstance by stating that the polish was occasioned by the wild bucks rubbing against them; but as they were often in such positions that the bucks could not get at them, such an explanation cannot be received.

Glacial agency.—Future investigations may modify some of the conclusions I have arrived at; but here are a number of phenomena that cannot be well explained by the theory of ordinary atmospheric and aqueous agencies,—the rounding-off of the hills in the interior of these ancient basins; the numerous dome-shaped rocks; the enormous erratic boulders, in positions where water could not have carried them; the frequency of unstratified clays; clays with imbedded angular boulders; drift and lofty mounds of boulders; large tracts of country thickly spread over with unstratified clays and superimposed fragments of rock; the Oliphant's Hoek clay and the vast piles of Enon Conglomerate—all these seem to indicate periods when the climate was far more severe than at present: these are phenomena, in fact, which in other countries are considered to indicate accumulations and deposits requiring the wearing action of ice and extreme cold to account for their production.

Succession of Periods &c.—Having thus tried to point out the probable causes of the vast denudation of the Dicynodon strata, I cannot help believing that it did not all take place at the same period; the Enon Conglomerate and the enormous gaps that I noticed as occurring between some of the different coast-formations seem to point to this. Another evidence of the same kind appears to be the remarkable "whirled" rock that I have alluded to (p. 539), found on the north side of the Bongolo Neck. This rock was evidently at one time the outlet of the present Quoquodala basin, before the deeper opening towards Glen Grey was formed. In this place we not only find unstratified clay with boulders, but this again is placed upon what I have called a "whirled" sandstone, because it looks as if, while it were yet soft, it had been stirred up, and rolled together by ice enveloping the boulders imbedded in it (Section AD). These last are mostly angular, and occur in every position, not having been deposited according to size, as would have been the case had water been the agent. This sandstone is evidently far more ancient than the superincumbent clay, which appears almost recent in comparison.

There seems little doubt that the whole of the Dicynodon formation, since the close of the period when its last strata were deposited, has been high above the level of the sea, and its elevated position has prevented any great accumulation of soil taking place; for since the great denudation, and since the present transverse river courses have been cut through the mountains (although, as I have before noticed, the closing up of these openings would turn large portions of the present flats into wide lakes), there are no traces of more recent lacustrine deposits that I know of; so that, with the exception of the unstratified clays and boulder-clays, and a little alluvial soil, nothing is found, in *this portion* of the area, of later date than the present drainage-system. This has, no doubt, tended in a great measure to prevent a spontaneous renewal of timber-growth after the extinction of the ancient forests (see p. 538), the soil having never been renovated by new deposits formed beneath the ocean, as it has in other countries. It must also be more difficult for the seeds of trees and plants to ascend to an elevated plateau than to spread over plains on a lower level, or just emerging from the waters.

Conclusion.—The foregoing collection of facts must, I think, tend to prove that vast climatal changes have taken place during the deposition of the various formations that have been brought under review in this and the foregoing portions of my paper. It may be objected that, with regard to such an extreme climate as is here inferred, South Africa is too far removed from the present Antarctic regions, and that the causes of great changes of climate are not understood.

The simple oscillation of the poles, however, taken together with the continual and necessary alteration in the distribution of land and water, would be surely sufficient to account for all the phenomena yet known, changing not only the geographical configuration of the surface of the earth itself, but carrying with it the most important changes of climate over every portion of the earth.

In such a case, when the London area possessed a tropical climate, the spot now occupied by Algoa Bay would be at some 68° south latitude; or when the site of modern London was within or near the Arctic circle, Algoa Bay would be within 5° or 6° of the equator, with a temperature congenial to the existence of the large *Venericardia* of the Zwartkops Pliocene limestone (p. 534). In the former case, South Africa would then possess (instead of mountains covered, as at present, with snow for a few days in winter) an Antarctic cold, with an ice-bound coast, and glaciers covering every portion of the country.

Lastly, I have to notice in connexion with the geology of South Africa the rare occurrence of the remains of either fish or mammals. What has opposed their preservation? And further, was South Africa the home of large Pachydermata during a period equivalent to the Mammoth age?

Until within a very few years, the rivers of South Africa swarmed with Hippopotami; and large herds of Elephants roamed over the wide plains, which were also the home of the Giraffe and the Rhinoceros, and where the large Carnivora, Leopard, Panther, and Lion, preyed upon the weaker animals. Are we, then, to find, in our Pliocene deposits, Ostriches of gigantic size, enormous Lions, and Elephants eclipsing the Mammoth itself—analogues of the great Marsupials of Australia, the Mylodon, Megatherium, and Glyptodon of South America, the Mastodon and Mammoth of the Northern

Hemisphere outvying the present inhabitants of those parts of the earth? This interesting problem will have to be solved by future geologists.

Appendix: on the probable existence of an ancient Southern Continent.

The many similar forms of life, either fossil or recent, that are found scattered over various parts of different countries now so widely separated by the Indian and Pacific Oceans, seem to indicate that in very remote periods they must have been more intimately connected with each other than they are at present.

To those who believe that all the species of the same genus, and that in all probability all genera of the same family, have a common origin, it will appear almost self-evident that it must have been so. Thus remains of Dicynodont Reptiles and Labyrinthodont Amphibia are found both in India and South Africa, "affording," as Professor Huxley stated in a paper upon those from the former country, "new and interesting links with the fossil fauna of the Karoo beds of South Africa." In another paper he said, "There are two other forms of Labyrinthodonts which exhibit many similarities to the *Micropholis*. These are the *Brachyops laticeps* of Prof. Owen, from Central India, and a new form allied to the *Brachyops*, but distinct from it, from Australia, the *Bothriceps australis*."

It is not only in the fauna of the Dicynodon formation, but in the flora also that connecting links are found; thus a *Glossopteris* that has frequently been found in the Karoo and others from India and Australia are so nearly allied to each other that a high authority has stated that he "can find no specific distinction." With regard to this flora Mr. Tate, in his paper "On some Secondary Fossils from South Africa," says that it "presents close analogy with that of the coal formation of Eastern Australia, and the plant-bearing beds of Burdwan and Nagpur in India. The characteristic plant in each of these deposits is a *Glossopteris*; and it seems that the Indian, Australian, and South-African plants are specifically identical."

Amongst the fossil Mollusca of the succeeding Uitenhage formation we find many other such connecting genera. Thus the *Exogyra*, *Trigonia*, *Cucullæa*, *Pinna*, and *Crassatella* of the Sundays and Zwartkops strata find their representatives in Mauritius, India, and Australia, the *Crassatella* extending as far as New Zealand. With regard to the plant-bearing beds of this series, Mr. Tate writes*, —"Of the four species of *Pecopteris*, one is not satisfactorily distinct from *P. lobata* of India; and two others are closely allied to *P. indica*, also from the Jurassic plant-beds of the Rajmahal Hills. . . . . . *Asplenites lobata* is common to these Indian and African strata; and though, with one exception, they are distinct, yet, on the whole, the Jurassic plants of South Africa recall those of Scarborough and the Rajmahal Hills."

* Quart. Journ. Geol. Soc. vol. xxiii. p. 148.

The *Pectunculus* and *Perna* of the Zwartkops Pliocene limestone, the *Cardium*, the large *Natica*, *Loripes*, *Panopæa*, and *Akera* of the more recent formations, are found spread over the same extensive areas as those previously mentioned. Of the recent flora the 'Encyclopædia Britannica' gives the following:—"On the coast of Guinea and Congo the flora is intermediate between that of America and Asia. Species of *Sorghum*, *Sterculia acuminata*, the Kela-nut, and the Poison-bean of Calabar belong to this region." "In Chili there are many genera of Composites which are also represented in Australia and the Cape of Good Hope."

The most recent evidences of an ancient southern continent consist most probably in the wide-spread coral-reefs and islands in the Indian and Pacific Oceans, extending from the southern portions of the Red Sea and the northern part of the Mozambique Channel on the west, to the Island of Ducie in the extreme east, thus including the Seychelles, Madagascar, Mauritius, parts of the coast of Australia, New Caledonia, the Pacific Islands, to the before-mentioned Island of Ducie; and on the north of the Equator the Caroline Islands, the Marianne and Philippine Islands, the Chinese Seas, along the

Fig. 17.—*Outline Sketch taken from Andrie's Neck.*

The dotted line *a b* indicates the level of the ancient plateau.

southern coast of Sumatra, and the Maldives and Laccadives, on the west of the Indian peninsula. As most of the species of the different corals forming these reefs cannot exist in water beyond a certain depth, the deep sea at present intervening between such widely separated groups of islands would have formed an impassable barrier to them; and thus the conviction seems forced upon us that most of these coral-reefs are now crowning the tops of the ancient mountains of a subsiding continent, along the shores of which the various genera of shells and other animals could have migrated—as much as we are impressed with the belief that the table tops of the Great Winterberg, the Groot Tafelberg, the Twee Tafelbergen, and others previously mentioned (see sketch, fig. 17) prove the existence of the elevated plateau that must at one time have occupied a large portion of Southern Africa.

Table of Elevations from Eland's Post (Kat River) to the Banks of the Orange River, near Aliwal. Taken by Mr. A. N. Ella, Government Inspector of Roads, and Mr. J. Graham, of Aliwal.

Locality.	Graham.	Ella.
	feet.	feet.
Eland's Post, Kat River	2200	
Katberg, highest point of road ...	......	5332
Ditto, flat on the north side, near road..................................	4800	
Whittlesea..............................	3100	
Queenstown	......	3432
Klopper's Fontein......................	4600	
Flat between Klopper's Fontein and foot of Pen Hoek	4800	
Foot of Pen Hoek, Stormberg......	......	5068
Summit of ditto, ditto	......	5596
Burghersdorp	......	4382
Aliwal	4300	
Banks of Orange River, near Aliwal	......	4224
The flat around Bloemfontein, capital of the Orange River, Free State	5300	

Locality.	Hall.	Hall.
	feet.	feet.
The Great Winterberg is the culminating point of the Kat and Winterberg Mountains.........	7800	Gaika's Kop, 6800
Hangklip is the culminating point of the Andriesberg, an outlier of the Stormberg	6800	
	Lieut. Sherwell.	
Spitzkop or Compassberg is the culminating point of the Stormberg and Sneewbergen	10,259*.	

* Monts-des-Sources, in Basouta-land, is said to be the highest point in South Africa; but its exact height is not known.

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ALPHABETICAL INDEX

TO THE

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

[The fossils referred to are described, and those of which the names are printed in italics are also figured.]

THE END.

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THE

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1871.

PART II. MISCELLANEOUS.

CONTENTS OF PART II.

Alphabetically arranged—the Names of the Authors in capital letters.

TRANSLATIONS AND NOTICES

OF

GEOLOGICAL MEMOIRS.

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1. Phylloceras *in the* Jurassic Series. By Dr. M. Neumayr.

[Imperial Geological Institute, Vienna, June 30, 1871.]

The abundance of species of this genus is a palæontological characteristic of the Mediterranean Jurassic rocks, their occurrence being comparatively rare in those of the neighbouring middle European region. In any well-known deposit containing these Cephalopods, four chief types of *Phylloceras* may be distinguished; the representatives brought together from all horizons constitute four great series of forms, besides which a few isolated species occur. The members of each series, nearest in geological age, present a striking mutual affinity, although the differences between them, accumulating in the same direction, produce a considerable discrepancy between the oldest and the youngest forms. In the first place, the *sutural line* is continuously modified in one direction, the division and complication of the *sellar leaves* gradually increasing. Analogous, but less important, modifications take place also in the *sculpture* of the shell; but very little regularity is noticeable in the modifications of the general form, transverse section, &c.

The four series of forms distinguished by the author are as follows :—

1. Series of *Phylloceras heterophyllum*.—Sculpture of shell only simple radial striæ or folds; saddles slender, nearly symmetrical; termination of the first lateral saddle of the inner side one-leafed. The species of this series are :—

Phylloceras heterophyllum, *Sow.* Upper Lias.
—— trifoliatum, sp. n., Inferior Dogger.
—— Kudernatschi, *Hauer*. Klaus beds.
—— Kunthi, sp. n. Kelloway group.
—— plicatum, sp. n. Oxford group.
—— isotypum, *Ben.* *Aspidoceras-acanthicum* beds.
—— saxonicum, sp. n. Ibid.
—— serum, *Opp.* Tithonian.
—— ptychostoma, *Ben.* Ibid.
—— Thetis, *D'Orb.* Neocomian.
—— ?velledæ, *Mich.* Gault.

2. Series of *Phylloceras Capitanei*.—Internal cast with simple furrows inclined forward, corresponding to prominences (never to furrows) of the shell; distinct radial striæ, bending forwards; saddles slender, unsymmetrical; first lateral lobe of the inner side with a two-leaved termination. Species :—

Phylloceras Capitanei, *Catullo*. Middle Lias.
—— Nilsoni, *Héb.* Upper Lias.
—— connectens, *Zitt.* Inferior Dogger.
—— heterophylloides, *Opp.* Middle Dogger.
—— disputabile, *Zitt.* Upper Dogger and Kelloway group.
—— Demidoffi, *Rouss.* Of uncertain age (Crimea).
—— Manfredi, *Opp.* Oxford group.
—— Puschi, *Opp.* Oxford group.
—— benacense, *Cat.* *Aspidoceras-acanthicum* beds.
—— Kochi, *Opp.* Tithonian.

3. Series of *Phylloceras ultramontanum.*—Kneed radial furrows; striæ of shell entirely wanting, or only next to the outer side, and then coarse and short; lobes and saddles clumsy; first lateral saddle of the inner side with two-leaved termination. Species:—

Phylloceras ultramontanum, *Zitt.* Inferior Dogger.
—— Zignodianum, *D'Orb.* Middle Dogger.
—— mediterraneum, sp. n. Klaus beds and Inferior Tithonian.
—— polyolcum, *Ben.* *Aspidoceras-acanthicum* beds.
—— silesiacum, *Opp.* Tithonian.
—— Calypso, *D'Orb.* (=?P. berriasense, *D'Orb.*). Neocomian.

4. Series of *Phylloceras tatricum.*—Rounded prominence on the external side; radial striation very faint, or entirely deficient; saddles clumsy, first lateral saddle on the internal side (?). Species:—

Phylloceras tatricum, *Pusch.* Inferior Dogger.
—— flabellatum, sp. n. Klaus beds.
—— Hommairei, *D'Orb.* Age uncertain (Crimea).
—— euphyllum, *Neum.* Kelloway and Oxford groups.
—— ptychoicum, *Quenst.* Tithonian.
—— semisulcatum, *D'Orb.* Neocomian.

5. *Isolated types.*

Phylloceras subobtusum, *Kud.* Klaus beds.
—— viator, *D'Orb,* Oxford group ?
—— Beneckei, *Zitt.* Tithonian.
—— haloricum, *Hauer.* Klaus beds.
—— tortisulcatum, *D'Orb.* Klaus beds and Tithonian.

The first three of these isolated forms, together with *P. Rouyanum,* D'Orb., from the Neocomian, may perhaps constitute a distinct series.

Each mutation within a series of forms presents very slight but constant differences, without any gradual transitions. The whole of the forms of a series may be considered either to belong to a single species, or to be specifically distinct. The last course seems to be best adapted for geological purposes; and the genetic connexion may be indicated by adding to the name of the altered form that of the form from which it has been derived, under the algebraic symbol $\sqrt{\quad}$, as proposed by Waagen.

The objections against these distinctions as representing *varities* rather than genuine *species,* may be of weight as regards existing forms, or extinct forms within a given horizon, considered independently of any succeeding or preceding formation; but in the whole chain of successive organisms the species extends into a *series* of forms, each representing a distinct phase in the gradual development of a fundamental form.

Wherever the internal lobes could be laid bare, the antisiphonal lobe was found to terminate in two points, and the termination of the adjacent internal saddle to be one-leafed. The termination of the first lateral saddle is said, by Quenstedt, to be one-leafed in *P. tortisulcatum.* The embryonal whorls are nearly alike in all the species examined, presenting a close external resemblance, on a very diminutive scale, to certain Goniatites, such as *Goniatites tridens,* Sandb. The lobes of examples about 2 millims. in diameter assume a Ceratitic character. [Count M.]

2. *On the* Nomenclature *of the* Living *and* Tertiary Brachiopoda *of the* Kingdom *of* Naples. By G. Seguenza.

[Bollettino Malacol. Ital., 1870.]

Professor Seguenza has published a critical revision of the Brachiopoda described by Professor Costa in his 'Fauna del regno di Napoli.' It is founded on the materials collected by Costa, and leads the author to the following results:—

Costa's names.	Corrected names.
A. Living species.	
1. Terebratula vitrea	Terebratula vitrea, *Born.* —— minor, *Phil.*
2. —— caput-serpentis	Terebratulina caput-serpentis, *Lin.*
3. —— truncata	Megerlia truncata, *Lin.*
4. Orthis detruncata	Argiope decollata, *Chemn.*
5. —— pera	—— curvata, *Risso.*
6. —— neapolitana	—— neapolitana, *Scacchi.*
7. —— bifida	—— neapolitana ?
8. —— lunifera	Megerlia monstruosa, *Scacchi, jun.*
9. —— monstruosa	—— monstruosa, *Sc.*
10. Platydia anomioides	Platydia anomioides, *Scacchi.*
11. Thecidea mediterranea	Thecidea mediterranea, *Risso.*
12. Crania personata	Crania turbinata, *Poli.*
B. Tertiary species.	
1. Terebratula vitrea 2. —— caput-serpentis 3. —— truncata	*Vide suprà.*
4. Terebratula grandis	Terebratula ampulla, *Brocchi.* —— *sp. nov.*
5. —— biplicata	—— sinuosa, *Brocchi.*
6. —— irregularis	—— sinuosa, *Brocchi.* —— minor, *Phil.* Waldheimia cranium, *Müll.* —— septigera, *Lovén.* Terebratella septigera, *Phil.*
7. —— amygdaloides	Waldheimia cranium, *Müll.*
8. —— euthyra	—— cranium, *Müll.*
9. —— lucinoides	Megerlia eusticta, *Phil.*
10. —— bipartita	Rhynchonella bipartita, *Brocchi.*
11. —— plicato-dentata	—— bipartita, *Brocchi.*
12. —— pauperata	—— pauperata, *Costa.*
13. Orthis plicifera	Argiope decollata, *Chemn.*
14. —— detruncata 15. Crania personata	*Vide suprà.*

[Count M.]

3. *On the* Flora *of the* Brown Coal *of* Sagor, Carniola.

By Professor C. von Ettingshausen.

[Imperial Academy of Sciences, Vienna, April 13, 1871.]

Up to the year 1820 only 9 species belonging to this flora were known, and these were described by Unger in his 'Genera et Species Plantarum fossilium.' In 1850 Prof. C. von Ettingshausen commenced a careful investigation of this Flora, representatives of which are now known to occur in fourteen distinct localities at Sagor and in the neighbouring districts of Carniola and Styria; and he has now completed the first part of his description, embracing the Thallophytes, Vascular Cryptogams, Gymnosperms, Monocotyledons and Apetala. A species of *Sphæria* from Sagor is most nearly allied to *Sphæria annulata* from Greenland. A Floridean Alga, analogous to *Laurencia,* indicates the presence of salt water, and is the only marine plant of the flora of Sagor.

The Gymnosperms number 15 species; and among them is an *Actinostrobus* of Australian type, the six-valved strobiles of which has been found in two localities. The prevalent conifers are *Glyptostrobus europæus* and *Sequoia Couttsiæ*, the branches, strobiles, and inflorescence of which have been met with at nearly every locality. Other species of *Sequoia* are *S. Langsdorfi, S. Tournali*, and *S. Sternbergi.* A new and remarkable fact is the presence of a *Cunninghamia* in these Tertiary deposits. A fragment of a branch strikingly similar in every respect to *Cunninghamia sinensis,* R. Brown, has been found in a quarry near Savine. The genus *Pinus* includes six species, each generally represented by complete clusters of leaves and by the cones.

As at Sotzka and Haring, the number of Gramineæ is very small. The Najadeæ are remarkable in numbers and forms, including two species of *Potamogeton,* one of *Zostera*, one of *Najadopsis,* and one of *Najadonium,* all inhabitants of fresh water. The Pandaneæ and Palms are each represented by one species. *Casuarina sotzkensis,* which is frequent in all Tongrian and Aquitanian floras, occurs here, and with it a new species, nearly allied to the existing *C. quadrivalvis.* The other apetalous families of the Sagor flora are represented as follows:—Myricaceæ by 3, Betulaceæ by 6, Cupuliferæ by 15, Ulmaceæ by 4, Celtideæ by 2, Artocarpeæ by 2, Salicineæ by 2, Nyctagineæ by 1, Monimiaceæ by 1, Santalaceæ by 4, Daphnoideæ by 2, Proteaceæ by 21, Laurineæ by 18, and Moreæ by 19 species. Most of the species of the last two families present a tropical aspect. [Count M.]

A

TOPOGRAPHICAL INDEX

TO

THE FELLOWS

OF THE

GEOLOGICAL SOCIETY OF LONDON,

Resident in the Country or Abroad.

BY

TOWNSHEND M. HALL, Esq., F.G.S.

[CORRECTED TO JANUARY 1st, 1872.]

NOTE.

The following Index is intended to form a Supplement to the ordinary Alphabetical List, by means of which the name of every Fellow residing in any part of the world may be ascertained at a glance.

To facilitate reference, the aim has been to group, in each county, the various localities around their respective post-towns. Names of streets and houses have been omitted; but those of parishes and more distant estates have been inserted whenever it appeared requisite. The only inconvenience attending the adoption of this rule will be found in the very few instances where the residence of a Fellow is situated in one county and his post-town in another.

Much of the difficulty experienced in the preparation of the Index has arisen from the incomplete and inaccurate descriptions frequently given. The attention of Fellows is therefore again directed to the request of the Council, that all changes of residence should be immediately communicated to the Secretary, who will also gladly receive corrections of any errors.

TOWNSHEND M. HALL.

Pilton, Barnstaple,
Jan. 1st, 1872.

I. RESIDENTS IN GREAT BRITAIN AND IRELAND,

EXCLUSIVE OF THOSE WHO LIVE WITHIN THE LIMITS OF THE LONDON POSTAL DISTRICT.

ENGLAND.

Bedfordshire.

Bedford—Sanders, Rev. S. J. T.
Bedford—Wyatt, J.

Berkshire.

Ascot—Everest, Rev. R.
Maidenhead (*Taplow*) — Serocold, C. P.
Newbury—Valpy, R. H.
Sandhurst—Fothergill, Capt. C. W.
Wallingford (*Aston Tirrold*)—Rome, Rev. J. L.
Wantage—Davey, E. C.
Windsor (*Clewer*)—Harris, W. H.
Wokingham—Bentinck, Gen. A. C.

Buckinghamshire.

Aylesbury—Hunt, Z. D.
—— (*Aston Abbots*) — Thornton, Rev. J.
Great Marlow—Woodman, W.
High Wycombe—Browne, Rev. T. H.
Newport Pagnell—Bull, Rev. J.

Cambridgeshire.

Cambridge—Babington, Prof. C. C.
—— Bonney, Rev. T. G.
—— Cartmell, Rev. J.
—— Danby, T. W.
—— Miller, Prof. W. H.
—— Phear, Rev. S. G.
Cambridge—Routh, E. J.
—— Sedgwick, Rev. Prof. A.
—— Seeley, H.
—— Worsley, Rev. T.
—— (*Harlton*)—Fisher, Rev. O.

Cheshire.

Alderley Edge—Waters, A. W.
Altrincham—Brooke, W.
Birkenhead—Bretherton, E.
—— Ferguson, W.
—— Ricketts, C.
Rock Ferry—Roberts, I.
Stockport—Barr, W. R.
—— (*Poynton*)—Greenwell, G. C.
Tarporley—Egerton, Sir P. de M. G.
Wallasey—Hall, H. F.

Cornwall.

Falmouth—Collins, J. H.
Helston—Vyvyan, Sir R. R.
Pelynt—Kendall, N.
Penryn (*Enys*)—Enys, J. S.
Penzance—Courtney, J. S.
—— Henwood, W. J.
—— Higgs, S.
Redruth—Davey, R.
—— Richards, T.
Scilly Isles—Smith, A.
Truro (*Goonvrea*) — Williams, Sir F. M.
—— (*Polwhele*)—Polwhele, T. R.

Cumberland.

Alston—Paull, J. M.
Carlisle (*Brigham Hill*)—Fletcher, W.
—— (*Haydon Bridge*)—Bewick, T. J.
—— (*Tarnbank*)—Fletcher, I.
Cockermouth (*Wood Hall*)—Fisher, J. C.
Keswick—Ward, J. C.
Penrith—Nicholson, H. A.
—— (*Ulleswater*)—White, Rev. F. Le G.
Whitehaven—Dees, J.
—— Dixon, G.
—— Moon, M. A.

Derbyshire.

Ashbourne (*Ilam*)—Russell, J. W.
Belper—Evans, T.
Chesterfield (*Brampton*)—Mello, Rev. J. M.
Derby—Fearn, S. W.
—— (*Milford*)—Strutt, Hon. A.

Devonshire.

Barnstaple—Hall, Townshend M.
—— Harding, Lt.-Col. W.
—— Hore, Rev. W. S.
Buckfastleigh—Gale, J.
Exeter—Jerwood, J.
—— Lingwood, R. M.
—— Templeton, J.
—— Vicary, W.
—— (*Kenton*)—Pycroft, G.
—— (*Lympstone*)—Edgell, A. W.
Honiton (*Holyshute*)—Swann, Capt. J. S.
North Lew—England, Rev. T.
Plymouth—Jackson, E. S.
Stonehouse—Coles, J.
Teignmouth—Cooke, H.
—— Ormerod, G. W.
Torquay—Hunt, A. R.
—— Lee, J. E.
—— Pengelly, W.
—— Tawney, E. B.
Totness—Champernowne, A.

Dorsetshire.

Blanford (*Whatcombe*) — Mansel-Pleydell, J. C.
Charmouth—Breton, Capt. W. H.
Dorchester (*Stafford*)—Floyer, J.
Langton Maltravers—Lester, L.
Sherborne (*Bradford Abbas*)—Buckman, J.
Sherborne (*Holwell*)—Wood, Rev. H. H.
Weymouth—Damon, R.
—— Drew, J.
Wimborne—Austen, Rev. J. H.

Durham.

Blaydon-on-Tyne—Simpson, J. B.
Darlington—I'Anson, J. C.
—— Koma, R.
—— Spark, H. K.
—— Tait, R.
—— (*Raby Castle*)—Scarth, W. T.
Durham—Farrar, Rev. A. S.
Ferry Hill (*Wingate Grange*)—Armstrong, W.
Gateshead—Favell, T. M.
—— (*Usworth*)—Coxon, S. B.
South Shields—Lyall, G.

Essex.

Brentwood—Wood, S. V.
—— Wood, S. V., Jun.
Buckhurst Hill—Babington, W.
Chelmsford—Church, J.
Colchester (*Stanway*)—Jenkyns, Rev. H.
Colchester (*Thorpe*)—Watson, J. Y.
Harlow (*Sheering*)—Hill, Rev. E.
Maldon (*Ulting*)—Piggot, J.
Saffron Walden (*Audley End*)—Oldham, Rev. J. L.

Essex (*continued*).

Saffron Walden (*Chesterford*)—Hervey, Rev. Lord C. A.
—— (*Wimbish*)—Montague, Rev. J.
Shoeburyness—Innes, Lieut. W.
Stratford—Brady, Sir A.
Wanstead—Walker, F.

Gloucestershire.

Bristol—Cossham, H.
—— Pease, T.
—— Stoddart, W. W.
—— (*Bitton*)—Parker, J.
—— (*Clifton*)—Brough, L.
—— —— King, W. P.
—— —— Sanders, W.
—— —— Sisson, W.
—— (*Henbury*)—Perceval, S. G.
—— (*Redland*)—Austen, Major T.
Cheltenham—Bevan, G. P.
—— Bloxam, T.
—— Bright, J.
—— Copeland, G. F.
—— Orchard, J. W.
—— Smithe, Rev. F.
—— Wright, T.
Cirencester—Bravender, J.
Gloucester—Cadle, C.
—— (*Brookthorpe*)—Lucy, W. C.
Gloucester (*Elmore Court*) — Guise, Sir W. V.
—— (*Hardwick Court*)—Baker, J. L. B.
—— (*Hucclecote*)—White, H. C.
—— (*Tibberton Court*)—Price, Capt. W. E.
Lydney—Philpot, Rev. B.
Newnham(*Bilson House*)—Thomas, A.
Stow-on-the-Wold—Witts, Rev. E. F.
Stroud—Paine, W. H.
—— Witchell, E.
Tewkesbury (*Forthampton*)—Yorke, J. R.
—— (*Kemerton*)—Thorp, Archdeacon.
—— (*Pendock*)—Symonds, Rev. W. S.
Wotton-under-Edge (*Tortworth*)—Ducie, Earl of.
—— (*Wickwar*)—Preston, L.

Hampshire.

Aldershot—Home, Capt. R.
—— Hutchinson, Capt. A. H.
Alton (*Selborne*)—Bell, T.
Fareham (*Crofton*)—Wingate, Sir G.
Horndean—Martin, J.
Portsmouth—Martin, J.
—— Weston, W.
Southampton—James, Sir H.
—— (*Merry Oak*)—Forbes, J. H.
Stoney Cross—Eyre, G. E.
Winchester—Shelley, G. E.
Winchfield (*Eversley*)—Kingsley, Rev. C.

Isle of Wight.

Freshwater—Pritchard, Rev. C.
Newport—Wilkins, E. P.

Herefordshire.

Hereford—Curley, T.
Ledbury (*Hatfield*)—Henry, W. C.

Hertfordshire.

Albans, St.—Kernahan, Rev. J.
—— (*Sandridge*)—Winbolt, J. S.
Cheshunt—Mayo, H.
Hemel Hempstead—Evans, J.
Hemel Hempstead—Longman, C.
Stevenage (*Gravely*)—Denton, J. B.
Watford—Humbert, C. F.
Welwyn (*Danesbury*)—Blake, W. J.

Kent.

Ashford (*Charing*)—Harris, W.
Bromley—Child, C.
—— Hamilton, A.
—— Lubbock, Sir J.
—— Norman, G. W.
Canterbury—Bell, M.
—— Collard, T. W.
Deal (*Northbourne*)—Cooke, Rev. S. H.
Dover—Knowles, Rev. J.

KENT (*continued*).

Folkestone—Langdon, Rev. E.
Gravesend—Gladdish, W.
—— Guest, Rev. W.
Hythe—Mackeson, H. B.
Sandwich (*Betteshanger*)—James, Sir W. C.
Sevenoaks—Browne, R. G. M.
—— (*Shoreham*)—Prestwich, J.
Tunbridge Wells—McClean, F.
—— Sharp, J.
—— Spratt, Capt. T. A. B.
—— Thornton, Rev. W.
—— (*Broadwater*)—Gibson, T. F.
—— (*Groombridge*)—Cooke, E. W.
West Malling—Timins, Rev. J. H.
Wingham (*Stourmouth*)—Dowker, G.

LANCASHIRE.

Blackburne—Eccles, J.
Lancaster—Diggens, J.
—— Rofe, J.
—— Prosser, W.
Liverpool—Cunningham, J.
—— Eskrigge, R. A.
—— Hall, H. F.
—— Morton, G. H.
—— Shoolbred, J. N.
—— (*Grassendale*)—Duckworth, H.
Manchester—Binney, E. W.
—— Brockbank, W.
—— Darbyshire, R. D.
—— Dickinson, J.
—— Dorning, E.
—— Forbes, J. E.
—— Greg, R. P.
—— Lingard, J. R.
—— Lynde, J. G.
—— Smith, F.
—— (*Ardwick*)—Fairbairn, Sir W.
Manchester (*Bacup*)—Aitken, J.
—— (*Broughton*)—Higson, P.
—— (*Castleton Moor*)—Bates, Rev. J. C.
—— (*Hollinwood*)—Booth, I.
—— (*Norcliffe*)—Greg, R. H.
—— (*Rusholme*)—Darbyshire, R. D.
—— —— Dawkins, W. B.
—— (*Salford*)—Plant, J.
—— —— Williamson, E.
Preston (*Samlesbury*)—Harrison, W.
Southport—Willacy, Rev. T. R.
Ulverston—Kennedy, M.
—— Salmon, W.
—— (*Grange*)—Beardsley, A.
Warrington (*Thelwall*)—Rylands, T. G.
Whalley—Norwood, Rev. S.
Wigan (*Ashfield*)—Lancaster, J.
—— (*Haigh*)—Hewlett, A.

LEICESTERSHIRE.

Ashby-de-la-Zouch (*Overseal*)—Woodhouse, J. T.
Leicester—Drake, F.
—— Everard, J. B.
—— Plant, N.
Leicester (*Humberstone*)—Bosworth, J. A.
Loughborough (*Barrow-on-Soar*)—Crossley, J. S.
—— —— Hambly, C. H. B.

LINCOLNSHIRE.

Boston—Shaw, J.
Brigg (*Appleby*)—Cross, Rev. J. E.
Gainsborough (*Highfield*)—Burton, F. M.
Gainsborough (*Saundby*)—Chamberlain, Rev. T. C. B.
Louth (*Elkington*)—Whinfield, E. W.

MIDDLESEX.

Enfield—Kitching, A. G.
Harrow—Leaf, C. J.
Stanwell—Waugh, H.
Sunbury House—Lendy, Capt. A. F.
Sunbury Park—Arden, R. E.
Uxbridge (*Dawley*)—De Salis, W. F.

Monmouthshire.

Caerleon—Lee, J. E.
Chepstow (*Sedbury*)—Ormerod, G.
Newport—Mitchell, F. J.
Newport—Roper, R. S.
Pont-y-Pool—Llewellyn, D.
Usk—Falconer, T.

Norfolk.

Downham Market (*Denver*)—Stokes, Rev. W. H.
Lynn (*Tilney*)—Currie, Rev. C.
Norwich—Charlesworth, E.
—— Fitch, R.
—— Morant, A. W.
—— (*Blofield*)—Turnbull, Rev. T. S.
Norwich (*Heigham*)—Harmer, F. W.
—— (*Irstead*)—Gunn, Rev. J.
Stoke Ferry (*Oxburgh*)—Thurtell, Rev. A.
Yarmouth, Great—McClean, W. C.
—— —— Rose, C. B.

Northamptonshire.

Kettering—Heighton, H. J.
Northampton (*Dallington*)—Sharp, S.
—— (*Overstone Park*)—Overstone, Lord.
Oundle (*Elton*)—Lawrance, J.
Rothwell—Glass, Rev. N.

Northumberland.

Berwick-on-Tweed—Home, D. M.
Newcastle-on-Tyne—Bainbridge, W.
—— Barkas, T. P.
—— Belt, T.
—— Brady, H. B.
—— Johnson, J.
—— Maclennan, Rev. A.
—— (*Blackworth*)—Foster, G. B.
Newcastle-on-Tyne (*Bywell*)—Beaumont, W. B.
—— (*Wallington*)—Trevelyan, Sir W. C.
North Shields (*Tynemouth*)—Daglish, J.
Riding Mill—Hurst, T. G.

Nottinghamshire.

Newark-upon-Trent—Brookes, J.
—— Kendall, Rev. W. C.
Nottingham—Dixon, Rev. R.
—— Lowe, E. J.
—— Tarbotton, M. O.
Nottingham (*Newstead Abbey*)—Webb, W. F.
Southwell—Warrand, Major W. E.
Worksop (*Shire Oak*)—Tylden-Wright, C.

Oxfordshire.

Banbury—Pidgeon, D.
Oxford—Gayner, C.
—— Macbride, J. D.
—— Parker, J.
—— Phillips, Prof. J.
—— Pritchard, Rev. C.
Oxford—Prout, Rev. T. J.
—— Wyndham, T. H. G.
Tetsworth (*Watlington*)—Lucas, Rev. S.
Witney (*Tynsham*)—Mason, J.

Shropshire.

Broseley (*Benthall*)—Maw, G.
Ludlow—Lightbody, R.
Madeley—Randall, J.
Market Drayton (*Norton-in-Hales*)—Silver, Rev. F.
Wellington (*Donnerville*)—Eyton, T. C.
Whitchurch—Egerton, Rev. W. H.

Somersetshire.

Bath—Blomefield, Rev. L.
—— Moore, C.
—— Robbins, G.
—— Walker, T. F. W.
—— Weston, C. H.
—— Winwood, Rev. H. H.
Bridgewater (*Fyne Court*)—Hamilton, J.
Bristol (*Long Ashton*)—Rogers, G.
Evercreech—Talbot de Malahide, Lord.
Glastonbury—Pope, C.
Somerton (*Kingweston*)—Dickinson, F. H.
Taunton—Jones, W. A.
Wellington (*Nynehead*)—Sanford, W. A.
Weston-super-Mare—Browne, Archdeacon, R. W.
—— Mortimer, W. H.
—— Pooley, C.
Wrington—Daubeny, R. H.

Staffordshire.

Bilston—Bowkley, S.
Burton-upon-Trent—Brown, E.
—— Knobel, E. B.
—— Molyneux, W.
Leek—Wardle, T.
Lichfield—Johnson, J. T.
Penkridge (*Rodbaston*)—Ward, H.
Stone—Wynne, T.
Walsall (*Cannock Chase*)—Brown, J.
—— (*Pleck*)—Bailey, S.
West Bromwich—Cooksey, J.
Wolverhampton—Beckett, H.
—— Cope, J.
—— Myers, E.
—— (*Donington*)—Jones, D.
—— (*Willinghall*)—Parton, T.

Suffolk.

Bury St. Edmunds (*Barton*)—Bunbury, Sir C. J. F.
Ipswich (*Grundisburgh*)—Colchester, W.
Saxmundham—Cavell, E.
Saxmundham (*Hurts Hall*)—Long, W.
Sudbury (*Assington*)—Gurdon, J.
Woodbridge (*Melton*)—Ansted, Prof. D. T.

Surrey.

Carshalton—Tylor, A.
—— Wallace, J.
Croydon—Crowley, J. S.
—— Flower, J. W.
—— Lee, H.
Dorking (*Kitlands*)—Heath, D. D.
Godalming—Nevill, W.
Godstone—Noel, E.
Guildford—Capron, J. R.
—— Sells, T. J.
—— Warren, Capt. C.
Guildford (*Chilworth*) — Godwin-Austen, R. A.
Moulsey, East—Whitaker, W. W.
Reigate—Lainson, H.
—— (*Merstham*)—Joliffe, Hon. H. H.
—— (*Redhill*)—Brass, Rev. H.
Weybridge—Colvin, A.
—— (*Addlestone*)—Rigby, J. B.
—— —— Tulk, J. A.
Yorktown—Jones, Prof. T. R.

Sussex.

Brighton—Davidson, T.
—— Jackson, A. W.
—— Laing, S.
—— White, J.
Chichester—Mackintosh, D.
—— (*Lavant*)—Robinson, A.
Clayton—Briggs, Gen. J.
Cuckfield—Hankey, J. A.
Forest Row—Slack, H. J.
Grinstead, E. (*Felbridge*)—Gatty, C. H.
Grinstead, E. (*Twyford*)—Trotter, R.
Hastings (*Hollington*) — Wollaston, G. H.
Petworth (*Bignor*)—Hawkins, J. H.
St. Leonard's-on-Sea—Beckles, S. H.
—— Bowerbank, J. S.
—— Parish, Sir W.
—— Peyton, J. E. H.
Shoreham (*Southwick*)—Pullen, M.

Warwickshire.

Birmingham—Allport, S.
—— Lloyd, G.
—— Shaw, G.
—— (*Aston Manor*)—Stone, J. B.
—— (*Edgbaston*)—Crosskey, Rev. H. W.
—— —— Matthews, W.
—— —— Ratcliff, C.
—— (*Moseley*)—Dawes, J. S.
—— —— Deane, Rev. G.
—— (*Saltley*)—Gover, Rev. W.
Birmingham(*West Heath*)—Dawson, G.
Coventry (*Allesley*)—Wyles, T.
—— (*Berkswell*)—Watson, Rev. H. W.
Rugby—Sharp, W.
—— Wilson, J. M.
—— (*Bilton*)—Lancaster, J.
Tamworth—Spruce, S.
Warwick—Kirshaw, J. W.
—— (*Rowington*)—Brodie, Rev. P. B.

Wiltshire.

Chippenham (*Castle Combe*)—Scrope, G. P.
Corsham—Randell, J. S.
Devizes (*Hilworth*)—Cunnington, W.
Pewsey—Dixon, S. B.
Ramsbury—Burdett, Sir R.
Salisbury—Duke, E.
—— Hamilton, Dean H. P.
—— (*Baverstock*)—Hony, Archdeacon W. E.

Worcestershire.

Broadway (*Middle Hill*)—Phillips, Sir T.
Bromsgrove (*Dale Cross*)—Walton, E.
Dudley (*Oakham*)—Minton, S.
Evesham (*Hampton, Gt.*)—Safford, J. B.
—— (*Harvington*)—Ingram, Rev. A. H. W.
Malvern, Great—Grindrod, R. B.
—— (*Cradley*)—Jauncey, W.
Stourbridge—Fletcher, Major T. W.
—— Pearce, H.
—— (*Wordsley*)—Pentecost, J.
Worcester—Baxter, T.
—— Lees, E.
—— (*Perdiswell*)—Holl, H. B.

Yorkshire.

Barnsley—Dawes, G.
Bedale (*Clifton Castle*)—Pulleine, J.
Beverley (*Brandsburton*) — Hymers, Rev. J.
Bradford—McLandsborough, J.
Doncaster—Armstrong, Prof. G. F.
Guisborough—Morgan, Rev. F. H.
Halifax—Gledhill, J.
—— (*Wellhead*)—Waterhouse, J.
Huddersfield (*Edgeston*)—Brooke, E.
—— (*Rastrick*)—Clay, J. T.
Hull (*Hessle*)—Smith, T. J.
Leeds—Filliter, E.
—— Lupton, A.
—— Marshall, A.
—— Marshall, J. G.
—— Richardson, J. W. H.
Normanton (*Altofts*)—White, J. T.
Oswaldkirk (*Wass*)—Brown, R. E.
Ouseburn—Abbay, Rev. R.
Richmond—Bradley, C. L.
—— Bradley, L.
—— Wood, E.
—— Yeoman, H. W.
—— (*Draycott*)—Denys, Sir G. W.
Saltburn-by-the-Sea—Jones, J.
Scarborough—Leckenby, J.
—— Rooke, C.
—— Woodall, J. W.
Sheffield—Carrington, T.
—— Jeffcock, T. W.
—— Wall, G. P.
—— (*Broomfield*)—Sorby, H. C.
—— —— Stuart, G.
Silkstone (*Bretton*)—Beaumont, W. B.
Skipton (*Carleton*)—Eddy, J. R.
Thirsk (*Brekenbrough*)—Hinks, T. C.
York—Allen, E.
—— Blake, Rev. J. F.
—— Gray, W.
—— Moiser, H. R.
—— Mosley, G.
—— Noble, T. S.
—— North, S. W.
—— Reed, W.
—— Walker, J. F.
—— (*Hayton*)—Arundell, Rev. T.
—— (*Whexley*)—Ford, J.
—— (*Whitwell*)—Harcourt, E. V. V

WALES.

Caermarthenshire.

Caermarthen—Morris, Rev. R. H.
—— (*Abergwili*)—St. David's, Lord Bishop of.
Llandeilo (*Dolau-cothy*)—Johnes, J.
Llanelly (*Nantglas*)—Norton, J. H.

Caernarvonshire.

Beddgelert (*Bryn Gwynant*)—Wyatt, J.
Portmadoc—Spooner, C. E.

Flintshire.

Hawarden—Moffat, T.
Mold (*Bryn Alyn*)—Cooke, Rev. R. B.
Wrexham (*Cymmau Hall*)—Sparrow, J.

Glamorganshire.

Aberdare—Clark, W. S.
—— Kirkhouse, H.
—— (*Mardy*)—Lewis, W. T.
Bridgend—Brogden, J.
—— (*Nottage*)—Jordan, H. K.
Cardiff—Adams, W.
—— Brown, T. F.
—— (*Wenvoe*)—Jenner, R. F. L.
Merthyr Tydvil (*Dowlais*)—Clark, G. T.
Neath—Richardson, J.
—— (*Cadoxton*)—Lewis, L. T.
Swansea—Benson, S.
—— Beor, E. J.
—— Moggridge, M.
—— Pearce, R.
—— Tremellen, J. H.
—— (*Bishwell*)—Brown, F. H.
—— (*Glenrafon*)—Richardson, J. C.
—— (*Hendrefoilan*)—Dillwyn, L. L.
—— (*Singleton*)—Vivian, H. H.
—— (*Stout Hall*)—Wood, Col. E. R.

Merionethshire.

Dolgelly—Williams, W. R.
Dolgelly (*Mallwyd*)—Readwin, T. A.

Pembrokeshire.

Haverfordwest (*Williamston*)—Scourfield, J. H.

Radnorshire.

Rhayader—Richardson, R.

SCOTLAND.

Aberdeenshire.

Aberdeen—Macdonald, A.
—— Nicol, Prof. J.
Aberdeen, Old—Dann, R.
Ellon—Jamieson, T. F.

Argyleshire.

Inverary Castle—Argyll, Duke of.
Islay—Campbell, J. F.
Toward Point—Lamont, J.

Berwickshire.

Kames—Hood, T. H. C.

Caithness.

Thurso—Miller, J.

Edinburghshire.

Edinburgh—Chambers, W.
—— Etheridge, R., Jun.
—— Geikie, Prof. A.
—— Gillespie, W.
—— Jack, R. L.
Edinburgh—Page, D.
—— Thomson, Prof. W.
—— Trotter, C.
Leith—Lundy, J. J.
Muir House—Davidson, T.

Fifeshire.

Falkland—Gibb, Sir G. D.
St. Andrews—McDonald, Prof. W.

Forfarshire.

Dundee—Boase, H.
Reswallie—Powrie, J.

Invernesshire.

Inverness—Mitchell, J.
Skye, Isle of—Matheson, Sir J.

Kirkcudbrightshire.

St. Mary's Isle—Selkirk, Earl of.

Lanarkshire.

Blantyre—Bryce, J.
Glasgow—Bryce, J.
—— Gregory, T. C.
—— Robertson, D.
Glasgow—Thomson, J.
—— Young, Prof. J.
Lanark—Lindsay, C.
Monkland—Murray, W.

Linlithgowshire.

Torbane Hill—Gillespie, W.

Perthshire.

Duncrub House—Rollo, Lord.
Perth—Sherwill, Lt.-Col. W. S.
Inchture (*Rossie Priory*)—Kinnaird, Lord.

Renfrewshire.

Johnstone Castle—Houstoun, G. L.

Stirlingshire.

Bridge of Allan—Miller, J.

IRELAND.

Antrim.

Belfast—Boyd, N.
—— Haslett, S.
—— Wright, J.
Belfast (*Holywood*)—Anderson, J.
Dunmurry—Murphy, J. J.
Larne—Holden, J. S.

Cork.

Charleville (*Killeedy*)—Petrie, Capt. F. W. H.
Cork—Harkness, Prof. R.
Cork—Jennings, F. M.
—— (*Drifney Castle*)—Colthurst, J.

Dublin.

Dublin—Baily, W. H.
—— Griffith, Sir R. J.
—— Hamilton, C. W.
—— Haughton, Rev. Prof. S.
Dublin—Hull, Prof. E.
—— (*Malahide*)—Talbot de Malahide, Lord.

Fermanagh.

Enniskillen (*Florence Court*)—Enniskillen, Earl of.

Galway.

Gort (*Lough Cultra*)—Gough, Viscount.

Kildare.

Curragh—Parker, Capt. F. G. S.

Limerick.

Limerick—Prevost, Lieut. L. de T.

Mayo.

Ballina—Symes, R. G.

Sligo.

Sligo (*Abbey View*)—Wheatley, J. H.

Tyrone.

Strabane—Ogilvy, W.

Waterford.

Waterford (*Summerville*)—Fortescue, Hon. D. F.

CHANNEL ISLANDS.

Guernsey.

Carey, Sir P. S.
Collings, Rev. W. T.
Musson, E. C.

Jersey.

Le Feuvre, W. H.
Peacock, R. A.

II. FOREIGN LIST.

AMERICA, UNITED STATES OF.

Alabama.

Montgomery—Tait, Col. I. L.

California.

San Francisco—Rowlandson, T.

Connecticut.

Newhaven—Dana, Prof. J. D.
—— Marsh, Prof. O. C.

Massachusetts.

Boston—Rogers, W. B.
Cambridge—Agassiz, Prof. L.

New York.

Albany—Hall, J.
New York—Bland, T.
—— Day, E. C. H.
New York—Hawkins, B. W.
—— Kimball, J. P.
—— (*Theresa*). Lloyd, T. G. B.

Ohio.

Cincinnati—Vincent, Prof. M. C.
Cleveland—Humiston, Prof. R. F.

Philadelphia.

Philadelphia—Leidy, J.
—— Lesley, Prof. J. P.

Virginia.

Richmond—Maury, M. F.

Wisconsin.

Madison—Hobbins, J.

ANGOLA.

Brand, G.

ARGENTINE REPUBLIC.

Buenos Ayres (*San Juan*)—Rickard, Major F. I.

AUSTRALIA.

.... Biden, W. D.

New South Wales.

Cassilis, Hunter River—Busby, A.
Newcastle—Keene, W.
St. Leonards—Clarke, Rev. W. B.
Sydney.—Hunt, R.
—— Josephson, J. F.

AUSTRALIA (*continued*).

Queensland.

Ipswich—Harlin, T.
Rockhampton—Plews, H. T.

South Australia.

Adelaide—Ayers, Hon. H.
Penola—Woods, Rev. J. E. T.

Victoria.

Maldon—Salter, W.
Melbourne—Clarke, J.
—— McCoy, Prof. F.
—— Smyth, R. B.
—— Stephen, G. M.
—— Ulrich, G. H. F.
—— (*St. Francis*)—Bleasdale, Rev. J.

AUSTRIA.

Vienna—Boué, A.
—— Breunner, Count A.
—— Hauer, F. R. von.
—— Marschall, Count A. G.
—— Reuss, Prof. A. E.
—— Suess, Prof. E.

Bohemia.

Prague—Barrande, J.

Hungary.

Pesth—Szabo, Prof. J.
Stuhlweissenberg—Schvarcz, J.

BELGIUM.

Brussels—Gomonde, W. H.
—— Nyst, P.
—— Van der Maelen, P.
Ciney (*Halloy*)—Halloy, J. J. d'O.
Liége—Dewalque, Prof. G.
—— Koninck, Prof. L. G. de.

CANADA.

.... Elwin, H.
Darlington (*Beaumanville*)—Reid, Capt. J. H.
Montreal—Armstrong, Prof. G. F.
—— Bell, Prof. R.
—— Billings, E.
—— Broome, G.
—— Colquhoun, J.
Montreal—Dawson, J. W.
—— Logan, Sir W. E.
—— Nicholson, Prof. H. A.
—— Selwyn, A. R.
—— Vennor, H. G.
—— Whiteaves, J. F.
Ottawa—Grant, J. A.

CAPE OF GOOD HOPE.

.... Bolton, Major-Gen. D.
.... Hertzog, W. F.
.... Thurburn, Capt. H.
Graham's Town—Atherstone, W. G.
Namaqualand (*Fontaux*) — Davis, J. F.

CEYLON.

.... Caley, J. A.
.... Kelaart, E. F.
Colombo—Roosmalecoeq, A. H.

DENMARK.

Copenhagen—Steenstrup, Dr

EGYPT.

Ayrton, F.

FRANCE.

Marseilles—Coquand, H.
Montpellier—Gervais, P.
—— Martins, C.
Nantes—Clipperton, Capt. R. C.
Paris—Barrande, J.
—— Basterot, Baron de.
—— Beaumont, E. de.
—— Brongniart, Prof. A. T.
—— Daubrée, Prof. A.
—— Delesse, Prof. A.
Paris—Deshayes, Prof. G. P.
—— Desnoyers, J.
—— Edwards, Prof. H. M.
—— Gaudry, A.
—— Hébert, Prof. E.
—— Quain, J.
—— Raulin, V.
—— Verneuil, E. de.
—— Vibraye, Marquis de.
—— Watson, J. G. W.

GERMAN EMPIRE.

Baden.

Heidelberg—Bunsen, Prof. R. W.

Bavaria.

Munich—Gümbel, C. W.
Würzberg—Sandberger, Prof. F.

Hanover.

Göttingen—Waltershausen, Baron W. S. von.

Hesse Darmstadt.

Darmstadt—Kaup, J. J.

Saxe Coburg Gotha.

Gotha—Credner, Herr.

Saxe Weimar Eisenach.

Eisenach—Senft, F.

Saxony.

Dresden—Geinitz, Prof. H. B.
Freiberg—Cotta, Prof. B.
Leipsig—Naumann, Prof. C. F.
—— Zirkel, Prof. F.

Würtemberg.

Stuttgart—Jäger, G. F.
Tübingen—Quenstedt, Prof.

GIBRALTAR.

Gibraltar, Lord Bishop of.
Luard, Capt. C. E.

GREENLAND.

Noungme—Taylor, J. W.

HOLLAND.

Maestricht—Bosquet, J.

INDIA.

.... Foote, R. B.
.... Margesson, Capt. P. D.
.... Oldfield, R. C.
.... Osborne, Lt.-Col. W.
.... Roberts, W. H.
.... Sowerby, W.

INDIA (*continued*).

Bengal.

.... Drummond, Capt. H.
.... Jack, Capt. A.
Allahabad—Carnac, H. R.
—— Mackesy, Major W. H.
Beerbhoom—Barker, R. A.
Calcutta—Binnie, A. R.
—— Blanford, Prof. H. F.
—— Blanford, W. T.
—— Leonard, H.
—— McClelland, J.
—— Mallet, F. R.
—— Mason, J. W.
—— Medlicott, H. B.
—— Oldham, T.
—— Phear, J. B.
—— Stoliczka, F.
Dacca—Clarke, C. B.
Deoghm—Calvert, J.
Raneegunge—Whitfield, J.

Bombay.

Bombay—Cooke, T.
—— Fedden, F.
Bombay—Goodenough, Lt.-Col. W. H.
—— Grant, Capt. C. W.
—— Rogers, A.

Central Provinces.

Nagpore—Cline, G. W.

Kashmere.

.... Drew, F.

Madras.

Madras—Aitchison, Major-Gen. J.
—— Ouchterlony, Lieut. J.

North-west Provinces.

Roorkee—Smith, Col. R. B.

Punjab.

.... Wynne, A. B.
Lahore—Purdon, W.
Madhapoor—Smithe, J. D.
?*Malcoa*—Sylvester, J. H.

ITALY.

Bologna—Capellini, Prof. G.
Florence—Devincenzi, G.
—— Sloane, F. J.
Milan—Borromeo, Count V.
Padua—Zigno, Baron A. de.
Piedmont (*Val d'Ossola*)—Foster, C. Le N.
Pisa—Fairman, E. St. J.
Pisa—Meneghini, Prof. G.
Rome—Ponzi, Sig.
Turin—Gastaldi, B.
—— Jervis, W. P.
—— Perazzi, C.
—— Sella, Q.
—— Sismonda, Prof. A.

JAPAN.

Nagasaki (*Takasima*)—Potter, F. A.
Yokohama—Brunton, R. H.

MADEIRA.

Watson, Rev. R. B.

MALTA.

Caruana, A. A.
Lewis, Lieut. J. F.
Williams, Capt. J.

MAURITIUS.

Cooke, Lt.-Col. A. C.

MEXICO.

Pike, J. W.

NATAL.

Wathen, G. H.

NEW ZEALAND.

Bay of Islands—Taylor, Rev. R.
Christ Church—Fraser, Rev. C.
—— Haast, J.
—— Hood, T. H. C.
Wanganui—Buller, W.
Wellington—Crawford, J. C.
—— Hector, J.
—— Hutton, F. W.
—— Lyon, W.
—— Mantell, W. B. D.

NEWFOUNDLAND.

St. John's—Murray, A.

NORWAY.

Christiania—Kjerulf, T.
Kragerœ—Dahll, T.

NOVA SCOTIA.

Cape Breton—Poole, H. S.
Halifax—Honeyman, Rev. D.

PERSIA, NORTH.

Tiflis—Abich, H.

PERU.

Lima—Quiros, F.

PORTUGAL.

Alemtejo (*Pomarou*)—Mason, J.

PRUSSIA.

Berlin—Beyrich, Prof. E.
—— Ehrenberg, Prof. C. G.
—— Rose, G.
Bonn—Burkart, J.
Bonn—Dechen, H. von.
Breslau—Goeppert, Prof. H. R.
—— Roemer, Prof. F.

RUSSIA.

Dorpat—Keyserling, Count A. von.
St. Petersburg—Brandt, J. F.
St. Petersburg—Helmersen, Gen. G. v.
—— Kokscharow, M. von.

SPAIN.

Gavey, G. E.

STRAITS SETTLEMENTS.

Singapore—Logan, J. R.

SWEDEN.

Lund—Nilsson, S.
—— Torell, Prof. O.
Orebro—Smith, H.
Stockholm—Lovén, S.
—— Nordenskiöld, Prof. A. E.

SWITZERLAND.

Basle—Merian, Prof. P.
Berne—Studer, Prof. B.
Geneva—Favre, Prof. A.
—— Pictet, Prof. F. J.
Geneva (Celigny)—Gordon, L. D. B.
Neuchâtel—Desor, E.
Zurich—Heer, Rev. Prof. O.
—— Linth, A. E. von der.

TASMANIA.

Hobart Town—Gould, C.
Hobart Town—Milligan, J.

WEST INDIES.

Antigua—Gilbert, Rev. N.
Trinidad—Guppy, R. J. L.