PALÆONTOGRAPHICAL SOCIETY.

VOL. LXIX.

# THE WEALDEN AND PURBECK FISHES.

PART I.

PAGES 1—48; PLATES I—X.

# THE PALÆOZOIC ASTEROZOA.

PART II.

PAGES 57—108; PLATES II—V.

---

ISSUED FOR 1915.

# PALÆONTOGRAPHICAL SOCIETY.

## VOLUME LXIX.

CONTAINING

1. THE WEALDEN AND PURBECK FISHES. Part I. By Dr. A. S. Woodward. Ten Plates.
2. THE PALÆOZOIC ASTEROZOA. Part II. By Mr. W. K. Spencer. Four Plates.

---

ISSUED FOR 1915.

---

LONDON:
PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

AGENTS FOR THE SOCIETY
DULAU AND CO., LTD., 37, SOHO SQUARE, W.

OCTOBER, 1916.

THE PALÆONTOGRAPHICAL SOCIETY was established in the year 1847, for the purpose of figuring and describing British Fossils.

*Each person subscribing* ONE GUINEA *is considered a Member of the Society, and is entitled to the Volume issued for the Year to which the Subscription relates. The price of the Volume to Non-subscribers is* TWENTY-FIVE SHILLINGS NET.

Subscriptions are considered to be due on the 1st of January in each year.

The Annual Volumes are now issued in *two forms of Binding:* 1st, with all the Monographs stitched together and enclosed in one cover; 2nd, with each of the Monographs in a paper cover, and the whole of the separate parts enclosed in an envelope. Members wishing to obtain the Volume arranged in the LATTER FORM are requested to communicate with the Secretary.

Most of the *back volumes* are in stock. Monographs or parts of Monographs already published can be obtained, apart from the annual volumes, from Messrs. DULAU AND CO., LTD., 37, Soho Square, London, W., who will forward a complete price list on application.

Members desirous of forwarding the objects of the Society can be provided with plates and circulars for distribution on application to the Secretary, Dr. A. SMITH WOODWARD, British Museum (Nat. Hist.), South Kensington, London, S.W.

The following Monographs are in course of preparation and publication:

The Graptolites, by Prof. Lapworth, Miss Elles, and Miss Wood.

The Cambrian Trilobites, by Mr. Philip Lake.

The Palæozoic Asterozoa, by Mr. W. K. Spencer.

The Ordovician and Silurian Mollusca, by Dr. Wheelton Hind.

The Pliocene Mollusca, by Mr. F. W. Harmer.

The Pleistocene Mammalia, by Prof. S. H. Reynolds.

The Wealden and Purbeck Fishes, by Dr. A. Smith Woodward.

# ANNUAL REPORT

OF THE

# PALÆONTOGRAPHICAL SOCIETY, 1915,

WITH

# LIST

OF

# The Council, Secretaries, and Members

AND

A LIST OF THE CONTENTS OF THE VOLUMES ALREADY PUBLISHED.

# Council and Officers elected March, 1915.

## President.

HENRY WOODWARD, Esq., LL.D., F.R.S., F.G.S.

## Vice-Presidents.

F. A. Bather, Esq., D.Sc., F.R.S.
Rev. Canon Bonney, D.Sc., F.R.S.
Sir Archibald Geikie, O.M., K.C.B., F.R.S.
E. T. Newton, Esq., F.R.S.

## Council.

C. W. Andrews, Esq., D.Sc., F.R.S.
G. Barrow, Esq., F.G.S.
Miss M. C. Crosfield.
H. Dewey, Esq., F.G.S.
Walcot Gibson, Esq., D.Sc., F.G.S.
John Hopkinson, Esq., F.L.S., F.G.S.
F. L. Kitchin, Esq., M.A., Ph.D., F.G.S.
Bishop Mitchinson, D.D., D.C.L.
A. W. Oke, Esq., LL.M., F.G.S.
Clement Reid, Esq., F.R.S.
W. K. Spencer, Esq., M.A., F.G.S.
A. Strahan, Esq., Sc.D., F.R.S.
S. Hazzledine Warren, Esq., F.G.S.
Prof. W. W. Watts, LL.D., F.R.S.
Henry Woods, Esq., M.A., F.G.S.

## Treasurer.

R. S. Herries, Esq., M.A., F.G.S.

## Secretary.

A. Smith Woodward, Esq., LL.D., F.R.S., British Museum (Nat. Hist.), South Kensington, London. S.W.

## Local Secretaries.

*Bath*—Rev. H. H. Winwood, M.A., F.G.S.
*Berlin*—Messrs. Friedländer & Son.
*Cambridge*—H. Woods, Esq., M.A., F.G.S.
*Hertfordshire*—J. Hopkinson, Esq., F.G.S.
*Oxford*—Prof. W. J. Sollas, F.R.S.
*Staffordshire*—Dr. Wheelton Hind, F.G.S.

# ANNUAL REPORT OF THE COUNCIL

FOR THE YEAR ENDING 31ST DECEMBER, 1914.

READ AND ADOPTED AT THE

## ANNUAL GENERAL MEETING,

HELD AT THE APARTMENTS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE,
26TH MARCH, 1915.

DR. HENRY WOODWARD, F.R.S., PRESIDENT,

IN THE CHAIR.

---

THE COUNCIL, in presenting their Sixty-eighth Annual Report, regret that the unfortunate circumstances of the time have this year hindered the usual progress of the Society's work. There was no diminution in the number of offers of contributions for the annual volume at the beginning of 1914, and a publication of the ordinary size was arranged; but by the time that war was declared none of the contributions had been completed, and the various exigencies of the new situation necessitated the abandonment of all the instalments of Monographs except that by Mr. F. W. Harmer on the "Pliocene Mollusca." The preparation of this part, which is illustrated by eight plates, was also unexpectedly delayed; but it is now complete, and will be published in the summer of 1915 as the volume for 1914. It is unfortunately the smallest annual volume hitherto issued by the Society, but as soon as circumstances permit it is hoped that the deficiency of published matter in 1914 will be made up by the issue of larger volumes in the immediate future.

The delay and diminution of the volume for 1914 have again made the analysis of the balance-sheet somewhat difficult; and the large increase in the bank-balance at the end of the year is merely due to the failure of the proposed contributors already mentioned. The preparation of the beautiful

plates illustrating Mr. F. W. Harmer's Monograph has proved to be unusually costly, and the thanks of the Society are due to him for a gift of £35 towards the expenditure.

Among the members who have died during the past year the Council desire especially to refer to Mr. A. J. Jukes-Browne, Mr. William Hill, Mr. F. W. Rudler, and Mr. W. E. Darwin. These were all old and valued supporters of the Society, and Mr. Hill and Mr. Rudler had done much service on the Council. To replace the losses sustained, the Council would welcome the help and personal influence of the members in making the work and needs of the Society more widely known among those who are interested in the study of fossils.

The thanks of the Society are due to the Council of the Geological Society for permission both to store the stock of back volumes, and to hold the Council Meetings and Annual General Meeting in their apartments.

In conclusion, it is proposed that the retiring members of the Council be Mr. Allen, Dr. Hinde, Dr. Reed, and Dr. Rowe; that the new members be Mr. John Hopkinson, Mr. Clement Reid, Mr. S. Hazzledine Warren, and Mr. Henry Woods; that the new Vice-President be Dr. F. A. Bather; that the President be Dr. Henry Woodward; the Treasurer, Mr. Robert S. Herries; and the Secretary, Dr. A. Smith Woodward.

Annexed is the Balance-sheet.

# The PALÆONTOGRAPHICAL SOCIETY in account with ROBERT S. HERRIES, Esq., M.A., F.G.S., Treasurer.

*Cr.* *From January 1st, 1914, to December 31st, 1914.* *Dr.*

| | | £ s. d. | £ s. d. |
|---|---|---|---|
| Balance from last Account | | | 377 13 3 |
| Members' Subscriptions—1909–1913 | 105 | 110 5 0 | |
| ,, ,, 1914 | 230 | 241 10 0 | |
| ,, ,, 1915 | 4 | 4 4 0 | |
| | 339 | | 355 19 0 |
| Carriage paid by Members | | | 1 9 2 |
| Sales of back stock to Members | | | 66 17 11 |
| Sales by Messrs. Dulau & Co., Ltd. | | | 91 9 8 |
| Donation from F. W. Harmer, Esq. | | | 35 0 0 |
| Repaid Income Tax (1 year) | | | 0 17 6 |
| Dividends on £500 Natal 3 per cent. Stock (less income tax) | | | 14 1 3 |
| Interest on Deposit | | | 7 4 8 |
| | | | £950 12 5 |

| | £ s. d. | £ s. d. |
|---|---|---|
| Printing, paper, etc., Vol. LXVII (balance of account) | | 82 4 8 |
| Binding Vol. LXVII | | 45 11 7 |
| Packing and distribution, Vol. LXVII | | 16 2 10 |
| Drawing plates | | 26 5 0 |
| Secretary's honorarium | | 52 10 0 |
| Postage | | 1 18 2 |
| Rent of unused lithographic stones | | 1 7 0 |
| Premium, Fire Insurance | | 0 15 0 |
| Cleaning and arranging Stock Room | | 1 5 0 |
| Petty charges—Porter | 1 0 0 | |
| Bank | 0 1 9 | |
| | | 1 1 9 |
| Returned subscription paid in error | | 1 1 0 |
| Purchase of out-of-print stock to make up set for sale | | 1 10 0 |
| Balance in hands of Secretary | | 5 5 0 |
| Balance at Bank—Current Account | 363 15 5 | |
| Deposit Account | 350 0 0 | |
| | | 713 15 5 |
| | | £950 12 5 |

We have examined the above account, compared it with the vouchers, and find it to be correct; we have also seen the receipt for £500 Natal 3 per Cent. Consolidated Stock.

Robert S. Herries,
Treasurer.

*March 15th*, 1915.

Henry A. Allen
John Hopkinson
Alfred W. Oke
S. Hazzledine Warren
} Auditors.

# LIST OF MEMBERS.*

CORRECTED TO 1st DECEMBER, 1915.

---

Aberdeen, University Library.
Aberystwith, National Library of Wales.
Adelaide (Australia) Public Library.
Adlard, R. E., Esq., Bartholomew Close. E.C.
Allen, Messrs. E. G. & Son, King Edward Mansions, 14, Grape Street, Shaftesbury Avenue. W.C.
Allen, H. A., Esq., F.G.S., 28, Jermyn Street. S.W.
Amsterdam, Royal Academy of Sciences.
Andrews, C. W., Esq., D.Sc., F.R.S., British Museum (Nat. Hist.), South Kensington. S.W.
Arlecdon and Frizington Public Library, Frizington, Cumberland.
Asher and Co., Messrs., 13, Bedford Street, Covent Garden. W.C.

Bâle (Switzerland), University Library.
Balston, W. E., Esq , F.G.S., Barvin, Potter's Bar.
Banks, W. H., Esq., Hergest Croft, Kington, Herefordshire.
Barclay, F. H., Esq., F.G.S., The Warren, Cromer, Norfolk.
Barnes, J., Esq., F.G.S., South Cliff House, Higher Broughton, Manchester.
Barrow, George, Esq., F.G.S., 202, Brecknock Road. N.
Bath, Royal Literary and Scientific Institution.
Bather, F. A., Esq., M.A., D.Sc., F.R.S., *Vice-President*, British Museum (Nat. Hist.). S.W.
Battersea Public Library, Lavender Hill. S.W.
Bedford, His Grace the Duke of, K.G., F.R.S., Woburn Abbey, Bedfordshire.
Belfast Linen Hall Library, Donegall Square North, Belfast.
Belfast, Queen's University.
Bell, W. Heward, Esq., F.G.S., Cleeve House, Seend, Melksham.
Bergen (Norway), Museums Bibliothek.
Berlin, Geological Library of Royal School of Mines, 44, Invalidenstrasse.
Birkenhead Public Library, Birkenhead.

* Members are requested to inform the Secretary of any errors or omissions in this list, and of any delay in the transmission of the Yearly Volumes.

Birmingham Central Public Library, Ratcliff Place, Birmingham.
Birmingham Library, Margaret Street, Birmingham.
Birmingham University Library.
Blackburn Public Library, Blackburn.
Blackmore, Humphrey P., Esq., M.D., F.G.S., Salisbury.
Blathwayt, Lieut.-Col. Linley, Eagle House, Batheaston, Bath.
Blundell, Harold, Esq., Fairlawn, Harpenden, Herts.
Bolton, Chadwick Museum.
Bonn (Germany), Geological-Palæontological Institute of the University.
Bonney, Rev. Canon T. G., D.Sc., F.R.S., *Vice-President*, 9, Scroope Terrace, Cambridge.
Bootle-cum-Linacre Public Library, Bootle, Liverpool.
Boston Society of Natural History, Boston, Mass., U.S.A.
Boston Public Library, Boston, Mass., U.S.A.
Bournemouth Natural Science Society, Municipal College, Bournemouth.
Bradley, F. L., Esq., F.G.S., Ingleside, Malvern Wells.
Brighton and Hove Natural History Society, Public Library, Brighton.
Bristol Naturalists' Society, Geological Section, *per* B. A. Baker, Esq., Henbury House, Henbury, near Bristol.
Bristol Central Public Library.
Bristol Museum of Natural History, Queen's Road, Bristol.
Bristol University Library.
Brown, Alexander Oestrand, Esq., B.A., F.G.S., Ridgeway Cottage, Mill Hill. N.W.
Brydone, R. M., Esq., F.G.S., The Stock Exchange, London.
Burrows, Henry W., Esq., F.G.S., 17, Victoria Street. S.W.
Burslem Public Library, Burslem.
Buxton Public Library, Town Hall, Buxton.

Calcutta, Geological Survey of India.
Cambridge Philosophical Society's Library, New Museums, Cambridge.
Cambridge, St. John's College.
Cambridge, Sidney Sussex College.
Cambridge, University Library.
Cambridge, Sedgwick Museum.
Canadian Geological Survey, Sussex Street, Ottawa, Canada.
Cardiff, National Museum of Wales.
Cardiff Public Library, Cardiff.
Cardiff, University College of South Wales and Monmouthshire.
Carlisle Public Library, Carlisle.
Carruthers, R. G., Esq., F.G.S., 33, George Square, Edinburgh.
Chelsea Public Library, Manresa Road. S.W.
Cheltenham College, Cheltenham.
Chicago (U.S.A.), University Library.
Chiswick Public Library, Chiswick. W.
Christiania (Norway), University Library.
Clarke, Mrs. Stephenson, Brook House, Ardingly, Sussex.
Clifton College, Clifton, Bristol.
Clough, C. T., Esq., M.A., F.G.S., 28, Jermyn Street. S.W.

Cobbold, E. S., Esq., F.G.S., All Stretton, Church Stretton, R.S.O., Shropshire.
Codd, J. Alfred, Esq., M.D., B.Sc., F.G.S., 7, Tettenhall Road, Wolverhampton.
Cooper, C. Forster, Esq., M.A., The End House, Fulbrooke Road, Cambridge.
Cornell University, Ithaca, U.S.A.
Coventry Public Library, Coventry.
Crosfield, Miss Margaret C., Undercroft, Reigate.
Crosse, Miss, The Yew House, Caterham Valley, Surrey.
Croydon Central Public Library, Town Hall, Croydon.
Cunnington, C. H., Esq., F.G.S., 28, Jermyn Street. S.W.

Dawkins, Prof. W. Boyd, D.Sc., F.R.S., F.G.S., Fallowfield House, Fallowfield, Manchester.
Dawson, Messrs. W., and Sons, St. Dunstan's House, Fetter Lane. E.C.
Deane, Henry, Esq., F.L.S., Campsie, 14, Mercer Road, Malvern, Victoria, Australia.
Derby Public Library and Museum, Derby.
Devonport Public Library, Devonport.
Dewey, Henry, Esq., F.G.S., 28, Jermyn Street. S.W.
Dixon, E. E. L., Esq., B.Sc., F.G.S., 28, Jermyn Street. S.W.
Dorset County Museum Library, Dorchester.
Dublin, National Library.
Dublin, Royal College of Science for Ireland, Stephen's Green.
Dublin, Royal Irish Academy, 19, Dawson Street.
Dublin, Trinity College.
Ducie, Right Hon. Earl of, F.R.S., Tortworth Court, Gloucestershire.
Dundee Free Library, Dundee.

Edinburgh Geological Society, 69a, George Street, Edinburgh.
Edinburgh, Royal Scottish Museum, Chambers Street, Edinburgh.
Edinburgh Public Library, Edinburgh.
Edinburgh, Royal Society.
Edinburgh, University Library.
Epsom College, Epsom.
Erlangen (Germany), Mineralogical-Geological Institute of the University.
Eton College, Windsor, *per* M. D. Hill, Esq., M.A.
Exeter, Royal Albert Memorial Public Library, Queen Street.

Florence (Italy), Geological Institute, *per* Prof. C. De Stefani.
Folkestone Public Library and Museum, Folkestone.
Foulerton, Dr. J., 44, Pembridge Villas, Bayswater. W.
Frankfurt-am-Main (Germany), Senckenbergische Naturforschende Gesellschaft.
Friedländer, Messrs., 11, Carlstrasse, Berlin.
Fuller, Rev. A., M.A., The Lodge, 7, Sydenham Hill. S.E.

Galashiels, N.B., Public Library.
Galway, University College.
Garwood, Prof. E. J., M.A., F.R.S., F.G.S., University College, Gower Street. W.C.
Gateshead-on-Tyne Public Library, Gateshead-on-Tyne.
Geikie, Sir Archibald, O.M., K.C.B., LL.D., F.R.S., *Vice-President*, Shepherd's Down, Haslemere, Surrey.
Gibson, Miss, Hill House, Saffron Walden.
Gibson, Ernest, Esq., F.L.S., F.G.S., 25, Cadogan Place. S.W.
Gibson, Walcot, Esq., D.Sc., F.G.S., 28, Jermyn Street. S.W.
Gilmour, M., Esq., F.Z.S., Saffronhall House, 1, Windmill Road, Hamilton. N.B.
Glasgow, Geological Society, 150, Hope Street.
Glasgow, Mitchell Library, North Street.
Glasgow, Royal Philosophical Society, 207, Bath Street.
Glasgow, Kelvingrove Museum.
Glasgow, University Library.
Gloucester Free Public Library.
Gotha (Germany), Herzogliche Bibliothek.
Great Yarmouth Public Library.
Green, Upfield, Esq., F.G.S., 8, Bramshill Road, Harlesden. N.W.
Greenly, Edward, Esq., F.G.S., Achnashean, near Bangor.
Gregory, Prof. J. W., D.Sc., F.R.S., The University, Glasgow.

Haileybury College, near Hertford.
Halifax Public Library, Halifax.
Halle (Germany), University Library.
Hammersmith Carnegie (Central) Library, Hammersmith. W.
Hampstead Public Library, Finchley Road, Hampstead. N.W.
Harker, Alfred, Esq., M.A., F.R.S., St. John's College, Cambridge.
Harley, Dr. John, F.L.S., Beedings, Pulborough, Sussex.
Harmer, F. W., Esq., F.G.S., Oakland House, Cringleford, near Norwich.
Hastings Public Library.
Hawick Public Library, Hawick. N.B.
Hawkins, Herbert L., Esq., M.Sc., F.G.S., University College, Reading.
Heidelberg (Germany), University Library.
Heron-Allen, Edward, Esq., F.L.S., F.G.S., Large Acres, Selsey Bill, Sussex.
Herries, Robert S., Esq., M.A., F.G.S., *Treasurer*, St. Julian's, Sevenoaks, Kent.
Hill, Rev. Canon Edwin, M.A., F.G.S., The Rectory, Cockfield, Bury St. Edmunds.
Hind, Wheelton, Esq., M.D.Lond., F.R.C.S., F.G.S., *Local Secretary*, Roxeth House, Stoke-on-Trent.
Hinde, Geo. J., Esq., Ph.D., F.R.S., 24, Avondale Road, South Croydon.
Hodges, Isaac, Esq., F.G.S., Vereeniging, Transvaal.
Hodges, Figgis, and Co., 104, Grafton Street, Dublin.
Holcroft, Sir Charles, Bart., The Shrubbery, Summerhill, Kingswinford, near Dudley.
Hooley, R. W., Esq., F.G.S., Earlescroft, St. Giles' Hill, Winchester.
Hopkinson, John, Esq., F.L.S., F.G.S., *Local Secretary*, Weetwood, Watford.
Hove Public Library, Hove, Brighton.
Hughes, Prof. T. M'Kenny, M.A., F.R.S., Sedgwick Museum, Cambridge.
Hull Public Library, Hull.

Hutchinson, Rev. H. N., M.A., F.G.S., 17, St. John's Wood Park, Finchley Road. N.W.
Hutton, Miss H. Mary, Putney Park, Putney Park Lane. S.W.

Ipswich Central Public Library, High Street, Ipswich.
Isle of Man Natural History Society, Ramsey, Isle of Man.

Jehu, Prof. T. J., M.D., D.Sc., F.G.S., University, Edinburgh.
Johnes, Lady E. Hills, Dolau Cothy, Llandeilo, R.S.O., South Wales.
Johns Hopkins University, Baltimore, U.S.A.
Johnston, Miss Mary S., Hazlewood, Wimbledon Hill. S.W.
Jones, E. Lloyd, Esq., M.D., 59, Trumpington Street, Cambridge.
Jones, Prof. O. T., M.A., F.G.S., University College, Aberystwyth.

Kettering Public Library, Kettering.
Kilmarnock Public Library, Kilmarnock. N.B.
King, W. Wickham, Esq., F.G.S., Winds Point, Hagley, near Stourbridge.
Kirkcaldy Naturalists' Society; John G. Low, Esq., 228, High Street, Kirkcaldy. N.B.
Kitchin, F. L., Esq., M.A., Ph.D., F.G.S., Geol. Survey of England, 28, Jermyn Street. S.W.
Knipe, H. R., Esq., F.L.S., F.G.S., 9, Linden Park, Tunbridge Wells.

Lake, P., Esq., M.A., F.G.S., St. John's College, Cambridge.
Lancaster Public Library, Lancaster.
Lang, W. D., Esq., M.A., F.G.S., British Museum (Nat. Hist.), South Kensington. S.W.
Lapworth, Prof. Charles, LL.D., F.R.S., 38, Calthorpe Road, Edgbaston, Birmingham.
Lausanne (Switzerland) Cantonal Library.
Leeds Philosophical and Literary Society, Leeds.
Leeds Public Library, Leeds.
Leeds, University Library.
Leek, Staffordshire, Nicholson Institute.
Leicester Town Museum, Leicester.
Leipzig (Germany), University Library.
Leyton Public Library, Leyton. N.E.
Liège (Belgium), Geological Laboratory of the University.
Lille (France), Geological Laboratory of the University, 159, Rue Brûle-Maison.
Lisbon, Geological Survey of Portugal.
Lissajous, Mons. M., 10, Quai des Marans, Mâcon, France.
Liverpool, Athenæum Library.
Liverpool, Public Library.
Liverpool, Geological Society of.
Liverpool, University Library.
London, Imperial College of Science, South Kensington. S.W.
London, British Museum, Bloomsbury. W.C.
London, British Museum (Nat. Hist.), Cromwell Road. S.W.

London, Corporation of, Library Committee of, Guildhall. E.C.
London, Geological Society, Burlington House. W.
London, King's College, Strand. W.C.
London, Linnean Society, Burlington House, Piccadilly. W.
London, Museum of Practical Geology, Jermyn Street. S.W.
London, Royal College of Surgeons, Lincoln's Inn Fields. W.C.
London, Royal Institution of Great Britain, Albemarle Street. W.
London, Royal Society of, Burlington House. W.
London, St. Martin's-in-the-Fields Public Library, 115, St. Martin's Lane, W.C.
London, Science Museum, South Kensington. S.W.
London, University College, Gower Street. W.C.
London, Zoological Society, Regent's Park. N.W.
Longstaff, Mrs., Highlands, Putney Heath. S.W.
Lund (Sweden), University Library.
Lyons, Major H. G., D.Sc., F.R.S., Science Museum, South Kensington. S.W.

McNeill, Bedford, Esq., F.G.S., Greenholme, Claygate, Surrey.
Madras Government Museum, *per* Messrs. Baker and Co., 6, Bond Court, Walbrook. E.C.
Maidstone Museum, *per* Brenchley Trustees, Maidstone.
Manchester Public Library.
Manchester, Geological Society of, 5, John Dalton Street, Manchester.
Manchester Literary and Philosophical Society, 36, George Street, Manchester.
Marburg (Germany), University of.
Marr, J. E, Esq., M.A., Sc.D., F.R.S., St. John's College, Cambridge.
Mawby, William, Esq., 7, Cross Street, Birkenhead.
Melbourne Public Library.
Melbourne, Dept. Mines, Geological Survey Branch.
Mennell, H. T., Esq., F.L.S., The Red House, Croydon.
Metcalfe, Henry F., Esq., Cyprus House, Exmouth.
Middlesbrough Public Library.
Milan (Italy), Societa Italiana di Scienze Naturali, Palazzo del Museo Civico.
Milner, H. B., Esq., B.A., F.G.S., Trinity College, Cambridge.
Mitchinson, Rt. Rev. J., D.C.L., D.D., Canon of Gloucester and Master of Pembroke College, Oxford.
Mond, Robert, Esq., M.A., F.R.S.E., F.G.S., The Elms, Avenue Road, St. John's Wood. N.W.
Munich (Germany), Alte Akademie, Geologisches Museum.
Munich Royal Library.

New South Wales, Royal Society of, Sydney.
New York (U.S.A.) Public Library.
Newcastle-on-Tyne, Armstrong College.
Newcastle-on-Tyne, Literary and Philosophical Society of, Westgate Street, Newcastle-on-Tyne.

Newcastle-on-Tyne Public Library.
Newport Public Library, Newport, Monmouthshire.
Newton, E. T., Esq., F.R.S., *Vice-President*, Florence House, Willow Bridge Road, Canonbury. N.
Noble, Arthur H., Esq., P.O. Box 238, Tampico (Tamaulipas), Mexico.
North Devon Athenæum, Barnstaple.
North Staffordshire Field Club, Stone, Staffordshire.
Northampton Natural History Society, Northampton.
Northumberland, His Grace the Duke of, K.G., F.R.S., Alnwick Castle.
Norwich Public Library.
Nottingham Public Library.

Odling, M., Esq., M.A., B.Sc., F.G.S., University, Leeds.
Oke, Alfred W., Esq., F.G.S., 32, Denmark Villas, Hove, Sussex.
Oldham Public Library.
Oswestry Public Library.
Oxford, Bodleian Library.
Oxford, Radcliffe Library.

Paisley Philosophical Institution.
Paris, École des Mines.
Paris, Geological Society of France, 7, Rue des Grands Augustins.
Paris, Muséum National d'Histoire Naturelle, Laboratoire de Paléontologie.
Paris, Sorbonne, Laboratoire de Géologie.
Part, G. M., Esq., B.A., F.G.S., Trinity College, Cambridge.
Peabody Institute, Salem, Mass., U.S.A.
Penzance, Royal Geological Society of Cornwall.
Peterborough Natural History, Scientific, and Archæological Society.
Philadelphia (U.S.A.), Academy of Natural Sciences.
Pittsburgh (U.S.A.), Carnegie Museum.
Plymouth Public Library.
Plymouth Institution, Library of, Athenæum, Plymouth.
Pocock, R. W., Esq., B.Sc., F.G.S., 28, Jermyn Street, S.W.
Poole Public Library.
Portis, Dr. A., Professor of Geology, The University, Rome.
Portsmouth Public Library.
Power, Edward John, Esq., F.G.S., 25, Ashburn Place, South Kensington. S.W.
Prague (Bohemia), Royal Geological Institution of the German Carl Ferdinand University.
Preston Public Library.
Pryor, M. R., Esq., Weston Manor, Stevenage, Herts.

Queensland Museum, Brisbane.

Reading, University College.
Reid, Clement, Esq., F.R.S., One Acre, Milford-on-Sea, Hants.

Reynolds, Prof. S. H., M.A., F.G.S., University, Bristol.
Rochdale Public Library.
Rogers, Arthur W., Esq., D.Sc., F.G.S., Cape Town.
Rowe, A. W., Esq., M.S., M.B., F.G.S., Shottendane, Margate.
Rudler, the late F. W., Esq., I.S.O., F.G.S., Ethel Villa, Tatsfield, Westerham, Kent.
Rugby School Natural History Society.

St. Andrews, University Library.
St. Helens Central Public Library, The Gamble Institute, St. Helens.
Salisbury Public Library.
Scarborough Philosophical Society.
Scharff, R. F., Esq., Ph.D., National Museum, Dublin.
Scott, D. H., Esq., M.A., Ph.D., F.R.S., East Oakley House, Oakley, Hants.
Sheffield Free Public Library.
Sheffield, Literary and Philosophical Society of, Church Street.
Sheffield, University of.
Sheffield, Weston Park Public Museum.
Sheppard, Thomas, Esq., F.G.S., Municipal Museum, Hull.
Sherborne, King's School, Library of.
Sherlock, R. L., Esq., D.Sc., F.G.S., 28, Jermyn Street. S.W.
Shrewsbury Public Library.
Smith, Mrs. Emma, Hencotes House, Hexham.
Smith, Stanley, Esq., B.A., D.Sc., F.G.S., University College, Aberystwyth.
Sollas, Professor W. J., D.Sc., F.R.S., *Local Secretary*, University Museum, Oxford.
Somersetshire Archæological and Natural History Society, Museum, Taunton.
Sophia, University of.
South Shields Public Library.
Southport Public Library.
Southwark, Central Library and Cuming Museum, Walworth Road. S.E.
Spencer, W. K., Esq., M.A., F.G.S., The Gables, Constable Road, Ipswich.
Stebbing, W. P. D., Esq., F.G.S., Frythe Park, Walton-on-the Hill, Epsom.
Stechert, G. E., Esq., 2, Star Yard, Carey Street, Chancery Lane. W.C.
Stepney Borough Reference Library, Bancroft Road, Mile End Road. E.
Stockholm, Royal Swedish Academy of Sciences.
Stoke Newington Public Library, Church Street, Stoke Newington. N.
Stoke-upon-Trent Public Library, Stoke-upon-Trent.
Stonyhurst College, Blackburn.
Storey, Charles B. C., Esq., M.A., F.G.S., Plâs Nantyr, Glyn, Ruabon.
Strahan, A., Esq., M.A., Sc.D., F.R.S., Geological Survey, 28, Jermyn Street. S.W.
Sunderland Corporation Museum.
Sunderland Subscription Library, Fawcett Street, Sunderland.
Swansea Public Library.
Swansea, Royal Institution of South Wales.
Swinnerton, Prof. H. H., D.Sc., University College, Nottingham.
Sydney, New South Wales, University of.
Sydney, New South Wales, Australian Museum.

Tasmania, Royal Society of.
Thornton, H. Gerard, Esq., B.A., Kingsthorpe Hall, Northampton.
Toronto (Canada), University Library.
Torquay Natural History Society, Museum, Babbacombe Road, Torquay.
Toulouse (France), University Library.
Trafford, H. H., Esq., The Bungalow, Croston, near Preston.
Treacher, Llewellyn, Esq., F.G.S., Somercroft, Twyford, Berks.
Trechmann, C. T., Esq., B.Sc., F.G.S., Hudworth Towers, Castle Eden, Co. Durham.
Truro, Royal Institution of Cornwall.
Tübingen (Germany), University Library.

Upsala (Sweden), University Library.

Vancouver (British Columbia), University Library.
Vienna, Royal Natural History Court Museum, Geological Department.

Walker, Sir B. E., C.V.O., LL.D., Canadian Bank of Commerce, Toronto, Canada.
Wandsworth Public Library, West Hill, Wandsworth. S.W.
Warren, S. Hazzledine, Esq., F.G.S., Sherwood, Loughton, Essex.
Warrington Public Museum and Library.
Warsaw, University Library.
Warwickshire Natural History and Archæological Society, The Museum, Warwick.
Washington, U.S. Geological Survey.
Watts, Professor W. W., M.A., LL.D., F.R.S., Imperial College of Science, South Kensington. S.W.
Weg, Max, 3, Königstrasse, Leipzig, Germany.
Wesley and Son, William, 28, Essex Street, Strand. W.C.
West Ham, Essex Museum, Municipal Technical Institute, Romford Road. E.
West Hartlepool Public Library.
Whitby Literary and Philosophical Society, Museum, Whitby.
Williams, J. Hughes, Esq., 24, Southdown Road, Wimbledon. S.W.
Wilmore, Albert, Esq., D.Sc., F.G.S., Fernbank, Colne, Lancashire.
Wiltshire Archæological and Natural History Society, Devizes.
Winchester College Natural History Society, Winchester.
Winwood, Rev. Henry H., M.A., F.G.S., *Local Secretary*, 11, Cavendish Crescent, Bath.
Wolverhampton Public Library.
Wood, J. G., Esq., M.A., F.S.A., F.G.S., 7, New Square, Lincoln's Inn. W.C.
Woodhead, J. H., Esq., F.G.S., Hindover, Pinner Road, Watford Heath, Hertfordshire.
Woods, Henry, Esq., M.A., F.G.S., *Local Secretary*, Sedgwick Museum, Cambridge.
Woodward, A. Smith, Esq., LL.D., F.R.S., *Secretary*, British Museum (Nat. Hist.), South Kensington. S.W.
Woodward, Henry, Esq., LL.D., F.R.S., *President*, 13, Arundel Gardens, Notting Hill. W.
Worcester Public Library and Hastings Museum, Worcester.

Wordie, James M., Esq., B.A., F.G.S., St. John's College, Cambridge.
Workington Public Library, Workington, Cumberland.
Würzburg (Germany), University Library.

Yorkshire Philosophical Society, Museum, York.
Young, George W., Esq., F.G.S., 20, Grange Road, Barnes. S.W.
Yule, Miss A. F., Tarradale House, by Muir-of-Ord, Ross-shire. N.B.

# CATALOGUE OF THE CONTENTS OF THE ANNUAL VOLUMES

ALREADY PUBLISHED BY

## THE PALÆONTOGRAPHICAL SOCIETY.



[1] The Volume for the year 1849 consists of two separate portions, each of which is stitched in a paper cover, on which are printed the dates 1848, 1849, and 1850. The one portion contains 'Cretaceous Entomostraca' and 'Permian Fossils'; the other, 'London Clay Reptilia,' Part II, and 'Fossil Corals,' Part I.

## CATALOGUE OF VOLUMES—Continued.

| | |
|---|---|
| Vol. VIII.[1] Issued May, 1855, for the Year 1854 | The Fossil Brachiopoda, Vol. I, Part II, No. 2, Cretaceous (pp. 55—117, pls. vi—xii), with Appendix and Index to Vol. I, by Mr. Davidson (pp. 1—30, pl. A).<br>The Reptilia of the Wealden Formations, Part II, Dinosauria, by Prof. Owen (pp. 1—54, pls. i—xix, xvi A).<br>The Mollusca of the Great Oolite, Part III, Bivalves, by Messrs. Morris and Lycett (pp. 81—147, pls. ix—xv).<br>The Fossil Corals, Part V, Silurian, by Messrs. Milne Edwards and Jules Haime (pp. 245—322, pls. lvii—lxxii).<br>The Fossil Balanidæ and Verrucidæ, by Mr. Charles Darwin (pp. 1—44, pls. i, ii).<br>The Mollusca of the Chalk, Part II, Cephalopoda, by Mr. D. Sharpe (pp. 27—36, pls. xi—xvi).<br>The Eocene Mollusca, Part III, No. 1, Prosobranchiata, by Mr. F. E. Edwards (pp. 123—180, pls. xvi—xxiii). |
| „ IX.[2] Issued Feb., 1857, for the Year 1855 | The Mollusca of the Crag, Part II, No. 3, Bivalves, by Mr. S. V. Wood (pp. 217—342, pls. xxi—xxxi).<br>The Reptilia of the Wealden Formations, Part III, by Prof. Owen (pp. 1—26, pls. i—xii).<br>The Eocene Mollusca, Part III, No. 2, Prosobranchiata, continued, by Mr. F. E. Edwards (pp. 181—240, pls. xxiv—xxvii).<br>The Mollusca of the Chalk, Part III, Cephalopoda, by Mr. D. Sharpe (pp. 37—68, pls. xvii—xxvii).<br>The Tertiary Entomostraca, by Mr. T. R. Jones (pp. i—xii, 1—68, pls. i—vi).<br>The Fossil Echinodermata, Oolitic, Vol. I, Part I, by Dr. Wright (pp. v—x, 1—154, pls. i—x). |
| „ X. Issued April, 1858, for the Year 1856 | The Fossil Echinodermata, Oolitic, Vol. I, Part II, by Dr. Wright (pp. 155—302, pls. xi—xxii).<br>The Fossil Crustacea, Part I, London Clay, by Prof. Bell (pp. i—viii, 1—44, pls. i—xi).<br>The Fossil Brachiopoda, Vol. II, Part IV, Permian, by Mr. Davidson (pp. 1—51, pls. i—iv).<br>The Fossil Brachiopoda, Vol. II, Part V, No. 1, Carboniferous, by Mr. Davidson (pp. 1—48, pls. i—viii).<br>The Reptilia of the Wealden Formations, by Prof. Owen, Part IV (pp. 8—26, pls. iv—xi), and Supplement No. 1 (pp. 1—7, pls. i—iii).<br>The Reptilia of the London Clay, Vol. I (Supplement), by Prof. Owen (pp. 77—79, pls. xxviii A, xxviii B). |
| „ XI. Issued Nov., 1859, for the Year 1857 | The Fossil Echinodermata, Oolitic, Vol. I, Part III, by Dr. Wright (pp. 303—390, pls. xxiii—xxxvi).<br>The Fossil Brachiopoda, Vol. II, Part V, No. 2, Carboniferous, by Mr. Davidson (pp. 49—80, pls. ix—xvi).<br>The Reptilia of the Cretaceous Formations (Supplement No. 1), by Prof. Owen (pp. 1—19, pls. i—iv).<br>The Reptilia of the Wealden Formations (Supplement No. 2), by Prof. Owen (pp. 20—44, pls. v—xii.)<br>The Polyzoa of the Crag, by Prof. Busk (pp. i—xiv, 1—136, pls. i—xxii). |
| „ XII. Issued March, 1861, for the Year 1858 | The Fossil Echinodermata, Oolitic, Vol. I, Part IV, by Dr. Wright (pp. 391—468, pls. xxxvii—xliii).<br>The Eocene Mollusca, Part III, No. 3, Prosobranchiata continued, by Mr. F. E. Edwards (pp. 241—330, pls. xxviii—xxxiii).<br>The Reptilia of the Cretaceous Formations (Supplements No. 2, No. 3), by Prof. Owen (pp. 27—30, pl. vii, pp. 1—25, pls. i—vi).<br>The Reptilia of the Purbeck Limestones, by Prof. Owen (pp. 31—39, pl. viii).<br>The Fossil Brachiopoda, Vol. II, Part V, No. 3, Carboniferous by Mr. Davidson (pp. 81—120, pls. xvii—xxvi). |
| „ XIII. Issued Dec., 1861, for the Year 1859 | The Fossil Brachiopoda, Part V, No. 4, Carboniferous, by Mr. Davidson (pp. 121—210, pls. xxvii—xlvii).<br>The Reptilia of the Oolitic Formations, No. 1, Lower Lias, by Prof. Owen (pp. 1—14, pls. i—vi).<br>The Reptilia of the Kimmeridge Clay, No. 1, by Prof. Owen (pp. 15, 16, pl. vii).<br>The Eocene Mollusca, Part IV, No. 1, Bivalves, by Mr. S. V. Wood (pp. 1—74, pls. i—xiii). |

[1] This Volume is marked on the outside 1855.
[2] This Volume is marked on the outside 1856.

## CATALOGUE OF VOLUMES—Continued.

| | |
|---|---|
| Vol. XIV. Issued May, 1863, for the Year 1860 | The Fossil Brachiopoda, Vol. II, Part V, No. 5, Carboniferous, by Mr. Davidson (pp. 211—280, pls. xlviii—lv).<br>The Reptilia of the Oolitic Formations, No. 2, Lower Lias, by Prof. Owen (pp. 1—26, pls. i—xi).<br>The Reptilia of the Kimmeridge Clay, No. 2, by Prof. Owen (pp. 27, 28, pl. xii).<br>The Fossil Estheriæ, by Prof. Rupert Jones (pp. i—x, 1—134, pls. i—v).<br>The Fossil Crustacea, Part II, Gault and Greensand, by Prof. Bell (pp. i—vii, 1—40, pls. i—xi). |
| „ XV. Issued May, 1863, for the Year 1861 | The Fossil Echinodermata, Oolitic, Vol. II, Part I (Asteroidea), by Dr. Wright (pp. 1—130, pls. i—x, x A, xi, xii).<br>Supplement to the Great Oolite Mollusca, by Dr. Lycett (pp. 1—129, pls. xxxi—xlv). |
| „ XVI. Issued Aug., 1864, for the Year 1862 | The Fossil Echinodermata, Cretaceous, Vol. I, Part I, by Dr. Wright (pp. 1—64, pls. i—iii, iii A, iv—vii, vii A, viii, xi).<br>The Trilobites of the Silurian, Devonian, &c., Formations, Part I (Devonian and Silurian), by Mr. J. W. Salter (pp. 1—80, pls. i—vi).<br>The Fossil Brachiopoda, Vol. III, Part VI, No. 1, Devonian, by Mr. Davidson (pp. 1—56, pls. i—ix).<br>The Eocene Mollusca, Part IV, No. 2, Bivalves, by Mr. S. V. Wood (pp. 75—136, pls. xiv—xx).<br>The Reptilia of the Cretaceous Formations (Supplement, No. 4), by Prof. Owen (pp. 1—18, pls. i—ix).<br>The Reptilia of the Wealden and Purbeck Formations (Supplement, No. 3), by Prof. Owen (pp. 19—21, pl. x). |
| „ XVII. Issued June, 1865, for the Year 1863 | The Trilobites of the Silurian, Devonian, &c., Formations, Part II, by Mr. J. W. Salter (pp. 81—128, pls. vii—xiv).<br>The Fossil Brachiopoda, Vol. III, Part VI, No. 2, Devonian, by Mr. Davidson (pp. 57—131, pls. x—xx).<br>The Belemnitidæ, Part I, Introduction, by Prof. Phillips (pp. 1—28).<br>The Reptilia of the Liassic Formations, Part I, by Prof. Owen (pp. 1—40, pls. i—xvi). |
| „ XVIII. Issued April, 1866, for the Year 1864 | The Fossil Echinodermata, Oolitic, Vol. II, Part II (Liassic Ophiuroidea), by Dr. Wright (pp. 131—154, pls. xiii—xviii).<br>The Trilobites of the Silurian, Devonian, &c., Formations, Part III, by Mr. J. W. Salter (pp. 129—176, pls. xv—xxv).<br>The Belemnitidæ, Part II, Liassic Belemnites, by Prof. Phillips (pp. 29–52, pls. i—vii).<br>The Pleistocene Mammalia, Part I, Introduction, Felis spelæa, by Messrs. W. Boyd Dawkins and W. A. Sanford (pp. i—l, 1—28, pls. i—v).<br>Title-pages, &c, to the Monographs on the Reptilia of the London Clay, Cretaceous, and Wealden Formations. |
| „ XIX.[1] Issued Dec., 1866, for the Year 1865 | The Crag Foraminifera, Part 1, by Messrs. T. Rupert Jones, W. K. Parker, and H. B. Brady (pp. i—vi, 1—72, pls. i—iv).<br>Supplement to the Fossil Corals, Part I, Tertiary, by Dr. Duncan (pp. i—iii, 1—66, pls. i—x).<br>The Fossil Merostomata, Part I, Pterygotus, by Mr. H. Woodward (pp. 1—44, pls. i—ix).<br>The Fossil Brachiopoda, Vol. III, Part VII, No. 1, Silurian, by Mr. Davidson (pp. 1—88, pls. i—xii). |
| „ XX. Issued June, 1867, for the Year 1866 | Supplement to the Fossil Corals, Part IV, No. 1, Liassic, by Dr. Duncan (pp. i—iii, 1—44, pls. i—xi).<br>The Trilobites of the Silurian, Devonian, &c., Formations, Part IV (Silurian), by Mr. J. W. Salter (pp. 177—214, pls. xxv*—xxx).<br>The Fossil Brachiopoda, Vol. III, Part VII, No. 2, Silurian, by Mr. Davidson (pp. 89—168, pls. xiii—xxii).<br>The Belemnitidæ, Part III, Liassic Belemnites, by Prof. Phillips (pp. 53—88, pls. viii—xx). |
| „ XXI. Issued June, 1868, for the Year 1867 | Flora of the Carboniferous Strata, Part I, by Mr. E. W. Binney (pp. 1—32, pls. i—vi).<br>Supplement to the Fossil Corals, Part IV, No. 2, Liassic, by Dr. Duncan (pp. 45—73, pls. xii—xvii).<br>The Fossil Echinodermata, Cretaceous, Vol. I, Part II, by Dr. Wright (pp. 65—112, pls. ix, x, xii—xxi, xxi A, xxi B).<br>The Fishes of the Old Red Sandstone, Part I, by Messrs. J. Powrie and E. Ray Lankester (pp. 1—32, pls. i—v).<br>The Pleistocene Mammalia, Part II, Felis spelæa, continued, by Messrs. W. Boyd Dawkins and W. A. Sanford (pp. 29—124, pls. vi—xix). |

[1] From 1865 onwards the Volumes are issued in two forms of binding: first, with all the Monographs stitched together and enclosed in one cover; secondly, with each of the Monographs separate, and the whole of the separate parts placed in an envelope. The previous Volumes are not in separate parts.

## CATALOGUE OF VOLUMES—Continued.

| | | |
|---|---|---|
| Vol. XXII. | Issued Feb., 1869, for the Year 1868 | Supplement to the Fossil Corals, Part II, No. 1, Cretaceous, by Dr. Duncan (pp. 1–26, pls. i—ix).<br>The Fossil Merostomata, Part II, Pterygotus, by Mr. H. Woodward (pp. 45–70, pls. x–xv).<br>The Fossil Brachiopoda, Vol. III, Part VII, No. 3, Silurian, by Mr. Davidson (pp. 169—248, pls. xxiii—xxxvii).<br>The Belemnitidæ, Part IV, Liassic and Oolitic Belemnites, by Prof. Phillips (pp. 89–108, pls. xxi–xxvii).<br>The Reptilia of the Kimmeridge Clay, No. 3, by Prof. Owen (pp. 1–12, pls. i–iv).<br>The Pleistocene Mammalia, Part III, Felis spelæa, concluded, with F. lynx, by Messrs. W. Boyd Dawkins and W. A. Sanford (pp. 125–176, pls. xx—xxii, xxii A, xxii B, xxiii). |
| „ XXIII. | Issued Jan., 1870, for the Year 1869 | Supplement to the Fossil Corals, Part II, No. 2, Cretaceous, by Dr. Duncan (pp. 27–46, pls. x—xv).<br>The Fossil Echinodermata, Cretaceous, Vol. I, Part III, by Dr. Wright (pp. 113–136, pls. xxii—xxix, xxix A, xxix B).<br>The Belemnitidæ, Part V, Oxford Clay, &c., Belemnites, by Prof. Phillips (pp. 109—128, pls. xxviii—xxxvi).<br>The Fishes of the Old Red Sandstone, Part I (concluded), by Messrs. J. Powrie and E. Ray Lankester (pp. 33–62, pls. vi—xiv).<br>The Reptilia of the Liassic Formations, Part II, by Prof. Owen (pp. 41—82, pls. xvii–xx).<br>The Crag Cetacea, No. 1, by Prof. Owen (pp. 1—40, pls. i—v). |
| „ XXIV. | Issued Jan., 1871, for the Year 1870 | The Flora of the Carboniferous Strata, Part II, by Mr. E. W. Binney (pp. 33—62, pls. vii–xii).<br>The Fossil Echinodermata, Cretaceous, Vol. I, Part IV, by Dr. Wright (pp. 137–160, pls. xxx—xxxix).<br>The Fossil Brachiopoda, Vol. III, Part VII, No. 4, Silurian, by Mr. Davidson (pp. 249—397, pls. xxxviii–l).<br>The Eocene Mollusca, Part IV, No. 3, Bivalves, by Mr. S. V. Wood (pp. 137—182, pls. xxi—xxv).<br>The Fossil Mammalia of the Mesozoic Formations, by Prof. Owen (pp. i—vi, 1—115, pls. i—iv). |
| „ XXV. | Issued June, 1872, for the Year 1871 | The Flora of the Carboniferous Strata, Part III, by Mr. E. W. Binney (pp. 63–96, pls. xiii—xviii).<br>The Fossil Merostomata, Part III, Pterygotus and Slimonia, by Mr. H. Woodward (pp. 71—120, pls. xvi—xx).<br>Supplement to the Crag Mollusca, Part I (Univalves), by Mr. S. V. Wood, with an Introduction on the Crag District, by Messrs. S. V. Wood, jun., and F. W. Harmer (pp. i—xxxi, 1–98, pls. i—vii, and map).<br>Supplement to the Reptilia of the Wealden (Iguanodon), No. IV, by Prof. Owen (pp. 1—15, pls. i—iii).<br>The Pleistocene Mammalia, Part IV, Felis pardus, &c., by Messrs. W. Boyd Dawkins and W. A. Sanford (pp. 177—194, pls. xxiv, xxv).<br>The Pleistocene Mammalia, Part V, Ovibos moschatus, by Mr. W. Boyd Dawkins (pp. 1—30, pls. i—v). |
| „ XXVI. | Issued Oct., 1872, for the Year 1872 | Supplement to the Fossil Corals, Part III (Oolitic), by Prof. Duncan (pp. 1—24, pls i—vii), with an Index to the Tertiary and Secondary Species.<br>The Fossil Echinodermata, Cretaceous, Vol. I, Part V, by Dr. Wright (pp. 161—184, pls. xl—xliv).<br>The Fossil Merostomata, Part IV (Stylonurus, Eurypterus, Hemiaspis), by Mr. H. Woodward (pp. 121—180, pls. xxi—xxx).<br>The Fossil Trigoniæ, No. I, by Dr. Lycett (pp. 1—52, pls. i—ix). |

## CATALOGUE OF VOLUMES—Continued.

| | |
|---|---|
| Vol. XXVII. Issued Feb., 1874, for the Year 1873 | The Fossil Echinodermata, Cretaceous, Vol. I, Part VI, by Dr. Wright (pp. 185—224, pls. xlv—lii).<br>Supplement to the Fossil Brachiopoda, Vol. IV, Part I (Tertiary and Cretaceous), by Mr. Davidson (pp. 1—72, pls. i—viii).<br>Supplement to the Crag Mollusca, Part II (Bivalves), by Mr. S. V. Wood (pp. 99—231, pls. viii—xi, and add. plate).<br>Supplement to the Reptilia of the Wealden (Iguanodon), No. V, by Prof. Owen (pp. 1—18, pls. i, ii).<br>Supplement to the Reptilia of the Wealden (Hylæochampsa), No. VI, by Prof. Owen (pp. 1—7).<br>The Fossil Reptilia of the Mesozoic Formations, Part I, by Prof. Owen (pp. 1—14, pls. i, ii). |
| ,, XXVIII. Issued July, 1874, for the Year 1874 | The Post-Tertiary Entomostraca, by Mr. G. S. Brady, Rev. H. W. Crosskey, and Mr. D. Robertson (pp. i—v, 1—232, pls. i—xvi).<br>The Carboniferous Entomostraca, Part I (Cypridinidæ), by Prof. T. Rupert Jones and Messrs. J. W. Kirkby and G. S. Brady (pp. 1—56, pls. i—v).<br>The Fossil Trigoniæ, No. II, by Dr. Lycett (pp. 53—92, pls. x—xix). |
| ,, XXIX. Issued Dec. 1875, for the Year 1875 | The Flora of the Carboniferous Strata, Part IV, by Mr. E. W. Binney (pp. 97—147, pls. xix—xxiv).<br>The Fossil Echinodermata, Cretaceous, Vol. I, Part VII, by Dr. Wright (pp. 225—264, pls. liii—lxii).<br>The Fossil Trigoniæ, No. III, by Dr. Lycett (pp. 93—148, pls. xx—xxvii).<br>The Fossil Reptilia of the Mesozoic Formations, Part II, by Prof. Owen (pp. 15—94, pls. iii—xxii). |
| ,, XXX. Issued Dec., 1876, for the Year 1876 | The Carboniferous and Permian Foraminifera (the genus Fusulina excepted), by Mr. H. B. Brady (pp. 1—166, pls. i—xii).<br>Supplement to the Fossil Brachiopoda, Vol. IV, Part II, No. 1 (Jurassic and Triassic), by Mr. Davidson (pp. 73—144, pls. ix—xvi).<br>Supplement to the Reptilia of the Wealden (Poikilopleuron and Chondrosteosaurus), No. VII, by Prof. Owen (pp. 1—7, pls. i—vi). |
| ,, XXXI. Issued Feb, 1877, for the Year 1877 | Supplement to the Eocene Mollusca (Bivalves), by Mr. S. V. Wood, 2 plates.<br>The Fossil Trigoniæ, No. IV, by Dr. Lycett (pp. 149—204, pls. xxviii—xl).<br>The Eocene Mollusca (Univalves), Part IV, by Mr. S. V. Wood (pp. 331—361, pl. xxxiv).<br>The Carboniferous Ganoid Fishes, Part I (Palæoniscidæ), by Dr. Traquair (pp. 1—60, pls. i—vii).<br>The Fossil Reptilia of the Mesozoic Formations, Part III, by Prof. Owen (pp. 95—97, pls. xxiii, xxiv).<br>The Fossil Elephants, Part I (E. antiquus), by Prof. Leith Adams (pp. 1—68, pls. i—v). |
| ,, XXXII. Issued Mar., 1878, for the Year 1878 | The Fossil Echinodermata, Cretaceous, Vol. I, Part VIII, by Dr. Wright (pp. 265—300, pls. lxii A, lxiii—lxix).<br>Index and Title Page to the Fossil Echinodermata, Oolitic, Vol. I (Echinoidea), by Dr. Wright (pp. 469—481).<br>The Fossil Merostomata, Part V (Neolimulus, &c.), by Dr. H. Woodward (pp. 181—263, pls. xxxi—xxxvi, and title-page).<br>Supplement to the Fossil Brachiopoda, Vol. IV, Part II, No. 2 (Jurassic and Triassic), by Mr. Davidson (pp. 145—242, pls. xvii—xxix).<br>The Lias Ammonites, Part I, by Dr. Wright (pp. 1—48, pls. i—viii).<br>The Sirenoid and Crossopterygian Ganoids, Part I, by Prof. Miall (pp. 1—32, pls. i, i A, ii—v).<br>Supplement to the Reptilia of the Wealden (Goniopholis, Petrosuchus, and Suchosaurus), No. VIII, by Prof. Owen (pp. 1—15, pls. i—vi).<br>The Pleistocene Mammalia, Part A (Preliminary Treatise), by Prof. Boyd Dawkins (pp. i—xxxviii). |

## CATALOGUE OF VOLUMES—Continued.

**Vol. XXXIII. Issued May, 1879, for the Year 1879**

- The Eocene Flora, Vol. I, Part I, by Mr. J. S. Gardner and Baron Ettingshausen (pp. 1—38, pls. i—v).
- Second Supplement to the Crag Mollusca (Univalves and Bivalves), by Mr. S. V. Wood (pp. i, ii, 1—58, pls. i—vi, and title-page).
- The Fossil Trigoniæ, No. V, by Dr. Lycett (pp. 205—245, pl. xli, and title-page).
- The Lias Ammonites, Part II, by Dr. Wright (pp. 49—164, pls. ix—xviii).
- Supplement to the Reptilia of the Wealden (Goniopholis, Brachydectes, Nannosuchus, Theriosuchus, and Nuthetes), No. IX, by Prof. Owen (pp. 1—19, pls. i—iv).
- The Fossil Elephants, Part II (E. primigenius), by Prof. Leith Adams (pp. 69—146, pls. vi—xv).

**,, XXXIV. Issued May, 1880, for the year 1880**

- The Eocene Flora, Vol. I, Part II, by Mr. J. S. Gardner and Baron Ettingshausen (pp. 39—58, pls. vi—xi).
- The Fossil Echinodermata, Oolitic, Vol. II, Part III (Asteroidea and Ophiuroidea), by Dr. Wright (pp. 155—203, pls. xix—xxi, pp. i—iv, and title-page)
- Supplement to the Fossil Brachiopoda, Vol. IV, Part III (Permian and Carboniferous), by Mr. Davidson (pp. 243—316, pls. xxx—xxxvii).
- The Lias Ammonites, Part III, by Dr. Wright (pp. 165—264, pls. xix—xl).
- The Reptilia of the London Clay, Vol. II, Part I (Chelone), by Prof. Owen (pp. 1—4, pls. i, ii).

**,, XXXV. Issued May, 1881, for the Year 1881**

- The Fossil Echinodermata, Cretaceous, Vol. I, Part IX, by Dr. Wright (pp. 301—324, pls. lxx—lxxv).
- Supplement to the Fossil Brachiopoda, Vol. IV, Part IV (Devonian and Silurian, from Budleigh-Salterton Pebble Bed), by Mr. Davidson (pp. 317—368, pls. xxxviii—xlii).
- The Fossil Trigoniæ (Supplement No. 1), by Dr. Lycett (pp. 1—4).
- The Lias Ammonites, Part IV, by Dr. Wright (pp. 265—328, pls. xxii A, xxii B, xli—xlviii).
- The Reptilia of the Liassic Formations, Part III, by Prof. Owen (pp. 83—134, pls. xxi—xxxiii, and title-page).
- The Fossil Elephants, Part III (E. primigenius and E. meridionalis), by Prof. Leith Adams (pp. 147—265, pls. xvi—xxviii, and title page).

**,, XXXVI. Issued June, 1882, for the Year 1882**

- The Eocene Flora, Vol. I, Part III, by Mr. J. S. Gardner and Baron Ettingshausen (pp. 59—86, pls. xii, xiii, and title-page).
- Third Supplement to the Crag Mollusca, by the late Mr. S. V. Wood (pp. 1—24, pl. i).
- The Fossil Echinodermata, Cret., Vol. I, Part X, by Dr. Wright (pp. 325—371, pls. lxxvi—lxxx, and title-page).
- Supplement to the Fossil Brachiopoda, Vol. IV, Part V, by Dr. Davidson (pp. 369—383, and title-page).
- Do., Vol. V, Part I (Devonian and Silurian), by Dr. Davidson (pp. 1—134, pls. i—vii).
- The Lias Ammonites, Part V, by Dr. Wright (pp. 329—400, pls. xlix—lii, lii A, liii—lxix).

**,, XXXVII. Issued Oct., 1883, for the Year 1883**

- The Eocene Flora, Vol. II, Part I, by Mr. J. S. Gardner (pp. 1—60, pls. i—ix).
- The Trilobites of the Silurian, Devonian, &c., Formations, Part V, by the late Mr. J. W. Salter (pp. 215—224, and title-page).
- The Carboniferous Trilobites, Part I, by Dr. H. Woodward (pp. 1—38, pls. i—vi).
- Supplement to the Fossil Brachiopoda, Vol. V, Part II (Silurian), by Dr. Davidson (pp. 135—242, pls. viii—xvii).
- The Fossil Trigoniæ (Supplement No. 2), by the late Dr. Lycett (pp. 5—19, pls. i—iv, and title-page).
- The Lias Ammonites, Part VI, by Dr. Wright (pp. 401—440, pls. lxx—lxxvii).

**,, XXXVIII. Issued Dec., 1884, for the Year 1884**

- The Eocene Flora, Vol. II, Part II, by Mr. J. S. Gardner (pp. 61—90, pls. x—xx).
- The Carboniferous Entomostraca, Part I, No. 2, by Prof. T. Rupert Jones, Mr. J. W. Kirkby, and Prof. G. S. Brady (pp. i—iii, 57—92, pls. vi, vii, and title-page).
- The Carboniferous Trilobites, Part II, by Dr. H. Woodward (pp. 39—86, pls. vii—x, and title-page).
- Supplement to the Fossil Brachiopoda, Vol. V, Part III, by Dr. Davidson (pp. 243—476, pls. xviii—xxi, and title-page).
- The Lias Ammonites, Part VII, by Dr. Wright (pp. 441—480, pls. lxxviii—lxxxvii).

## CATALOGUE OF VOLUMES—Continued.

| | |
|---|---|
| Vol. XXXIX. Issued Jan., 1886, for the Year 1885 | The Eocene Flora, Vol. II, Part III, by Mr. J. S. Gardner (pp. 91—159, pls. xxi—xxvii, and title-page).<br>The Stromatoporoids, Part I, by Prof. Alleyne Nicholson (pp. i—iii, 1—130, pls. i—xi).<br>The Fossil Brachiopoda (Bibliography), Vol. VI (pp. 1—163), by the late Dr. Davidson and Mr. W. H. Dalton.<br>The Lias Ammonites, Part VIII, by the late Dr. Wright (pp. 481—503, pl. lxxxviii, and title-page). |
| ,, XL. Issued Mar., 1887, for the Year 1886 | The Morphology and Histology of Stigmaria Ficoides, by Prof. W. C. Williamson (pp. i—iv, 1—62, pls. i—xv).<br>The Fossil Sponges, Part I, by Dr. G. J. Hinde (pp. 1—92, pls. i—viii).<br>The Jurassic Gasteropoda, Part I, No. 1, by Mr. W. H. Hudleston (pp. 1—56).<br>The Inferior Oolite Ammonites, Part I, by Mr. S. S. Buckman (pp. 1—24, pls. i—vi).<br>The Pleistocene Mammalia, Part VI, by Prof. Boyd Dawkins (pp. 1—29, pls. i—vii). |
| ,, XLI. Issued Jan., 1888, for the Year 1887 | The Fossil Sponges, Part II, by Dr. G. J. Hinde (pp. 93—188, pl. ix).<br>The Palæozoic Phyllopoda, Part I, by Prof. T. R. Jones and Dr. Woodward (pp. 1—72, pls. i—xii).<br>The Jurassic Gasteropoda, Part I, No. 2, by Mr. W. H. Hudleston (pp. 57—136, pls. i—vi).<br>The Inferior Oolite Ammonites, Part II, by Mr. S. S. Buckman (pp. 25—56, pls. vii—xiv). |
| ,, XLII. Issued Mar., 1889, for the Year 1888 | The Stromatoporoids, Part II, by Prof. Alleyne Nicholson (pp. 131—158, pls. xii—xix).<br>The Tertiary Entomostraca (Supplement), by Prof. T. Rupert Jones and Mr. C. D. Sherborn (pp. 1—55, pls. i—iii).<br>The Jurassic Gasteropoda, Part I, No. 3, by Mr. W. H. Hudleston (pp. 137—192, pls. vii—xi).<br>The Inferior Oolite Ammonites, Part III, by Mr. S. S. Buckman (pp. 57—144, pls. xv, xxiii A).<br>The Devonian Fauna of the South of England, Part I, by the Rev. G. F. Whidborne (pp. i, ii, 1—46, pls. i—iv).<br>Title-pages and Prefaces to the Monographs on the Reptilia of the Wealden and Purbeck (Supplements), Kimmeridge Clay, and Mesozoic Formations, and on the Cetacea of the Red Crag. |
| ,, XLIII. Issued Mar., 1890, for the Year 1889 | The Cretaceous Entomostraca (Supplement), by Prof. T. Rupert Jones and Dr. G. J. Hinde (pp. i—viii, 1—70, pls. i—iv).<br>The Jurassic Gasteropoda, Part I, No. 4, by Mr. W. H. Hudleston (pp. 193—224, pls. xii—xvi).<br>The Inferior Oolite Ammonites, Part IV, by Mr. S. S. Buckman (pp. 145—224, pls. xxiv—xxxvi).<br>The Devonian Fauna of the South of England, Part II, by the Rev. G. F. Whidborne (pp. 47—154, pls. v—viii, viii A, ix—xv). |
| ,, XLIV. Issued Apr., 1891, for the Year 1890 | The Stromatoporoids, Part III, by Prof. Alleyne Nicholson (pp. 159—202, pls. xx—xxv).<br>The Fossil Echinodermata, Cretaceous, Vol. II, Part I (Asteroidea), by Mr. W. Percy Sladen (pp. 1—28, pls. i—viii).<br>The Inferior Oolite Ammonites, Part V, by Mr. S. S. Buckman (pp. 225—256, pls. xxxvii—xliv).<br>The Devonian Fauna of the South of England, Part III, by the Rev. G. F. Whidborne (pp. 155—250, pls. xvi—xxiv).<br>Title-pages to the Supplement to the Fossil Corals, by Prof. Duncan. |
| ,, XLV. Issued Feb., 1892, for the Year 1891 | The Jurassic Gasteropoda, Part I, No. 5, by Mr. W. H. Hudleston (pp. 225—272, pls. xvii—xx).<br>The Inferior Oolite Ammonites, Part VI, by Mr. S. S. Buckman (pp. 257—312, pls. xlv—lvi).<br>The Devonian Fauna of the South of England, Part IV (*Conclusion of* Vol. I) (pp. 251—344, pls. xxv—xxxi, and title-page).<br>,, ,, Vol. II, Part I, by the Rev. G. F. Whidborne (pp. 1—56, pls. i—vi). |

## CATALOGUE OF VOLUMES—Continued.

| | | |
|---|---|---|
| Vol. XLVI. | Issued Nov., 1892, for the Year 1892 | The Stromatoporoids, Part IV (*Conclusion*), by Prof. Alleyne Nicholson (pp. 203—234, pls. xxvi—xxix, and title-page).<br>The Palæozoic Phyllopoda, Part II, by Prof. T. R. Jones and Dr. Woodward (pp. 73—124, pls. xiii—xvii).<br>The Jurassic Gasteropoda, Part I, No. 6, by Mr. W. H. Hudleston (pp. 273—324, pls. xxi—xxvi).<br>The Inferior Oolite Ammonites, Part VII, by Mr. S. S. Buckman (pp. 313—344, pls. lvii—lxxvi).<br>The Devonian Fauna of the South of England, Vol. II, Part II, by the Rev. G. F. Whidborne (pp. 57—88, pls. vi—x). |
| ,, XLVII. | Issued Dec., 1893, for the Year 1893 | The Fossil Sponges, Part III, by Dr. G. J. Hinde (pp. 189—254, pls. x—xix).<br>The Fossil Echinodermata, Cretaceous, Vol. II, Part II (Asteroidea), by Mr. W. Percy Sladen (pp. 29—66, pls. ix—xvi).<br>The Inferior Oolite Ammonites, Part VIII, by Mr. S. S. Buckman (pp. 345—376, pls. lxxvii—xcii).<br>The Devonian Fauna of the South of England, Vol. II, Part III, by the Rev. G. F. Whidborne (pp. 89—160, pls. xi—xvii). |
| ,, XLVIII. | Issued Nov., 1894, for the Year 1894 | The Jurassic Gasteropoda, Part I, No. 7, by Mr. W. H. Hudleston (pp. 325—390, pls. xxvii—xxxii).<br>Carbonicola, Anthracomya, and Naiadites, Part I, by Dr. W. Hind (pp. 1—80, pls. i—xi).<br>The Inferior Oolite Ammonites, Part IX, by Mr. S. S. Buckman (pp. 377—456, pls. xciii—ciii).<br>The Fishes of the Old Red Sandstone, Part II, No. 1, by Dr. R. H. Traquair (pp. 63—90, pls. xv—xviii). |
| ,, XLIX. | Issued Oct., 1895, for the Year 1895 | The Crag Foraminifera, Part II, by Prof. T. R. Jones (pp. 73—210, pls. v—vii).<br>The Jurassic Gasteropoda, Part I, No. 8, by Mr. W. H. Hudleston (pp. 391—444, pls. xxxiii—xl).<br>Carbonicola, Anthracomya, and Naiadites, Part II, by Dr. W. Hind (pp. 81—170, pls. xii—xx).<br>The Devonian Fauna of the South of England, Vol. II, Part IV, by the Rev. G. F. Whidborne (pp. 161—212, pls. xviii—xxiv). |
| ,, L. | Issued Oct., 1896, for the Year 1896 | The Crag Foraminifera, Part III, by Prof. T. R. Jones (pp. 211—314).<br>The Jurassic Gasteropoda, Part I, No. 9, by Mr. W. H. Hudleston (pp. 445—514, pls. xli—xliv, and title-page).<br>Carbonicola, Anthracomya, and Naiadites, Part III, by Dr. W. Hind (pp. 171—182, pl. xxi, and title-page).<br>The Carboniferous Lamellibranchiata, Part I, by Dr. W. Hind (pp. 1—80, pls. i, ii).<br>The Devonian Fauna of the South of England, Vol. III, Part I, by the Rev. G. F. Whidborne (pp. 1—112, pls. i—xvi). |
| ,, LI. | Issued Dec., 1897, for the Year 1897 | The Crag Foraminifera, Part IV, by Prof. T. R. Jones (pp. vii—xv, 315—402, and title-page).<br>The Carboniferous Lamellibranchiata, Part II, by Dr. W. Hind (pp. 81—208, pls. iii—xv).<br>The Carboniferous Cephalopoda of Ireland, Part I, by Dr. A. H. Foord (pp. 1—22, pls. i—vii).<br>The Devonian Fauna of the South of England, Vol. III, Part II, by the Rev. G. F. Whidborne (pp. 113—178, pls. xvii—xxi). |
| ,, LII. | Issued Dec., 1898, for the Year 1898 | The Palæozoic Phyllopoda, Part III, by Prof. T. R. Jones and Dr. Woodward (pp. 125—176, pls. xviii—xxv).<br>The Carboniferous Lamellibranchiata, Part III, by Dr. W. Hind (pp. 209—276, pls. xvi—xxv).<br>The Inferior Oolite Ammonites, Part X, by Mr. S. S. Buckman (pp. i—xxxii, Suppl. pls. i—iv).<br>The Carboniferous Cephalopoda of Ireland, Part II, by Dr. A. H. Foord (pp. 23—48, pls. viii—xvii).<br>The Devonian Fauna of the South of England, Vol. III, Part III, by the Rev. G. F. Whidborne (pp. 179—236, pls. xxii—xxxviii). |

## CATALOGUE OF VOLUMES—Continued.

| | | |
|---|---|---|
| Vol. LIII. | Issued Dec., 1899, for the Year 1899 | The Palæozoic Phyllopoda, Part IV, by Prof. T. R. Jones and Dr. Woodward (pp. i—xv, 175, 176, 177—211, pls. xxvi—xxxi, and title-page).<br>The Cretaceous Lamellibranchia, Part I, by Mr. H. Woods (pp. 1—72, pls. i—xiv).<br>The Carboniferous Lamellibranchiata, Part IV, by Dr. W. Hind (pp. 277—360, pls. xxvi—xxxix).<br>The Inferior Oolite Ammonites, Part XI, by Mr. S. S. Buckman (pp. xxxiii—lxiv, pls. v—xiv). |
| „ LIV. | Issued Dec., 1900, for the Year 1900 | The Cretaceous Lamellibranchia, Part II, by Mr. H. Woods (pp. 73—112, pls. xv—xix).<br>The Carboniferous Lamellibranchiata, Part V, by Dr. W. Hind (pp. 361—476, pls. xl—liv).<br>The Carboniferous Cephalopoda of Ireland, Part III, by Dr. A. H. Foord (pp. 49—126, pls. xviii—xxxii).<br>The British Pleistocene Mammalia, Title-page for Vol. I, by Messrs. Dawkins and Sanford.<br>The Structure of Carboniferous Plants, Title-page, by Mr. E. W. Binney. |
| „ LV. | Issued Dec., 1901, for the Year 1901 | The Cretaceous Lamellibranchia, Part III, by Mr. H. Woods (pp. 113—144, pls. xx—xxvi).<br>The Carboniferous Lamellibranchiata, Vol. II, Part I, by Dr. W. Hind (pp. 1—34, pls. i—vi), Title-page and Index for Vol. I.<br>The Carboniferous Cephalopoda of Ireland, Part IV, by Dr. A. H. Foord (pp. 127—146, pls. xxxiii—xxxix).<br>British Graptolites, Part I, by Miss Elles and Miss Wood, edited by Prof. Lapworth (pp. 1—54, pls. i—iv).<br>Ganoid Fishes of British Carboniferous Formations—Part I, Palæoniscidæ, No. 2, by Dr. Ramsay H. Traquair (pp. 61—87, pls. viii—xviii). |
| „ LVI. | Issued Dec., 1902, for the Year 1902 | The Cave Hyæna, by Prof. S. H. Reynolds (pp. 1—25, pls. i—xiv).<br>The Fishes of the English Chalk, Part I, by Dr. A. Smith Woodward (pp. 1—56, pls. i—xiii).<br>The Cretaceous Lamellibranchia, Part IV, by Mr. H. Woods (pp. 145—196, pls. xxvii—xxxviii).<br>British Graptolites, Part I, No. 2,, by Miss Elles and Miss Wood, edited by Prof. Lapworth (pp. i—xxviii, 55—94, pls. v—xiii). |
| „ LVII. | Issued Dec., 1903, for the Year 1903 | The Fishes of the English Chalk, Part II, by Dr. A. Smith Woodward (pp. 57—96, pls. xiv—xx).<br>The Cretaceous Lamellibranchia, Part V, by Mr. H. Woods (pp. i—xliii, 197—232, pls. xxxix—xlii), Title-page and Index for Vol. I.<br>The Carboniferous Lamellibranchiata, Vol. II, Part II, by Dr. W. Hind (pp. 35—124, pls. vii—xxi).<br>The Carboniferous Cephalopoda of Ireland, Part V, by Dr. A. H. Foord (pp. 147—234, pls. xl—xlix), Title-page and Index.<br>The Lower Palæozoic Trilobites of Girvan, Part I, by Mr. F. R. Cowper Reed (pp. 1—48, pls. i—vi).<br>British Graptolites, Part III, by Miss Elles and Miss Wood, edited by Prof. Lapworth (pp. xxix—lii, 103—134, pls. xiv—xix). |
| „ LVIII. | Issued Dec., 1904, for the Year 1904 | The Fishes of the Old Red Sandstone, Part II, No. 2, by Dr. R. H. Traquair (pp. 91—118, pls. xix—xxvi).<br>The Cretaceous Lamellibranchia, Vol. II, Part I, by Mr. H. Woods (pp. 1—56, pls. i—vii).<br>The Carboniferous Lamellibranchiata, Vol. II, Part III, by Dr. W. Hind (pp. 125—216, pls. xxii—xxv).<br>The Inferior Oolite Ammonites, Part XII, by Mr. S. S. Buckman (pp. lxv—clxviii, pls. xv—xix).<br>The Lower Palæozoic Trilobites of Girvan, Part II, by Mr. F. R. Cowper Reed (pp. 49—96, pls. vii—xiii).<br>British Graptolites, Part IV, by Miss Elles and Miss Wood, edited by Prof. Lapworth (pp. liii—lxxii, 135—180, pls. xx—xxv). |

## CATALOGUE OF VOLUMES—Continued.

| | | |
|---|---|---|
| Vol. LIX. | Issued Nov., 1905, for the Year 1905 | The Fossil Echinodermata, Cretaceous, Vol. II, Part III, by Mr. W. K. Spencer (pp. 67—90, pls. xvii—xxvi).<br>The Cretaceous Lamellibranchia, Vol. II, Part II, by Mr. H. Woods (pp. 57—96, pls. viii—xi).<br>The Carboniferous Lamellibranchiata, Vol. II, Title-pages and Index, by Dr. W. Hind.<br>The Inferior Oolite Ammonites, Part XIII, by Mr. S. S. Buckman (pp. clxix—ccviii, pls. xx—xxiv).<br>The Cornbrash Fauna, Part I, by the Rev. J. F. Blake (pp. 1—100, pls. i—ix). |
| „ LX. | Issued Dec., 1906, for the Year 1906 | The Pleistocene Bears, by Prof. S. H. Reynolds (pp. 1—35, pls. i—viii).<br>The Fishes of the Old Red Sandstone, Part II, No. 3, by Dr. R. H. Traquair (pp. 119—130, pls. xxvii—xxxi).<br>The Cretaceous Lamellibranchia, Vol. II, Part III, by Mr. H. Woods (pp. 97—132, pls. xii—xix).<br>The Lower Palæozoic Trilobites of Girvan, Part III, by Mr. F. R. Cowper Reed (pp. 97—186, Title-page and Index, pls. xiv—xx).<br>The Cambrian Trilobites, Part I, by Mr. P. Lake (pp. 1—28, pls. i, ii).<br>British Graptolites, Part V, by Miss Elles and Miss Wood, edited by Prof. Lapworth (pp. lxxiii—xcvi, 181—216, pls. xxvi, xxvii). |
| „ LXI. | Issued Dec., 1907, for the Year 1907 | The Sirenoid Ganoids, Part II, by Prof. L. C. Miall (pp. 33—34, Title-page, Preface, and Postscript).<br>Ganoid Fishes of British Carboniferous Formations, Part I, Palæoniscidæ, No. 3, by Dr. R. H. Traquair (pp. 87—106, pls. xix—xxiii).<br>The Fishes of the English Chalk, Part III, by Dr. A. Smith Woodward (pp. 97—128, pls. xxi—xxvi).<br>The Inferior Oolite Ammonites, Part XIV, by Mr. S. S. Buckman (pp. ccix—cclxii, Title-pages, Preface, and Index).<br>The Cretaceous Lamellibranchia, Vol. II, Part IV, by Mr. H. Woods (pp. 133—180, pls. xx—xxvii).<br>The Fossil Echinodermata, Cretaceous, Vol. II, Part IV, by Mr. W. K. Spencer (pp. 91—132, pls. xxvii—xxix).<br>The British Conulariæ, by Miss Ida L. Slater (pp. 1—40, pls. i—v, Title-page and Index).<br>The Cambrian Trilobites, Part II, by Mr. P. Lake (pp. 29—48, pls. iii, iv).<br>British Graptolites, Part VI, by Miss Elles and Miss Wood (Mrs. Shakespear), edited by Prof. Lapworth (pp. xcvii—cxx, 217—272, pls. xxviii—xxxi).<br>The Devonian Fauna of the South of England, Vol. II, Part V, and Vol. III, Part IV, by the Rev. G. F. Whidborne (Vol. II, pp. 215—222, Title-page and Index; Vol. III, pp. 237—247, Title-page and Index).<br>The Cornbrash Fauna, Part II, by the Rev. J. F. Blake (pp. 101—102, Title-page and Index). |
| „ LXII. | Issued Dec., 1908, for the Year 1908 | The Fishes of the English Chalk, Part IV, by Dr. A. Smith Woodward (pp. 129—152, pls. xxvii—xxxii).<br>Illustrations of Type Specimens of Inferior Oolite Ammonites (pls. i—vii).<br>The Cretaceous Lamellibranchia, Vol. II, Part V, by Mr. H. Woods (pp. 181—216, pls. xxviii—xxxiv).<br>The Fossil Echinodermata, Cretaceous, Vol. II, Part V, by Mr. W. K. Spencer (pp. 133—138, Title-page and Index).<br>The Cambrian Trilobites, Part III, by Mr. P. Lake (pp. 49—64, pls. v, vi.)<br>British Graptolites, Part VII, by Miss Elles and Miss Wood (Mrs. Shakespear), edited by Prof. Lapworth (pp. cxxi—cxlviii, 273—358, pl. xxxii—xxxv). |
| „ LXIII. | Issued Dec., 1909, for the Year 1909 | The Pleistocene Canidæ, by Prof. S. H. Reynolds (pp. 1—28, pls. i—vi).<br>Ganoid Fishes of British Carboniferous Formations, Part I, Palæoniscidæ, No. 4, by Dr. R. H. Traquair (pp. 107—122, pls. xxiv—xxx).<br>The Fishes of the English Chalk, Part V, by Dr. A. Smith Woodward (pp. 153—184, pls. xxxiii—xxxviii).<br>The Cretaceous Lamellibranchia, Vol. II, Part VI, by Mr. H. Woods (pp. 217—260, pls. xxxv—xliv).<br>The Mollusca of the Chalk, Part I, Cephalopoda, by Mr. D. Sharpe (Title-page and Index).<br>The Belemnitidæ, by Prof. Phillips (Title-page and Index). |

## CATALOGUE OF VOLUMES—Continued.

| | | |
|---|---|---|
| Vol. LXIV. | Issued Jan., 1911, for the Year 1910 | Ganoid Fishes of British Carboniferous Formations, Part I, Palæoniscidæ, No. 5, by Dr. R. H. Traquair (pp. 123—158, pls. xxxi—xxxv).<br>The Fishes of the English Chalk, Part VI, by Dr. A. Smith Woodward (pp. 185—224, pls. xxxix—xlvi).<br>The Cretaceous Lamellibranchia, Vol. II, Part VII, by Mr. H. Woods (pp. 261—284, pls. xlv—l).<br>The Carboniferous Arachnida, by Mr. R. I. Pocock (pp. 1—84, pls. i—iii).<br>British Graptolites, Part VIII, by Miss Elles and Miss Wood (Mrs. Shakespear), edited by Prof. Lapworth (pp. 359—414, pls. xxxvi—xli). |
| „ LXV. | Issued Feb., 1912, for the Year 1911 | The Pleistocene Mustelidæ, by Prof. S. H. Reynolds (pp. 1—28, pls. i—viii).<br>Ganoid Fishes of British Carboniferous Formations, Part I, Palæoniscidæ, No. 6, by Dr. R. H. Traquair (pp. 159—180, pls. xxxvi—xl).<br>The Fishes of the English Chalk, Part VII, by Dr. A. Smith Woodward (pp. i—viii, 225—264, pls. xlvii—liv, including Title-page and Index).<br>The Cretaceous Lamellibranchia, Vol. II, Part VIII, by Mr. H. Woods (pp. 285—340, pls. li—liv).<br>The Fossil Sponges, Title-page and Index to Vol. I, by Dr. G. J. Hinde (pp. 255—264). |
| „ LXVI. | Issued Feb., 1913, for the Year 1912 | British Graptolites, Part IX, by Miss Elles and Miss Wood (Mrs. Shakespear), edited by Prof. Lapworth (pp. 415—486, pls. xlii—xlix).<br>The Cambrian Trilobites, Part IV, by Mr. P. Lake (pp. 65—88, pls. vii—x).<br>The Cretaceous Lamellibranchia, Vol. II, Part IX, by Mr. H. Woods (pp. 341—473, pls. lv—lxii, including Title-page and Index).<br>The Fossil Malacostracous Crustacea, by Prof. T. Bell (Title-page and Index). |
| „ LXVII. | Issued Feb., 1914, for the Year 1913 | British Graptolites, Part X, by Miss Elles and Miss Wood (Mrs. Shakespear), edited by Prof. Lapworth (pp. 487—526, pls. l—lii).<br>The Palæozoic Asterozoa, Part I, by Mr. W. K. Spencer (pp. 1—56, pl. i).<br>The Lower Palæozoic Trilobites of Girvan.—Supplement, by Dr. F. R. Cowper Reed (pp 1—56, pls. i—viii, including Title-page and Index).<br>The Pliocene Mollusca, Part I, by Mr. F. W. Harmer (pp. 1—200, pls. i—xxiv).<br>Ganoid Fishes of British Carboniferous Formations, Part I, Palæoniscidæ, No. 7, by Dr. R. H. Traquair (pp. i—vi, 181—186, including Title-page and Index).<br>The Fishes of the Old Red Sandstone, Part II, No. 4, by Dr. R. H. Traquair (pp. 131—134, including Title-page and Index). |
| „ LXVIII. | Issued July, 1915, for the Year 1914 | The Pliocene Mollusca, Part II, by Mr. F. W. Harmer (pp. 201—302, pls. xxv—xxxii). |
| „ LXIX. | Issued Oct., 1916, for the year 1915 | The Wealden and Purbeck Fishes, Part I, by Dr. A. Smith Woodward (pp. 1—48, pls. i—x).<br>The Palæozoic Asterozoa, Part II, by Mr. W. K. Spencer (pp. 57—108, pls. ii—v). |

# CATALOGUE OF THE COMPLETED VOLUMES OF MONOGRAPHS

PUBLISHED BY

## THE PALÆONTOGRAPHICAL SOCIETY.

ADAMS (A. L.) Monograph on the British Fossil Elephants. 1877—81. 3 parts, 28 plates. £1 5*s*.

BELL (T.) A Monograph of the Fossil Malacostracous Crustacea of Great Britain. 1857—62. 2 parts, 22 plates. 15*s*.

———— *See* Owen.

BINNEY (E. W.) Observations on the Structure of Fossil Plants found in the Carboniferous Strata. 1867—75. 4 parts, 24 plates. £1 1*s*.

BLAKE (J. F.) A Monograph of the Fauna of the Cornbrash. 1905—7. 2 parts, 9 plates. 10*s*.

BRADY (H. B.) A Monograph of Carboniferous and Permian Foraminifera (the genus Fusulina excepted). 1876. 12 plates. 12*s*.

———— *See* Jones, Parker, etc.

BRADY, CROSSKEY, and ROBERTSON. A Monograph of the Post-Tertiary Entomostraca of Scotland, including species from England and Ireland. 1874. 16 plates. 16*s*.

BUCKMAN (S. S.) A Monograph on the Inferior Oolite Ammonites of the British Islands. 1887—1907. 14 parts, 128 plates. £5 15*s*.

———— [and SECRETARY]. Illustrations of Type Specimens of Inferior Oolite Ammonites in the Sowerby Collection. 1908. 7 plates. 7*s*.

BURROWS (H. W.) *See* Jones, Parker, etc.

BUSK (G.) A Monograph of the Fossil Polyzoa of the Crag. 1859. 22 plates. 15*s*.

CHAPMAN (F.) *See* Jones, Parker, etc.

Crosskey (H. W.) *See* G. S. Brady.

Darwin (C.) A Monograph of the Fossil Cirripedes of Great Britain (Lepadidæ, Balanidæ, Verrucidæ). 1851—4. 2 parts, 7 plates. 10*s*.

Davidson (T.) British Fossil Brachiopoda. 1851—86. 6 vols., 234 plates. £10 10*s*.

Dawkins and Sanford. The British Pleistocene Mammalia. 1866—9. Vol. I. 3 parts, 25 plates. £1 1*s*.

——— *See* S. H. Reynolds.

Duncan (P. M.) A Monograph of the British Fossil Corals. Second Series, being a Supplement to the Monograph of the British Corals by Milne-Edwards and Haime. 1866—91. 7 parts, 49 plates. £2 2*s*.

Edwards (F. E.) A Monograph of the Eocene Mollusca, or Descriptions of Shells from the older Tertiaries. 1849—77. Part I, out of print. Part II, Pulmonata, 7 plates, 5*s*. Part III, Prosobranchiata, 18 plates, 12*s*. Part IV, Pulmonata and Prosobranchiata, 1 plate, 3*s*. 6*d*.

Ettingshausen (C.) *See* J. S. Gardner.

Foord (A. H.) Monograph on the Carboniferous Cephalopoda of Ireland. 1897—1903. 5 parts, 49 plates. £2 5*s*.

Forbes (E.) Monograph of the Echinodermata of the British Tertiaries. 1852. 4 plates. 3*s*.

Gardner and Ettingshausen. A Monograph of the British Eocene Flora. 1879—86. 2 vols, 40 plates. £1 16*s*.

Haime (J.) *See* Milne-Edwards.

Hind (Wheelton). A Monograph of the British Carboniferous Lamellibranchiata. 1896—1905. 2 vols., 79 plates. £3 16*s*.

——— A Monograph on Carbonicola, Anthracomya, and Naiadites. 1894—6. 3 parts, 21 plates. £1 1*s*.

Hinde (G. J.) A Monograph of the British Fossil Sponges. 1887—1912. 4 parts, 19 plates. £1.

——— *See* T. R. Jones.

Holland (R.) *See* Jones, Parker, etc.

Hudleston (W. H.) A Monograph of the British Jurassic Gasteropoda. Part I, Gasteropoda of the Inferior Oolite. 1887—96. 9 parts, 44 plates. £2 2*s*.

Jones (T. R.) Monograph of the Entomostraca of the Cretaceous Formation of England. 1849. 7 plates. Out of print.

——— A Monograph of the Fossil Estheriæ. 1862. 5 plates. 6*s*.

Jones and Hinde. A Supplementary Monograph of the Cretaceous Entomostraca of England and Ireland. 1890. 4 plates. 5*s*.

Jones, Kirkby, and Brady. A Monograph of the British Fossil Bivalved Entomostraca from the Carboniferous Formations. 1874—84. Part I (complete). 7 plates. 7*s*. 6*d*.

Jones, Parker, Brady, Burrows, Sherborn, Millett, Holland, and Chapman. A Monograph of the Foraminifera of the Crag. 1866—97. 4 parts, 7 plates. £1 5*s*.

Jones and Sherborn. A Monograph of the Tertiary Entomostraca of England. 1857—89. 2 parts, 9 plates. 10*s*.

Jones and Woodward. A Monograph of the British Palæozoic Phyllopoda. 1887—99. 4 parts, 31 plates. £1 10*s*.

King (W.) Monograph of the Permian Fossils of England. 1850. 29 plates. Out of print.

Kirkby (J. W.) *See* T. R. Jones.

Lankester (E. R.) *See* Powrie.

Lycett (J.) Supplementary Monograph on the Mollusca from the Stonesfield Slate, Great Oolite, Forest Marble, and Cornbrash. 1863. 15 plates. 12*s*.

——— A Monograph of the British Fossil Trigoniæ. 1872—83. 7 parts, 45 plates. £2 2*s*.

——— *See* J. Morris.

Miall (L. C.) Monograph on the Sirenoid and Crossopterygian Ganoids. 1878—1907. 2 parts, 6 plates. 6*s*.

Millett (F. W.) *See* Jones, Parker, etc.

Milne-Edwards and Haime. A Monograph of the British Fossil Corals. 1850—5. Part I. 11 plates. Out of print. Part II. Oolitic. 19 plates. 10*s*. Part III. Permian and Mountain Limestone. 16 plates. 10*s*. Part IV. Devonian. 10 plates. 6*s*. Part V. Silurian. 16 plates. 10*s*.

——— *See* P. M. Duncan.

Morris and Lycett. A Monograph of the Mollusca from the Great Oolite, chiefly from Minchinhampton and the Coast of Yorkshire. 1851—63. 4 parts, 45 plates. £2 2*s*.

Nicholson (H. A.) A Monograph of the British Stromatoporoids. 1886—92. 4 parts, 29 plates. £1 10*s*.

Owen (R.) Monograph of the British Fossil Cetacea from the Red Crag. 1870—89. 5 plates. 5*s*.

——— Monograph of the Fossil Mammalia of the Mesozoic Formations. 1871. 4 plates. 5*s*.

——— A Monograph on the Fossil Reptilia of the Cretaceous Formations. 1851—64. 59 plates. £2 2*s*.

——— A Monograph of the Fossil Reptilia of the Liassic Formations. 1861—81. 5 parts, 50 plates. £1 10*s*.

——— Monograph on the Fossil Reptilia of the Mesozoic Formations. 1874—7. 3 parts, 24 plates. £1.

——— Monograph of the Fossil Reptilia of the Wealden and Purbeck Formations. 1853—89. With 9 Supplements and 83 plates. £3.

——— Monograph on the Reptilia of the Kimmeridge Clay and Portland Stone. 1859—89. 6 plates. 5*s*.

Owen and Bell. Monograph on the Fossil Reptilia of the London Clay. Vol. I. 1849—59. 58 plates. Out of print.

——— ——— Vol. II. Part I. 1880. 2 plates. 2*s*. 6*d*.

Parker (W. K.) *See* Jones, Parker, etc.

Phillips (J.) A Monograph of British Belemnitidæ. 1865—70. 5 parts, 36 plates. £1 10*s*.

Pocock (R. I.) The Carboniferous Arachnida. 1911. 3 plates. 4*s*.

Powrie, Lankester, and Traquair. A Monograph of the Fishes of the Old Red Sandstone of Britain. 1867—1914. 2 vols. in 7 parts, 49 plates. £2 5*s*.

Reed (F. R. C.) The Lower Palæozoic Trilobites of the Girvan District, Ayrshire. 1903—6. 3 parts, 20 plates. £1.

——— Supplement to above. 1914. 8 plates. 8*s*.

Reynolds (S. H.) A Monograph of the British Pleistocene Mammalia. Vol. II. 1902—9. 3 parts, 28 plates. £1 8*s*.

Robertson (D.) *See* G. S. Brady.

Salter (J. W.) A Monograph of British Trilobites. 1864—83. 5 parts, 21 plates £1 5*s*.

Sanford (W. A.) *See* W. B. Dawkins.

Sharpe (D.) Description of the Fossil Remains of Mollusca found in the Chalk of England. 1853—6. 3 parts, 27 plates. £1 1*s*.

Sherborn (C. D.) *See* T. R. Jones.

——— *See* Jones, Parker, etc.

Sladen (W. P.) *See* T. Wright.

Slater (I. L.) A Monograph of British Conulariæ. 1907. 5 plates. 5*s*.

Spencer (W. K.) *See* T. Wright.

Traquair (R. H.) The Ganoid Fishes of the British Carboniferous Formations. Part I. Palæoniscidæ. 1877—1914. 7 parts, 40 plates. £1.

——— *See* Powrie.

Whidborne (G. F.) A Monograph of the Devonian Fauna of the South of England. Vols. I and II. Fauna of the Limestones of Lummaton, Wolborough, Chircombe Bridge, and Chudleigh. 1889—95. 8 parts, 56 plates. £2 10*s*.

——— Devonian Fauna. Vol. III. The Fauna of the Marwood and Pilton Beds of North Devon and Somerset. 1896—1907. 4 parts, 38 plates. £1 10*s*.

Williamson (W. C.) A Monograph of the Morphology and History of Stigmaria Ficoides. 1887. 15 plates. 12*s*.

Wood (S. V.) A Monograph of the Crag Mollusca or Descriptions of Shells from the Middle and Upper Tertiaries of the East of England. 1848—82. 2 vols. with 3 Supplements, 71 plates. £3 3*s*.

——— A Monograph of the Eocene Bivalves of England. 1861—77. Vol. I with Supplement (all published). 27 plates. £1 1*s*.

Woods (H.) A Monograph of the Cretaceous Lamellibranchia of England. 1899—1913. 2 vols., 104 plates. £5.

Woodward (A. S.) The Fossil Fishes of the English Chalk. 1902—12. 7 parts, 54 plates. £2 10*s*.

Woodward (H.) A Monograph of the British Carboniferous Trilobites. 1883—4. 2 parts, 10 plates. 10*s*.

WOODWARD (H.) A Monograph of the British Fossil Crustacea belonging to the Order Merostomata. 1866—78. 5 parts, 36 plates. £1 10*s*.

WRIGHT (T.) A Monograph on the British Fossil Echinodermata of the Oolitic Formations. 1857—80. 2 vols., 65 plates. £2 10*s*.

——— Monograph on the Lias Ammonites of the British Islands. 1876—86. 8 parts, 91 plates. £3 3*s*.

——— SLADEN (W. P.), and SPENCER (W. K.) A Monograph on the British Fossil Echinodermata from the Cretaceous Formations. 1864—1908. 2 vols., 116 plates. £5 10*s*.

The Monographs are on sale by Messrs. Dulau & Co., Ltd., 37, Soho Square, London, W., at the prices affixed. Separate parts are charged at the rate of one shilling per plate. Discount is allowed to members of the Palæontographical Society who order the volumes or parts through the Secretary.

Enquiries concerning the volumes and parts marked out of print may be addressed to Messrs. Dulau & Co., Ltd.

Palæontographical Society, 1915.

# THE FOSSIL FISHES OF THE ENGLISH WEALDEN AND PURBECK FORMATIONS.

BY

ARTHUR SMITH WOODWARD, LL.D., F.R.S.,

KEEPER OF THE DEPARTMENT OF GEOLOGY IN THE BRITISH MUSEUM; SECRETARY OF THE PALÆONTOGRAPHICAL SOCIETY.

PART I.

Pages 1—48, Plates I—X.

LONDON:

PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

October, 1916.

PRINTED BY ADLARD AND SON AND WEST NEWMAN, LONDON AND DORKING.

# THE FOSSIL FISHES

OF THE

# ENGLISH WEALDEN AND PURBECK FORMATIONS.

## INTRODUCTION.

The fishes of the Wealden and Purbeck formations are of special interest as representing the latest of the typical Jurassic faunas. Certain families and genera range even to Upper Cretaceous horizons, but here they are rare and mingled with a multitude of more modern fishes. The great estuary in which the Wealden and Purbeck beds were deposited must have opened into a sea in which there were none but Jurassic forms; and the only noteworthy features of the fishes discovered in these formations are certain marks of senility and an occasional dwarfing of the species. The remains are usually fragmentary, though most of the ganoids are now known by nearly complete specimens, and there are many pieces showing important osteological characters. The fragments in the Wealden are often much waterworn and abraded, while the better preserved fishes in the Purbeck limestones have frequently been so much crushed that the details of their structure are obscured.

Fish-remains seem to have been first noticed in the Wealden formations by Dr. Gideon A. Mantell, who described them in his early works.[1] A fine collection was also made on the Sussex coast by Mr. Samuel H. Beckles, and important series of Wealden specimens have been obtained during more recent years by Messrs. Charles Dawson, Philip Rufford, E. J. Baily, and Reginald W. Hooley. The Mantell, Beckles, Dawson, and Rufford collections are now in the British Museum, while that of Mr. Baily is in the Hastings Museum. Fossil fishes from the Purbeck Beds of Swanage, Dorset, were noticed at least so long ago as 1816[2] and are preserved in many museums. They are especially well represented in the British Museum, the Museum of Practical Geology, and the Dorset County

[1] G. A. Mantell, 'The Fossils of the South Downs' (1822), pp. 45, 46 (description only); 'Illustrations of the Geology of Sussex' (1827).

[2] T. Webster in H. C. Englefield, 'The Isle of Wight' (London, 1816), p. 192.

Museum at Dorchester. Similar fishes from the Purbeck Beds of the Vale of Wardour, Wiltshire, were collected many years ago by the Rev. P. B. Brodie, and more recently by the Rev. W. R. Andrews and Mr. T. T. Gething. All their finest specimens are now in the British Museum and the Museum of Practical Geology. There are also a few fish-remains from the Purbeck Beds of Buckinghamshire in the John Lee Collection at Hartwell House, near Aylesbury.

## BIBLIOGRAPHY.

1. Agassiz, L.—'Recherches sur les Poissons Fossiles,' vols. i—v. Neuchâtel, 1833—44.
2. Branco, W.—"Beiträge zur Kenntniss der Gattung *Lepidotus*," 'Abhandl. k. preuss. geol. Landes-Anstalt,' vol. vii, pt. 4 (1887).
3. Brodie, P. B.—'A History of the Fossil Insects in the Secondary Rocks of England.' London, 1845. [With notes on fossil fishes by Egerton.]
4. Davies, W.—"A New Species of *Pholidophorus* from the Purbeck Beds of Dorsetshire," 'Geol. Mag.' [3], vol. iv. (1887), pp. 337—339, pl. x.
5. Egerton, P. M. G.—"Description of the Mouth of a *Hybodus* found by Mr. Boscawen Ibbetson in the Isle of Wight," 'Quart. Journ. Geol. Soc.,' vol. i. (1845), pp. 197—199, pl. iv.
6. —— "On some new Genera and Species of Fossil Fishes," 'Ann. Mag. Nat. Hist.' [2], vol. xiii (1854), pp. 433—436. [Abstract of following work.]
7. —— 'Memoirs of the Geological Survey of the United Kingdom: Figures and Descriptions Illustrative of British Organic Remains,' dec. viii (1855).
8. Mansel-Pleydell, J. C.—"On a New Specimen of *Histionotus angularis*, Egerton," 'Geol. Mag.' [3], vol. vi (1889), pp. 241, 242, pl. vii.
9. Mantell, G. A.—"Illustrations of the Geology of Sussex, with Figures and Descriptions of the Fossils of Tilgate Forest.' London, 1827.
10. Reid, C., and Strahan, A.—"The Geology of the Isle of Wight," Second Edition, 'Mem. Geol. Surv.,' 1899.
11. Strahan, A.—"The Geology of the Isle of Purbeck and Weymouth," 'Mem. Geol. Surv.,' 1898.
12. Topley, W.—"The Geology of the Weald," 'Mem. Geol. Surv.,' 1875.
13. Woodward, A. S.—'Catalogue of Fossil Fishes in the British Museum,' Parts I—III (1889—1895).
14. —— "On some New Fishes from the English Wealden and Purbeck Beds, referable to the Genera *Oligopleurus*, *Strobilodus*, and *Mesodon*," 'Proc. Zool. Soc.,' 1890, pp. 346—353, pls. xxviii, xxix.

15. Woodward, A. S.—"On the Cranial Osteology of the Mesozoic Ganoid Fishes, *Lepidotus* and *Dapedius*," 'Proc. Zool. Soc.,' 1893, pp. 559—565, pls. xlix, l.
16. —— "A Contribution to Knowledge of the Fossil Fish Fauna of the English Purbeck Beds," 'Geol. Mag.' [4], vol. ii (1895), pp. 145—152, pl. vii.
17. —— "A Description of *Ceramurus macrocephalus*," 'Geol. Mag.' [4], vol. ii (1895), pp. 401—402.
18. —— "Note on the Affinities of the English Wealden Fish-Fauna," 'Geol. Mag.' [4], vol. iii (1896), pp. 69—71.
19. —— "On a new Leptolepid Fish from the Weald Clay of Southwater, Sussex," 'Ann. Mag. Nat. Hist.' [7], vol. xx (1907), pp. 93—95, pl. i.

The following is the most important work on Wealden Fishes from the European Continent.

20. Traquair, R. H.—"Les Poissons Wealdiens de Bernissart," 'Mém. Mus. roy. d'Hist. nat. Belgique,' vol. vi (1911).

## SYSTEMATIC DESCRIPTIONS.

Subclass *ELASMOBRANCHII.*

Order *SELACHII.*

Family Cestraciontidæ.

Genus **HYBODUS,** Agassiz.

*Hybodus*, L. Agassiz, Poiss. Foss., vol. iii, 1837, p. 41.
*Sphenonchus*, L. Agassiz, *op. cit.*, vol. iii, 1843, p. 201 (in part).
*Meristodon*, L. Agassiz, *op. cit.*, vol. iii, 1843, p. 286.

*Generic Characters.*—Trunk fusiform, moderately elongated; the first dorsal fin opposite to the space between the pectoral and pelvic fins, the second in advance of the anal fin. Snout not prominent but mouth inferior; pterygo-quadrate cartilage not articulated with the preorbital region of the skull. Teeth conical or cuspidate, the crown more or less striated, with one principal elevation, and one or more lateral prominences on either side diminishing from the centre; root depressed, but not expanded inwards. Symphysial teeth few and large. Notochord persistent; slender ribs, not reaching the ventral border; intercalary cartilages almost or completely absent. Dorsal fin-spines longitudinally ridged and grooved, the ridges not denticulated; posterior denticles in two longitudinal series, often alternating, not marginal but placed close together on a mesial ridge. Shagreen consisting of small conical, radiately-grooved tubercles, sometimes two or

three fused together. One or two large hook-shaped dermal spines, each on a triradiate base, immediately behind the orbit, at least in males.

*Type Species.*—The generic name *Hybodus* appears to have been given by Agassiz first to some teeth from the German Muschelkalk known as *Hybodus plicatilis* (quoted, without description, by F. A. v. Alberti, Jahrb. f. Min., Geogn., etc., 1832, p. 227). It was not defined until he had examined specimens from the Lower Lias of Lyme Regis, Dorsetshire, showing the teeth and dorsal fin-spines in natural association (L. Agassiz, Poiss. Foss., vol. iii, pp. 41, 178). *Hybodus reticulatus*, from that formation and locality, was the first species satisfactorily described, and may therefore be regarded as the type (L. Agassiz, *tom. cit.*, p. 180, pl. xxiv, fig. 26; pl. xxii *a*, figs. 22, 23).

*Remarks.*—The known specimens of the several species of *Hybodus* from the Lower Lias of Lyme Regis exhibit not only the arrangement of the dentition and

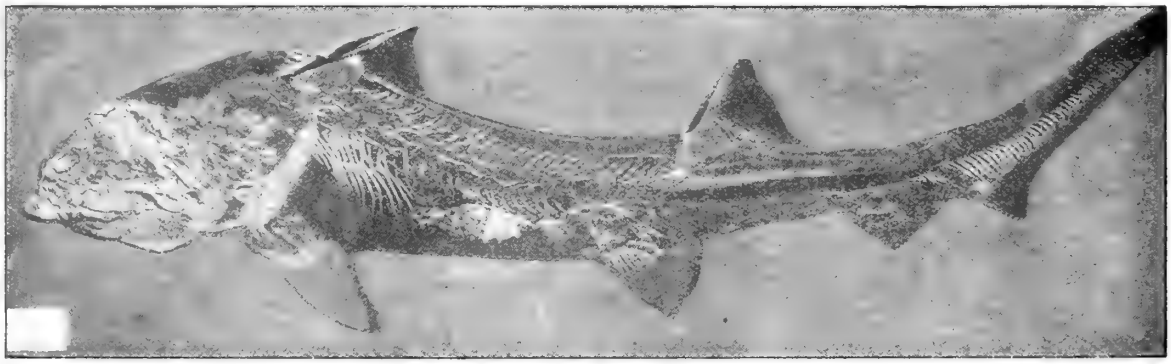


Fig. 1.—*Hybodus hauffianus*, Fraas; fish in left side view, with traces of soft parts, including the fins, about one-fifteenth nat. size.—Upper Lias; Holzmaden, Würtemberg. University Geological Museum, Tübingen.

the dermal armature, but also the cartilages of the jaws, the neural and hæmal arches of the trunk bounding a vacant space for the notochord, and the cartilages of the pectoral arch. Specimens of another species from the Upper Lias of Würtemberg are still more satisfactory, and one example prepared by Mr. Bernhard Hauff shows distinct remains even of the fins (Text-fig. 1).[1] A specimen from the Lithographic Stone (Lower Kimmeridgian) of Bavaria displays the five branchial arches and the cartilages of the pectoral fin.[2] A more imperfect specimen from the same formation in the Montsech, Lérida, Spain, shows the neural arches, slender ribs, and the cartilaginous support of the anterior dorsal fin.[3] Another fragment from the Upper Beaufort Beds of Orange River Colony, South Africa, exhibits the supports of a dorsal fin.[4] The well-preserved skulls and portions of

[1] *Hybodus hauffianus*, E. Fraas, E. Koken, Geol. u. Palæont. Abhandl., n. s., vol. v (1907), pp. 261—276, pls. xi—xiii.

[2] *Hybodus fraasi*, C. Brown, Palæontographica, vol. xlvi (1900), pp. 151—158, pl. xv.

[3] *Hybodus woodwardi*, L. M. Vidal, Bol. Inst. Geol. España, 1915, p. 22, pl. ii, text-figs. 4—6.

[4] *Hybodus africanus*, R. Broom, Ann. S. African Museum, vol. vii (1909), p. 252, pl. xii, fig. 2.

trunk of *Hybodus basanus* from the Wealden of the Isle of Wight and Sussex show still better the shape of the jaws and branchial arches, besides the usual notochordal axial skeleton of the trunk, and the supports of the two dorsal fins.

*Hybodus basanus* is the only Wealden species sufficiently well known for definition. The other Wealden and Purbeck species are represented by isolated teeth and spines, which bear merely provisional names.

1. **Hybodus basanus,** Egerton. Plate I, figs. 1, 2; Plate II, fig. 1; Text-figures 3—5.

1845. *Hybodus basanus*, P. M. G. Egerton, Quart. Journ. Geol. Soc., vol. i, p. 197, pl. iv.
1889. *Hybodus basanus*, A. S. Woodward, Catal. Foss. Fishes B. M., pt. i, p. 273, pl. xii, figs. 1–5.
1891. *Hybodus basanus*, A. S. Woodward, Proc. Yorks. Geol. Polyt. Soc., vol. xii, p. 63, pl. i; pl. ii, fig. 1.

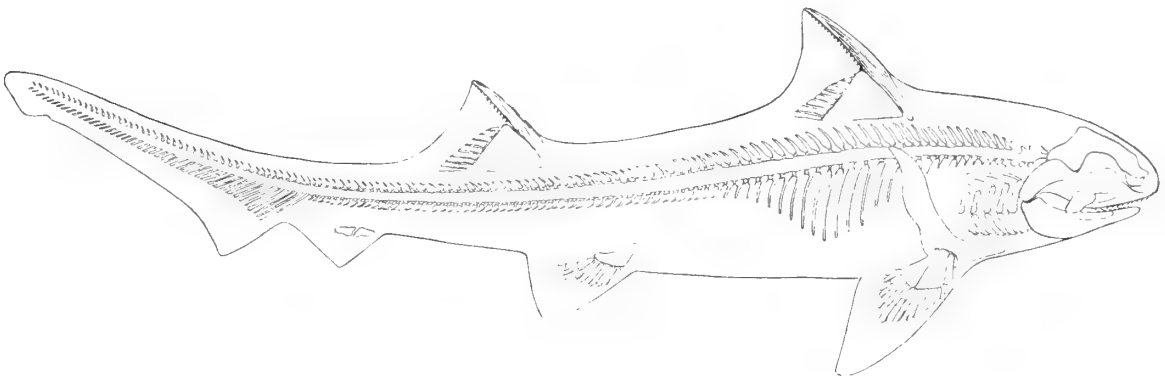


Fig. 2.—*Hybodus hauffianus*, Fraas; restoration of skeleton, about one-fifteenth nat. size.—Upper Lias; Holzmaden, Würtemberg.

*Type.*—Imperfect skull and mandible with dentition; Museum of Practical Geology, Jermyn Street, London.

*Specific Characters.*—Teeth with a very high, much compressed crown; median cone, narrow, slender, slightly arched inwards; lateral cones two, sometimes with a rudiment of a third, short but sharply pointed; coronal surface marked by numerous very fine vertical wrinkles, often extending to the apices of the lateral cones, but always absent on the smooth upper portion of the median cone. Dorsal fin-spines rather slender and not much arched, laterally compressed, with a sharp anterior keel; lateral face of exserted portion completely covered with sharp but fine longitudinal ridges, about eight being widely spaced, and those near the posterior border closely arranged; inserted base slender and tapering, its anterior border sometimes inclined at an angle to that of the exserted portion. A single pair of large postorbital cephalic spines with a terminal barb. Conical dermal granules small and fluted.

*Description of Specimens.*—The type specimen is an imperfect skull and

mandible discovered by Capt. L. L. Boscawen Ibbetson at the top of the Wealden near Atherfield, Isle of Wight, and is now in the Museum of Practical Geology. Since its description by Egerton (*loc. cit.*, 1845), it has been cleaned from the matrix, and new drawings of the specimen from the right side and from below are given in Pl. I, figs. 1, 1 *a*. All the cartilages are distorted by crushing, and the waterworn teeth are less distinct than indicated in Egerton's original figure, where each principal cusp appears too wide and smooth.

All the other known specimens are similar heads and fragments of the trunk picked up on the beach of Pevensey Bay, Sussex, where a large collection, now in the British Museum, was made by Mr. S. H. Beckles. From these fossils the principal characters of the species and several interesting anatomical features can be determined.

The cartilages agree with those of modern sharks in being only superficially calcified in the usual small polygonal tesseræ. They are therefore often distorted, not merely by crushing during fossilisation, but also by contraction before burial in the sediment. Under such circumstances their state of preservation is remarkable. In most cases the hollow left by the decay of the internal uncalcified cartilage is filled with ordinary matrix; but sometimes (as in the original of Pl. II, fig. 1) it still remains partly vacant.

The cranium as shown in the type specimen (Pl. I, fig. 1) is rather short and wide, with a relatively large orbit (*orb.*), short postorbital and rostral regions, and a large anterior fontanelle (*a.f*). Its special features, however, are better seen in other specimens, particularly in the unique skull represented in Pl.II, figs. 1, 1 *a*, 1 *b*. This lacks only the occipital region, which is preserved in another specimen in the Enniskillen Collection (B. M. no. P. 3172 *c*), and is seen to slope backwards and downwards, while it is raised in the middle into a sharp vertical ridge extending from the occipital border to the foramen magnum. The cranial roof throughout its length (Pl. II, fig. 1) is gently convex from side to side, is produced downwards into a large postorbital process (fig. 1 *a*), and extends above the orbit into a thin supraorbital flange, which merges in front into the depressed and only slightly expanded region of the nasal capsule. In the middle of the roof of the postorbital region the posterior fontanelle (*p.f.*) is elongate-oval in shape. In front of and between the nasal capsules, the large anterior fontanelle (*a.f.*) is much broader than deep and is directed forwards; while the flat base of the mesethmoidal region soon terminates in a very short but well-marked rostral prominence (*r.*).

The mandibular suspensorium is inclined backwards, so that, since the jaws extend forwards as far as the end of the snout, they are longer than the cranium. As shown by the type specimen (Pl. I, fig. 1) they are also relatively large and massive, with labial cartilages at the angle of the mouth. The hyomandibular (Pl. II, figs. 1, 1 *a*, *hm.*) is a comparatively slender cartilage, laterally compressed

and produced somewhat forwards at its upper end, antero-posteriorly compressed but less expanded at its lower end. The pterygo-quadrate (as seen especially in Pl. II, figs. 1, 1 *a* (*ptq.*), and in the specimen figured in Catal. Foss. Fishes, Brit. Mus., pt. i, pl. xii, fig. 1) is weak and depressed at its anterior symphysis, but deepens rapidly backwards, so that by the middle of the orbit its depth equals at least a quarter of its total length. Its upper border is then slightly concave, and finally rises a little to its highest point behind. It can scarcely have articulated with the postorbital prominence of the cranium. The outer face of its posterior half is indented below, and this hollow is overhung by an arched ridge which runs upwards and forwards from the articular end and dies out before reaching the

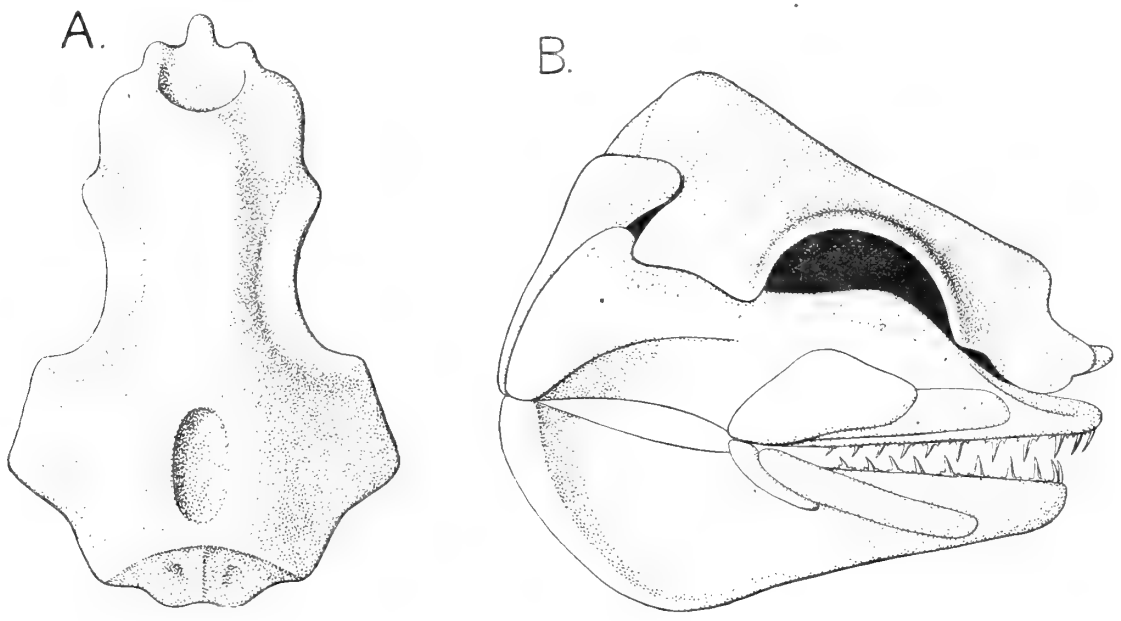



Fig. 3.—*Hybodus basanus*, Egerton; restoration of cranium, upper view (A), and of skull with jaws, right side view (B), about one-half nat. size.—Weald Clay; Pevensey Bay, Sussex.

upper border. The rami of the mandible (Pl. I, figs. 1, 1 *a*; Pl. II, figs. 1 *a*, 1 *b*; *md.*), though deep and massive behind, rapidly taper forwards and meet in a comparatively feeble symphysis, which does not extend so far as the front of the upper jaw. There are two pairs of large labial cartilages, best shown in Pl. II, figs. 1 *a*, 1 *b* (*u.l.* 1, 2, *l.l.* 1, 2). Those of the upper and lower anterior pairs are long and band-like; those of the upper posterior pair (Pl. II, fig. 1 *a*, *u.l.* 2) are large, irregular laminæ; while those of the lower posterior pair (Pl. II, fig. 1 *b*, *l.l.* 2) are short but stout rounded rods. An attempted restoration of the skull with jaws is given in Text-fig. 3.

As shown by the type specimen (Pl. I, fig. 1) the teeth are in contact round the margin of the jaws, and at least three or four series, one behind the other, must have been simultaneously in use. An examination of several specimens

proves that each ramus in both jaws bears ten or eleven transverse rows of teeth; while one skull in the British Museum (no. P. 3172 *a*) seems to exhibit an unpaired symphysial row in the lower jaw. In all the teeth the principal cusp is high and narrow, compressed to two sharp lateral edges, with the incurved apex smooth and the expanded base vertically striated. The one or two pairs of well-defined lateral denticles are striated to the apex. From the symphysis backwards to the middle of each ramus the teeth are highest and about equally elevated; but in this series those at and near the symphysis have a less extended base than those further back, with less space for the lateral denticles, which are usually in two pairs (the outer very small), but may be flanked by a third minute cusp (Pl. I, fig. 1 *b*). In the hinder half of each ramus the teeth rapidly diminish in size and elevation, with the principal cusp curving sharply backwards (Text-fig. 4). There is no essential difference between the teeth of the upper and lower jaws.

The ceratohyals are massive cartilages seen in several specimens, and the

Fig. 4.—*Hybodus basanus*, Egerton; four upper and lower teeth from hinder half of jaws, nat. size.—Weald Clay; Pevensey Bay, Sussex.

basihyal is also large, somewhat broader than long, as already described in Catal. Foss. Fishes, Brit. Mus., pt. i (1889), p. 274, pl. xii, fig. 2. The branchial arches are only five in number, as shown by the ceratobranchials preserved in series in a specimen already described, *loc. cit.*, p. 274, pl. xii, fig. 3, and as still better seen in another head in the Beckles Collection (B. M. no. P. 11872). The hindmost or fifth arch is comparatively small. Each ceratobranchial is expanded and sharply truncated at its lower end, where it would articulate with the hypobranchial; but the cartilages of this lower series remain undiscovered.

The trunk is known only by fragments, of which the best is represented in Text-fig. 5. The notochord must have been persistent, but the neural arches and spines (*n.s.*) are well calcified in the usual granular form. They are narrow bands of cartilage arranged in close series. Below the space for the notochord in the abdominal region there are also traces of comparatively slender hæmal elements or ribs in a specimen described in Proc. Yorks. Geol. Polyt. Soc., vol. xii (1891), p. 65, pl. ii, fig. 1.

Of the fins, only parts of the dorsals have hitherto been discovered in the original of Text-fig. 5. In this specimen the anterior dorsal (*d.* 1) probably remains in its natural position, but the second dorsal (*d.* 2) is accidentally

overturned and displaced. Each is shown to have been supported in the usual manner by a dorsal fin-spine fixed to a triangular basal cartilage, which extends from the inserted end of the spine throughout the whole length of the fissure on its hinder face. At the distal border of the basal cartilage of the posterior fin five small radials also occur, gradually increasing in length towards the hinder edge of the fin; and there are traces of delicate filiform rays for the support of the fin-membrane. As in *Hybodus fraasi* and *H. hauffianus*, the basal cartilage of the anterior fin is narrower and deeper than that of the posterior fin.

The dorsal fin-spines are much laterally compressed and very little arched, with a comparatively slender base of insertion. The sides of the exserted portion

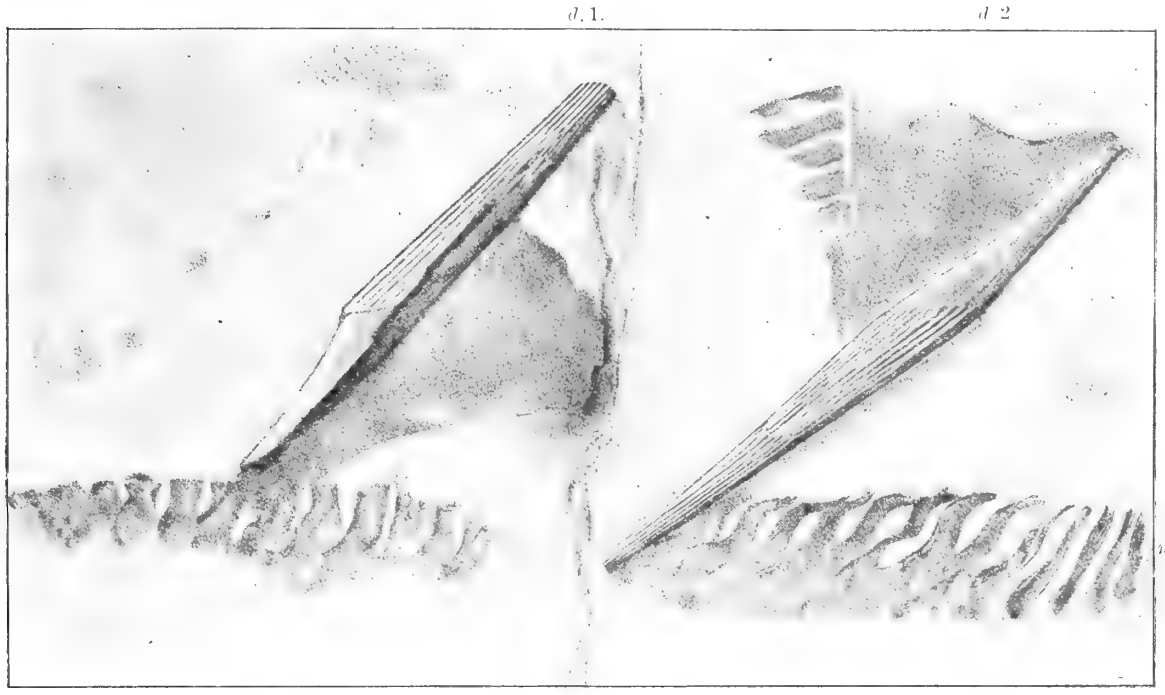



Fig. 5.—*Hybodus basanus*, Egerton; fragment of trunk in left side view, showing the neural arches (*n.s.*) of the vertebral axis, with the spines and cartilages of the anterior (*d.* 1) and posterior (*d.* 2) dorsal fins, the latter overturned and displaced, nearly one-half nat. size.—Weald Clay: Pevensey Bay, Sussex. Beckles Collection (B. M. no. P. 6357).

are completely covered with fine and sharp longitudinal ridges, which are sometimes slightly nodulose where crossed by growth-lines. Near the base about eight ridges are widely spaced, while four or five at the posterior border are crowded. The posterior denticles are numerous, small, and closely arranged. As shown in Text-fig. 5, the spine of the anterior fin is broader than that of the posterior fin.

In some specimens, which are probably to be regarded as males, there is also a single pair of spines immediately behind the head. This is best shown in the partially decayed skull represented in Pl. I, fig. 2. The spine (*s.*) is placed

laterally just behind the position of the hyomandibular, and seems to have been fixed on a special cartilaginous support (*x*.). It is of the form originally named *Sphenonchus*, with a trifid inserted base, from which rises a sigmoidally arched enamelled spine, barbed at the apex (fig. 2 *a*). As observed in B. M. no. P. 11872, the postero-inferior limb of the base is largest and longest and truncated at the end, while its long axis is slightly oblique to that of the other two limbs, which are nearly in the same line but curved. The exserted spine, which rises as usual at the place of meeting of the three basal limbs, is at least as long as the postero-inferior limb, laterally compressed, and sufficiently unsymmetrical to show that it is not a median structure. It is completely covered with enamel, which is smooth at the barbed apex and along the narrow upper face; but its basal portion is marked with irregular sharp ridges, which cover the greater part of the antero-lateral face and here terminate abruptly above at a sharp longitudinal ridge which extends to the apex.

The head and at least the anterior portion of the trunk are covered with a spinous shagreen, which is always fine, but varies a little in size in different regions. Each tubercle (Pl. II, figs. 1 *c*, 1 *d*) is hollow, with an expanded trumpet-shaped base, more or less crimped round the edge, and marked with radiating ridges on its outer face. It rises in the middle into a laterally-compressed recurved hooklet, on which the vertical ridges end abruptly at the arched anterior border.

*Horizon and Localities.*—Weald Clay: Atherfield, Isle of Wight; Cooden Beach, Pevensey Bay, Sussex.

*Addendum.*—Isolated teeth of the same general type as those of *H. basanus* also occur in lower horizons of the Wealden series, but are not sufficiently similar to be referred with certainty to this species. Some obtained by Mantell from the Tunbridge Wells Sand of Tilgate Forest seem to have the principal cone less compressed and the inner lateral denticles more slender and acuminate than in *H. basanus* (as shown in Catal. Foss. Fishes, Brit. Mus., pt. i, 1889, pl. xi, figs. 14, 15). Rolled and waterworn fragments of such teeth were named *Oxyrhina* (*Meristodon*) *paradoxa* or *Meristodon paradoxus* by Agassiz, Poiss. Foss., vol. iii (1843), p. 286, pl. xxxvi, figs. 53—56.

Abraded and fragmentary small dorsal fin-spines from the Tunbridge Wells Sand of Tilgate Forest also closely resemble those of *H. basanus*, but can scarcely be described as identical. They were named *Hybodus subcarinatus* by Agassiz, Poiss. Foss., vol. iii (1837), p. 46, pl. x, figs. 10—12; and an early figure of one specimen was given in Trans. Geol. Soc. [2], vol. ii (1829), pl. vi, fig. 9. Two nearly complete fin-spines, less abraded than usual, from the Wadhurst Clay near Hastings, are shown in Pl. III, figs. 6, 7, and appear to be essentially identical with those of *H. basanus*, having the same fine longitudinal ridges and small posterior denticles. The broader spine (fig. 6) is a little widened by crushing; the narrower spine (fig. 7) exhibits only the broken bases of the posterior denticles.

2. **Hybodus ensis,** sp. nov. Plate II, figs. 2—7.

*Type.*—Tooth ; British Museum.

*Specific Characters.*—Teeth sometimes 2 cm. in diameter, longest usually smaller. Median cone high, much compressed, broad at the base, tapering gradually to a blunt apex; two or three lateral cones, slender and sharply pointed, close to the median cone; coronal surface marked at the base with numerous delicate vertical wrinkles, which nearly reach the apices of the lateral cones.

*Description of Specimens.*—This species is definitely known only by isolated teeth, of which the original of Pl. II, fig. 6, may be regarded as the type specimen. Here the median cone is complete, except for slight abrasion of its apex ; the characteristic slender inner lateral cone is also well shown ; and there is a trace of a minute outer cone on one side. Near the base the fine vertical wrinkles are conspicuous, and they do not extend quite to the apex of the inner lateral cones. The original of fig. 3 is a crushed larger tooth of nearly similar form, with the left lateral cone broken away at the apex. A still larger tooth, much abraded, with imperfect lateral cones, is shown in fig. 5. In the tooth represented in fig. 2 the apex of the median cone is blunted by fracture, while in the original of fig. 4 it is complete. Both these teeth have a minute outer pair of lateral cones. Fig. 7 shows a smaller tooth with the median cone much inclined backwards, evidently referable to the hinder part of the jaw. It has three lateral cones in front. In all the teeth the compression of the median cone causes its lateral borders to be especially thin.

The teeth now described have sometimes been referred to the typically Lower Oolitic species, *Hybodus grossiconus*, Ag., but most of them are of smaller size, and they are readily distinguished by the less lateral expansion of their base-line and the somewhat blunter apex of their median cone.

*Dorsal Fin-spines.*—It is interesting to notice that in the same horizon as the teeth of *Hybodus ensis* there also occur dorsal fin-spines almost identical with those named *H. dorsalis* (L. Agassiz, Poiss. Foss., vol. iii, 1837, p. 42, pl. x, fig. 1), which are found in Bathonian formations with the teeth of *H. grossiconus*. These spines, of which three are shown in Pl. III, figs. 1—3, may therefore possibly belong to *H. ensis*. They are rather stout, with coarser and rounder ridges than the other Hybodont fin-spines met with in Purbeck and Wealden deposits, and their posterior denticles are relatively large. The crushed specimen represented in fig. 1 is short and wide, with regular smooth ribbing, but only traces of the posterior denticles. The original of fig. 2 is an abraded fragment with very coarse and partly nodulose or wavy ridging. Fig. 3 represents a smaller and more elongated spine with large, irregular, hooked posterior denticles.

*Horizons and Localities.*—Middle Purbeck Beds: Swanage. Wealden: Tilgate Forest.

3. **Hybodus parvidens,** sp. nov. Pl. II, figs. 8—14.

1889. *Hybodus*, sp. inc., A. S. Woodward, Catal. Foss. Fishes, B. M., pt. i, p. 276, pl. xi, fig. 16.

*Type.*—Tooth; British Museum.

*Specific Characters.*—Teeth small, rarely exceeding a centimetre in longest diameter; median cone stout and large, elevated and acute in the anterior teeth, low and blunter in the lateral and posterior teeth; lateral cones two or three on each side, also low and stout; coronal surface marked by sparse vertical wrinkles, which extend to the apices of the lateral cones, some usually also to the apex of the median cone; occasional small excrescences at the base of the crown.

*Description of Specimens.*—This species is known only by small, isolated teeth, of which the original of Pl. II, fig. 8, may be regarded as the type specimen. Its median cone is only moderately elevated, flanked with two pairs of very blunt lateral cones, and marked with especially prominent and sparse wrinkles. The original of fig. 9 has a broader and stouter median cone, with three imperfectly separated lateral cones on one side, two on the other, all marked with less sparse wrinkles. This tooth passes into those shown in figs. 10 and 12, which have a still stouter and less elevated median cone, and doubtless belong to the back of the jaw. They are noteworthy for the slight arching of their base-line, and a larger tooth of nearly the same form (figured in Catal. Foss. Fishes, B. M., pt. i, pl. xi, fig. 16) shows some traces of basal excrescences. Fig. 13 represents a larger tooth, with three pairs of lateral denticles, perhaps referable to the middle part of the ramus of the jaw. The originals of figs. 11 and 14, with a more elevated median cone and two pairs of relatively small lateral cones, are evidently anterior teeth, and are remarkable for the small excrescence at the middle of the base of the crown.

Though much smaller, these teeth closely resemble those of the Upper Jurassic *Hybodus obtusus*, Ag., in which the small excrescences at the base of the crown are especially numerous and prominent.

*Horizons and Localities.*—Wealden (chiefly Wadhurst Clay): Hastings. Weald Clay: Berwick, Sussex.

4. **Hybodus striatulus,** Agassiz. Plate III, fig. 8.

1827. "Resembling *Silurus*," G. A. Mantell, Illustr. Geol. Sussex, p. 58, pl. x, fig. 4.
1837. *Hybodus striatulus*, L. Agassiz, Poiss. Foss., vol. iii, p. 44, pl. viii *b*, fig. 1.

*Type.*—Portion of dorsal fin-spine; British Museum.

*Specific Characters.*—Dorsal fin-spines attaining a length of nearly 25 cm.,

stout and not much arched, with slightly rounded sides and blunt anterior keel; lateral face of exserted portion covered with coarse rounded longitudinal ridges, which are closely arranged and in the distal portion tend to become subdivided into tubercles.

*Description of Specimens.*—Like most of the fossils from the Wealden of Tilgate, the only two known specimens of this form of dorsal fin-spine are much water-worn and abraded. The large spine figured by Mantell (figure copied by Agassiz) is especially abraded, so that traces of the rounded longitudinal ridges (not shown in the published figure) are observable only in the distal half near the front border. The smoothness of the specimen and the bluntness of the posterior denticles are due entirely to abrasion. The second specimen (Pl. III, fig. 8) is part of the distal half of a spine with the ridged ornament better preserved, and interesting as exhibiting a tendency to the subdivision of the ridges into tubercles.

There is considerable resemblance between this form of spine and that mentioned above (p. 11) in connection with *Hybodus ensis;* but the longitudinal ridges in the latter are very rarely nodulose and still more rarely subdivided.

*Horizon and Locality.*—Tunbridge Wells Sands: Tilgate Forest.

### 5. **Hybodus strictus,** Agassiz. Plate III, figs. 4, 5.

1837. *Hybodus strictus,* L. Agassiz, Poiss. Foss., vol. iii, p. 45, pl. x, figs. 7—9.

*Type.*—Dorsal fin-spine; Bristol Museum.

*Specific Characters.*—Dorsal fin-spines attaining a length of about 12 or 13 cm., slender and not much arched, laterally compressed, with a sharp anterior keel; lateral face of exserted portion covered with sharp, strong, longitudinal ridges, well spaced except near the lower part of the posterior border, where they are finer and crowded; posterior denticles moderately large; inserted base slender and tapering.

*Description of Specimens.*—The two examples of this fin-spine shown in Pl. III, figs. 4, 5, are typical, and its characters are very constant in the numerous known specimens. It is of the same general form as the spines named *H. subcarinatus* and *H. basanus*, but is distinguished by its stronger ribs and larger posterior denticles.

*Horizon and Locality.*—Middle Purbeck Beds: Swanage.

### 6. **Hybodont Cephalic Spines.** Plate I, figs. 3, 4.

The cephalic spine already described in *Hybodus basanus* (p. 10) is closely similar in shape to that of the typical *Hybodus* from the Lower Lias; and several

portions of spines found isolated both in Wealden and Purbeck formations agree with these in their striated ornament and terminal barb. Two fragments, obtained by Mantell from the Tunbridge Wells Sands of Tilgate Forest and apparently worn smooth by abrasion, were described under the name of *Sphenonchus elongatus* by Agassiz, Poiss. Foss., vol. iii, 1843, p. 202, pl. xxii *a*, figs. 18, 19. Besides these typical cephalic spines, however, there also occur in Wealden beds comparatively small specimens in which the enamelled exserted portion is reduced to a smooth pointed hook without any barb. One is well seen in side view in Pl. I, fig. 3, and a nearly complete example is shown both in side and outer view in Pl. I, figs. 4, 4 *a*. Here the inserted triradiate base is remarkably large, with its postero-inferior limb small and the two lateral limbs much enlarged and inclined downwards. This, indeed, seems to represent the final degenerate condition of the Hybodont cephalic spine.

## Genus **ACRODUS**, Agassiz.

*Acrodus*, L. Agassiz, Poiss. Foss., vol. iii, 1838, p. 139.
*Sphenonchus*, L. Agassiz, *op. cit.*, vol. iii, 1843, p. 201 (in part).
*Thectodus*, H. von Meyer and T. Plieninger, Beitr. Paläont. Würtembergs, 1844, p. 116.

*Generic Characters.*—Only differing from *Hybodus* in the rounded, non-cuspidate shape of the teeth.

*Type Species.*—The generic name appears to have been given by Agassiz first to the teeth of *Acrodus gaillardoti* from the German Muschelkalk, in Gaillardot, Ann. Sci. Nat., ser. 2, vol. iii (Zoologie), 1835, p. 49, and in Mougeot, Bull. Soc. Géol. France, vol. vi, 1835, p. 20, but it was not defined until the discovery and description of *Acrodus nobilis* from the Lower Lias of Lyme Regis (Agassiz, Poiss. Foss., vol. iii, 1838, p. 140, pl. xxi). The latter must therefore be regarded as the type species.

*Remarks.*—*Acrodus* is best known by the remains of *A. nobilis* and *A. anningiæ* from the Lower Lias of Lyme Regis, described in Catal. Foss. Fishes, Brit. Mus., pt. i, 1889, pp. 283–295, pls. xiii, xiv. The arrangement of the dentition is shown in Text-fig. 6.

### 1. **Acrodus ornatus**, A. S. Woodward. Plate II, figs. 15—18.

1889. *Acrodus ornatus*, A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. i, p. 296, pl. xiii, fig. 10.

*Type.*—Detached tooth; British Museum.

*Specific Characters.*—A very small species known only by detached teeth, which do not exceed about 7 mm. in length. The dental coronal contour is low

and gently rounded, marked by a longitudinal median wrinkle; the laterally directed wrinkles are short, unusually stout, and marginal, but few tapering and extending to the middle line.

*Description of Specimens.*—The type tooth from Brixton, Isle of Wight, is elongate-ovoid in shape, about twice as long as wide, probably belonging to one of the principal lateral rows. A second specimen, obtained by the Rev. William Fox from the same locality, is slightly longer and more attenuated at the extremities. A somewhat larger tooth from Brook, of nearly similar shape, broken at one end and naturally curved at the other tapering end, is shown enlarged five

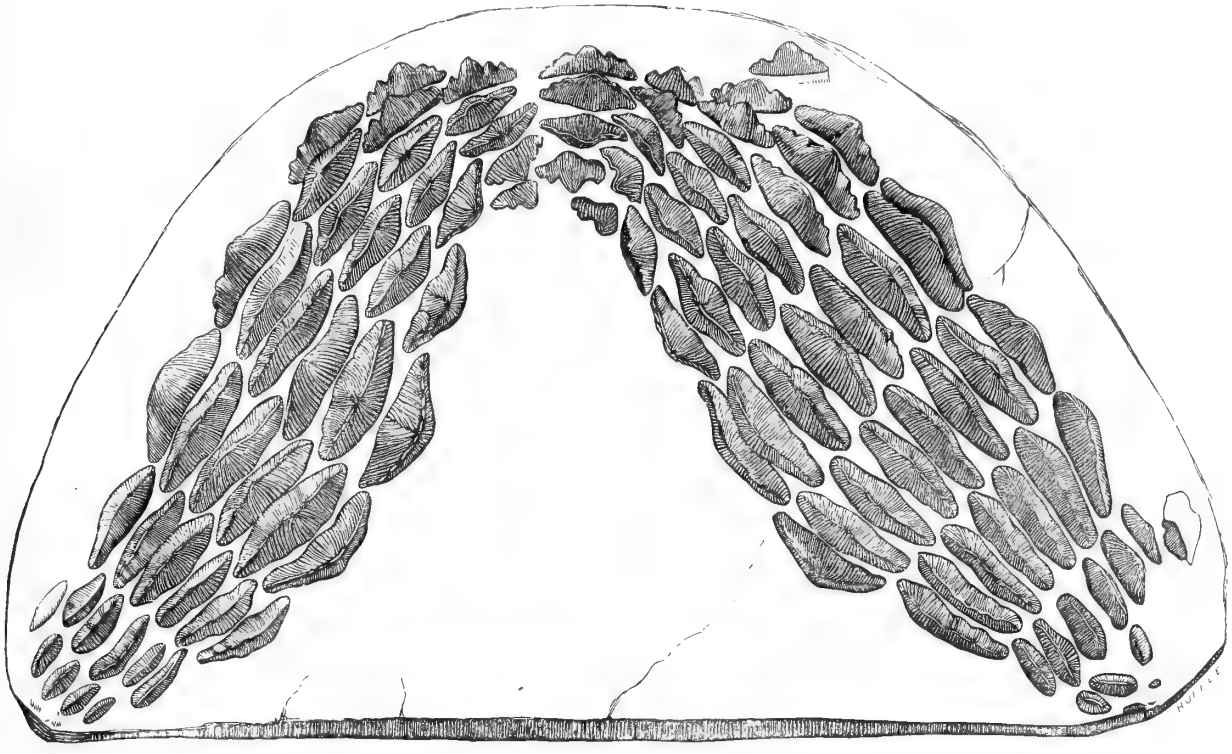


Fig. 6.—*Acrodus anningiæ*, Agassiz; dentition in matrix, almost undisturbed, nat. size.—Lower Lias; Lyme Regis, Dorset. British Museum, no. 39925. After E. C. H. Day, Geol. Mag., vol. i (1864), pl. iii.

times in Pl. II, fig. 15. This is completely unworn, and exhibits well the longitudinal median wrinkle, with the few and thick lateral wrinkles, which taper towards the middle line but rarely reach it. Another specimen of more regular shape (Pl. II, fig. 16), with almost equally well preserved wrinkles, also belongs to a principal row. The relatively short and wide teeth which may be referred to the rows near the symphysis, such as the original of Pl. II, fig. 17, do not exhibit any trace of lateral elevations or denticles. Other teeth, more irregular in shape and wrinkling, probably belong to the hinder part of the jaw (Pl. II, fig. 18).

*Horizon and Localities.*—Wealden: Brixton and Brook, Isle of Wight; Hastings and Bexhill, Sussex. Waterworn specimens of nearly similar teeth have also been found in the Lower Greensand of Godalming, Surrey.

Fig. 7.—*Asteracanthus verrucosus*, Egerton; dorsal fin-spine lacking posterior denticles, right side view, two-thirds nat. size.—Middle Purbeck Beds: Swanage, Dorset. Egerton Collection (B. M. no. P. 2259).

## Genus **ASTERACANTHUS**, Agassiz.

*Asteracanthus*, L. Agassiz, Poiss. Foss., vol. iii, 1837, p. 31.
*Strophodus*, L. Agassiz, *op. cit.*, vol. iii, 1838, p. 116.
*Sphenonchus*, L. Agassiz, *op. cit.*, vol. iii, 1843, p. 201 (in part).
*Curtodus*, H. E. Sauvage, Catal. Poiss. Form. Second. Boulonnais (Mém. Soc. Acad. Boulogne-sur-Mer, vol. ii), 1867, p. 53.

*Generic Characters.*—Principal teeth elongated, irregularly quadrate, with slightly arched but flattened crown; symphysial teeth few and large, much arched, without lateral denticles, longitudinally keeled; all superficially marked by fine reticulate wrinkles or ridges. Dorsal fin-spines ornamented by stellate tubercles, sometimes in part fused into short longitudinal ribs; posterior denticles in two longitudinal series, often alternating, not marginal, but placed close together on a mesial ridge. One or two large hook-shaped dermal spines, each on a triradiate base, immediately behind the orbit, at least in males.

*Type Species.*—*Asteracanthus ornatissimus* (L. Agassiz, Poiss. Foss., vol. iii, 1837, p. 31, pl. viii), typically from the Upper Jurassic of Western Europe.

*Remarks.*—This genus is closely related to *Acrodus* and *Hybodus*, but the complete fish is unknown, and the teeth and spines have hitherto been found associated only in a variety of the type species discovered by Mr. Alfred N. Leeds in the Oxford Clay of Peterborough (A. S. Woodward, Ann. Mag. Nat. Hist. [6], vol. ii, 1888, pp. 336—342, pl. xii). Although dorsal fin-spines occur both in Wealden and in Purbeck formations, no teeth have yet been met with in the same horizons and localities.

### 1. **Asteracanthus verrucosus**, Egerton. Text-fig. 7.

1854. *Asteracanthus verrucosus*, P. M. G. Egerton, Ann. Mag. Nat. Hist. [2], vol. xiii, p. 433.
1855. *Asteracanthus verrucosus*, P. M. G. Egerton, Figs. and Descripts. Brit. Organic Remains (Mem. Geol. Surv.), dec. viii, pl. ii.
1889. *Asteracanthus verrucosus*, A. S. Woodward, Catal. Foss. Fishes, B. M., pt. i, p. 313.

*Type.*—Dorsal fin-spine; Dorset County Museum, Dorchester.

*Specific Characters.*—Dorsal fin-spines attaining a maximum length of about

35 cm.; more or less gently arched and laterally compressed, but not keeled anteriorly; posterior face slightly raised, with denticles relatively smaller than in the type species; ornamental tubercles very numerous and closely arranged, mostly oval in form, and not only forming longitudinal series but also tending to arrangement in regular transverse series; the tubercles more or less fused into longitudinal ridges near the apex of the spine.

*Description of Specimens.*—The type spine is well preserved, lacking only the apex and the posterior denticles. The specimen shown in Text-fig. 7 is still finer, with the apex only a little worn and the posterior denticles again lacking. The rounded front border and the characteristic ornament are especially well seen. The posterior face is not sharply keeled, but only gently rounded, and in some other specimens in the British Museum its rather small denticles are arranged in two well-separated close series. The degree of curvature varies, and some spines are nearly straight, but all must have have been very obliquely inserted. It seems impossible at present to distinguish that of the anterior from that of the posterior dorsal fin.

*Horizon and Locality.*—Middle Purbeck Beds: Swanage, Dorset.

FIG. 8.—*Asteracanthus semiverrucosus*, Egerton; imperfect dorsal fin-spine, left side view, in matrix, two-thirds nat. size.—Middle Purbeck Beds: Swanage, Dorset. Dorset County Museum, Dorchester. After Egerton.

2. **Asteracanthus semiverrucosus**, Egerton. Text-fig. 8.

1854. *Asteracanthus semiverrucosus*, P. M. G. Egerton, Ann. Mag. Nat. Hist. [2], vol. xiii, p. 434.

1855. *Asteracanthus semiverrucosus*, P. M. G. Egerton, Figs. and Descripts. Brit. Organic Remains (Mem. Geol. Surv.), dec. viii, pl. iii.

*Type.*—Imperfect dorsal fin-spine; Dorset County Museum, Dorchester.

*Specific Characters.*—Dorsal fin-spine about 25 cm. in length, much arched, laterally compressed and keeled anteriorly; ornamental tubercles ovate, very large, sparsely and rather irregularly arranged, some fused into longitudinal ribs.

*Description of Specimen.*—The type spine of this species still remains unique (Text-fig. 8). It lacks both the apex and much of the inserted base, but otherwise

exhibits well its characters. The anterior tubercles in the basal half are the largest, those near the posterior border being relatively small and few. The fused ridges are in part slightly beaded. Some of the posterior denticles, preserved in the apical half, are rather large. The sharply arched form of the spine is especially noteworthy.

*Horizon and Locality.*—Middle Purbeck Beds: Swanage, Dorset.

Fig. 9.—*Asteracanthus granulosus*, Egerton; dorsal fin-spine, right side view, slightly more than one-half nat. size.—Wealden (Wadhurst Clay): Ecclesbourne, near Hastings, Sussex. Rufford Collection (B. M. no. P. 8939).

3. **Asteracanthus granulosus,** Egerton. Text-fig. 9.

1854. *Asteracanthus granulosus*, P. M. G. Egerton, Ann. Mag. Nat. Hist. [2], vol. xiii, p. 433.

1855. *Asteracanthus granulosus*, P. M. G. Egerton, Figs. and Descripts. Brit. Organic Remains (Mem. Geol. Surv.), dec. viii, pl. i.

1859. *Asteracanthus granulosus*, Pictet and Campiche, Foss. Terr. Cretacé St. Croix, p. 98, pl. xii, fig. 11.

*Type.*—Dorsal fin-spine; British Museum.

*Specific Characters.*—Dorsal fin-spine nearly similar in form and proportions to that of *A. verrucosus*, but with the ornamental tubercles relatively smaller and less closely arranged.

*Description of Specimens.*—The type spine, although uncrushed, is a little abraded, incomplete at the apex, and without the posterior denticles. The front border is clearly shown to be rounded, and the posterior face is also only rounded, not keeled. The basal fragment of a second specimen described and figured by Egerton proves that the species sometimes attained a larger size than *A. verrucosus*. Another fine specimen, 30·5 cm. in length, found by Mr. Philip Rufford in the Wadhurst Clay at Ecclesbourne, near Hastings (Text-fig. 9), displays the side view a little fractured by crushing. The sparse ornamental tubercles tend to be arranged not only in longitudinal, but also sometimes in transverse series; while near the pointed tapering apex they are fused as usual into longitudinal ridges. The posterior denticles are seen to be relatively small.

*Horizon and Localities.*—Wealden: Tilgate Forest, and Ecclesbourne, near Hastings, Sussex. Also in the Lower Neocomian of St. Croix, Switzerland.

Family Myliobatidæ (?).

## Genus **HYLÆOBATIS**, novum.

*Generic Characters.*—Teeth more or less transversely elongated, with truncated ends, the crown overhanging the root on all borders. Oral surface of crown gently tumid, sloping down to its low and rounded anterior border, but sharply separated behind from a deep and concave posterior surface; covered with enamel which is variously marked with wrinkles.

*Type Species.—Hylæobatis problematica*, described below.

*Remarks.*—This genus is known only by a few small isolated teeth evidently of one species, and its affinities are uncertain. The teeth must have been arranged in a close tessellated pavement, as in the Cretaceous *Ptychodus* and the Tertiary Myliobatid skates. The slight bevelling of their ends shows that they alternated in transverse series; and occasional pressure-scars denote crowding. The superficial wrinkling of the enamel is rather suggestive of the rugosity round the margin of some teeth of *Ptychodus;* the deep concave posterior face of the crown and the low rounded anterior border also recall corresponding features in the same Cretaceous teeth. It may even be added that their microscopical structure (Text-fig. 10) agrees with that of the teeth of *Ptychodus* (Text-fig. 11) though there is nothing in this to distinguish them definitely from Cestraciont teeth. It is thus possible that *Hylæobatis* may prove to be one of the long-sought forerunners of *Ptychodus*.

### 1. **Hylæobatis problematica**, sp. nov. Plate V, figs. 1—5; Text-fig. 10.

*Type.*—Tooth without root; York Museum.

*Specific Characters.*—The type species, founded on isolated teeth measuring from 6 to 13 mm. in longest (transverse) diameter. Oral surface of dental crown feebly marked with coarse vermiculating wrinkles, which are more or less reticulate and pass at the front border into stronger vertical wrinkles; concave posterior face smooth or marked with slight vertical flutings; the anterior and posterior borders nearly straight and nearly parallel.

*Description of Specimens.*—The type tooth from Brook (Pl. V, fig. 1) lacks the root, but is otherwise well preserved. It is not bilaterally symmetrical, one end being wider and deeper than the other and distinctly bevelled for contact with two teeth. Its oral surface (fig. 1) is gently tumid, a little worn during life in its hinder half, but well preserved laterally and anteriorly, and feebly marked with

irregular wrinkles which are directed chiefly along the longer (transverse) axis of the tooth. Seen from below (fig. 1 *a*) the crown clearly overhangs the root on all borders. In anterior view (fig. 1 *b*) the vertical wrinkling is conspicuous, and the crown is seen to be deepest at the wider end. In posterior view (fig. 1 *c*) the sharp margin of the oral surface forms a prominent ledge over the comparatively smooth, concave posterior face. The narrower end (fig. 1 *d*) is gently rounded, but marked by two well-separated small pressure-scars. The bevelled wider end (fig. 1 *e*) is also marked by two larger pressure-scars. A second tooth from Brook (Pl. V, fig. 2) is very strongly worn in its posterior half, and the worn surface is widest in the middle with a nearly semicircular margin. One end of the tooth is

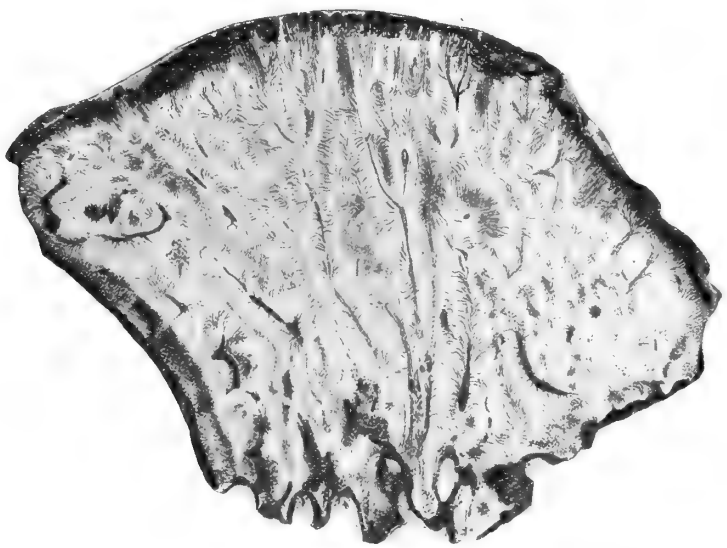


Fig. 10.—*Hylæobatis problematica*, gen. et sp. nov.; vertical antero-posterior section of crown of tooth, enlarged about 20 times.—Wealden: Sevenoaks, Kent. Sedgwick Museum, Cambridge.

again wider than the other and more distinctly bevelled for contact with two teeth; and its rounded anterior border (fig. 2 *a*) exhibits the vertical wrinkling. On the unworn part of the oral surface the irregular wrinkles are mainly in the direction of the long axis of the tooth. A larger and more transversely-elongated tooth from Sevenoaks (Pl. V, fig. 3) displays well the vertical wrinkling of its anterior border, but the oral surface seems to have been worn nearly smooth. One extensive pressure-scar occurs at each lateral end of the tooth, and the specimen is broken across to exhibit the transverse section (fig. 3 *a*). The microscopical structure of this transverse section is shown highly magnified in Text-fig. 10, where the darkly-stained enamel-layer (ganodentine) extends both over the upper oral surface and over the posterior concave surface, while the ordinary dentine is traversed by radiating and bifurcating vascular canals, which are bordered with canaliculi throughout their length and terminate in a tuft of canaliculi beneath the ganodentine.

A closely similar arrangement is seen in *Ptychodus* (Text-fig. 11). Another transversely-elongated tooth (Pl. V, fig. 5) has been so much worn during life that most of its surface markings have been removed; but it is interesting as showing a distinct bevelling at one end and a single well-marked pressure-scar at the other. The original of Pl. V, fig. 4, which is a less elongated tooth, has also been worn during life, but its oral face remains convex and seems to have been opposed to two teeth of a transverse series in the mouth. One lateral end of this tooth is strongly bevelled for articulation with two teeth.

*Horizon and Localities.*—Wealden: Brook, Isle of Wight; Sevenoaks, Kent.

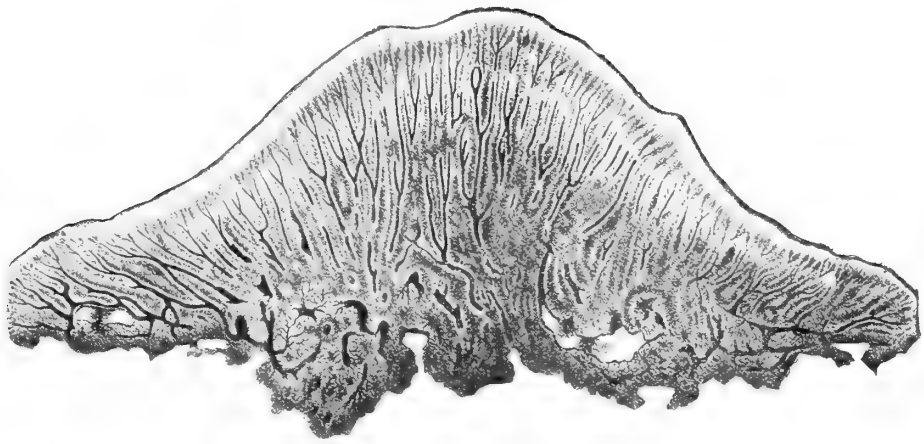


Fig. 11.—*Ptychodus mammillaris*, Agassiz; vertical transverse section of crown of tooth, highly magnified.—English Chalk. After Agassiz.

## Subclass *TELEOSTOMI.*

## Order *CROSSOPTERYGII.*

### Family Cœlacanthidæ.

### Genus **UNDINA**, Münster.

*Undina*, G. von Münster, Neues Jahrb. f. Min., etc., 1834, p. 539.
*Holophagus*, P. M. G. Egerton, Figs. and Descripts. Brit. Organic Remains, dec. x (Mem. Geol. Surv., 1861), p. 19.

*Generic Characters.*—External bones and scales superficially ornamented with tubercles or fine interrupted ridges of ganoine; parafrontal and circumorbital bones plate-like, without superficial excavations. Teeth absent on the margin of the jaws, but a few hollow conical teeth within. Supplementary caudal fin prominent; the rays of all the fins robust, often expanded, and with numerous articulations in the distal portion; small upwardly-pointing denticles on the preaxial rays of the first dorsal and caudal fins.

*Type Species.—Undina penicillata* (Münster, *loc. cit.* and A. Wagner, Abhandl. math.-phys. Cl. k.-bay. Akad. Wiss., vol. ix, 1863, p. 696) from the Lithographic Stone (Lower Kimmeridgian) of Bavaria.

1. **Undina purbeckensis**, sp. nov. Plate IV, fig. 1.

*Type.*—Imperfect fish; British Museum.

*Specific Characters.*—A stout species attaining a length of at least 40 cm. Length of head with opercular apparatus about one quarter the total length of the fish, and somewhat less than the maximum depth of the trunk. Rays of first dorsal and caudal fins not expanded in the distal part, where the articulations are not very close; first dorsal fin with ten rays, caudal fin with about twenty rays above and below. Scales ornamented with coarse elongated tubercles, which are irregularly and rather sparsely arranged, shortest and most numerous on the dorsal scales, longest and fewest on the ventral scales.

*Description of Specimen.*—This species is known only by the single imperfect fish, shown of one half the natural size in Pl. IV, fig. 1. Of the head very little remains, but its shape and proportions are indicated by a fragment of the cranium at the bend of the frontal profile and by the nearly complete lower edge of the mandible (or perhaps gular plate) in cross-section. The hinder limit is marked by an imperfect impression of the clavicle. Part of the smooth outer face of the left pterygoquadrate bone is seen in position, and a displaced imperfect ceratohyal occurs beneath it. The neural arches of the vertebral axis of the trunk are well preserved, and about forty-five can be counted as far as the origin of the caudal fin, the hinder arches of the series gradually becoming longer and stouter. The ribs, seen only in the hinder half of the abdominal region, are small and delicate; but the hæmal arches in the tail are larger and more nearly symmetrical with the opposed neurals.

Of the paired fins, only one of the characteristic pelvic bones (*plv.*) remains, showing that the corresponding fin was inserted closer to the pectoral arch than to the tail. The ten stout rays of the first dorsal fin are distinct ($d^1$), but their laminar support is covered by the scales. No denticles are seen upon them, but there are shallow pits on the articulated distal portion of some rays indicating their original presence. The forked support for the second dorsal fin is preserved ($d^2$), and there are also some traces of the comparatively delicate rays. The anal fin is represented only by displaced fragments (*a*). The caudal fin, as usual, is preceded by two or three free supports above, probably also below; and its total number of rays cannot have been less than twenty above and below. The characteristic denticles are seen on some of the rays in the anterior part of the fin.

Many of the scales are sufficiently well preserved to exhibit their characteristic ornament. Near the dorsal border between the two fins some comparatively

large scales bear numerous short and small elongated tubercles, which are very irregularly arranged (fig. 1 *a*). On the middle of the flank of the caudal region shorter and deeper scales are seen, with a somewhat coarser and sparser ornament of slightly elongated tubercles (fig. 1 *c*). At the ventral border, below the remains of the pelvic fins, the small and elongated scales are marked with closely arranged and much elongated tubercles (fig. 1 *b*).

The air-bladder is large, as usual, extending in the fossil from a point shortly behind the clavicle to the extreme posterior end of the abdominal region.

*Affinities.*—*Undina purbeckensis* appears to be closely related to the type species, *U. penicillata*, from the Lithographic Stone of Bavaria, but differs in being a stouter fish, with a finer tubercular ornament on the principal scales.

*Horizon and Locality.*—Middle Purbeck Beds: Swanage, Dorset.

## Order *ACTINOPTERYGII.*

### Family Palæoniscidæ.

The latest known members of this family occur in the Purbeck and Wealden formations, and are referable to the highly specialised genus *Coccolepis*.

### Genus **COCCOLEPIS**, Agassiz.

*Coccolepis*, L. Agassiz, Poiss. Foss., vol. ii, pt. i, 1844, p. 300.

*Generic Characters.*—Trunk elegantly fusiform. Mandibular suspensorium oblique; dentition consisting of an inner series of large laniaries flanked externally with minute teeth; external bones tuberculated or rugose. Fins large or of moderate size, the rays of all articulated and branching distally; fulcra minute or absent. Pelvic fins with extended base-line; dorsal and anal fins triangular, the former opposed to the space between the latter and the pelvic fins; upper caudal lobe much elongated, the fin deeply cleft and somewhat unsymmetrical. Scales thin and deeply imbricating, ornamented with tuberculations of ganoine.

*Type Species.*—*Coccolepis bucklandi* (L. Agassiz, Poiss. Foss., vol. ii, pt. i, 1844, p. 303, pl. xxxvi, figs 6, 7), from the Lithographic Stone (Lower Kimmeridgian) of Bavaria.

*Remarks.*—This genus ranges upwards from the Lower Lias of Lyme Regis (*Coccolepis liassica*, A. S. Woodward, Ann. Mag. Nat. Hist. [6], vol. v, 1890, p. 435, pl. xvi, figs. 2—4) to the Wealden of Bernissart, Belgium (*Coccolepis macropterus*, R. H. Traquair, Mém. Mus. Roy. Hist. Nat. Belg., vol. vi, 1911, p. 11, pl. i, text-figs. 1—3). It also has a wide geographical distribution, one species being

known from the Jurassic of Talbragar, New South Wales (*Coccolepis australis*, A. S. Woodward, Mem. Geol. Surv. New South Wales, Palæont. no. 9, 1895, p. 5, pl. i; pl. ii, fig. 4; pl. v, fig. 1).

1. **Coccolepis andrewsi**, A. S. Woodward. Plate IV, figs. 2, 3.

1890. *Coccolepis andrewsi*, Woodward and Sherborn (*ex* Traquair, MS.), Cat. Brit. Foss. Vertebrata, p. 37 (name only).
1891. *Coccolepis andrewsi*, A. S. Woodward, Catal. Foss. Fishes, B. M., pt. ii, p. 524.
1895. *Coccolepis andrewsi*, A. S. Woodward, Geol. Mag. [4], vol. ii, p. 145, pl. vii, fig. 1.

*Type.*—Fish, wanting pectoral fins; Museum of Practical Geology, London.

*Specific Characters.*—A small species attaining a length of about 6 cm.: maximum depth of trunk contained about six times in the total length; upper caudal lobe excessively elongated and slender. Fin-rays smooth, with distant articulations. Dorsal fin arising somewhat in advance of the middle point of the back, partly opposed to the hinder portion of the pelvic fins, at least as deep as long, and its maximum depth nearly equalling that of the trunk at its point of origin; anal fin scarcely deeper than long, about two-thirds as extended as the dorsal, arising completely behind the latter and situated close to the caudal fin. Scales very coarsely granulated; fulcra of upper caudal lobe slender, much elongated, and very numerous.

*Description of Specimens.*—This species is known only by two specimens discovered by the Rev. W. R. Andrews, F.G.S., the one nearly complete (Pl. IV, fig. 2), the other showing the posterior abdominal and caudal regions (Pl. IV, figs. 3, 3 *a*).

The head of the type specimen appears to be typically Palæoniscid, but it is too imperfect for description. The only noteworthy features are a few slender conical teeth in the mandible, and traces of delicate broad branchiostegal rays below. The axial skeleton of the trunk is well exhibited through the thin squamation in both specimens, and is also typically Palæoniscid. The neural and hæmal arches, which bound the vacant space for the persistent notochord throughout the length of the fish, are only superficially ossified, appearing hollow in the fossilised state when broken. Their total number to the base of the caudal fin is about forty, and of these fifteen or sixteen may be reckoned as caudal. The neural spines in the abdominal region are stout and relatively large, not fused with their supporting arches; but both these and the hæmal spines are firmly fixed to their arches in the tail. There are no ribs, the hæmal arches in the abdominal region being merely a series of diminutive cartilages, best seen in the counterpart of the type specimen. At the beginning of the caudal region the hæmal arches suddenly become elongated, and five are distinct in advance of the anal fin in both specimens. Behind these

there is some displacement of the hæmals in the type, but ten can be clearly counted in the second specimen as far as the origin of the caudal fin. The neural arches at the base of the upper caudal lobe are aborted, and a series of at least nine slender rods above them support the large fulcra. The hæmal arches in the basal part of the same lobe are enlarged for the direct support of the dermal rays; and the series is continued for some distance along the lobe by very small though stout ossified cartilages.

The pectoral fins are missing, but all the other fins are well preserved in both fossils. Ordinary fulcra are absent, but at the origin of each fin there are from three to six simple, though distantly articulated rays, gradually increasing in length to the apex of the fin, where the normal rays begin. These are also crossed by distant articulations, and, in the caudal fin at least, they are distally bifurcated. The pelvic fin is about as long as deep, arising nearly midway between the pectoral arch and the anal fin; its rays are shown to be not less than twenty in number, but the supports are unfortunately not observable. The number of rays in the dorsal fin is uncertain, but nineteen or twenty endoskeletal supports can be counted in the second specimen (fig. 3). The anal fin is somewhat smaller than the dorsal, with fourteen endoskeletal supports, of which the foremost is much the longest (fig. 3). The extreme elongation of the upper caudal lobe is best seen in the second specimen (fig. 3).

The whole of the trunk is covered with small, thin scales, which have the appearance of overlapping. They are, however, too obscure for detailed description, and it can only be noted that those of the lateral line in the caudal region are slightly thickened, and form a conspicuous smooth band along the flank as far as the beginning of the upper caudal lobe. Rather large tubercles of ganoine ornament the scales, and are especially well seen in parts of the abdominal region. A smooth thick ovate scale, pointed in front, occurs at the origin of the anal fin in both specimens (fig. 3*a*). The oat-shaped scales on the slender caudal lobe are comparatively thick and smooth.

*Horizon and Locality.*—Lower Purbeck Beds: Teffont, Wiltshire.

2. **Coccolepis,** sp. Plate IV, fig. 4.

*Coccolepis* or a related Palæoniscid genus also occurs in the English Wealden, as shown by an imperfect maxilla discovered by Mr. Charles Dawson, F.G.S., in the Wadhurst Clay of Hastings (Pl. IV, fig. 4). The upper margin of the bone is incomplete, but the oral border is well preserved, and is seen to be bent sharply downwards behind. The outer face of the bone is smooth on the anterior extension, but very finely rugose in the hinder portion, where there is a tendency

to delicate ridges concentric with the hinder and upper borders. The outer face is also traversed by a slight longitudinal groove inclined forwards and downwards. The minute outer teeth, so far as preserved, are very slender, but the large smooth conical teeth of the spaced inner series are tumid at the base.

## Family Semionotidæ.

### Genus **LEPIDOTUS**, Agassiz.

*Lepidotes*, L. Agassiz, Jahrb. f. Min., Geogn., etc., 1832, p. 145.
*Lepidotus*, L. Agassiz, Poiss. Foss., vol. ii, pt. i, 1833, pp. 8, 233.
*Sphærodus*, L. Agassiz, *tom. cit.*, pt. i, 1833, p. 15 (in part).
*Scrobodus*, G. von Münster, Neues Jahrb. f. Min., etc., 1842, p. 38.
*Plesiodus*, A. Wagner, Abh. k. bayer. Akad. Wiss., math.-phys. Cl., vol. xi, 1863, p. 632.
*Prolepidotus*, R. Michael, Zeitschr. deutsch. geol. Ges., vol. xlv, 1893, p. 729.

*Generic Characters.*—Trunk fusiform and only moderately compressed. Marginal teeth robust, styliform; inner teeth stouter, tritoral but smooth. Opercular apparatus well developed, with a narrow arched preoperculum, but with few branchiostegal rays and no gular plate. Ribs ossified. Fin-fulcra very large and biserial, present on all the fins. Paired fins small or of moderate size; dorsal and anal fins short and deep, the former just in advance of the latter caudal fin slightly forked. Squamation regular and continuous, the scales rhombic, very robust, smooth or feebly ornamented; flank-scales not much deeper than broad, with their wide overlapped margin produced forwards at the upper and lower angles; scales of dorsal and ventral aspect nearly as deep as broad; dorsal and ventral ridge-scales usually inconspicuous.

*Type Species.*—*Lepidotus elvensis* (*Cyprinus elvensis*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., vol. xxvii, 1818, p. 394; *Lepidotus gigas*, L. Agassiz, Poiss. Foss., vol. ii, pt. i, 1833—37, pp. 8, 235, pls. xxviii, xxix) from the Upper Lias of France, Würtemberg, Bavaria, and England. It is described in detail by F. A. Quenstedt, "Ueber *Lepidotus* im Lias ε" (Tübingen, 1847); and the French type specimen in the National Museum of Natural History, Paris, is described and figured by F. Priem, Annales de Paléontologie, vol. iii (1908), p. 5, pl. ii. A closely related species, *Lepidotus semiserratus*, Agassiz, is described by A. S. Woodward, Proc. Yorks. Geol. and Polyt. Soc., n. s., vol. xiii, 1897, pp. 325—336, pls. xlvi—xlviii.

On comparing the head of one of the earlier species of *Lepidotus* (Text-fig. 12) with that of one of the latest (Text-fig. 13), it will be noticed that as the teeth become stouter, the jaws are shortened and the mouth is relatively smaller. The

supratemporals and the cheek-plates become more or less irregularly subdivided; and the wavy median suture between the parietal and frontal bones of the cranial roof becomes nearly straight.

Fig. 12.

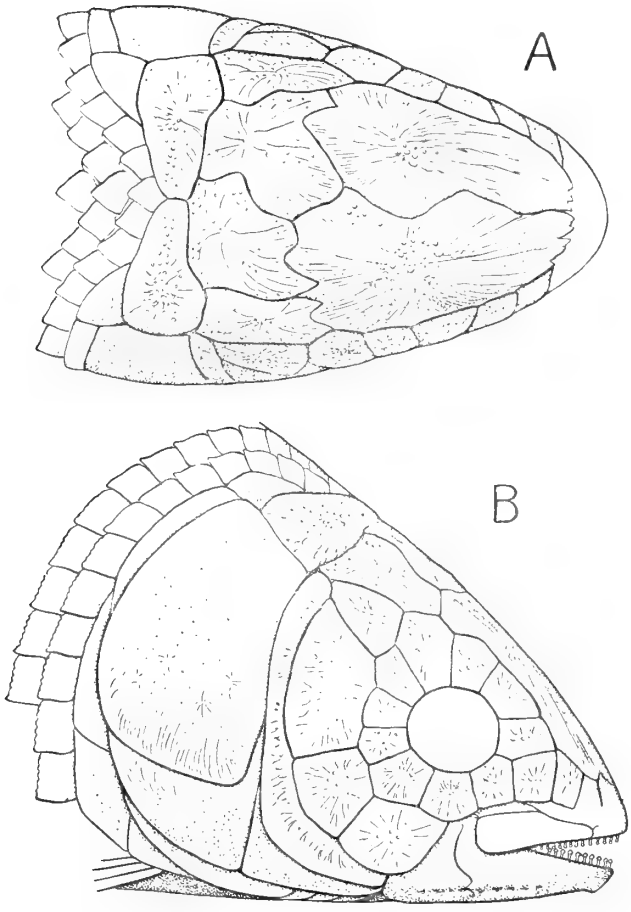



Fig. 13.

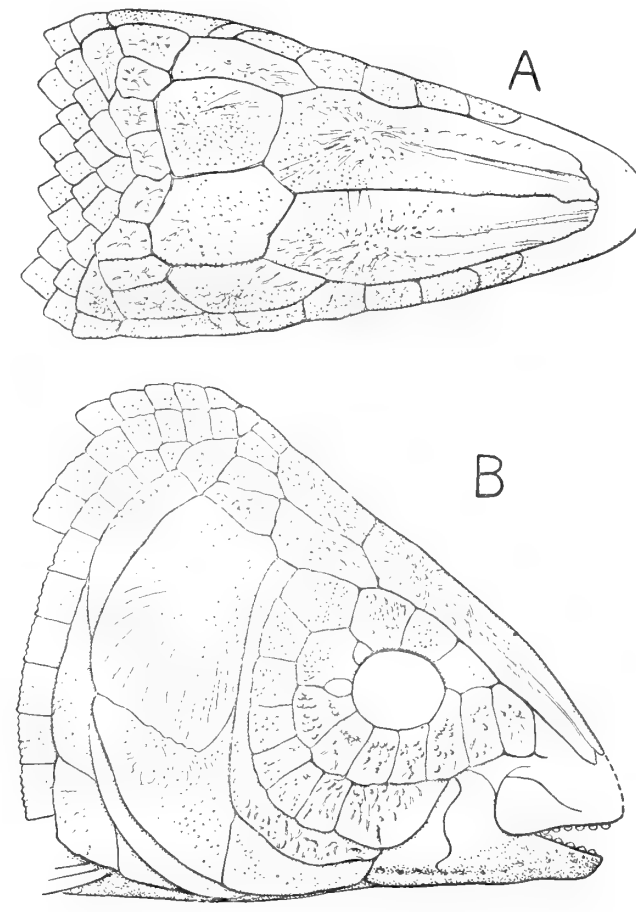



Fig. 12.—*Lepidotus semiserratus*, Agassiz; restoration of head, upper (A) and right side view (B), one-half nat. size.—Upper Lias: Whitby, Yorkshire.

Fig. 13.—*Lepidotus mantelli*, Agassiz; restoration of head, upper (A) and right side view (B), one-half nat. size.—Wealden: Sussex.

1. **Lepidotus minor**, Agassiz. Plate V, figs. 6—11; Plate VI; Plate VII, figs. 1—5; Text-figure 14.

1833–37. *Lepidotus minor*, L. Agassiz, Poiss. Foss., vol. ii, pt. i, pp. 9, 260, pl. xxxiv (*non* pl. xxix *c*, fig. 12).

1887. *Lepidotus minor*, W. Branco, Abh. geol. Specialk. Preussen u. Thüring. Staaten, vol. vii, p. 363, pl. vi, fig. 2 (? *non* p. 366, pl. vi, fig. 1).

1893. *Lepidotus minor*, A. S. Woodward, Proc. Zool. Soc., p. 562, pl. xlix, fig. 3.

1895. *Lepidotus minor*, A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. iii, p. 94, text-fig. 22.

*Type*.—Imperfect fish; School of Mines, Paris.

*Specific Characters*.—A species attaining a length of about 40 cm., but usually

less. Length of head with opercular apparatus exceeding three-quarters the maximum depth of the trunk, and slightly less than one-quarter the total length of the fish. Frontal profile steep and snout acute; parietal bones about one third as long as the frontals, which are four times as long as their maximum width, narrow in front, and united by a nearly straight median suture; two postorbital plates, the lower large and much deeper than wide, and both wider than the circumorbitals; mandibular symphysis not much deepened or extended; external bones rugose and more or less tuberculated, except the maxilla and premaxilla, which are smooth. A single pair of supratemporal plates. Teeth on moderately long pedicles, constricted below the crown, and all with a small pointed apex when unworn. Operculum about three-fifths as wide as deep, its width contained three times in the length of the head. Fin-fulcra very large, the principal dorsal fulcra

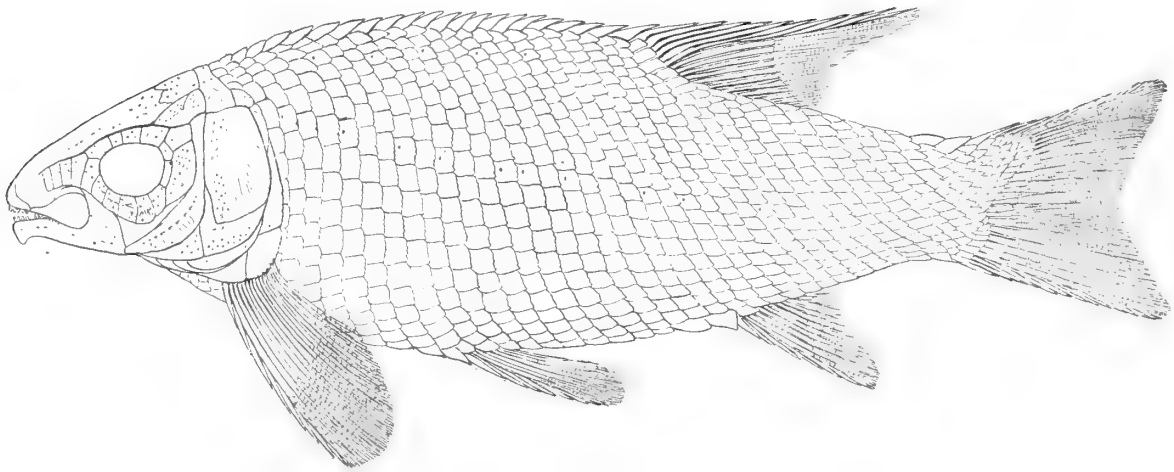


Fig. 14.—*Lepidotus minor*, Agassiz; restoration, from half to three-eighths nat. size.—Middle Purbeck Beds: Swanage, Dorset.

more than half as long as the anterior dorsal fin-rays, and four to six directly inserted in the ridge of the back; pelvic fins arising midway between the pectorals and the anal; dorsal fin much larger than the anal, but each with ten or eleven rays. Scales smooth, usually more less serrated on the flank; scales of lateral line notched; dorsal ridge-scales acutely pointed and rather prominent.

*Description of Specimens.*—This species varies considerably in the shape of the trunk, and the fossils are often distorted by crushing. The degree of serration of the flank-scales and the relative size of the fin-fulcra are also variable. Every gradation, however, can be found between the deepened form with rounded back, shown in the type specimen and in our Pl. VI, and the more slender type which is figured by Branco (*loc. cit.*, 1887), and represented here in Text-fig. 14. A careful study of a large series of specimens also seems to show that the nature of the serrations of the scales is not correlated either with the size of the fish or with its shape.

The chondrocranium is unknown, but it must have been imperfectly ossified, and, as shown by specimens in the British Museum (Pl. V, fig. 6) and the Warwick Museum, the membrane bones of the roof were readily detachable from it. The parietal bones (Pl. V, figs. 6, 7, *pa.*) form a nearly symmetrical pair united in a slightly wavy median suture; and that of one side extends a little further forwards on the cranial roof than that of the other side. Each bone is about one and a half times as long as broad, and its outer face is not only rugose, but also coarsely and irregularly tuberculated, and marked in the middle by a short transverse groove for the slime-canal. The squamosal on each side is a longer and narrower bone, united in a slightly wavy suture with the parietal, extending from the occiput behind to the postorbital prominence of the frontal forwards. Its outer face (Pl.V, figs. 7, 8, *sq.*) is also rugose and coarsely tuberculated, while its inner face (Pl. V, fig. 6, *sq.*) bears the usual elongated articular facette for the upper end of the hyomandibular. The frontals (Pl. V, figs. 6—8, *fr.*) are at least two and a half times as long as the parietals, and are also united in a slightly wavy median suture. Each is widest behind, the maximum width being about a quarter of the total length; and its comparatively narrow anterior portion ends in a few pointed digitations. Its outer margin is regularly excavated for the relatively large orbit, thus producing definite postorbital and preorbital prominences. Its outer face is coarsely and irregularly tuberculated as far forwards as the middle of the orbit, while the anterior portion is marked only with a few irregular longitudinal grooves. The longitudinal slime-canal, which opens on the outer face in rather large pores, is enclosed by bone which forms a rounded ridge on the inner face (Pl. V, fig. 6, *fr.*). The ethmoid region and the nasals remain unknown. The parasphenoid (Pl. V, fig. 9) which is commonly ascribed to this species but has not yet been definitely seen in position, closely resembles that of *Lepidotus latifrons*.[1] It is narrowest at the small digitate basipterygoid processes, expanding much behind and exhibiting a deep cleft in its hinder margin. It is pierced between the basipterygoid processes by a foramen for the passage of the internal carotids, and it is toothless.

The cheek is completely covered with plates, which form a circumorbital ring, bounded behind by postorbitals and continued in front by a few preorbitals. All are irregularly tuberculated, while the circumorbitals behind and below the orbit, as well as the preorbitals, are also marked by the usual slime-canal. Of the circumorbital ring, four plates occur above the eye, occupying the excavation in the frontal border between the preorbital and postorbital prominences and extending backwards to bound the anterior end of the squamosal (see Pl. V, figs. 7, 8). These plates are variable in shape, but the foremost is usually the longest. The two posterior circumorbitals are comparatively small and narrow, while the lower

[1] A. S. Woodward, 'On the Cranial Osteology of the Mesozoic Ganoid Fishes, *Lepidotus* and *Dapedius*,' Proc. Zool. Soc., 1893, p. 561, text-fig. 3.

of the two is also deep (see Pl. V, figs. 6, 8); and the five lower circumorbitals (*co.*) are relatively large and deep, followed in front by the still deeper and narrower plates of the preorbital series (Pl. V, fig. 8, and Pl. VI, *pro.*). The upper plate of the postorbital series (best seen in Pl. V, fig. 7, *po.*), articulating with the middle part of the squamosal border, is in contact with both the posterior upper and the upper posterior circumorbital plates, and bounds above the relatively large principal postorbital plate. This element (Pl. V, figs. 6—8; Pl. VI; *po.*) is about twice as deep as broad, of irregularly rhomboidal form, with the postero-inferior angle rounded, and its outer face sparsely ornamented by tubercles of ganoine, which tend to elongate by irregular fusion. There is no clear evidence of other cheek-plates of the outer or postorbital series; but in the original of Pl. VI, and in another specimen in the Museum of Sherborne School, there are fragments which may perhaps be interpreted as representing comparatively thin plates below the large postorbital continuing this series downwards and forwards.

The mandibular suspensorium is inclined forwards so that the quadrate articulation is beneath the middle of the orbit. The hyomandibular (Pl. V, fig. 10) is a thin lamina of bone, slightly more than twice as deep as wide, and strengthened on its outer face by a longitudinal ridge, from which a cross-ridge arises at the level of the prominence for the support of the operculum. The quadrate, not yet clearly seen, must also have been a delicate bone, while the entopterygoid and metapterygoid are comparatively thin laminæ (as shown in B. M. no. P. 5591). The ectopterygoid, however, is stout and horizontally expanded for the support of at least three rows of teeth parallel with the outer border. Its outer face (Pl. VII, fig. 1 *a*), which is conspicuous in several specimens, is smooth and flattened or very slightly concave, appearing as a narrow band, with the oral border gently concave and the upper anterior and posterior angles rounded off. This face is mistaken for that of the maxilla in the restoration published in the 'Catalogue of Fossil Fishes in the British Museum,' pt. iii (1895), p. 95, fig. 22. The horizontal extension of the ectopterygoid (Pl. VII, fig. 1) is widest in front, where its bevelled end passes under the hinder margin of the equally expanded but relatively small and thin palatine element (well seen in the specimen in Sherborne School Museum). Its clustered teeth, as also those of the imperfectly known vomer, are relatively larger and stouter than the ectopterygoid teeth. The maxilla (Pl. VI, *mx.*) is a delicate smooth lamina of bone, deepest and rounded behind, tapering forwards and terminating in front in a slender, inwardly directed process for articulation with the palatine. Its oral border, at least in the middle and anterior portion, bears a spaced series of comparatively small and slender teeth (some seen in B. M. no. 42308); while the upper border of its hinder expansion is capped by a single long and narrow supramaxilla (seen in Pl. VI). The premaxilla (Pl. V, fig. 11), seen in position in Pl. V, fig. 7, and in Pl. VI (*pmx.*), is a stouter smooth bone occupying only about half as much of the oral border as the maxilla, but bearing a regular

spaced series of six or seven styliform teeth. Its hinder half tapers backwards to a blunt point, which meets the maxilla; its anterior half is continued upwards in a narrow laminar process, which is so long that (as in *Amia*) it passes beneath the nasal bone to articulate in a squamous suture with the inner face of the frontal (Pl. V, fig. 6, *pmx.*). This process, also as in *Amia*, is hollowed on its superior face and pierced by a large oval vacuity. The mandible is short and much deepened in the coronoid region. As seen from the outer face (Pl. VI, *md.*) the angular bone is comparatively short and deep, and marked near its lower margin by a row of large pits and rugosities for the slime-canal. The dentary bone (Pl. VII, fig. 2) is still deeper in the coronoid region just in front of the angular, but rapidly contracts to the tooth-bearing portion, which forms a narrow bar curving inwards and slightly deepening at the symphysis. This portion bears a regular spaced series of nine or ten styliform teeth somewhat larger than those of the upper jaw; while its outer face is a little rugose and bears a row of large pits for the course of the slime-canal. The summit of the coronoid region is formed by a long and narrow coronoid bone, exactly as in *Amia* (seen in Pl. VI). The articular end of the meckelian cartilage is slightly ossified (seen in B. M. no. 41157), and on the inner face of the mandible only one splenial element has been observed. This is comparatively stout, enters the mandibular symphysis, and bears a cluster of about three rows of teeth which are stouter than those of the dentary and diminish to comparatively small teeth behind (Pl. V, fig. 6, *md.*). All the teeth are hollow and fused with the supporting bone, not in sockets. When unworn the smooth and rounded enamelled crown rises to a sharp median apex, while the comparatively long pedicle is slightly swollen just below the crown and a little expanded at its base, which sometimes exhibits short vertical grooves. Successional teeth have been observed as in other species of *Lepidotus*.

In the hyoid arch the ceratohyal is relatively large, laterally compressed, constricted in the middle, and deepest behind (Pl. V, fig. 8, *ch.*). It does not appear to bear any branchiostegal rays.

The preoperculum, best seen in Pl. V, fig. 8, *pop.*, but also shown in Pl. V, fig. 6, and Pl. VI, is narrow and gently curved at the angle. The ascending limb is slightly constricted in its lower half, but expands upwards where its outer face is smooth and its truncated end is in contact with the squamosal bone. Its curved lower limb is more expanded and traversed by the usual longitudinal ridge, behind and below which the large openings of the slime-canal are conspicuous. The anterior border exhibits a smooth overlapped surface for the cheek-plates as far as this ridge; while the expansion behind, when unabraded, is marked by a few radiating crimpings, and the posterior edge usually bears a spaced row of large tubercles of ganoine. The operculum, also best seen in Pl. V, fig. 8, *op.*, where the postero-superior angle alone is incomplete, is somewhat wider below than above, and its maximum width measures about three-fifths of its depth. Its

upper and anterior portions are sparsely ornamented with tubercles, which fuse together more or less irregularly and rarely spread over the whole plate. The suboperculum is usually about one-quarter as deep as the operculum, with a relatively large ascending process in front, and sparsely tuberculated near the anterior and inferior margins (Pl. V, fig. 8, *sop.*; Pl. VI, *sop.*). The interoperculum is small, elongate-triangular in shape, also sparsely ornamented with large irregular tubercles (Pl. V, fig. 8, *iop.*; Pl. VI, *iop.*). Only four branchiostegal rays have been clearly seen (Pl. V, fig. 8, *br.*), though there appear to be traces of two or three more in the original of Pl. VI. The uppermost is largest and bears a few tubercles, while the others are smooth. There is no gular plate.

The notochord must have been persistent, and there are no surrounding ossifications. The neural and hæmal arches are incompletely ossified, so that they appear hollow and are frequently crushed in the fossils. The neural spines in the abdominal region so far back as the origin of the dorsal fin, are stout and a little widened distally where they nearly reach the dorsal border (Pl. VII, fig. 3, *n*): they appear to be slightly curved, with the concavity forwards. The neural spines in the caudal region are shorter and more slender. The ribs (*r.*) are round or ovoid in section, comparatively slender, and extend almost to the ventral border. The hæmal arches within the base of the caudal fin are especially stout and somewhat expanded distally (as seen in B. M. no. P. 4989 *a*).

A single pair of large supratemporal plates (Pl. V, fig. 7, *st.*) overlaps the occiput, exhibiting the same rugosity and sparse tuberculation as the hinder bones of the cranial roof, and marked by the usual groove for the transverse slime-canal. Each supratemporal is wider than long and tapers towards the middle line of the fish, where it meets its fellow of the opposite side. The comparatively small exposed face of the post-temporal (Pl. V, fig. 7, *ptt.*) is triangular in shape and also tuberculated. Its inner face is smooth, and in the original of Pl. V, fig. 6, *ptt.*, shows no feature beyond the articular facette for the supraclavicle; but beneath the same bone in B. M. no. P. 5591, there is a displaced long slender process which seems to correspond with the internal descending process of the post-temporal in *Amia*. Such a process has already been discovered by Mr. Alfred N. Leeds on a post-temporal of *Lepidotus* from the Oxford Clay of Peterborough. The supraclavicle is a deep and narrow plate of bone, only rugose at its upper end where it is crossed obliquely by the slime-canal, and not serrated along its posterior edge. The clavicle curves well forwards and its large expanded lower end is seen from within below and just behind the mandible in Pl. VI. When the concave anterior margin is exposed (as in the Sherborne School specimen), it is seen to be covered with short oblique rows of small granulations. There are three large enamelled post-clavicular plates, of which the upper two are shown in Pl. V, fig. 8, *pcl.*, and in Pl. VI. They are smooth and exhibit a variable amount of serration of the posterior edge in the lower portion. The upper postclavicular is deep and narrow,

and its tapering upper end is in contact with the lower part of the supraclavicle. The second plate, directly beneath the first, is not much deeper than wide, with a gently rounded postero-inferior angle; the third plate (not seen in the specimens figured, but shown in Text-fig. 14) is directly in front of the second plate, comparatively small and triangular in shape. The pectoral fin, as shown in Pl. VI, is rather large, the longest of its sixteen or seventeen closely pressed rays almost reaching the origin of the pelvic fins. The fin is fringed in front with a paired series of about eight enamelled fulcra, and all the rays, which are almost without enamel, are articulated and divided in their distal half. The pelvic fins nearly resemble the pectorals, but are much smaller, with only seven rays, of which the longest attains about three-quarters of the length of the longest pectoral. The dorsal and anal fins are characterised by their very stout fulcra, which are covered with smooth enamel and paired like those of the pectoral and pelvic fins. In the dorsal fin, four, five, or even six stout fulcra of gradually increasing length are directly inserted in the ridge of the back, and their long crowded supports (causing a break in the squamation in Pl. VI) penetrate the muscles almost as far as the position of the notochord. As shown in Pl. VI, the length of the longest of these fulcra much exceeds half the extreme height of the fin; while there are also a few large fulcra fringing the foremost ray. The rays are about eleven or twelve in number, closely arranged and rapidly diminishing in size backwards, each articulated and finely divided in the distal half: they are destitute of enamel or marked only by the slightest streak. The anal fin, with ten rays, nearly resembles the dorsal in shape, but it is much smaller and its anterior fulcra are less stout, only two or at most three being directly inserted in the ridge of the body. The great support for the fulcra, however, is deeply inserted in the muscles of the trunk (Pl. VII, fig. 5 *a*, *f.s.*). The caudal fin consists of about eighteen comparatively stout rays, which are closely articulated and divided nearly to the base, and differ from the other fin-rays in being well covered with enamel in their basal half. The fin is slightly excavated behind (as shown in B. M. no. 19006), and its fringing fulcra are about as large as those of the anal fin.

All the scales are smooth, sometimes with a faintly concave face; and their hinder margin is often slightly convex, while their upper and lower margins are sigmoidally curved. None of the principal flank-scales are much deeper than broad, but they are comparatively deeper in the typical stout forms (Pl. VI) than in the more slender forms (Text-fig. 14). They also appear sometimes smaller in the former than in the latter, but the total number of transverse series of scales is always approximately the same (about thirty-eight to forty as counted along the lateral line), while the number in a series above the origin of the pelvic fin is nineteen or twenty. In this position the lateral line always traverses the eleventh scale from the ventral border; while above the origin of the anal fin it traverses the thirteenth or fourteenth scale in the stout forms (Pl. VI), the ninth scale in the

more slender forms (Text-fig. 14). The flank-scales in the abdominal region are nearly always feebly and coarsely serrated, but the serrations are usually restricted to the lower portion of each posterior margin; the scales of the lateral line are also often notched at the posterior margin, and a varying number are pierced by a simple foramen for the passage of the slime-canal. As the serrations of the flank-scales disappear towards the caudal region, the postero-inferior angle of each scale tends to become produced into a slender point, and this may even be strengthened by a slight ridge (B. M. no. 19006). Towards the dorsal and ventral borders, and in the hinder part of the caudal region, the scales become slightly broader than deep; and the third row from the dorsal border, between the occiput and the origin of the dorsal fin, is marked at intervals with the orifices of an upper slime-canal. The dorsal ridge-scales from a point shortly behind the occiput to the origin of the dorsal fin (accidentally removed from the original of Pl. VI, but seen in Pl. VII, fig. 4, and in Text-fig. 14), are relatively large and pointed, and form a conspicuous imbricated row; there are also two or three enlarged ridge-scales, not so deeply imbricating, at the origin of the caudal fin above and below. The three enlarged scales, with denticulated posterior margin, surrounding the anus just in front of the anal fin, are well shown somewhat displaced in Pl. VI. At the base of the fulcra of the dorsal fin about four scales in a regular row are elongated in the direction of the fin-rays; at the base of the caudal fin small elongated scales are similarly related to the rays, while a notch in the end of the caudal pedicle marks the limit of the triangular remnant of the upper caudal lobe.

The scales of the abdominal region are united in the usual manner by a complicated overlap and a peg-and-socket articulation. On the flank, the wide overlapped margin of each scale is produced at its upper angle into a large bluntly rounded process, at its lower angle into a smaller acute process (Pl. VII, fig. 5); while there is sometimes a minute prominence in the excavation between the two (*e. g.* in B. M. no. P. 4989 *a*). In the ventral scales (Pl. VII, fig. 5 *b*), the antero-superior process becomes especially large, produced upwards as well as forwards, and the antero-inferior process disappears. In all these scales, the peg-and-socket articulation, strengthened by a vertical ridge, is also present; in the caudal scales only the strengthening ridge, more or less widened, remains.

*Horizon and Locality.*—Middle Purbeck Beds: Swanage, Dorset.

2. **Lepidotus notopterus,** Agassiz. Plate VII, fig. 6.

1835–37. *Lepidotus notopterus*, L. Agassiz, Poiss. Foss., vol. ii, pt. i, p. 257, pl. xxxv.
1850. *Lepidotus notopterus ?*, V. Thiollière, Ann. Sci. Phys. Nat. Lyon [2], vol. iii, p. 138.
1852. *Lepidotus notopterus*, F. A. Quenstedt, Handb. Petrefakt., p. 197, pl. xv, fig. 4.
1863. *Lepidotus notopterus*, A. Wagner, Abhandl. k. bayer. Akad. Wiss., math.-phys. Cl., vol. ix, p. 628.

1873. *Lepidotus notopterus ?*, V. Thiollière, Poiss. Foss. Bugey, pt. ii, p. 15, pl. iv.
1887. *Lepidotus notopterus*, W. Branco, Abhandl. geol. Specialk. Preussen u. Thüring. Staaten, vol. vii, p. 382, pl. viii, fig. 5.
1887. *Lepidotus notopterus*, K. A. von Zittel, Handb. Palæont., vol. iii, p. 209, fig. 218.
1895. *Lepidotus notopterus*, A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. iii, p. 92.

*Type.*—Imperfect fish; British Museum.

*Specific Characters.*—A species attaining a length of about 40 cm. Length of head with opercular apparatus nearly equal to the maximum depth of the trunk, and occupying about one-quarter the total length of the fish. Snout acute; cranial roof-bones with few sparse tuberculations; teeth on moderately long pedicles. Operculum twice as deep as its maximum breadth, which is contained at least three times in the length of the head. Fin-fulcra very large, the principal dorsal fulcra sometimes half as long as the anterior dorsal fin-rays, and three or four directly inserted in the ridge of the back; the pelvic fins arising much nearer to the anal than to the pectorals; dorsal and anal fins deeper than long, the former larger than the latter. Scales smooth, very few serrated, but those of the lateral line and sometimes a few anterior flank-scales slightly notched on the hinder margin.

*Description of Specimen.*—An imperfect fish lacking most of the head (Pl. VII, fig. 6), obtained by the late Earl of Enniskillen from the Purbeck Beds of Swanage, differs from *L. minor* in its smaller and more delicate dorsal fin-fulcra, and agrees well, so far as it can be compared, with *L. notopterus* from the Lithographic Stone (Lower Kimmeridgian) of Germany and France. It may therefore be recorded provisionally under the latter specific name.

Traces of unusually stout ribs are exposed by the removal of the scales in the anterior part of the abdominal region. On the rest of the trunk the scales are in regular order, and the outline of the fish is only marred by the accidental removal of the ventral part of the abdominal region and by slight crushing in front of the position of the anal fin. The principal flank-scales in the abdominal region are slightly deeper than wide, with a smooth and somewhat convex hinder margin; above and below they are more nearly equilateral; and the dorsal ridge-scales are acuminate, though not enlarged. The scales in the caudal region are less deep, with a tendency towards the production of the postero-inferior angle; some of the ventral scales are much wider than deep; and two of the acuminate dorsal ridge-scales at the origin of the upper caudal lobe are a little enlarged. The scales of the lateral line are pierced at irregular intervals with large pores, and the hinder margin of each scale is notched near the postero-inferior angle. In the dorsal fin only eight rays can be counted, rapidly decreasing in length backwards, where two or three may be missing; the fulcra are very slender, the longest scarcely exceeding one-third of the length of the anterior fin-ray, and not more than three being directly inserted in the ridge of the back. The position of

the anal fin, behind the dorsal, is indicated by traces of fulcra and the bases of fin-rays. The end of the caudal pedicle is deeply excavated at the base of the caudal fin, and the stout upper lobe is considerably produced. The caudal fin-rays exhibit the usual stoutness and close articulation, while the fulcra on the lower margin are large though slender.

*Horizon and Locality.*—Middle Purbeck Beds: Swanage, Dorset.

### 3. **Lepidotus mantelli,** Agassiz. (Plate VII, fig. 7; Plates VIII, IX, X; Plate XI, figs. 1—14; Text-figs. 13, 16—18.)

1826. Figure of dentary by T. Webster, Trans. Geol. Soc. [2], vol. ii, pl. vi, figs. 5, 6.
1827. "Scales of a Quadrangular Form," G. A. Mantell, Illustr. Geol. Sussex and Foss. Tilgate Forest, p. 58, pl. v, figs. 3, 4, 15, 16.
1833. *Lepidotus subdenticulatus*, L. Agassiz, Poiss. Foss., vol. ii, pt. i, p. 9. [Scales, afterwards referred to *L. fittoni*, Agassiz, *tom. cit.*, p. 265; National Museum of Natural History, Paris.]
1833–37. *Lepidotus mantelli*, L. Agassiz, Poiss. Foss., vol. ii, pt. i, pp. 9, 262, pl. xxx, figs. 10—15; pl. xxx *a*, figs. 4—6; pl. xxx *b*, fig. 2; pl. xxx *c*, figs. 1—7.
1834–44. *Lepidotus fittoni*, L. Agassiz, Poiss. Foss., vol. ii, pt. i, p. 265, pl. xxx, figs. 4—6; pl. xxx *a* (excl. figs. 4—6); pl. xxx *b* (excl. fig. 2). [Portion of fish, British Museum.]
1836–44. *Tetragonolepis mastodonteus*, L. Agassiz, Poiss. Foss., vol. ii, pt. i, p. 216, pl. xxiii *e*, figs. 3, 4 (*non* fig. 5). [Small dentary.]
1841. *Lepidotus mantelli*, R. Owen, Odontogr., p. 69, pl. xxx, fig. 1; pl. xxxi. [Structure of teeth.]
1849. *Lepidotus mantelli*, W. C. Williamson, Phil. Trans., p. 444. [Structure of scales.]
1860. *Lepidotus fittoni*, J. E. Lee, Geologist, vol. iii, p. 458, pl. xii. [Structure of scales.]
1887. *Lepidotus mantelli*, W. Branco, Abhandl. geol. Specialk. Preussen u. Thüring. Staaten, vol. vii, p. 345, pl. iii, figs. 1, 2.
1895. *Lepidotus mantelli*, A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. iii, p. 108, text-figs. 23, 24.

*Type.*—Portion of fish; British Museum.

*Specific Characters.*—A stout species attaining a length of about 1 metre. Length of head with opercular apparatus considerably less than the maximum depth of the trunk and contained slightly more than four times in the total length of the fish. Snout acute and frontal profile somewhat bent; external bones more or less rugose or tuberculated; parietal bones much less than half as long as the frontals, which are about three times as long as their maximum width, very narrow in front, and united throughout their length by a nearly straight median suture; orbit unusually small, with a relatively large circumorbital ring, and the postorbital plates much subdivided, the lowest and foremost plate of this series being the largest. Mouth small, the mandibular articulation below the middle of the orbit; maxilla smooth, with deep rounded expansion behind; mandibular symphysis very robust, the dentary being much horizontally extended to support the large tooth-bearing splenial. Inner teeth very short and stout, smooth, usually

with slightly acuminate crown when unworn; marginal teeth also stout, smooth and acuminate. Maximum width of operculum nearly two-thirds as great as its depth, and equalling about one-third the length of the head. Ring-vertebræ present in the adult. Fin-fulcra very large; pelvic fins much smaller than the pectorals and inserted nearer to the latter than to the anal fin; dorsal and anal fins almost equally elevated, with about fourteen and ten rays respectively, and the former fin with four or five fulcra directly inserted in the back; anal fin arising opposite hinder end of dorsal. Scales smooth, but showing coarse oblique corrugations when abraded, and those on the flank more or less finely serrated; principal flank-scales somewhat deeper than broad, those of the lateral line notched; dorsal ridge-scales acuminate, but usually inconspicuous.

*Description of Specimens.*—The type specimen of *Lepidotus mantelli* is the hinder portion of the head, with a fragment of the abdominal region and the base of a pectoral fin (Pl. VIII, fig. 1), in the Mantell Collection. The type specimen of the so-called *L. fittoni* is a vertically crushed and much abraded head, with part of the abdominal region (Pl. VIII, figs. 2, 2 *a*, 2 *b*). There are notable differences between these two fossils, as already pointed out by Agassiz; but the large collection in the British Museum seems to show that these differences are due partly to crushing, partly to abrasion, and partly to great variation in one and the same species. The earliest form is represented by a small specimen from the Purbeck Beds of Netherfield, Sussex, in the Hastings Museum (Pl. X, fig. 3).

The general shape and proportions of the fish are best shown in a specimen discovered by Mr. Charles Dawson in the Wadhurst Clay near Hastings (Pl. VII, fig. 7). This fossil is almost uncrushed, only slightly bent sideways at the base of the caudal fin, and the gently arched contour of the back is especially well displayed. The maximum depth of the trunk is somewhat less than a third of the total length of the fish, while the head must have occupied nearly a quarter of the same length. The greater part of the caudal fin is, of course, missing in this specimen.

The chondrocranium is well ossified, the various elements appearing in the fossil as pieces of thick, spongy bone. No supraoccipital has been observed, but its ordinary place in the occiput is occupied by the inner part of the large epiotics which meet in the middle line (Pl. X, fig. 1, *epo.*). These bones, which have a triangular posterior face, form about half the depth of the occiput and rest directly on the exoccipitals (*exo.*), which also meet in the middle line above the foramen magnum (*f.m.*). In the fossil shown in Pl. X, figs. 1, 1 *a*, the exoccipitals are slightly crushed above, so that the epiotics form an overhanging ledge, but the general shape of the bones is well indicated. Each exoccipital ends postero-inferiorly in an occipital condyle, and its concave posterior face slopes upwards and forwards, separated by a sharp angulation from its lateral face, which is extensive, since the bone enters for a considerable distance into the lateral wall of

the brain-case, as in the salmon (Pl. X, fig. 1 *a*, *exo.*). A large oval foramen for the exit of the vagus nerve (x) is conspicuous in this lateral face. The lower limit of the exoccipital is not seen in the fossil represented in Pl. X, figs. 1, 1 *a*, owing to the water-worn condition of the basioccipital (*bo.*), of which only the upper part, forming the roof of the notochordal cavity, is preserved. Its upper limit is also obscure laterally, but it appears to be capped by a small opisthotic (*opo.*), which forms the floor of the diminutive temporal fossa, and unites inside with a lateral prominence of the epiotic. The exoccipital and opisthotic are suturally united in front with a large pro-otic element (*pro.*), which doubtless meets the epiotic postero-superiorly, and is capped by a small sphenotic (or post-

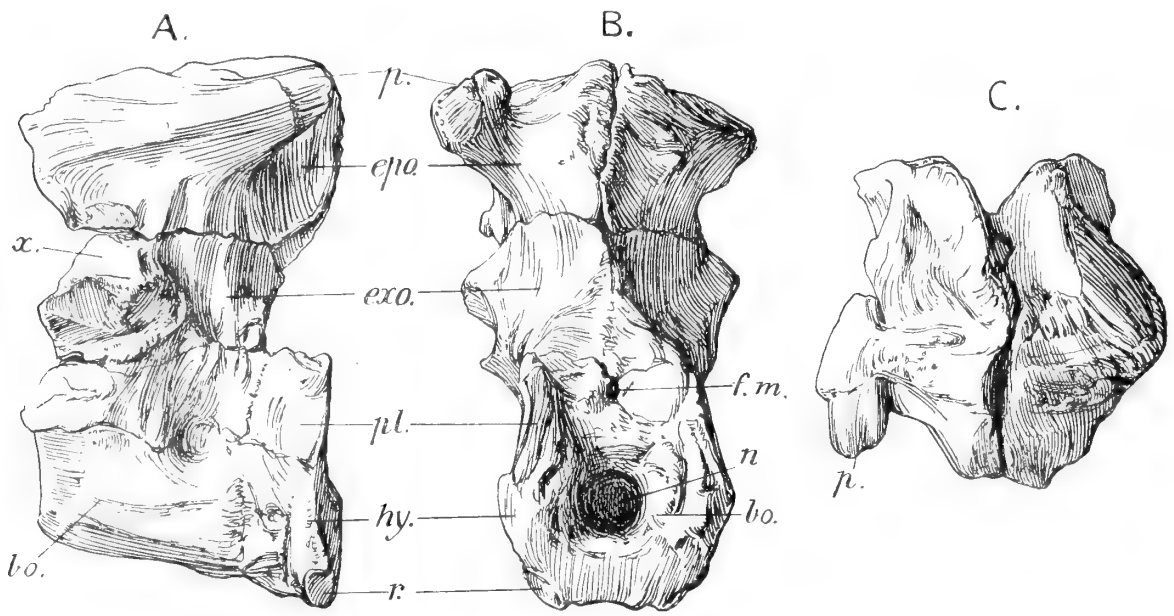



Fig. 15.—*Lepidotus* sp.; occipital portion of skull, left lateral (A), posterior (B), and superior (C) views, nat. size.—Oxford Clay: Peterborough. Leeds Collection (B. M. no. P. 9998). *bo.*, basi-occipital; *epo.*, epiotic; *exo.*, exoccipital; *f.m.*, foramen magnum, reduced by distortion; *hy.*, hypo-centrum of first vertebra; *n.*, pit in basioccipital for notochord; *pl.*, pleurocentrum of first vertebra; *p.*, process of epiotic, nature undetermined; *r.*, facet on hypocentrum for articulation of rib; *x.*, facet probably for opisthotic.

frontal) antero-superiorly. The sphenotic is not clearly seen in the original of Pl. X, fig. 1 *a*, but is partly shown in another specimen in the British Museum (no. P. 6342).

It is interesting to note that a similar arrangement of the epiotic bones in the occiput has been discovered by Mr. Alfred N. Leeds in a skull of *Lepidotus* from the Oxford Clay of Peterborough (Brit. Mus., no. P. 9998). The various elements are somewhat crushed and broken (Text-fig. 15), but the epiotics (*epo.*) are complete, and can be handled separately, proving that they meet in the middle line not only behind but above the brain-cavity throughout their entire length. They rest directly on the exoccipitals (*exo.*), which are fractured behind and so much crushed as almost to obscure the foramen magnum (*f.m.*). The exoccipital extends

considerably into the lateral wall of the brain-case, and bears an articular surface antero-superiorly (*x.*) probably for a small opisthotic, which is missing in the fossil. Posteriorly it is fused with the pleurocentrum (*pl.*) of the first ring-vertebra. Inferiorly the exoccipital is firmly united with the large basioccipital (*bo.*), which is grooved below for the basicranial canal, pierced behind by a deep excavation for the notochord (*n.*), and fused with the large hypocentrum (*hy.*) of the first vertebra. This hypocentrum bears a pair of prominent facets (*r.*) for the ribs. The pro-otic bone of the same specimen is relatively large and must have articulated both with the exoccipital and the opisthotic, while it was capped in front with a sphenotic or postfrontal.

It may be added that the epiotics unite in a median suture above the exoccipitals in some existing Teleostean fishes, such as *Acanthurus*.

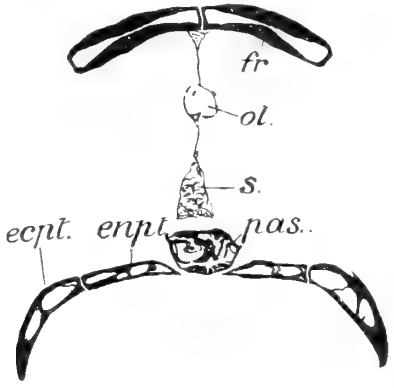



Fig. 16.—*Lepidotus mantelli*, Agassiz; transverse section of skull between orbits, two-thirds nat. size.—Wealden: Hastings. Beckles Collection (B. M. no. P. 6342). *ecpt*, ectopterygoid; *enpt.*, entopterygoid; *fr.*, frontal; *ol.*, interorbital passage for olfactory nerves; *pas.*, parasphenoid; *s.*, interorbital septum.

There are also ossifications in the interorbital septum, but their precise character is uncertain. A transverse section of one skull at the middle of the orbit is shown in Text-fig. 16. In this position the septum ends above and below in very coarsely cancellated bone, triangular in transverse section (*s.*), while the intervening part is merely a thin, ossified lamina, which widens in the middle into a tube, doubtless for the passage of the olfactory nerves (*ol.*). Below the interorbital septum the parasphenoid is seen (*pas.*), with the superficially ossified hinder part of the entopterygoids (*enpt.*) and ectopterygoids (*ecpt.*). Further forwards there are indications of bone in the ethmoid region in several specimens, with apparently two separate tubes for the passage of the olfactory nerves.

The external bones are thick and vary much in appearance according to their state of abrasion in the fossils. They are all more or less rugose, and unworn specimens exhibit a variable extent of tuberculation. The parietal bones (Pl. VIII, fig. 2 *a*; Pl. IX, figs. 1, 1 *a*; Pl. X, fig. 3; *pa.*) form an unsymmetrical pair, of which one is both wider and longer than the other; they unite in a nearly straight

median suture, which has sometimes one small sinuosity behind; and their superficial rugosity is both coarsest and strongest near the outer border, especially behind, where the slime-canal traverses the bone in an L-shaped groove. The squamosal (*sq.*) on each side is a narrower bone, extending as far forwards as the parietals, but not quite so far backwards. It unites with the adjacent parietal in a slightly wavy suture, and its outer face is very coarsely rugose, while the groove for the transverse slime-canal behind is well marked. The squamosal is narrowest in front, where it bounds the hinder end of the frontal, and meets the circumorbital ring, from which a small dermo-postfrontal is sometimes detached. The frontals (Pl. VIII, fig. 2 *a*; Pl. IX, figs. 1, 1 *a*; Pl. X, fig. 3; *fr.*) are nearly three times as long as the parietals, and unite in a very slightly wavy median suture. Each is widest behind, the maximum width being about a third of the total length; and its comparatively narrow anterior portion ends in a few pointed digitations. The absence of these digitations in the frontal ascribed to *Lepidotus fittoni* by Agassiz (Poiss. Foss., vol. ii, pt. 1, p. 264, pl. xxx *b*, fig. 3) is due to the imperfection of the specimen. The outer margin of the bone immediately in front of the squamosal is slightly indented by the overlap of the three upper plates of the circumorbital ring. Its outer face is usually rugose and tuberculated only in the hinder half, where the markings are coarsest near the outer margin; it then tends to rise into a rounded boss at the median suture between the orbits; and the slender anterior half is nearly smooth, only with a longitudinal channeling. The nasals and other dermal bones of the ethmoid region are unknown.

The cheek is completely covered with plates, which form a circumorbital ring (Pl. VIII, figs. 2, 2 *a*; Pl. IX, fig. 1; Pl. X, fig. 3; *co.*) bounded behind by postorbitals (*po.*), and continued in front by a few preorbitals (*pro.*). They are all more or less rugose and tuberculated, but the most delicate and easily destroyed markings are on the upper postorbitals. Of the circumorbital ring, three plates occur above the eye, the hindmost being the largest and sometimes transversely subdivided, so that a separate piece in contact with both the squamosal and the frontal may be regarded as a dermo-postfrontal (*e. g.* B. M. no. P. 6338). The two posterior circumorbitals, though of irregular shape, are about as deep as wide, while the other four plates completing the ring antero-inferiorly are much deeper than wide. The slime-canal is not conspicuous. There are at least four plates in the preorbital series. The irregularly pentagonal upper postorbital (see especially Pl. IX, fig. 1, *po.*) is comparatively large, in contact with the squamosal and two circumorbitals; but the other plates of the postorbital series, very irregular in shape, usually from five to seven in number, though sometimes further subdivided, are not wider than the circumorbitals. The foremost and lowest plate is always longer than wide and tapers to a blunt point below the foremost circumorbital.

The mandibular suspensorium is inclined forwards so that the quadrate articulation is beneath the middle of the orbit. The hyomandibular (Pl. VIII,

fig. 1, *hm.*) is a narrow lamina of bone, with a broad prominence behind for the support of the operculum, and strengthened below this on the outer face by a longitudinal ridge. The metapterygoid (Pl. VIII, fig. 1, *mpt.*) is imperfectly known, but is a relatively large thin lamina of bone probably shaped almost as in *Amia*. The entopterygoid has already been mentioned as a thin toothless lamina seen in section in Text-fig. 16, *enpt.* The ectopterygoid, though thin and toothless at its hinder end (Text-fig. 16, *ecpt.*) and rising above into a longitudinal sharp

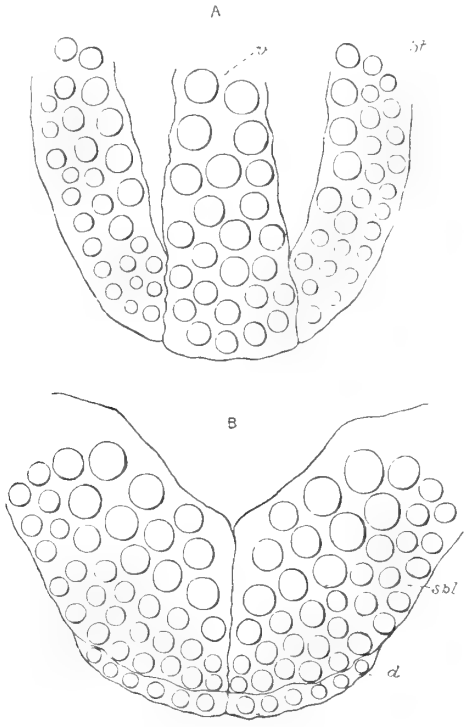



FIG. 17.—*Lepidotus mantelli*, Agassiz; diagram of arrangement of teeth in upper (A) and lower (B) jaws, about nat. size.—Wealden: Sussex. *d.*, dentary; *pt.*, pterygo-palatine; *spl.*, splenial; *v.*, vomer. From Catal. Foss. Fishes, Brit. Mus., pt. iii, 1895.

crest throughout its length (Pl. XI, fig. 3 *a*), is much thickened at the oral border to bear the powerful dentition, and seems to be completely fused in front with the equally thickened palatine, which abuts against the vomer. The slightly concave oral face of the pterygo-palatine thus formed bears the irregular longitudinal series of teeth, of which the inner are the largest and the most anterior are the smallest (Pl. XI, figs. 3, 4). An outer fourth row of very small teeth is sometimes present. The single vomer (Pl. XI, figs. 2, 4) is also much thickened (fig. 2 *b*), and its long and narrow oral face bears teeth almost as far back as the hinder limit of teeth on the ectopterygoids. The vomerine teeth are irregularly arranged, but the largest are in two pairs behind, and they decrease in size forwards, where they are in four or even five longitudinal rows. The maxilla is a relatively small and delicate lamina of bone, forming a deep expansion behind but tapering forwards

(Pl. IX, fig. 1, *mx.*). Its outer face is smooth, and teeth have not been observed on the oral border in the known specimens. A small narrow supramaxilla, pointed behind, occurs above its hinder expansion (*smx.*). The premaxillæ are known only in the small specimen shown in Pl. X, figs. 3, 3 *a*, *pmx.*, where they are shaped nearly as in *Lepidotus minor* (see p. 30). The broad anterior ascending process of each bone clearly passes up beneath the anterior end of the frontal; and the comparatively small portion extended along the oral border bears a row of styliform teeth, each capped by enamel. The mandible is short and stout, much deepened in the coronoid region, much horizontally expanded at the symphysis. As seen from the outer face (Pl. IX, fig. 1, *ag.*), the angular bone is especially short and deep, smooth above but more or less coarsely rugose below, above the longitudinal groove for the passage of the slime-canal. It is capped by a very small coronoid bone (B. M. no. P. 6342). The hinder ascending part of the dentary (*d.*) is as deep as the angular and coronoid bones together, and its outer convex face is either smooth or faintly rugose. Just in front of this ascending part the bone is of least depth, and it then deepens slightly again towards the symphysis (Pl. VIII, fig. 2 *b*), which slopes sharply backwards, sometimes approaching a horizontal plane for the support of the massive splenial. The oral border in front bears a single row of six to nine comparatively small but stout styliform teeth (Pl. XI, fig. 6); and the outer face of the bone is more or less coarsely rugose, with the course of the slime-canal marked by a row of large pits. The tooth-bearing end of a very small dentary has already been described under the name of *Tetragonolepis mastodonteus* by L. Agassiz, Poiss. Foss., vol. ii., pt. i (1837), p. 216, pl. xxiii *e*, figs. 3, 4. The massive splenial (Pl. XI, fig. 5, *spl.*) meets its fellow in an extensive symphysis, and its slightly concave oral face is covered by five or six rows of tritoral teeth, which are largest within. There is some ossification in the meckelian cartilage, but its shape and extent are uncertain.

All the teeth are fused with the supporting bone, not in sockets, and they have a large pulp-cavity, from which very minute, irregularly branching tubuli radiate into the dentine. Successional teeth are abundant in the thick cancellated bone beneath the functional teeth (Pl. XI, fig. 1), and they clearly turn through an angle of 180° in the course of development as in other species of *Lepidotus* (Pl. XI, figs. 1, 3 *b*, 5 *b*). The enamelled crown, when unworn, rises to a sharp median apex; and occasionally, as in the hinder teeth of Pl. XI, fig. 2, there is a slight apical constriction which tends to make it mammilliform (fig. 2 *c*). Even in the type specimen of *Lepidotus fittoni* (contrary to the statement by Agassiz) some of the inner teeth exhibit the median apex. When worn they become first rounded, then flattened, and eventually sometimes have the pulp-cavity exposed; but there is no uniformity in the degree of wear in any group of teeth, and they appear to be shed in indefinite order. In all undoubted specimens of *L. mantelli* the enamel

of the dental crown is smooth; but in one example of upper dentition from the Isle of Wight (Pl. XI, fig. 4) some of the teeth exhibit faint irregular wrinkles radiating from the apex to an encircling wrinkle which forms a kind of cingulum round the base (figs. 4 *a*, 4 *b*).

In the hyoid arch (Pl. X, fig. 2), the epihyal (*eph.*) is comparatively large and stout, bearing about six branchiostegal rays, of which the uppermost (*br.*) forms a long and narrow delicate lamina. The ceratohyal (*ch.*) is less than twice as long as the epihyal, comparatively small in front of its constriction, and without branchiostegal rays. The hypohyal (*hyh.*) is a short and stout bone, also constricted in the middle.

The branchial arches are unknown, but delicate calcified gill-supports are seen in a specimen in the Beckles Collection (B. M. no. P. 6343).

The preoperculum, best seen in Pl. IX, fig. 1, *pop.*, is narrow and gently curved at the angle. It is much overlapped by the postorbital cheek-plates, but extends upwards to the hinder end of the squamosal in the cranial roof. Its ascending limb is especially narrow, and marked with a slight rugosity or tuberculation only near its upper end. Its lower limb is wider, with an irregular coarse rugosity radiating downwards and backwards from the deep groove for the slime-canal. The operculum and suboperculum vary considerably, but some of the differences observed are probably due to imperfections in preservation. As shown in Pl. IX, fig. 1, *op.*, the operculum is somewhat wider below than above, and its maximum width is about two-thirds of its depth. Its anterior margin is sigmoidally curved, and its outer face is finely tuberculated, especially in the upper half. In the type specimen of *Lepidotus mantelli* (Pl. VIII, fig. 1, *op.*), the operculum appears to be narrower, but this may be due at least in part to crushing and fracturing. In the type specimen of *L. fittoni* (Pl. VIII, fig. 2, *op.*), the bone is broken above and behind, obscured in front with ironstone, and so much abraded that its outer surface appears to be only rugose. In other abraded specimens its maximum width scarcely equals two-thirds of its depth. The suboperculum (Pl. VIII, fig. 2; Pl. IX, fig. 1; *sop.*) is usually more than half as deep as wide, with a relatively large anterior ascending process, and the outer face very feebly ornamented either with rugæ or tubercles. In the type specimen of *L. mantelli*, however, the suboperculum (Pl. VIII, fig. 1, *sop.*) is not half so deep as wide, and its outer face is strongly tuberculated. The interoperculum (Pl. IX, fig. 1, *iop.*), is much extended and tapering forwards, with the ornament as variable as that of the other bones. Not more than six branchiostegal rays have been clearly seen, and the uppermost is relatively large (Pl. X, fig. 2, *br.*). There is no gular plate.

The notochord must have been persistent, but at least in the anterior part of the abdominal region there are surrounding ossifications. These are only imperfectly known in a few weathered specimens, of which the best is shown in Text-fig. 18. Encircling the upper part of the space left vacant by the decay of the notochord

and its sheath are two sectors of spongy bone (*pl.*) which thicken upwards, until they nearly surround the canal for the spinal cord and form the expanded base of the neural arch (*n.a.*). Two similar but larger sectors of spongy bone (*hy.*) encircle the lower part of the notochordal space, each bearing a short transverse process or parapophysis (*t.*) for the support of the rib. Each dorsal piece is directly continuous with the rod-shaped lamina of the neural arch, which is inclined backwards and does not appear to be fused with its fellow of the opposite side at the upper end, where it is in contact with the long rod-shaped neural spine (*n.s.*), also inclined backwards and curved so as to be a little concave anteriorly. The ribs are com-

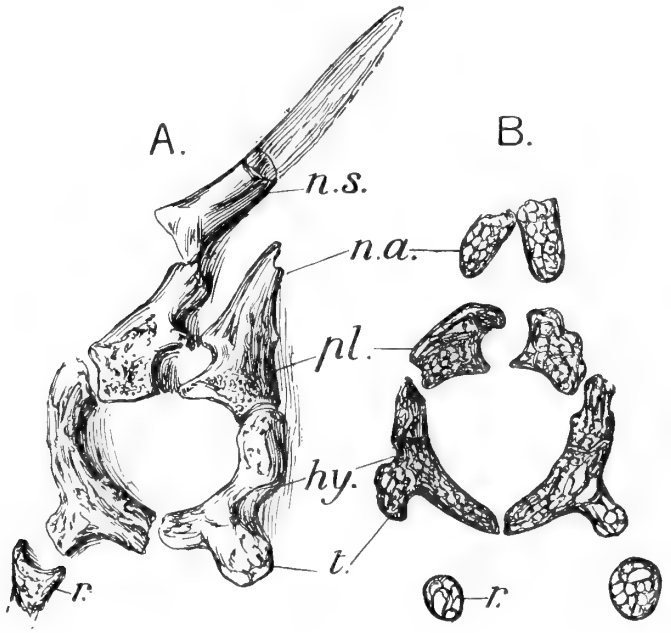



FIG. 18.—*Lepidotus mantelli*, Agassiz; anterior vertebra in front view (A) and in transverse section (B), nat. size.—Wealden: Hastings. Beckles Collection (B. M. no. P. 6348 *c*). *hy.*, hypocentrum; *n.a.*, neural arch; *n.s.*, neural spine; *pl.*, pleurocentrum; *r.*, rib; *t.*, process on hypocentrum for articulation of rib.

paratively slender and extend considerably more than half-way towards the ventral border of the fish.

The supratemporal plates are small, and usually in four pairs, as shown in the type specimen of *L. fittoni* (Pl. VIII, fig. 2 *a*, *st.*), and in the immature head represented in Pl. IX, *st.* Two, however, are sometimes fused together, so that the series becomes unsymmetrical (Pl. VIII, fig. 3). All are marked with a coarse and irregular rugose ornament, with occasional indications of the traversing slime-canal. Each of the inner pair of plates is wider than long, and extends along at least half of the parietal border. The next two plates are much smaller, being longer than wide, the inner plate in contact solely with the parietal, the outer plate bordering an angle between the parietal and squamosal bones. The outermost plate of the series, which is slightly larger than the two latter, bounds both the

hinder border of the squamosal and the greater part of the upper border of the operculum. In the specimen shown in Pl. VIII, fig. 3, the two inner supratemporal plates are fused together on both sides, while the two outer plates are fused together only on the right side. The exposed face of the post-temporal (Pl. VIII, figs. 2 *a*, 3; Pl. IX, figs. 1, 1 *a*; Pl. X, fig. 3; *ptt.*) is irregularly triangular in shape, wider than long, with its inner apex extending to the second supratemporal plate; it is also coarsely rugose. The supraclavicle is a deep and narrow plate of bone, fragmentary in the type specimen (Pl. VIII, fig. 1, *scl.*) but well shown in Pl. IX, fig. 1, *scl.* It is truncated and thickest at its upper end where it articulates with the post-temporal; while its outer face and hinder border are smooth, except in the upper part, where there is some coarse rugosity posteriorly. The clavicle is relatively large and curves well forwards, with its narrow exposed portion smooth, only slightly notched at the place of origin of the pectoral fin (Pl. VIII, fig. 1; Pl. IX, fig. 1; *cl.*). As seen in the type specimen, the anterior edge of the exposed portion is marked as usual by a few rows of small granulations; and as seen in a detached specimen in B. M. no. 23624, the thin inner or anterior wing of the bone is so wide that the maximum width of the clavicle equals one-third of its depth. The postclavicular plates are smooth, with no enamel except occasionally in the form of a slight tuberculation. The upper postclavicular, which is nearly complete in the type specimen (Pl. VIII, fig. 1, *pcl.*), is deep and narrow, and its tapering upper end bounds the lower part of the supraclavicle. In this specimen it is tuberculated, but in the original of Pl. IX, fig. 1, it is entirely smooth so far as preserved. The second plate, directly beneath the first, is best seen in the type specimen of *L. fittoni* (Pl. VIII, fig. 2, *pcl.*), where it is also slightly tuberculated; it is nearly as wide as deep, and irregularly triangular in shape with a truncated apex. The series is completed below by two relatively small and narrow plates, of which the lower is the larger and fits into the notch of the clavicle at the origin of the pectoral fin (as shown in Pl. IX, fig. 1, *pcl.*). At least part of the endoskeleton of the pectoral arch is well ossified, and a bone which may probably be identified as coracoid occurs in the type specimen (Pl. VIII, fig. 1, *cor.*). It is constricted postero-superiorly into a wide and thickened pedicle which ends in an articular facette. Remains of long and slender basal bones or radials are scattered near the pectoral fin in the same specimen, and at least five of these elements in series are also seen in another specimen in the British Museum (no. 23624). As shown in the type specimen, the rather slender pectoral fin-rays have a long unsegmented basal part (Pl. VIII, fig. 1, *pct.*); and the stout, deeply-overlapping fulcra on the anterior ray are in double series, while two relatively large basal fulcra are directly inserted in line with the fin-rays. The number of pectoral fin-rays is unknown. The pelvic fins are much smaller than the pectorals, and inserted nearer to the latter than to the anal fin. They are fringed with a paired row of small fulcra. The dorsal and anal fins are best shown in a fine specimen discovered by Mr. Charles

Dawson (Pl. VII, fig. 7), where they are equally elevated, their greatest height measuring about two-thirds of the depth of the trunk at the insertion of the dorsal. The enamelled biserial fulcra of the dorsal fin are comparatively large, and four or even five (B. M. no. P. 6336) of these fulcra, of gradually increasing length, are directly inserted in the ridge of the back. The dorsal fin-rays, about fourteen in number, decrease in length backwards, and each is very finely divided and articulated for more than half of its length. The anal fin is closely similar to the dorsal, but with smaller biserial fulcra, only about ten rays, and the undivided bases of these rays relatively short. The caudal fin is known only by its basal part, which resembles that in other species (Pl. VII, fig. 7).

All the scales are usually smooth, sometimes with a faintly concave face, but there is a tendency to coarse oblique grooving, especially when the enamel is partly removed and the subjacent structure which causes this grooving becomes evident (Pl. VIII, fig. 4). Irregularly tuberculated or rugose scales have only been observed in the anterior dorsal region of one small specimen (Pl. IX). The scales on the anterior part of the abdominal region, especially on the flank (Pl. XI, fig. 7), are usually finely serrated, but the degree of serration varies considerably from the extreme in the original of Pl. IX, through the apparently partial serration in the type specimen (Pl. VIII, fig. 1), to the more irregular serration in the so-called *L. fittoni* (Pl. VIII, fig. 2). In the scales of other parts the hinder margin is smooth. As counted along the lateral line, the total number of transverse series of scales is about forty, while the number in a series above the origin of the pelvic fin is nineteen or twenty. The principal flank-scales in the abdominal region are somewhat deeper than broad, and those of the lateral line, in the eleventh or twelfth row above the pelvic fins (Pl. IX, fig. 1, *l.*), are notched just above their postero-inferior angle and usually pierced by an oval foramen near their anterior margin. The scales more dorsally and ventrally, and in the caudal region, are nearly equilateral or even broader than deep; and many of those in the dorsal region between the occiput and the dorsal fin are pierced by a large foramen for the exit of slime-apparatus, without any definite arrangement in lines (Pl. VII, fig. 7; Pl. VIII, figs. 2 *a*, 3). Beneath the base of the dorsal and anal fins the scales become small and irregular, with rounded angles, and with enamel often failing to extend to the edge. At the base of the caudal fin the scales are also small and irregular, but rather elongate-rhomboidal in shape. The dorsal ridge-scales are not much, if at all, enlarged; but most of them are acuminate, and they vary much in shape from the slight prominence seen in Pl. VIII, fig. 3, to the extreme acumination made conspicuous by crushing in the original of Pl. VII, fig. 7. The ventral ridge-scales are neither enlarged nor more acuminate than the other scales; the usual enlarged scales occur near the origin of the anal fin.

All the scales are thick, and those of the abdominal region are united in the usual manner by deep overlap and a peg-and-socket articulation (Pl. XI, figs. 7, 8).

This articulation, however, is comparatively feeble, while the inner vertical ridge connected with it is low and irregularly widened (fig. 8). On the middle of the flank, the upper process of the wide overlapped margin of each scale is longer and more slender than the lower process (figs. 7, 8). In the dorsal, ventral, and caudal scales, the inner face is tumid, and there is no peg-and-socket articulation (Pl. XI, figs. 10 *a*—13 *a*). Some of the scales in the dorsal part of the abdominal region are nearly square, and their straight overlapped border is prolonged upwards into a strong process (Pl. XI, figs. 9, 10). In the more elongated scales of the ventral part of the abdominal region the overlapped margin is forked as in the scales of the flank, with the upper process much longer than the lower process and often inclined upwards (Pl. XI, figs. 11, 12). In the caudal region (Pl. XI, fig. 13), the anterior overlapped margin is comparatively narrow, and the inner face (fig. 13 *a*) remarkably tumid. An isolated scale of the lateral line in the caudal region (figs. 14, 14 *a*) shows especially well the two orifices on the outer face for the slime-canal and its posterior exit on the inner face.

*Affinities.*—*Lepidotus mantelli* appears to be most closely related to *Lepidotus lævis*, Agassiz, as interpreted by F. Priem, who describes the greater part of a fish from the Lower Kimmeridgian of Cerin (Ain), France, in Annales de Paléontologie, vol. iii (1908), p. 2, pl. i.

*Horizon and Localities.*—Wealden: Sussex and (?) Isle of Wight. Upper Purbeck Beds: Sussex.

Undetermined species of *Lepidotus* about as large as *L. mantelli* are known by fragments from the Middle Purbeck Beds of Swanage, Dorset. Part of a trunk about 25 cm. in maximum depth in the Dorset County Museum, has smooth scales without serrations. The opercular and anterior region of an equally large fish in the British Museum exhibits a coarse irregular serration of the smooth scales.

One or more undetermined dwarf species of *Lepidotus* also occur in the Purbeck Beds of the Vale of Wardour, Wiltshire.

## Family Pycnodontidæ.

### Genus **ATHRODON**, Sauvage.

*Athrodon*, H. E. Sauvage, Bull. Soc. Géol. France [3], vol. viii, 1880, p. 530.

*Generic Characters.*—Splenial bone unusually stout, with a deep symphysial facette; its oral face covered with rounded teeth, which are arranged in more or less irregular longitudinal series, the one principal series generally not well differentiated from the others.

*Type Species.*—*Athrodon dourillei* (H. E. Sauvage, Bull. Soc. Géol. France [3], vol. viii, 1880, p. 530, pl. xix, fig. 5) from the Lower Portlandian of Boulogne, France.

*Remarks.*—This genus is still known only by the dentition, which appears to be less specialised than that of any other Pycnodont. It ranges from the Kimmeridgian to the Senonian in Western Europe.

1. **Athrodon intermedius,** A. S. Woodward. Text-figure 19.

1893. *Athrodon intermedius*, A. S. Woodward, Geol. Mag. [3], vol. x, p. 434, pl. xvi, fig. 1.

*Type.*—Left splenial dentition; British Museum.

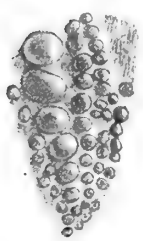


Fig. 19.—*Athrodon intermedius*, A. S. Woodward; left splenial dentition, oral aspect, nat. size. — Purbeck Beds: Aylesbury. The type specimen (B. M. no. 40314).

*Specific Characters.*—Splenial bone comparatively elongated, with closely arranged teeth, mostly smooth and nearly round, a few exhibiting an apical pit with feebly crimped margin, disposed in about five or six irregular longitudinal series, the largest forming a principal series near the symphysial margin of the bone.

*Description of Specimen.*—The only known example of this species is shown of the natural size in Text-fig. 19. Many of the teeth have been much worn during life, but those of the largest series seem to have been gently rounded, not pitted. Some of the marginal teeth are broken away, but they appear to have been all small. The slight apical pit is well seen in the hindmost tooth of one of these series.

*Horizon and Locality.*—Purbeck Beds: Aylesbury, Buckinghamshire.

## Genus **MESODON**, Wagner.

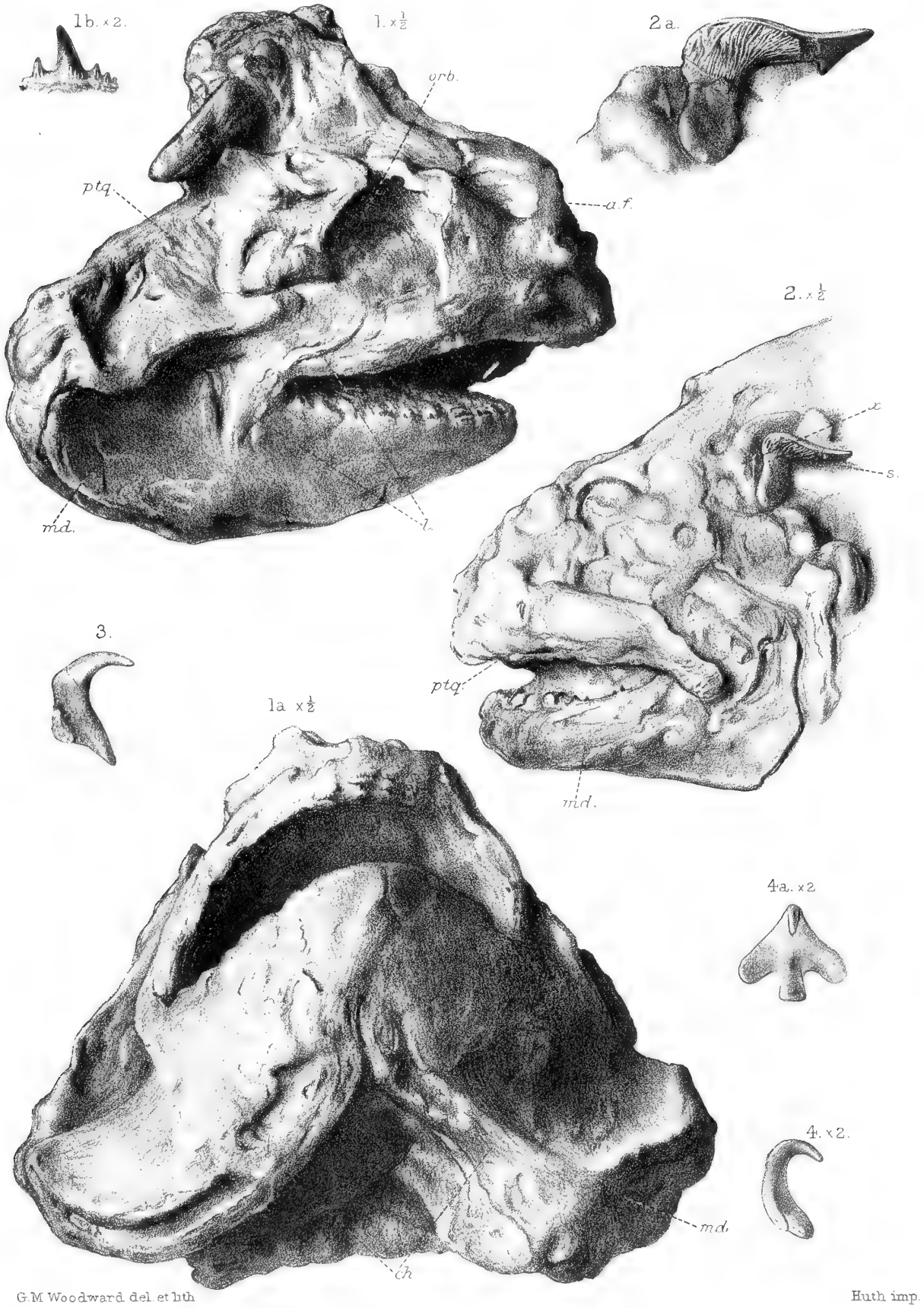
*Mesodon*, A. Wagner, Abhandl. k. bay. Akad. Wiss., math.-phys. Cl., vol. vi, 1851, p. 56.
(?) *Typodus*, F. A. Quenstedt, Der Jura, 1858, p. 781.
*Macromesodon*, J. F. Blake, Mon. Fauna Cornbrash (Pal. Soc., 1905), p. 32.

*Generic Characters.*—Trunk discoidal, not produced at the caudal pedicle. Head and opercular bones more or less ornamented with granulations; cleft of mouth very oblique; teeth smooth, or with feeble indentation and rugæ; vomerine teeth in five longitudinal series, the lateral pairs often irregular; splenial bone with symphysial facette not deepened; splenial dentition comprising one principal series of teeth with three or more outer series and one or two inner series, usually irregularly arranged. Neural and hæmal arches of axial skeleton

## PLATE I.

| Fig. | | Page. |
|---|---|---|
| 1. | *Hybodus basanus*, Egerton; skull and mandible, right side view and (1 *a*) lower view, one-half nat. size, with a lower lateral tooth (1 *b*) enlarged twice.—Weald Clay; Atherfield, Isle of Wight. The type specimen. Museum of Practical Geology, London, no. 27973. *a.f.*, anterior fontanelle; *ch.*, ceratohyals; *l.*, labial cartilages; *md.*, mandible; *orb.*, orbit; *ptq.*, pterygo-quadrate (upper jaw). | 6. |
| 2. | Ditto; partially decayed skull and mandible, left side view, one-half nat. size, with the cephalic spine (2 *a*) nat. size.—Weald Clay; Cooden Beach, Pevensey Bay, Sussex. Beckles Collection (B. M. no. P. 11871). *md.*, mandible; *ptq.*, pterygo-quadrate (upper jaw); *s.*, cephalic spine; *x.*, cartilage at base of cephalic spine. | 9. |
| 3. | Hybodont Cephalic Spine; left side view, nat. size.—Wealden; Hastings. Rufford Collection (B. M. no. P. 6738). | 14. |
| 4. | Hybodont Cephalic Spine; left side view and (4 *a*) hinder view, twice nat. size.—Wadhurst Clay; Brede, near Hastings. Teilhard & Pelletier Collection (B. M. no. P. 11895). | 14. |

A.S.Woodward, Wealden & Purbeck Fishes. Plate I.

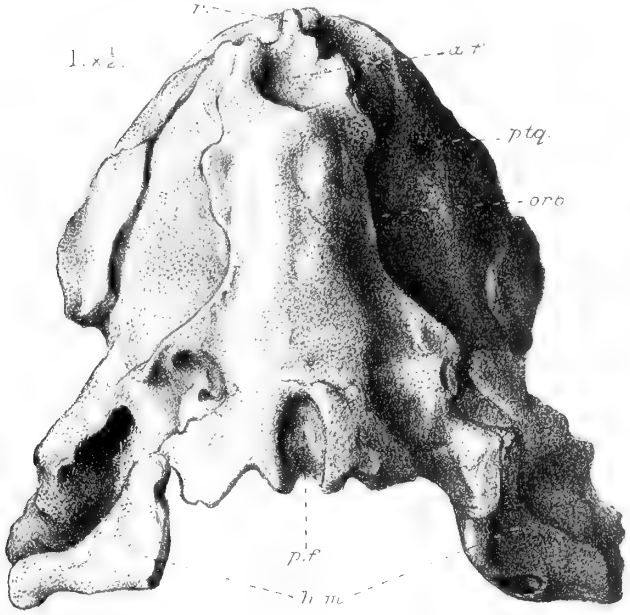


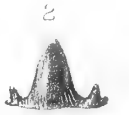

G.M. Woodward del. et lith. Huth imp.

Hybodus

## PLATE II.

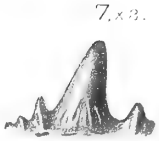
A.S.Woodward, Wealden & Purbeck Fishes. Plate II.









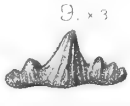




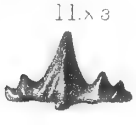
















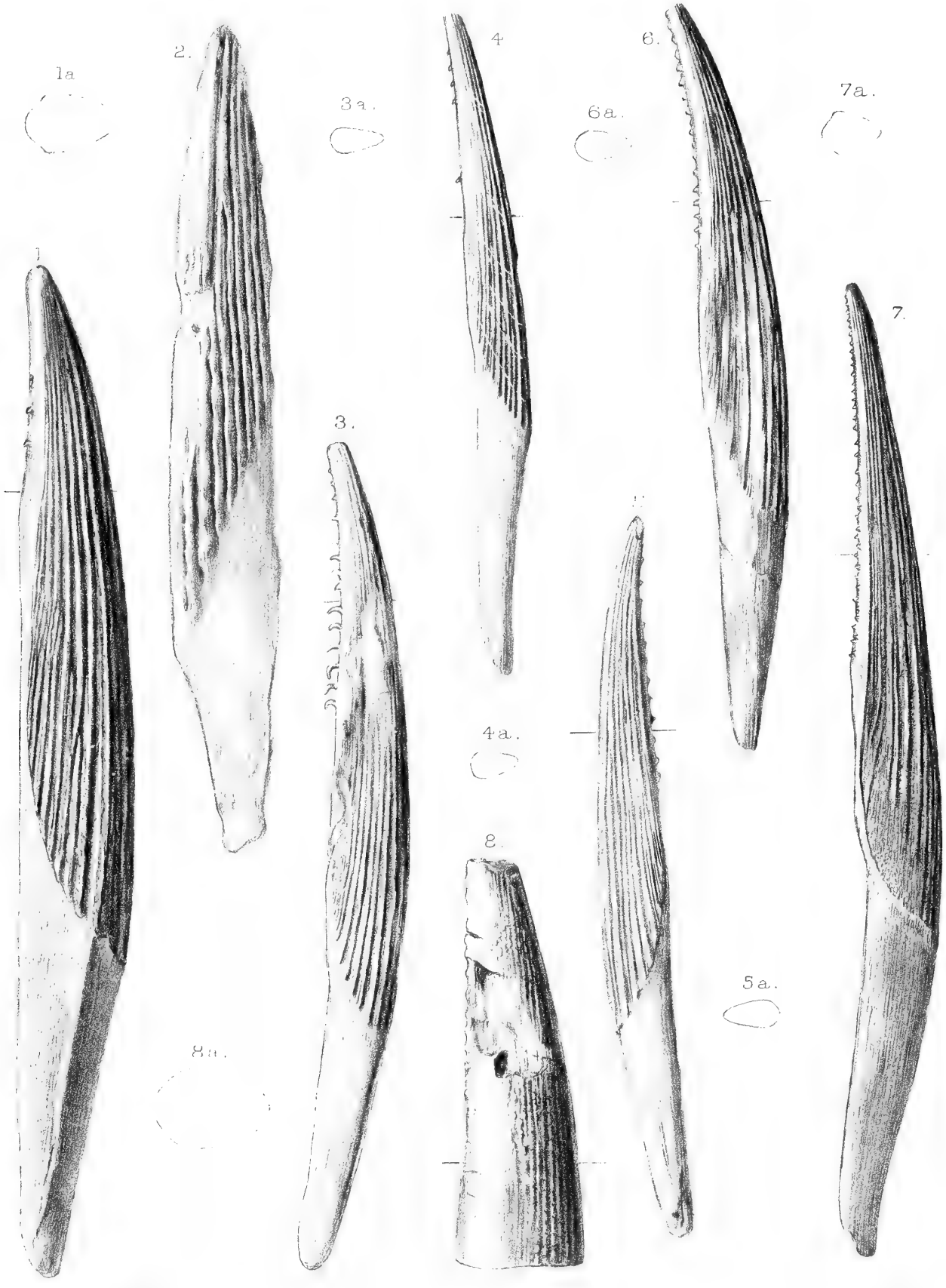
Huth imp.

## PLATE III.

| Fig. | | Page. |
|---|---|---|
| 1. | *Hybodus ensis*, sp. nov. (?); dorsal fin-spine.—Middle Purbeck Beds; Swanage, Dorset. B. M. no. 46908. | 11. |
| 2. | Ditto; imperfect large dorsal fin-spine.—Ibid. Dorset County Museum. | 11. |
| 3. | Ditto; small dorsal fin-spine.—Ibid. B. M. no. 33476. | 11. |
| 4, 5. | *Hybodus strictus*, Agassiz; two dorsal fin-spines, the first exhibiting growth-lines.—Ibid. B. M. nos. 28447, P. 2835. | 13. |
| 6. | *Hybodus basanus*, Egerton (?); dorsal fin-spine.—Wadhurst Clay; Eccles-bourne, near Hastings. Rufford Collection (B. M no. P. 8938). | 10. |
| 7. | Ditto; dorsal fin-spine.—Wealden; Hastings. Rufford Collection (B. M. no. P. 6936). | 10. |
| 8. | *Hybodus striatulus*, Agassiz; part of distal half of spine.—Tunbridge Wells Sands; Tilgate Forest. Mantell Collection (B. M. no. 2686). | 13. |

All the figures are of the natural size. The outlines 1 *a*–8 *a* represent transverse sections of the spines at the points marked by cross-lines.

A.S.Woodward, Wealden & Purbeck Fishes. Plate III.



## PLATE IV.

| Fig. | | Page. |
|---|---|---|
| 1. | *Undina purbeckensis*, sp. nov.; imperfect fish, one-half nat. size, with dorsal scales (1 *a*), ventral scales (1 *b*), and caudal flank scales (1 *c*) enlarged three times.—Middle Purbeck Beds; Swanage, Dorset. The type specimen. B. M. no. P. 11925. *a.*, fragment of anal fin; $d^1$, $d^2$, remains of two dorsal fins; *plv.*, base of pelvic fin. | 22. |
| 2. | *Coccolepis andrewsi*, A. S. Woodward; fish wanting pectoral fins, three-halves nat. size.—Lower Purbeck Beds; Teffont, Wiltshire. The type specimen. Museum of Practical Geology, London, no. 419. | 24. |
| 3. | Ditto; hinder half of fish, three-halves nat. size, with anal scale (3 *a*) enlarged ten times.—Ibid. B. M. no. P. 6302. | 25. |
| 4. | *Coccolepis* sp.; imperfect right maxilla, outer view, twice nat. size. Wadhurst Clay; Buckshole Quarry, Silverhill, Hastings. Charles Dawson Collection (B. M. no P. 11924). | 25. |

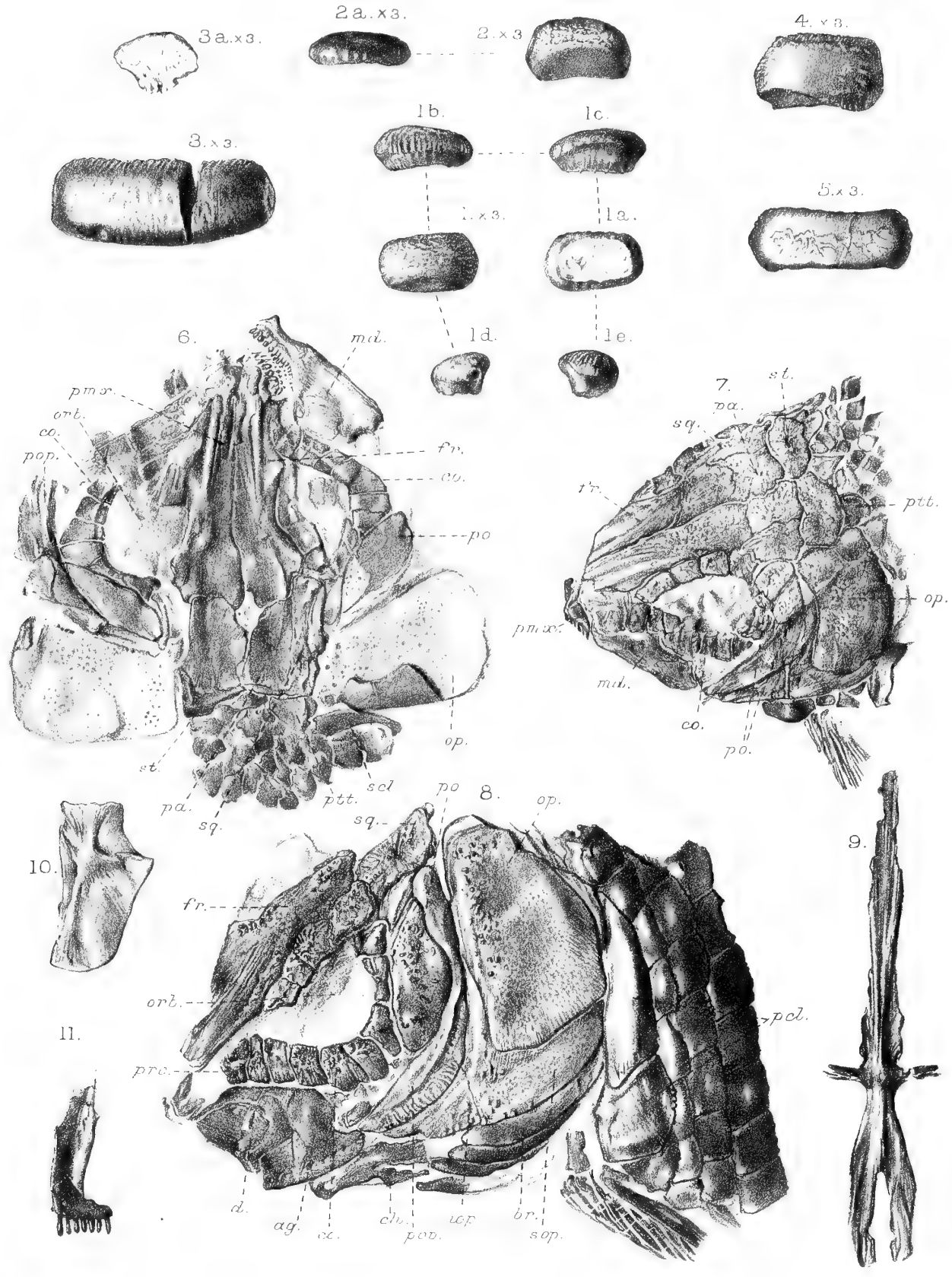

G.M.Woodward, del. et lith.

Huth imp.

1. Undina. 2–4. Coccolepis.

# PLATE V.

A. S. Woodward, Wealden & Purbeck Fishes. Plate V.




G. M. Woodward, del. et lith. Huth imp.

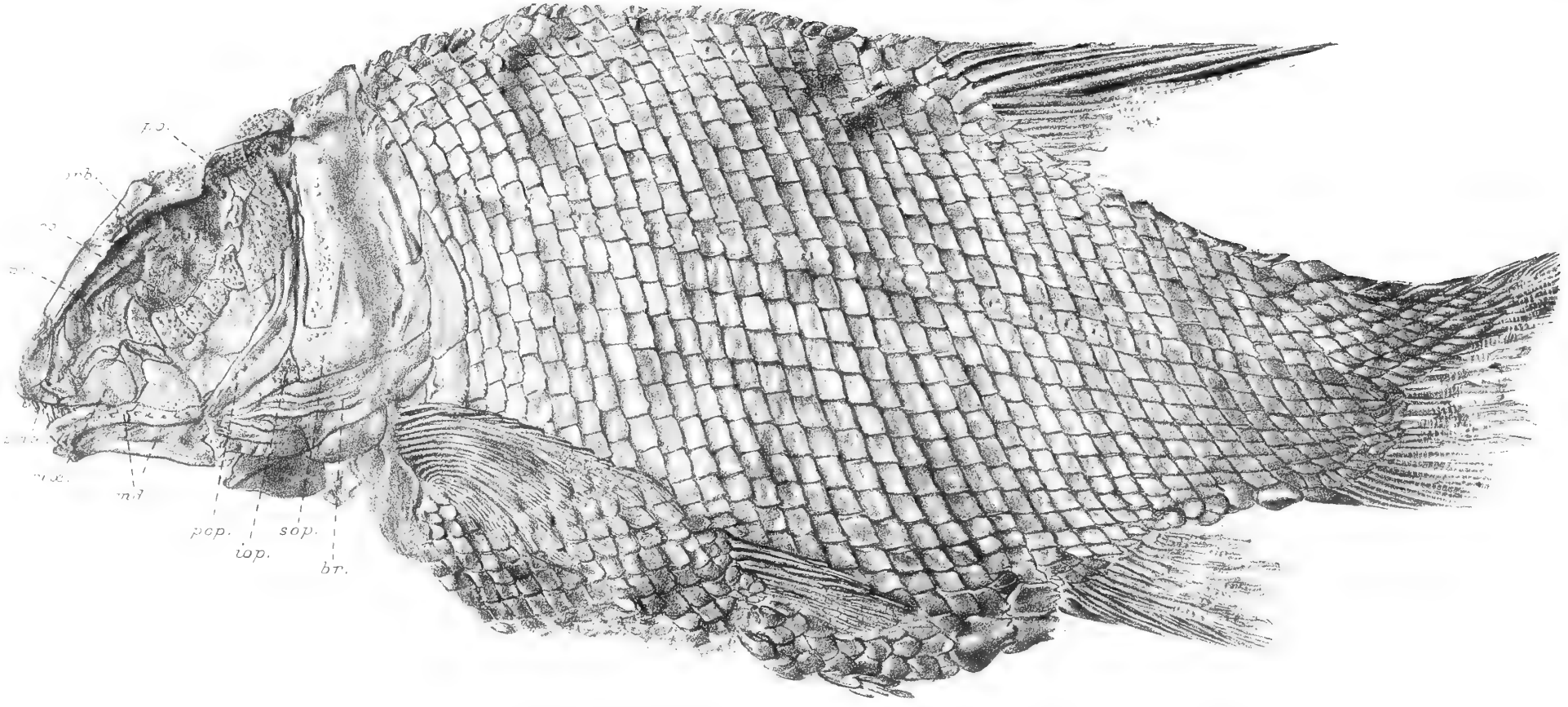
1–5. Hylæobatis. 6–11. Lepidotus

## PLATE VI.

| Fig. | | Page. |
|---|---|---|
| 1. | *Lepidotus minor*, Agassiz; nearly complete fish, left side view, nat. size, the left side of the head slightly displaced upwards, the ventral region of the trunk crushed downwards, and the dorsal ridge-scales lacking.—Middle Purbeck Beds; Swanage, Dorset. Museum of Practical Geology, London, no. 27975. *br.*, branchiostegal rays; *co.*, circumorbitals; *iop.*, interoperculum; *md.*, two rami of mandible, the left crushed upwards; *mx.*, maxilla, capped by supramaxilla; *orb.*, orbit; *pmx.*, premaxilla; *po.*, postorbital; *pop.*, preoperculum; *pro.*, preorbitals; *sop.*, suboperculum. | 28. |

A.S.Woodward, Wealden & Purbeck Fishes.

Plate VI.




J.M.Woodward del. et lith.

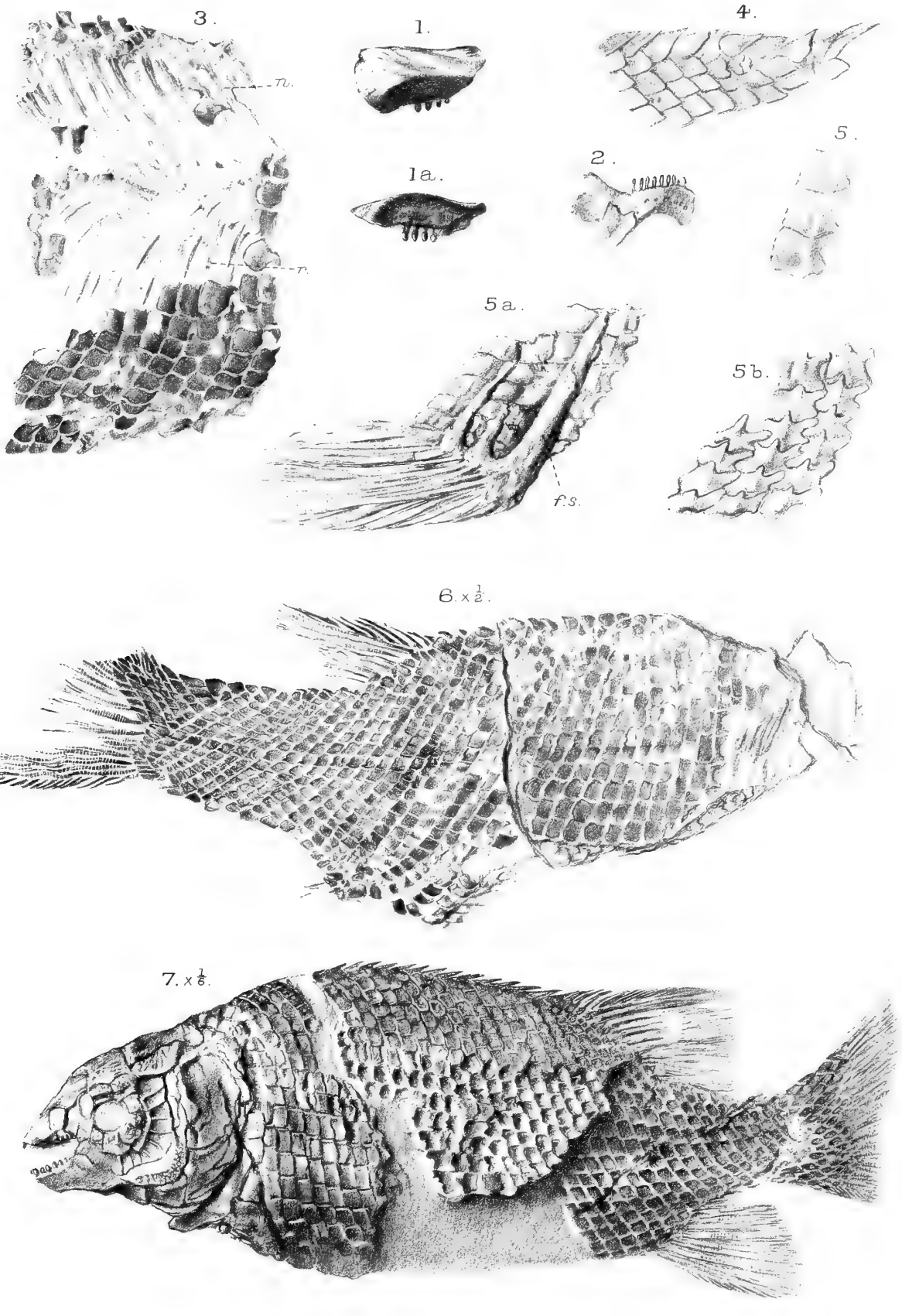
Hutt. Imp.

Lepidotus.

## PLATE VII.

| Fig. | | Page. |
|---|---|---|
| 1. | *Lepidotus minor*, Agassiz; left ectopterygoid, upper and outer (1 *a*) view, nat. size.—Middle Purbeck Beds; Swanage, Dorset. B.M. no. 21349. | 30. |
| 2. | Ditto; right dentary, nat. size.—Ibid. B. M. no. 21974 *a*. | 31. |
| 3. | Ditto; portion of trunk showing neural spines (*n.*) and ribs (*r.*), nat. size.—Ibid. B. M. no. 45903. | 32. |
| 4. | Ditto; dorsal ridge-scales, nat. size.—Ibid. Egerton Collection (B. M. no. P. 2006). | 34. |
| 5. | Ditto; inner view of three flank-scales of left side, with inner view of abdominal ventral scales (5 *b*) and base of anal fin (5 *a*), nat. size.—Ibid. B. M. no. 41157. *f. s.*, endoskeletal support of fulcrated front border of anal fin. | 33, 34. |
| 6. | *Lepidotus notopterus*, Agassiz; imperfect trunk, right side view, one-half nat. size.—Ibid. Enniskillen Collection (B. M. no. P. 4220). | 35. |
| 7. | *Lepidotus mantelli*, Agassiz; imperfect fish, left side view, one-sixth nat. size.—Wadhurst Clay; Hastings. Charles Dawson Collection (B. M. no. P. 11832). | 37. |

A.S.Woodward, Wealden & Purbeck Fishes. Plate VII.




G.M.Woodward del. et lith. Huth imp.

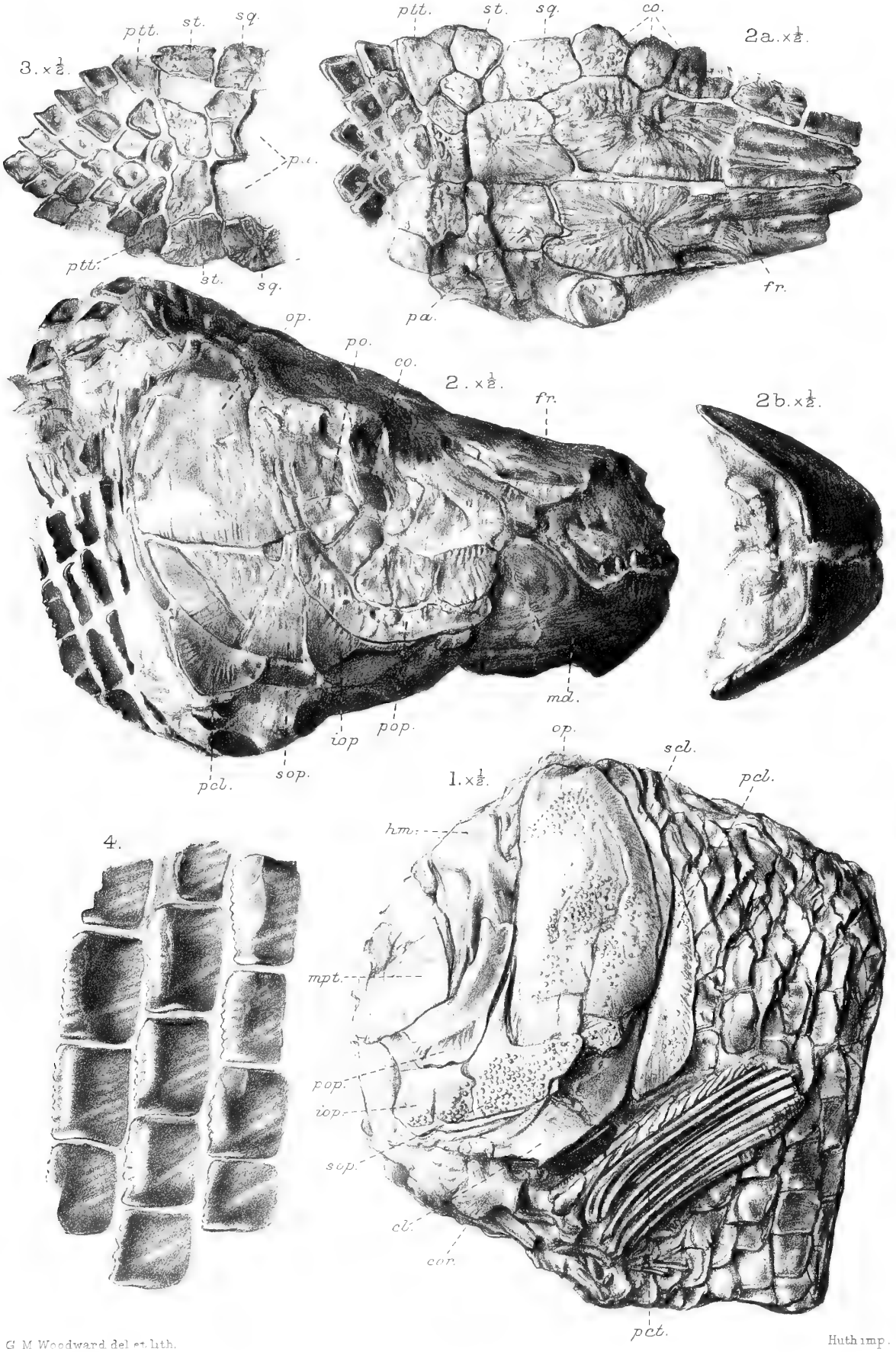
Lepidotus.

## PLATE VIII.

FIG. PAGE.

1. *Lepidotus mantelli*, Agassiz; hinder portion of head, with anterior scales and base of pectoral fin, one-half nat. size.—Wealden; Heathfield, Sussex. The type specimen. Mantell Collection (B. M. no. 2456). *cl.*, clavicle; *cor.*, coracoid; *hm.*, hyomandibular; *iop.*, interoperculum; *mpt.*, metapterygoid; *op.*, operculum; *pcl.*, postclavicular scale; *pct.*, pectoral fin; *pop.*, preoperculum; *scl.*, supraclavicle; *sop.*, suboperculum. 37.
2. Ditto; vertically crushed head in right side view and upper view (2 *a*), with a lower view of the dentary bones (2 *b*), one-half nat. size.—Wealden; Highfure, Billingshurst, Sussex. The type specimen of the so-called *Lepidotus fittoni*, Agassiz. B. M. no. 20673 *a*. *co.*, circumorbitals; *fr.*, frontal; *md.*, mandible; *pa.*, parietal; *po.*, postorbitals; *ptt.*, post-temporal; *sq.*, squamosal; *st.*, supratemporals; other letters as in fig. 1. 37.
3. Ditto; hinder margin of skull and anterior dorsal scales, upper view, one-half nat. size.—Wealden; Sussex. Mantell Collection (B. M. no. 2401). Lettering as in fig. 2. 44.
4. Ditto; flank scales, partially decayed, showing coarse oblique grooving, nat. size.—Wealden; Horsham, Sussex. B. M. no. P. 5129. 46.

A.S.Woodward, Wealden & Purbeck Fishes. Plate VIII.




G. M. Woodward, del. et lith. Huth imp.

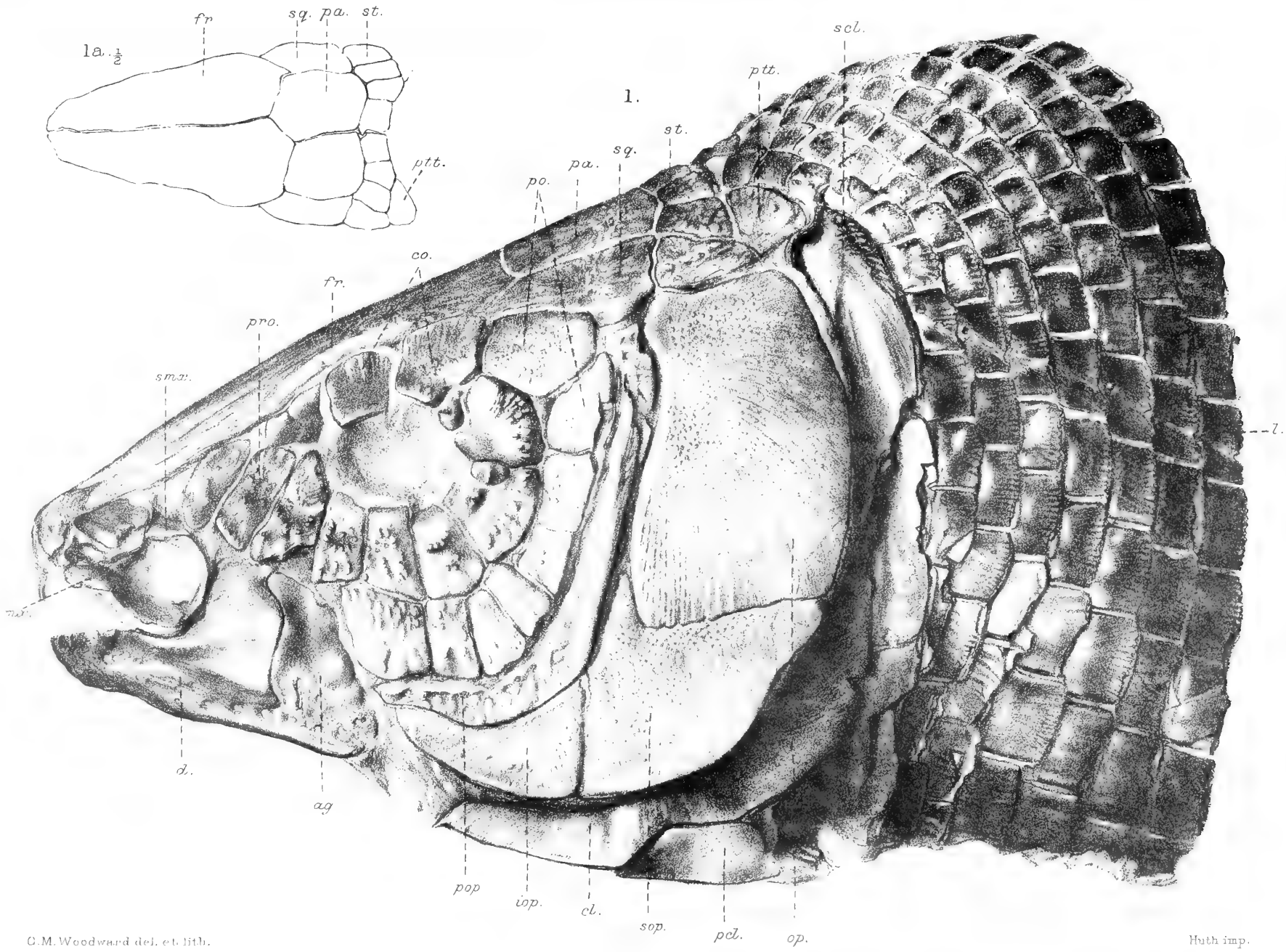
Lepidotus.

## PLATE IX.

| Fig. | | Page. |
|---|---|---|
| 1. | *Lepidotus mantelli*, Agassiz; small head and anterior scales, left side view, nat. size, with bones of cranial roof in outline (1 *a*), one-half nat. size. —Wealden; Hastings. Rufford Collection (B. M. no. P. 6933). *ag.*, angular; *cl.*, clavicle; *co.*, circumorbitals; *d.*, dentary; *fr.*, frontal; *iop.*, interoperculum; *l.*, scales of lateral line; *mx.*, maxilla; *op.*, operculum; *pa.*, parietal; *pcl.*, postclavicular scale; *po.*, postorbitals (the large foremost plate of the series lacking); *pop.*, preoperculum; *pro.*, preorbitals; *ptt.*, post-temporal; *scl.*, supraclavicle; *smx.*, supramaxilla; *sop.*, suboperculum; *sq.*, squamosal; *st.*, supratemporal. | 39. |

A. S. Woodward, Wealden & Purbeck Fishes.

Plate IX.




C. M. Woodward del. et lith.

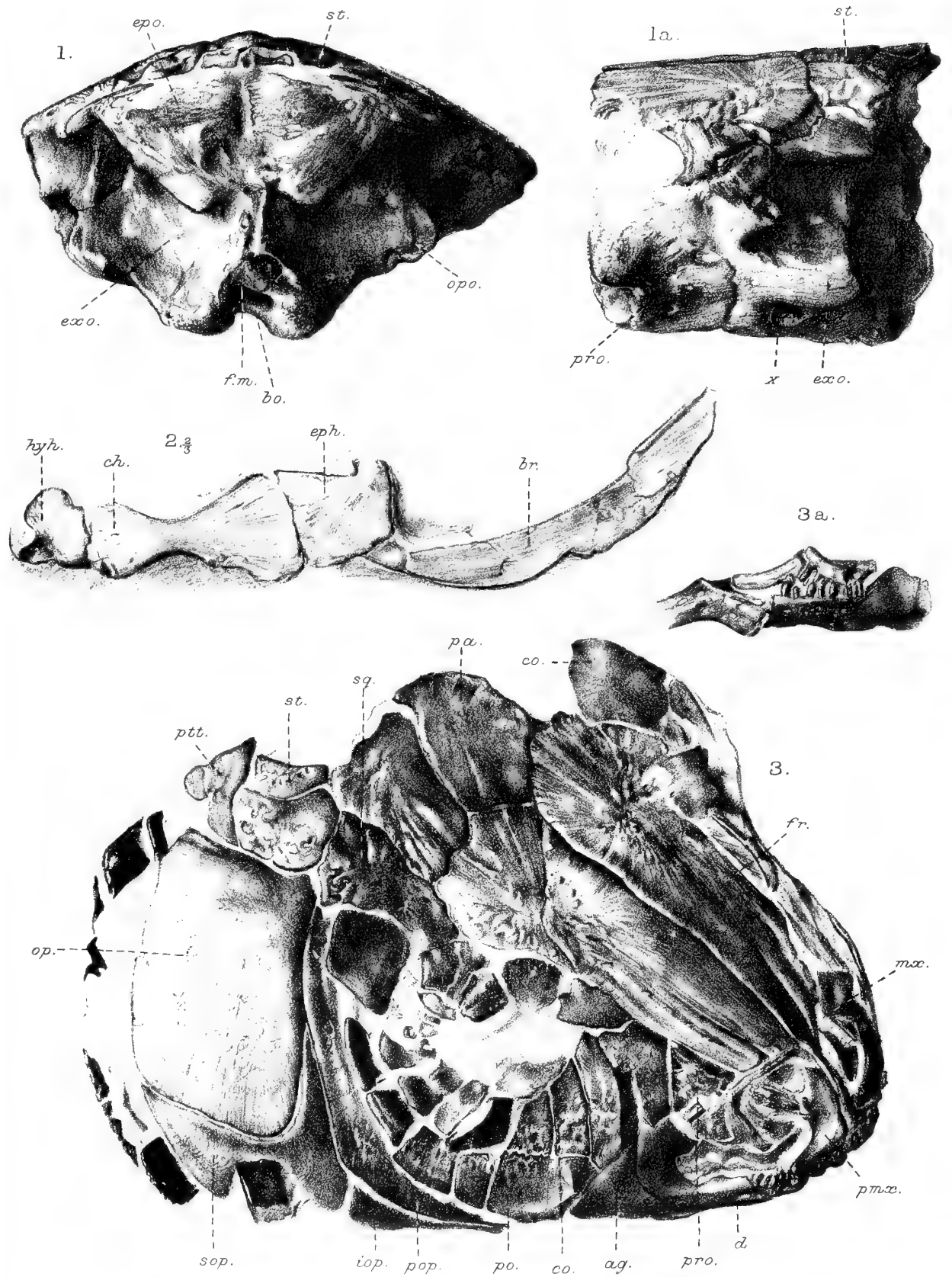
Huth imp.

*Lepidotus.*

## PLATE X.

| Fig. | | Page. |
|---|---|---|
| 1. | *Lepidotus mantelli*, Agassiz; occipital portion of skull, abraded below, hinder view and left side view (1 *a*), nat. size.—Wealden; Hastings. Egerton Collection (B. M. no. P. 1124). *bo.*, fragment of basi-occipital; *epo.*, epiotic; *exo.*, exoccipital; *f. m.*, foramen magnum; *opo.*, opisthotic; *pro.*, pro-otic; *st.*, supratemporals; x., foramen for exit of vagus nerve. | 37. |
| 2. | Ditto; hyoid arch, two-thirds nat. size.—Upper Purbeck Beds; Perch Hill, Brightling, Sussex. B. M. no. 23624. *br.*, upper branchio-stegal ray; *ch.*, ceratohyal; *eph.*, epihyal; *hyh.*, hypohyal. | 43. |
| 3. | Ditto; head in upper and right side view, and remains of jaws in front view (3 *a*), nat. size.—Upper Purbeck Beds; Netherfield, Battle, Sussex. E. J. Baily Collection (Hastings Museum). *ag.*, angular; *co.*, circumorbitals; *d.*, dentary; *fr.*, frontal; *iop.*, interoperculum; *mx.*, maxilla; *op.*, operculum; *pa.*, parietal; *pmx.*, premaxilla; *po.*, postorbitals; *pop.*, preoperculum; *pro.*, preorbitals; *ptt.*, post-temporal; *sop.*, suboperculum; *sq.*, squamosal; *st.*, supratemporals. | 37. |

A.S.Woodward, Wealden & Purbeck Fishes. Plate X.




G.M Woodward del et lith

Huth imp

Lepidotus.

Palæontographical Society, 1915.

A MONOGRAPH

OF THE

# BRITISH PALÆOZOIC

# ASTEROZOA

BY

W. K. SPENCER, M.A., F.G.S.

PART II.

Pages 57—108; Plates II—V.

LONDON:

PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

October, 1916.

PRINTED BY ADLARD AND SON AND WEST NEWMAN, LONDON AND DORKING.

84. Schuchert, C.—"Fossilium Catalogus: 1. Animalia, Editus a F. Frech," 'Stelleroidea Palæozoica.' W. Junk, Berlin, 1914.
85. —— "Revision of Paleozoic Stelleroidea, with Special Reference to North American Asteroidea," 'Bull. 88, U.S. National Museum,' 1915.
86. Vaughan, A., "Correlation of Dinantian and Avonian," 'Quart. Journ. Geol. Soc.,' vol. lxxxi, p. 3, 1915.
87. Spencer, W. K., "A Monograph on the British Fossil Echinodermata from the Cretaceous Formations. Vol. 2: The Asteroidea and Ophiuroidea," 'Mon. Palæont. Soc.,' 1908.
88. Woodward, A. Smith, "Anniversary Address of the President," 'Quart. Journ. Geol. Soc.,' vol. lxxxi, p. lxii, 1915.
89. Bather, F. A., "Studies in Edrioasteroidea, IV. The Edrioasters of the Trenton Limestone [Part II]" 'Geol. Mag.,' dec. vi, vol. i, pp. 162-171, 1914.
90. —— "Studies in Edrioasteroidea, VIII. A Comparison with the Structure of Asterozoa," 'Geol. Mag.,' dec. vi, vol. ii, pp. 316–322, 1915.
91. —— "Studies in Edrioasteroidea, I—IX" reprinted, with additional pp. i–xii, from 'Geol. Mag.' and published by the author at Wimbledon' October, 1915.
92. —— [Review of Schuchert] 'Geol. Mag.,' dec. vi, vol. ii, pp. 425, 426, 1915.

### Addendum to Literature.

Since I wrote the previous section of this Monograph, Professor Schuchert (84, 85) has published a valuable and interesting account of the North American Palæozoic Asterozoa, which is very illuminating and of special importance to English workers since it now, for the first time, enables clear comparisons to be made between the American and English species. Certain of his theoretical conclusions can also undoubtedly be maintained, and constitute a very appreciable advance in our knowledge. I am, however, unable to agree with his contention that a certain Palæozoic Starfish, *Hudsonaster*, is "very near the radicle that gave rise through modification and inheritance to all subsequent Stelleroidea" (85, p. 34), and that "in any event, whatever the pre-*Hudsonaster* evolution was, we are on safe ground in indicating what the developmental changes were, starting with this genus" (p. 36).

It seems to me that if Professor Schuchert's duties had allowed him to make the same exhaustive studies of the American Ophiuroidea that he has made of the Asteroidea, he would not himself have held to this conclusion. It is to be hoped that he will sometime find leisure to complete his studies, for it is obvious that the American "Ophiuroidea" are worthy of much better description than has, as yet, been given them. Schuchert's classification is as follows:

## Class **STELLEROIDEA**.

### Sub-class **Asteroidea**.

PHANEROZONIA, Sladen.

Super-family Promopalæasteracea, Schuchert.

Family Hudsonasteridæ, Schuchert. Genera: *Hudsonaster*, Stürtz (syn. *Protopalæaster*, Hudson), *Siluraster*, Jaekel.

Family Palæasteridæ, Gregory. Genera: *Palæaster*, Hall, *Australaster*, Schuchert.

Family Promopalæasteridæ, Schuchert.

Sub-family Mesopalæasterinæ, Schuchert. Genera: *Mesopalæaster*, Schuchert (? syn. *Argaster*, Hall), *Spaniaster*, Schöndorf (syn. *Cœlaster*, Sandberger), *Miomaster*, Schöndorf, *Devonaster*, Schuchert.

Sub-family Promopalæasterinæ, Schuchert. Genus: *Promopalæaster*, Schuchert.

Sub-family Anorthasterinæ, Schuchert. Genus: *Anorthaster*, Schuchert.

Family Xenasteridæ, Schöndorf. Genera: *Xenaster*, Simonovitsch (syn. *Archæasterias*, Müller), *Agalmaster*, Schöndorf, *Rhenaster*, Schöndorf, *Eifelaster*, Schöndorf, *Trimeraster*, Schondorf.

Family Neopalæasteridæ, Schuchert. Genus: *Neopalæaster*, Schuchert.

Super-family Palasterinacea, Schuchert.

Family Palasterinidæ, Gregory. Genus: *Petraster*, Billings, *Lindströmaster*, Gregory (syn. *Hisingeraster*, Stürtz), *Palasterina*, Salter, *Uranaster*, Gregory, *Palæostella*, Stürtz (syn. *Palænectria*, Stürtz), *Pseudopalasterina*, Stürtz.

Super-family Lepidasteracea, Schuchert.

Family Lepidasteridæ, Gregory. Genera: *Lepidaster*, Forbes, *Helianthaster*, Roemer, *Lepidasterella*, Schuchert.

**Relationship unknown.**

*Ataxaster*, Jaekel.

CRYPTOZONIA, Sladen.

Super-family Stenasteracea, Schuchert.

Family Stenasteridæ, Schuchert. Genera: *Stenaster*, Billings, *Tetraster*, Nicholson and Etheridge.

Family Monasteridæ, Schuchert. Genus: *Monaster*, Etheridge (syn. *Etheridgaster*, Gregory).

Super-family Urasterellacea, Schuchert.

Family Urasterellidæ, Schuchert. Genus: *Urasterella*, McCoy (syn. *Rœmeraster*, *Protasteracanthion* and *Salteraster*, Stürtz).

Family Calliasterellidæ, Schuchert. Genus: *Calliasterella*, Schuchert (syn. *Calliaster*, Trautschold).

Family Compsasteridæ, Schuchert. Genera: *Jaekelaster*, Stürtz, *Compsaster*, Worthen and Miller.

Super-family Schuchertiacea, Schuchert.

Family Schuchertiidæ, Schuchert. Genus: *Schuchertia*, Gregory (syn. *Trentonaster*, Stürtz).

Family Palasteriscidæ, Gregory. Genera: *Palasteriscus*, Stürtz, *Echinasterella*, Stürtz, *Loriolaster*, Stürtz, *Cheiropteraster*, Stürtz.

Family Schœnasteridæ, Schuchert. Genus: *Schœnaster*, Meek and Worthen.

Super-family Palæosolasteracea, Schuchert.

Family Palæosolasteridæ, Schuchert. Genera: *Palæosolaster*, Stürtz, *Echinasterias*, Stürtz, *Echinodiscites*, Schuchert (syn. *Echinodiscus*, Stürtz), *Echinostella*, Stürtz, *Medusaster*, Stürtz.

Sub-class **Auluroidea**, Schöndorf.

Order Lysophiuræ, Gregory.

Family Protasteridæ, Miller. Genera: *Tæniaster*, Billings (syn. *Tæniura*, Gregory), *Eophiura*, Jaekel, *Bohemura*, Jaekel, *Palæura*, Jaekel, *Protaster*, Forbes, *Alepidaster*, Meek (syn. *Protasterina*, Ulrich), *Gregoriura*, Chapman, *Bundenbachia*, Stürtz, *Palæophiomyxa*, Stürtz.

Family Palæophiuridæ, Gregory. Genera: *Palæophiura*, Stürtz, *Stürtzura*, Gregory, *Eugasterella*, Schuchert (syn. *Eugaster*, Hall), *Ptilonaster*, Hall.

Family Encrinasteridæ, Schuchert. Genus: *Encrinaster*, Haeckel (syn. *Aspidosoma*, Goldfuss).

Order Streptophiuræ, Bell.

Family Ophiurinidæ, Gregory. Genera: *Ophiurina*, Stürtz, *Tremataster*, Worthen and Miller.

Family Lapworthuridæ, Gregory. Genera: *Squamaster*, Ringueberg, *Lapworthura*, Gregory, *Stürtzaster*, Etheridge (syn. *Palæocoma*, Salter), *Bdellacoma*, Salter, *Rhopalocoma*, Salter, *Hallaster*, Stürtz, *Sympterura*, Bather, *Furcaster*, Stürtz, *Palastropecten*, Stürtz (syn. *Palæspondylus*, Stürtz).

Family Eoluidiidæ, Gregory. Genera: *Eoluidia*, Stürtz (syn. *Eophiurites*, Stürtz), *Eospondylus*, Gregory, *Miospondylus*, Gregory.

Family Aganasteridæ, Stürtz. Genus: *Aganaster*, Miller and Gurley (syn. *Ophiopege*, Böhm).

Family Cholasteridæ, Worthen and Miller. Genus: *Cholaster*, Worthen and Miller.

Sub-class **Ophiuroidea**, Gray.

Family Onychasteridæ, Miller. Genus: *Onychaster*, Meek and Worthen.

**Incertæ Sedis.**

Genus *Cribellites*, Tate.

Order Ophiocistia, Sollas.

Family Eucladiidæ, Gregory. Genera: *Eucladia*, Woodward, *Euthemon*, Sollas.

It should be noted that Schuchert does not use the term Cryptozonia in the same sense as Sladen. He himself states that "as the inframarginals are seemingly or actually lost independently in a number of phyla the term is here used as expressive of this condition, and not necessarily of relationship."

# SYSTEMATIC SECTIONS.

*Section A.*—Family Hudsonasteridæ, Schuchert;
„ Promopalæasteridæ, Schuchert;
„ Xenasteridæ, Schöndorf;
„ Uranasteridæ, nov.

The forms included in the above families are those Palæozoic Asterozoa which are most similar to the Asteroidea of the present day. They possess—

(1) Distinct rows of supero- and infero-marginalia. All Recent Asteroidea possess this double row of marginalia either persistent through life or in the early ontogenetic stages.

(2) An apical madreporite. All Recent Asteroidea possess an apical madreporite.

(3) Adambulacralia for the greater part confined to the oral (actinal) surface and only assisting to form the margin at the extremity of the arms. This is a well-known Asteroid character.

(4) An "adambulacral" mouth-region. Recent forms may possess an "ambulacral" mouth-region, but embryological research shows that the early stages have a mouth-region of the primitive "adambulacral" type.

Further, Schuchert has shown that the early members of these families possess the same primitive arrangement of the plates of the disc as do the early stages in the development of the Recent Asteroidea. It is seen, therefore, that the evidence of relationship of these families with the Recent Asteroidea is very complete.

### Method of Study.

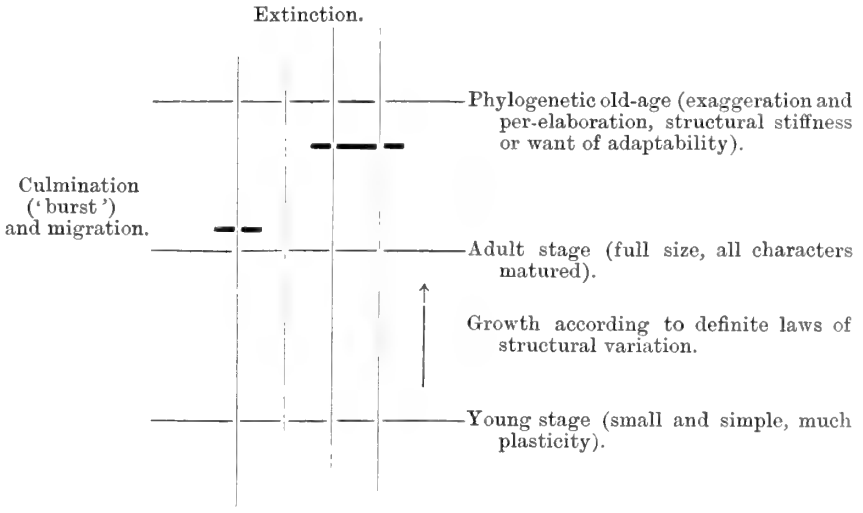
The method of study which I have adopted is that based on the work of Hyatt and other palæontologists and followed by myself when investigating the Asteroidea of the Cretaceous period. It is briefly this:

(1) That the world has been peopled by successive races (or lineages), each of which has gone through a period of rise (elaboration) and fall (regression).

(2) That the early stages of a lineage may be recognised by the fact that the forms are small, comparatively rare and unspecialised. The more mature stages are characterised by large, more specialised forms, which occur in comparative abundance. In the old age of the lineage there are marked loss of ornament and other specialised characters, and the forms are obviously tending to disappear.

(3) That in the various lineages there is frequently an assumption of parallel characters which may make individuals of different descents look, at first sight, very similar. Care must be taken consequently in classification to select characters peculiar to the lineage and not characters paralleled in other lineages. Neglect of this point has caused several classifications of Palæozoic Asterozoa to be fallacious.

The late Dr. Vaughan (86) recently published the following diagram, which most usefully illustrates lineage changes:




The above diagram shows a sheaf of parallel gentes which arrive at the same structural stages at the same time, but retain each its distinctive specific characters and time of burst. Such a sheaf is more usual than a single line, and the laws of structural development can be deduced from any one or more of the lines.

It will be seen that the assumption that the evolution of Palæozoic Asterozoa follows these broad lines, is of great value when studying them.

## The Lineage Changes.

Before dealing with the details upon which the classification of the various forms is based, it is best to give some account of the various lineage changes. It will be seen that a knowledge of these changes is very important for a thorough understanding of the classification suggested by Schuchert.

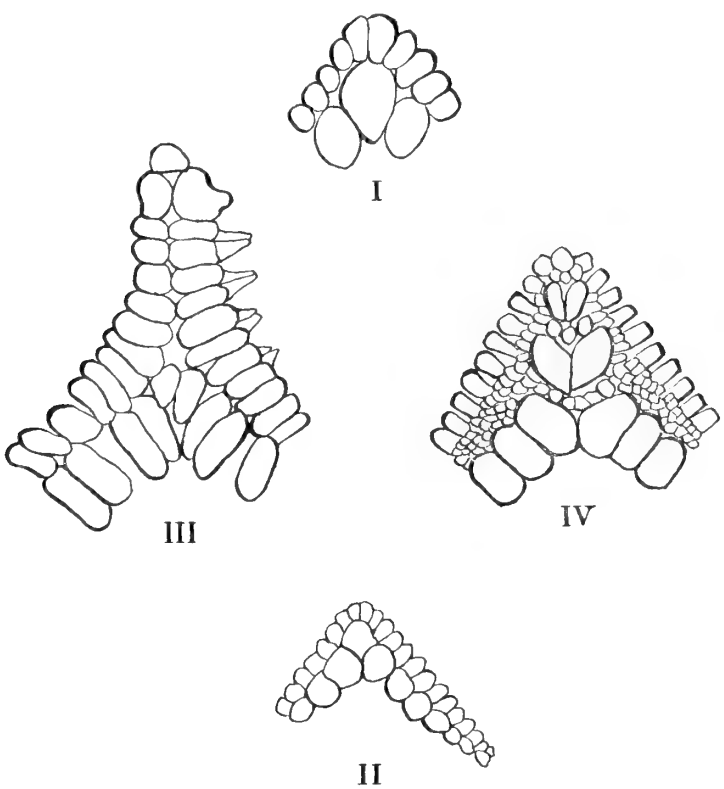
No Asterozoa are known before the Middle Ordovician, and, as Schuchert states (*op. cit.*, p. 31), "we may confidently add that the varied organisation of those of the Middle Ordovicic proves that there is a long previous history of which palæontology knows nothing."

The simplest Asteroidea known are the Hudsonasteridæ, which have almost exactly the structure met with in the early plated stages of the Recent Asteroidea. The disc possesses a centrale surrounded by five or six accessory plates which are again encircled by five primary radialia and five primary interradialia. The marginalia are large and conspicuous, and there are prominent radialia but no accessory plates, such as adradialia and ventrolateralia. A good idea of one of these primitive forms can be obtained from an examination of Text-figs. 34, 35, 38, and 39 (pp. 71, 76). From the Hudsonasteridæ certain lineages have developed in ways which are, for the greater part, peculiar to these older Asteroidea. These changes may be classified as follows:

### (A) Changes Connected with the Increase in Size of the Disc.

#### (1) *Changes connected with the Oral Surface.*

These can best be followed by comparison of the component figures of Text-fig. 32. In the axil of the arms of the Hudsonasteridæ there is a single plate called by Schuchert the axillary interbrachial. It is really, I believe (see pp. 72, 96), the odontophor exposed to external view, not hidden by the proximal infero-




TEXT-FIG. 32.—Figures showing the migration of the odontophor and infero-marginalia. *I, Coccaster bulbiferus*; *II, Mesopalæaster primus*; *III, Promopalæaster bellulus* (after Schuchert). The odontophor has probably dropped away from the specimen figured (Schuchert, *op. cit.*, p. 105); *IV, Xenaster margaritatus* (after Schöndorf).

marginalia as in Recent forms. Throughout my descriptions I have, therefore, except in quotations from Schuchert, definitely called this plate the odontophor.

In the Mesopalæasterinæ the infero-marginalia come together along the interradii so as to shut off the odontophor from the margin. In the more advanced forms, the Promopalæasterinæ and the Xenasteridæ, the disc is often increased considerably in size by the approximation of several of the proximal pairs of infero-marginalia. This method of increase of size of the disc appears to be peculiar to the Palæozoic Asteroidea.

(2) *Changes connected with the Lateral and Apical Surface.*

The method of increase of the apical surface is also very characteristic of these older families, being brought about largely by the development of a considerable number of rows of plates between the supero- and infero-marginalia of the base of the arms. The added plates are known as intermarginalia. Schöndorf (62, p. 95), who studied the Devonian Xenasteridæ, was the first to draw attention to this intermarginal area, and Schuchert has traced its gradual development in the earlier Mesopalæasterinæ and the Promopalæasterinæ.

Intermarginalia are only rarely present in Recent forms. It is interesting to note that the Cretaceous family of Stauranderasteridæ have the area well developed.

## (B) Changes in the Appearance of the Plates.

(1) *Changes in the Marginalia.*

As is well known, the Recent Asteroidea are commonly divided into two great divisions, the Phanerozonia (Sladen) and the Cryptozonia (Sladen). The Phanerozonia are the more primitive, and are distinguished by clearly defined marginal ossicles and by a more unbroken calcareous covering. The Cryptozonia are derived from the Phanerozonia since they pass through a Phanerozonate stage when young, but when the forms become adult the marginal ossicles can no longer be clearly separated from the remaining ossicles. This is undoubtedly due partially to the fact that the marginalia are cut away to provide additional lung-surface by exposure of the skin blood-vascular system.

We can notice among some of the older Asteroidea a similar reduction in the size and importance of the marginalia. They do not grow proportionately as the members of the lineage series increase in size, as may be seen if we compare the supero-marginalia of a "*Hudsonaster*" (Text-fig. 36, p. 74) with those of a *Promopalæaster* (Text-fig. 51, p. 93). A comparison of these same two text-figures shows that, while the most proximal supero-marginalia are the largest in the more primitive form, in the later form this is not the case. The first pairs of supero-marginalia which have been pushed from a marginal into an adapical position by the development of the intermarginalia, are reduced and are often not easy to distinguish from the remaining plates of the disc. The supero-marginalia also change in shape. Those of the Middle Ordovician "*Hudsonaster*," as described by Schuchert (85, pl. v, fig. 2), are polygonal and straight sided, while those of the majority of the Upper Ordovician and later forms have their proximal inner margin cut away so that the ossicle is shaped like a bent finger. The shape of these plates is very well seen in Text-fig. 34, p. 71 (*Girvanaster sculptus*). Here undoubtedly the spaces between the successive supero-marginalia have some con-

nection with respiration. It is interesting to note that similarly shaped superomarginalia are also met with in the Cretaceous genus *Stauranderaster*. In this genus the outer edge is usually also cut away, so that the ossicle appears breast-plate-shaped (87, pl. xix, fig. 1, and text-fig. 28, pp. 120, 125).

(2) *Changes in the Ossicles of the Disc and Median Regions of the Arms.*

Studies of the Promopalæasteridæ show that in the most advanced species the accessory plates of the disc, as well as the radialia and the adradialia, tend to lose their regular shape and arrangement, and even to break up into smaller pieces (see Text-fig. 52, p. 93). The same change may take place in other lineages. Thus *Palæaster* appears to be a "*Hudsonaster*" which has undergone secondary alterations of this type, as also do *Neopalæaster crawfordsvillensis* (p. 102) and *Mesopalæaster? ketleyi* (p. 101).

The arrangement of the lineages and their changes is perhaps most easily followed from the table and diagram on p. 65.

The most reasonable interpretation appears to be, that the primitive stock gave rise at various times to offshoots. Some of these offshoots never went beyond the "*Hudsonaster*" stage, and reached their highest elaboration in that stage. *Girvanaster sculptus* (see p. 70) is a British form which obviously reached a high degree of specialisation in the "*Hudsonaster*" stage. Other offshoots went through the "*Hudsonaster*" stage in pre-Middle Ordovician times, and appear among the earliest known Asterozoa as the Mesopalæasterinæ. Probably several lineages are represented here. The English "*Caractacaster*" (p. 80) is, for instance, apparently quite distinct from the true American "*Mesopalæaster*." Probably other lineages also are represented, but the imperfect condition of the known specimens of many of the species does not allow the forms to be examined in detail. Some such lineage must have given rise to the Devonian Xenasteridæ.

A remarkable offshoot sheaf gave rise to the Promopalæasterinæ. These appear in the Middle Ordovician as large, highly specialised forms which have already gone through both the "*Hudsonaster*" and "*Mesopalæaster*" stages. The lineage illustrates clearly the principle that the maximum of elaboration is often quickly followed by extinction, for no "*Promopalæaster*" has been found beyond the Upper Ordovician. Smith Woodward (88) has made observations on fossil fishes which recall the secondary alterations in the plates of Asteroids, and especially those changes to be noticed in "*Promopalæaster*." He remarks: "There was also a constant tendency for the primitive symmetry of the parts of the skeleton in successive members of a group to become marred by various more or less irregular fusions, suppressions, and subdivisions. Finally, some of the successive species of each group gradually increased in bodily size until the maximum was reached, just before the time for extinction had arrived." The

comparison between the lineage-history of fossil fishes and that of *Promopalæaster* is almost complete. It is probable that, as our knowledge grows, the same series of changes will be followed in other Palæozoic Asterozoa (see also p. 100).

| | Size. | Geological horizon. | Oral surface. | Apical surface. |
|---|---|---|---|---|
| Hudsonasteridæ . | Small | Mainly Ordovician | Odontophor helps to form the margin | Primary radialia and interradialia pronounced. No accessory plates. |
| Mesopalæasterinæ . | Small to large | Ordovician to Carboniferous? | Odontophor enclosed by one pair only of infero-marginalia | Accessory plates, ad-radialia and inter-marginalia present. |
| Promopalæasterinæ | Large | Ordovician | Odontophor enclosed by several infero-marginalia | Accessory plates well developed. Radialia may break up. |
| Xenasteridæ . . | Large | Devonian | Ditto, ventro-lateralia also present | Accessory plates usually developed. |

(For Schuchert's families Palæasteridæ, Gregory (emend.), and Neopalæasteridæ, see pp. 102–104).

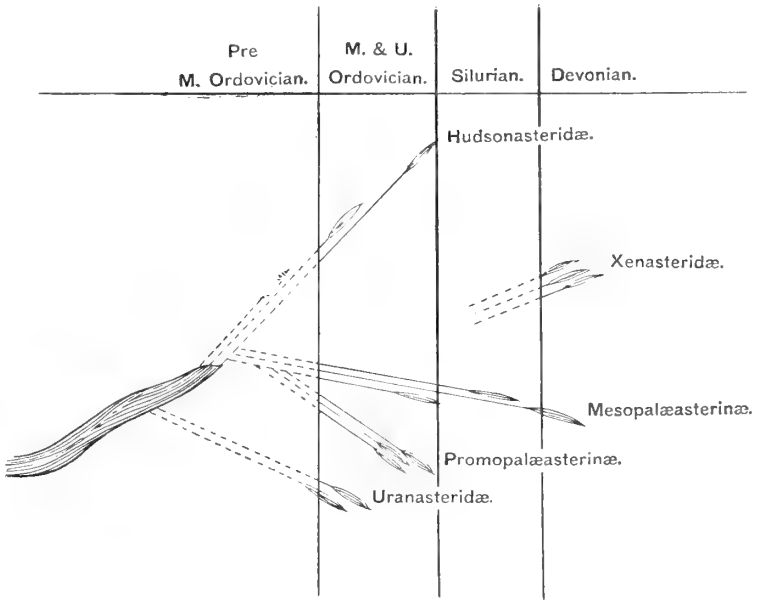
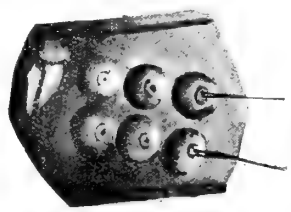



Diagram illustrating the sheaves of the various lineages and their derivation from a common stock. The thickened portions of each line are meant to suggest that the stage of highest elaboration of each lineage in individual lineages of a sheaf may be reached at varying periods. This is purely an illustrative diagram, and our knowledge is not sufficient to work out the lineage-history of each sheaf in detail.

### (C) **Changes in Ornament.**

The ornament on these early Palæozoic forms is also of great interest. In, at any rate, the more primitive species it recalls very strongly the pustulose ornament of *Edrioaster*, which has been described by Bather (89, p. 167) as follows: "The surface in well-preserved tracts is coarsely pustulate (pl. xi, fig. 1). The pustules are distinct, and spring from an irregularly reticular surface. . . . These

pustules are not due to the breaking up of growth-lines by radial stresses, but they may very well have been tubercles bearing minute spines. Such spines, being very loosely attached, would readily fall off after death, and would in any case escape observation owing to their minute size. I have searched for them in the very small amount of available material, but in vain, unless a tiny rod (·8 mm. × ·25 mm.) in the left anterior interradius of E. 15930 may possibly be one." The plates of the primitive Starfishes show the same ornament. This has led them to be described by some authors (*e. g.* Schuchert, 85, p. 31) as "granulated." It is probable, however, that these granulations are not merely rugose outgrowths of calcite such as are found in certain lineage stages of Cretaceous Starfishes (Spencer, 74, p. 103), but are more comparable with the spine-bearing mammillations on the plates of Echinoids. In certain cases, where the conditions of preservation were exceptionally favourable, the actual spines are preserved, as, *e. g.*, on the infero-



Text-fig. 33.—An infero-marginal of *Coccaster bulbiferus*, showing ornament. × 60.

marginalia of *Coccaster bulbiferus* (Text-fig. 33). Schuchert has also figured similar spine-bearing mammillations on apical ossicles of *Promopalæaster dyeri* (85, pl. 20, fig. 6).

These observations show that the ornament on the primitive Asterozoa, the Echinoidea, and the Edrioasteroidea, has many features in common. Whether this is due to common ancestry or to parallel evolution in several groups, remains as yet to be decided. The connection is not so clear in the later Asteroidea, because in these forms the spine-pits are very frequently flush with the plates, and not situate upon articulatory prominences.

### (D) **Miscellaneous Details.**

The following details are of general importance:

(1) Schuchert (85, p. 45) states that "in *Hudsonaster* the prominent supramarginal plates of the dorsal side are placed decidedly inside of the inframarginals, though the former clearly overlap the latter. This primitive position is retained in many Palæozoic genera, and apparently not before the Devonic do these two columns of ossicles come to lie wholly upon one another, and then they together margin the animals. It is apparently always a rare condition in the Palæozoic, but as the post-Devonic asterids are as yet little known, we can more accurately

say that the modern type of Phanerozonia is unknown before Devonic time. It should be added here that complete superposition of the supra- upon the infra-marginals took place in more than one stock and at different times." It is my own belief that the infero-marginalia preceded the supero-marginalia in development and are of more general importance than these latter ossicles. This point will be returned to later.

(2) Bather (90, p. 317) points out that I state (Introductory Section to this Monograph, p. 18) that in the older Asterozoa the ambulacralia form a complete floor to the ambulacral groove, and there are no podial pores to allow the ampullæ to penetrate into the body-cavity, and adds that "were that view correct, *Edrioaster* itself would be more advanced in this respect than the older Palæozoic Asterozoa, and would find its analogue in such a form as the Lower Devonian *Xenaster*, where the pores have the same relative size and position. . . . If pores were absent in all the pre-Devonian Asterozoa, it would be very difficult to understand how the relatively narrow pores of *Xenaster* were formed. Starting with pressure of an incipient ampulla outside the floor-plates, one would expect to observe a gradual deepening of the excavation until it broke through into the thecal cavity as a relatively wide hole. Such is, in fact, the appearance presented by Prof. Jaekel's drawing of *Siluraster perfectus*, from the uppermost Ordovician of Bohemia. As our knowledge increases it may be that we shall find among the early Asterozoa, as among the Edrioasteroidea, some genera with podial pores, others without, forming parallel lines of descent. The presence of endothecal ampullæ is necessarily dependent on the existence in the rays of a thecal cavity large enough to contain them."

My further studies enable me to amend my previous statement. Careful modelling of the ambulacral groove of *Schuchertia*, n. sp., has convinced me that podial pores may be present in many primitive Asterozoa between the bases of the adambulacralia and just at the outer extremity of the lines of junction of two neighbouring ambulacralia. In further evolution, this pore gradually eats inwards so that eventually it approaches well towards the middle of the groove. The beginnings of this encroachment can be seen in *Xenaster* and even in some Ordovician Asteroidea, *e. g.* in the mouth-region of *Promopalæaster elizæ* (Pl. IV, fig. 3). It is obvious that these podial pores are analogous to rather than homologous with the pores of *Edrioaster*.

(3) Generally the adambulacralia are equal in number to the ambulacralia. In very advanced species of the Promopalæasteridæ such as *P. magnificus*, there is, however, a tendency for the adambulacralia to break up and to lose their form, so that they are irregularly situate to, and outnumber the ambulacralia. These changes appear to be comparable with the changes of the apical plates already dealt with.

(4) The most primitive arrangement of the adambulacralia with respect to the

infero-marginalia may naturally be looked for in the distal, growing region of the arm, where the newly formed ossicles may be expected to recapitulate the ancestral arrangement. Here in very many forms the adambulacralia are equal in number to, and alternate with, the infero-marginalia. Proximally the adambulacralia tend to outnumber the infero-marginalia, possibly because (1) the infero-marginalia tend to fuse and become larger plates, and (2) there is some actual reduction in size, accompanied by multiplication in number, of the adambulacralia themselves. In primitive genera belonging to other groups it will be seen that the adambulacralia are equal in number to the infero-marginalia throughout the arm. The proportionate length of arm through which the primitive arrangement persists, appears to be some indication of the point at which lineages branched off from the parent stock.

(5) Schuchert (85, p. 48) endeavours to draw certain theoretical conclusions from the apparent absence of ocular plates among the older Asteroidea, stating that he "knows of but a single occurrence, in the Lower Carboniferous genus *Neopalæaster*." I do not agree with him on this point, for it seems to me that an ocular plate can be seen on all the forms in which the tip of the arm has been sufficiently well preserved for the plate to be recognised.

## Geographical Distribution.

As Schöndorf predicted would be the case when the forms were examined, there is a great similarity between the American and British Palæozoic Asterozoan faunas. The relationship, however, is generic rather than specific, as may be seen from the following descriptions.

### Family Hudsonasteridæ, Schuchert, 1914.

1914. Schuchert, C., Fossilium Catalogus, Animalia, pt. 3, p. 6.
1915. ,, ,, Bull. 88, U.S. Nat. Mus., p. 53.

"The most primitive known Phanerozonia. Small, five-rayed, heavily plated asterids, with narrow ambulacral furrows and slightly alternate ambulacralia. The incipient interbrachial arcs are occupied by single axillary marginal plates. Abactinally the rays have five columns of ossicles, the radials in the center being bounded on either side by the supramarginals and inframarginals; the latter margin the rays, and the ossicles of adjoining columns alternate with one another. There are no accessory ray-plates of any kind. The disc has a prominent central disc-piece separated by a small number of accessory disc-plates from a ring of five large basal radials and five large basal interradial ossicles. Spines rudimentary and apparently restricted to the adambulacrals and inframarginals."

I have quoted Schuchert's diagnosis in full, but I cannot agree with the

concluding portion of the last sentence. The pustulose elevations which carry spines are present on supero- and infero-marginalia alike, and the spines themselves are probably present on the supero-marginalia of *Coccaster bulbiferus* (see p. 77).

The family contains the genera *Hudsonaster*, Stürtz; *Siluraster*, Jaekel; *Girvanaster*, nov. gen.; *Belaster*, nov. gen.; and *Coccaster*, nov. gen.

All the American species of this family are included by Schuchert in one genus, *Hudsonaster*. *Siluraster*, the only other genus known to him, has not as yet been described in detail, and its generic characters are at present obscure. Schuchert therefore refrains from placing its single species, *S. perfectus*, in his comprehensive genus *Hudsonaster*.

The phylogenetic considerations already advanced teach us that the family, as defined, may contain diverse lineages:

(1) All the forms in the early stages of the *Mesopalæaster*, *Promopalæaster*, and *Xenaster* lineages would necessarily be included in the family. It is one disadvantage of Schuchert's classification, that it does not separate vertical lines of descent but merely collects together parallel stages of the different lines.

(2) Other forms probably represent the highest development of offshoot lineages.

Our knowledge of Palæozoic Starfishes is not sufficiently complete to determine exactly to which of these categories many of the species belong. It is evident, however, that *Girvanaster* is a highly specialised type and worthy of a new generic name. *Belaster* and *Coccaster* also contain species which are quite distinct from the American forms which have as yet been described. It is perhaps significant that the British species of "*Hudsonaster*" are more distinct from the American species than are the more highly developed British and American Mesopalæasterinæ and Promopalæasterinæ. This may be because the culmination and migration of the forms of "*Hudsonaster*" occurred at an earlier period than that of the descendant genera, and the forms have consequently had more time to take on different characters in the two areas. It is also to be noticed that *Coccaster* is a Silurian genus and so later than any "*Hudsonaster*" known to Schuchert, who only had forms from the Middle and Upper Ordovician.

That the known species of "*Hudsonaster*" are to some extent specialised, has also been noted by Schuchert, who points out that in these forms there are always accessory plates separating the centro-dorsal from the ring of primary radialia and primary interradialia (see Text-fig. 38, p. 76). He notes (85, p. 49) that "in the young of the cryptozonian *Urasterella* (*U. ulrichi*) and in mature *Calliasterella* there are none of these accessory pieces present. For this reason it is thought that in the Ordovicic there will be found a small asterid, even more primitive than *Hudsonaster*, that will be devoid of accessory disc pieces."

## Genus **GIRVANASTER,** novum.

*Generic Characters.*—The most proximal supero- and infero-marginalia large and high, producing a swollen disc; arms short and stumpy. Primary radials umbrella-shaped, primary interradials small. Adambulacralia many more than the infero-marginalia.

The only known species is *Girvanaster sculptus*, n. sp., of which moulds are found very abundantly in the Upper Ordovician (Ashgillian) of Thraive Glen, Ayrshire.

### 1. **Girvanaster sculptus,** n. sp. Plate II, fig. 7; Plate III, fig. 6; Text-figs. 34, 35.

*Material.*—The collection of Mrs. Gray contains more than thirty specimens, many of them possessing counterparts. Very good casts can be obtained from the moulds, and it is thus possible to give a full account of the form. The specimens figured, Pl. II, fig. 7, and Pl. III, fig. 6, are taken as the cotypes of the species. Moulds showing the oral surface of two individuals, and the apical surface of a third, also occur on a slab from the same horizon in the collection of J. Wright, 1886.

*Apical Surface* (Plate II, fig. 7; Text-fig. 34).—The central portion of the disc sank somewhat after death, but the ossicles have only been slightly displaced. It will be seen from the description that the arrangement of the ossicles is fundamentally of a very primitive nature, although individual ossicles have been modified somewhat profoundly. There is a small centrale surrounded by a circlet of six plates, all somewhat flat and ornamented. Outside these, again, is a circlet which must represent the five primary radialia and five primary interradialia. These, however, have been considerably modified, and differ much from the appearance usually presented.

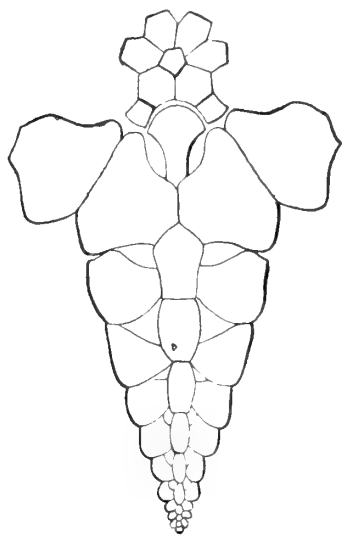
The primary radialia are flat, and shaped very much as the silhouette of an open umbrella with a stout handle. The top of the umbrella and the median portion of the handle are stoutly calcified. It is this portion of the plate which is shown in the plan as figured. There are, however, lateral extensions from the handle which are much less stoutly calcified, and which fit on to the edges of the neighbouring supero-marginalia. The flexible extensions would allow the dorsal surface of the disc to rise and fall, a movement possibly connected with respiration.

The primary interradialia are flat, and not nearly so large as is usual amongst the Hudsonasteridæ. There is no trace of a special madreporiform plate, or of a space in which such a plate could have been lodged. Possibly one of the primary interradialia was perforated to serve as a madreporite. The second radial is separated from the primary plate by inner prolongations from the first pair of

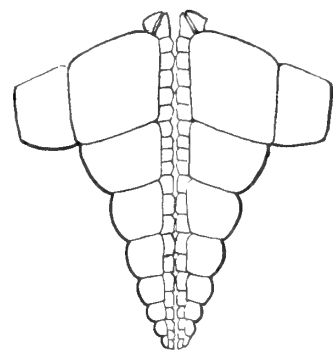
supero-marginalia. The remaining radialia are contiguous, and opposite to, rather than alternate with, the supero-marginalia. They are almost oblong, and continue throughout the length of the arm. A very small ocular terminates the series.

The first pair of supero-marginalia are tall and high, and, as already mentioned, meet across the median axis of the arm. The second supero-marginal has its outside edge in the same straight line as that of the preceding ossicle, but is conspicuously smaller. The third, fourth, and fifth supero-marginalia decrease gradually in size. The remaining five members of the series are very small, and, in consequence, occupy only a small portion of the length of the arm. Some or all

34



35



Text-fig. 34 (on left).—Plan of the apical surface of the disc and one arm of *Girvanaster sculptus* (based on D. 152). × 12.
Text-fig. 35 (on right).—Plan of the oral surface of the disc and one arm of *Girvanaster sculptus* (based on D. 169). × 12.

of these more distant ossicles are not shown in the majority of the moulds. It is only exceptional good fortune which allowed of their complete preservation.

Nearly all the supero-marginalia are finger-shaped, and the more proximal ossicles, in particular, are strongly swollen. In consequence, it is only by focussing somewhat deeply that they are seen to be in reality almost in contact and not separate as shown in the figured plan, in which the space between the neighbouring ossicles is somewhat exaggerated. The swollen ossicles slope so that only a narrow slit is left between them. Some forms do not show this slit. It is obvious that considerable movement was possible. The slits are widest when the arm is high and narrow, and disappear when the arm is flattened and broad. Probably these movements of the arm, and those of the disc already referred to, were brought about by compression of the cœlomic fluid.

*Oral Surface* (Plate III, fig. 6; Text-fig. 35).—The most conspicuous plates

seen in this aspect are the large odontophors. They are rhomboid in form, and approach more nearly to the primitive rounded shape shown by the American Ordovician species of "*Hudsonaster*" than do the corresponding plates of any other English Asteroidea in this stage. In some specimens these odontophors are completely enclosed by the neighbouring infero-marginalia; in others their distal margin is free. It is not clear whether this variability is due to relative movement of the ossicles or to true variations in position.

The first infero-marginal is much smaller than the odontophor, and from this point the decrease in size of members of the series follows the same course as that of the supero-marginalia. Probably more infero-marginalia are present than those shown in the plan, for the infero-marginalia at the extremity of the arm tend to pass over to the apical surface, and, as mentioned above, this portion of the arm is slender and difficult of preservation.

The mouth-angle plates are small, triangular, and not much larger than the neighbouring adambulacralia. These latter are small, meet across the middle line of the narrow groove, and they are much more numerous than the infero-marginalia.

*Side View.*—D. 55 and other specimens show a side view of the arms. Occasionally the proximal supero-marginalia fit exactly over the infero-marginalia, while the distal ossicles of the two series alternate. At other times all the ossicles of the two series alternate. This is in conformity with the power of movement of the ossicles already dealt with. The supero-marginalia are much higher than the infero-marginalia.

*Interior View.*—In making the casts I frequently found the mould filled with a small ball of sandstone, which came away with the cast, but could be detached from it. The cast then showed the inner view of the fossil just as if the apical covering had fallen away and allowed one to look into the body-cavity. Unfortunately, the small size of the plates does not allow exact description of the various parts. Nevertheless, it is clear that the ambulacralia were exactly opposite, except perhaps those nearest the mouth, where they appear to alternate slightly. The first pair of ambulacralia have the usual slope towards the entrance of the mouth.

An internal cast of D. 60*c* allows one to look down on the odontophor which distally is swollen but proximally somewhat flattened and grooved (almost **Y**-shaped). The arms of the **Y** distinctly support the ossicles of the mouth-region just as does the odontophor of Recent Asteroidea (compare Pl. I, fig. 1).

*Ornament.*—All the extra-ambulacral plates are covered with very small granule-like eminences. I have not succeeded in determining the ornament of the adambulacralia.

*Measurements.*—Largest specimen, D. 128. R : r : : 6·5 mm. (about) : 2·5 mm.

One of the smaller specimens, D. 169. R. : r : : 4 mm. (about) : 1·8 mm.

*Horizon and Localities.*—Upper Ordovician (Ashgillian) of Thraive Glen, Girvan, Ayrshire.

## Genus **BELASTER**, novum.

*Generic Characters.*—Arms long, straight-sided, with no great differentiation between the proximal and median marginalia. Radialia stout, almost square. Mouth-angle plates large and conspicuous.

Only one species is known, *Belaster ordovicus*, n. sp.

### 1. **Belaster ordovicus**, n. sp. Plate II, figs. 6, 6*a*; Plate III, fig. 3; Text-fig. 36.

*Material.*—One specimen in the collection of Mrs. Gray shows both the imprint (D. 44) and the counterpart (D. 44*c*).

*Apical Surface* (Plate II, figs. 6, 6*a*; Text-fig. 36).—The cast shows one arm in full length, the bases of two other arms and scattered ossicles of the disc region. The arm has three rows of ossicles; the radialia bordered by two rows of supero-marginalia. All these plates are strongly tumid. The proximal radialia are somewhat crushed together by post-mortem change.

The most proximal radial is somewhat rounded, whilst the three following radialia are approximately square. The diagonal of the square runs along the main axis of the arm. Each of the sides of the square is indented. All these radialia lie alternately with the supero-marginalia. From this point the radialia become elongated and rounded, and tend to lie opposite to the supero-marginalia, persisting through the entire length of the arm. At the extremity of the arm there is a distinct ocular shown more distinctly in the fossil than in the photograph of the cast.

The supero-marginalia are very conspicuous, and certainly not subordinated to the infero-marginalia (see above, p. 66). They are finger-shaped almost throughout the length of the arm. The most proximal pairs of the plates meet across an interradius and form a broad margin to the disc. The second supero-marginalia meet these proximal supero-marginalia at a very obtuse angle, and from this point the margin is continued almost as a straight line throughout the arm.

A side view of the arm shows that the marginal wall is high and that the supero- and infero-marginalia distinctly alternate. At the extremity of the arm the infero-marginalia as usual pass over to the apical surface. There are five infero-marginalia corresponding to the distal three supero-marginalia.

*Oral Surface* (Plate III, fig. 3).—The mould on the counterpart gives a cast of only a portion of the arm, photographed in Pl. III, fig. 3. The measurements, form, and arrangement of the infero-marginalia and the adambulacralia are very similar to those of the specimen described below from the Ruddy Collection.

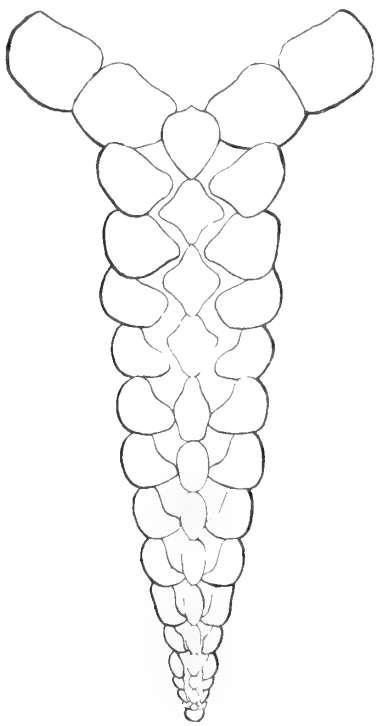
*Ornament.*—The plates are covered with granule-like eminences. These are seen clearly on Pl. II, fig. 6*a*.

*Measurements.*—R : r : : 16·5 mm. : 4·5 mm. Width of arm at base is 5 mm. There are fifteen supero-marginalia, and seventeen infero-marginalia.

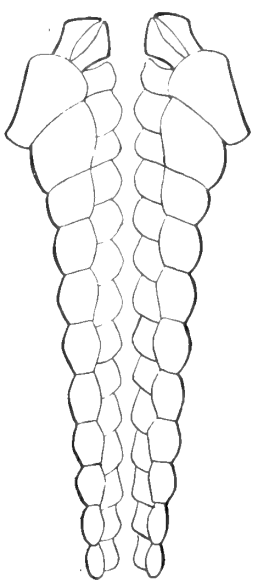
*Horizon and Locality.*—Upper Ordovician (Ashgillian) Starfish bed at Girvan, Ayrshire, Scotland.

A specimen (E. 13532) from the collection of T. Ruddy in the British Museum (Nat. Hist.) is apparently the oral side of *B. ordovicus*. I hesitate, however, to assign it to this species, as the holotype and this specimen were obtained from such widely different horizons.

36



37



Text-fig. 36 (on left).—Plan of the apical surface of one arm and the margin of the disc of *Belaster ordovicus* (based on D. 44). × 6.
Text-fig. 37 (on right).—Plan of the oral surface of the greater part of an arm and the disc of *Belaster ordovicus?* (based on E. 13532). × 6.

*Description* (Plate III, fig. 4; Text-fig. 37).—The odontophor is long and narrow. Its proximal side is wide and rounded, the sides bordering the infero-marginalia are indented, whilst the distal side is short and almost straight. The proximal pair of infero-marginalia are large. Each is widely separated by the odontophor from the corresponding infero-marginal of the neighbouring arm. The second pair of infero-marginalia are distinctly smaller than the first pair, but from this point there is little differentiation in the series. The mouth-angle plates are very conspicuous. The base which fits on the odontophor is slightly shorter than the base of the proximal adambulacralia, but the plate widens considerably proximalwards, and projects well into the mouth-cavity. The adambulacralia are

slightly more numerous than the infero-marginalia in the proximal portion of the arm, but from the sixth infero-marginal onwards they become equal in number and alternate with the infero-marginalia. In the arm figured the adambulacralia are turned slightly outwards, so that the nose which fits upon the ambulacral ridge is brought into view. This accounts for the shape figured. The remaining arms show, on the other hand, the adambulacralia in the usual position, namely, with the nose hidden.

One of the ambulacrals may be seen at the extremity of the arm. It is oblong, and has the customary ridge.

*Measurements.*—r is 3·4 mm. Width of arm at base is 4·8 mm.

*Horizon and Locality.*—This specimen was found in the lane to Gelli Grin Farmhouse, 2½ miles south-east of Bala. The zone is given by Ruddy as that of "*Strophomena expansa*," which, according to Bather (91, p. vi), is situate just above the "Little Ash" of the Geological Survey Memoirs, at the base of the Bala series.

## Genus **COCCASTER**, novum.

*Generic Characters.*—Disc covered with moderately large plates consisting of a centrale surrounded by five intermediate plates, which are again enclosed by ten large primary radialia and interradialia. Adambulacralia considerably more numerous than the infero-marginalia. Odontophor almost pentagonal, with a re-entrant angle at its base.

The genoholotype and only species is *C. bulbiferus*, n. sp., from the Lower Ludlow (Silurian) mudstones of Leintwardine, Herefordshire.

The fact that the genus is found in the Silurian, makes it later than any "*Hudsonaster*" described by Schuchert. It has five accessory plates on the disc instead of the six or seven often found. The shape of the odontophor is also peculiar. It may be a late offshoot from the "*Hudsonaster*" stem.

### 1. **Coccaster bulbiferus**, n. sp. Plate II, fig. 1; Plate III, fig. 2; Text-figs. 33, 38, 39.

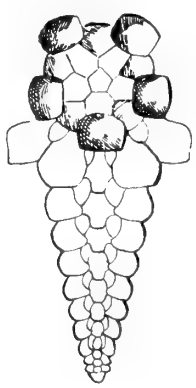
*Material.*—Both the imprint of the apical surface and its counterpart are known, and these specimens comprise the sole known material of the species. The former is in the Scottish National Museum (65/158*a*), the latter in the Ludlow Museum.

*Apical Surface* (Plate II, fig. 1; Text-fig. 38).—The cast of the imprint of the apical surface is very clear, and shows the ossicles with but little displacement. There is a large centrale surrounded by a circlet of five intermediate plates. Outside these, again, are the large primary radialia and interradialia. The primary interradialia are flat and breastplate-shaped. In the reconstruction they are figured as being symmetrically arranged round the disc. In the specimen,

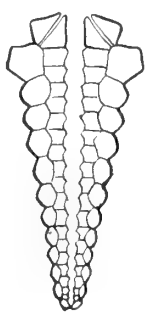
however, two of the plates touch along their length. This, I think, is due to post-mortem displacement. A madreporite may be present in one of the small spaces figured immediately distal to a primary interradial and between two supero-marginalia. It is difficult, however, to be quite sure of the presence of this plate. By far the most prominent plates of the disc are the primary radialia, which are remarkably large and swollen, reminding one very much of the corresponding plates of the Cretaceous Starfish *Stauranderaster bulbiferus*, Forbes.

The proximal radialia immediately behind the primary radial are breastplate-shaped and alternate with the supero-marginalia. Distally, as usual, they become rounded and opposite to the supero-marginalia.

38



39



Text-fig. 38 (on left).—Plan of the apical surface of the disc and one arm of *Coccaster bulbiferus* (based on the specimen in the Royal Scottish Museum). × 6.
Text-fig. 39 (on right).—Plan of the oral surface of an arm and mouth-region of *Coccaster bulbiferus* (based on the specimen in the Ludlow Museum). × 6.

The majority of the supero-marginalia are finger-shaped and swollen. The first pair are much the largest of the series.

The arm is terminated by a distinct ocular.

*Oral Surface* (Plate III, fig. 2; Text-fig. 39).—The mould of the oral surface also gives very clear impressions. The ossicles appear to have been somewhat disturbed, but it is not difficult to make a restoration. The odontophor is a prominent plate of characteristic form. Its proximal extremity is distinctly pointed, and the sides which border the ambulacral grooves are slightly concave. Its distal side is notched in the middle. From the notch a groove passes on to the face of the ossicle, which is distinctly swollen. The infero-marginalia are of the usual shape and are not conspicuously differentiated. Their ornament is described below. There are approximately three ambulacralia to each two infero-marginalia throughout the arm, except possibly at the extreme tip. Small detached spines are seen overlying the adambulacralia.

The ossicles bordering the mouth have fallen inwards, and the appearance is somewhat confused as the cast shows the inner sides of the apical ossicles. The

mouth-angle plates can be clearly distinguished as somewhat large triangular plates, but it is not easy to see whether there was a torus.

Post-mortem alterations have caused the adambulacralia to fall away and expose the ambulacralia. Each of these possesses a strong ridge. The depressions for the radial water-vascular vessel and the ventral cross-muscles are only slight. The plates appear to me to touch throughout their entire length, and not to leave spaces for the passage of ampullæ.

*Side View.*—The supero- and infero-marginalia are seen to alternate distinctly in side view.

*Ornament.*—Text-fig. 33 (p. 66) shows an enlarged view of the ornament of an infero-marginal. There are a number of very slender spines which are carried on small tubercles occupying a distinct ridge on the face of the ossicle. It may be that spine-bearing tubercles are common amongst Palæozoic Starfishes, and that the exceptionally fine mudstones in which these specimens were embedded have afforded special opportunities for the recognition of the true character of the ornament. I also think that I can detect spines on the supero-marginalia, but it is difficult to make quite certain on the point.

TABLE OF THE SPECIES OF THE HUDSONASTERIDÆ.

| | Formation. | R. | r. | Remarks. |
|---|---|---|---|---|
| *Hudsonaster matutinus*, Hall | M. Ordovician | 14 mm. | 3·5 mm. | "Intermediate in structure between the older *H. narrawayi* and the younger *H. incomptus*" (Schuchert 85, p. 58). |
| *H. narrawayi*, Hudson . . | M. Ordovician | 12 mm. (about) | 4 mm. | This was originally described by Hudson as "A fossil Starfish with ambulacral covering plates" under the name of *Protopalæaster narrawayi*. Its true orientation was shown by Raymond. In the Introductory Section to this Monograph (p. 21, for which see references) I stated that I considered the species to be identical with *Palæaster caractaci*, Gregory, and gave copies of Hudson's excellent illustrations. Schuchert (p. 59) places the species in the genus "*Hudsonaster*," but states that the ambulacral plates are large and solid, rectangular, with slightly rounded ends, not ⊢-shaped as in other species of the genus. He gives his opinion that "it may be shown that this character is of generic value, in which case *Protopalæaster* will have to be revived." It is very clear that the systematic position of the form is not settled. The good specimens only show the oral sides. The specimens from St. Paul, Minnesota, placed by Schuchert in the species are much smaller than the holotype described by Hudson, and have different proportions of the major and minor radius. |
| *H. milleri*, Schuchert . . | M. Ordovician | 12 mm. (about) | 3 mm. | — |
| *H. incomptus*, Meek . . | U. Ordovician | 11 mm. | 6 mm. | A well known species. Madreporite apical. |
| *H. rugosus*, Billings . . | U. Ordovician | 22 mm. (about) | 8·5 mm. | The holotype of the genus. |
| *H. batheri* Schuchert . . | U. Ordovician (Ashgillian) | — | — | The specimens from which the species was described belong really to *Tetraster wyville thomsoni* (Bather, 92). |
| *Girvanaster sculptus*, n. sp. . | U. Ordovician (Ashgillian) | 7 mm. | 2·5 mm. | See p. 70. |
| *Belaster ordovicus*, n. sp. . | U. Ordovician (Ashgillian) | 16·5 mm. | 4·5 mm. | See p. 73 |
| *Coccaster bulbiferus*, n. sp . | Silurian (L. Ludlow) | 6·5 mm. | 3·2 mm. | See p. 75. |

*Measurements.*—R : r : : 6·5 mm. : 3·2 mm. Breadth of arm at base is 2·6 mm.

*Horizon and Locality.*—Lower Ludlow (Silurian) mudstones of Leintwardine, Herefordshire.

### Family Promopalæasteridæ, Schuchert.

1914. Schuchert, C., Fossilium Catalogus, Animalia, pt. 3, p. 6.
1915. ,, ,, Bull. 88, U.S. Nat. Mus., p. 73.

"Progressive Phanerozonia with distinct columns of inframarginal plates. Interbrachial areas more or less complex, composed either of inframarginals, axillary interbrachials and ambulacrals, or of these with the addition of interbrachial marginals and accessory interbrachials, or entirely of adambulacral plates. Ambulacrals as a rule opposite, but they may also be slightly alternating. Podial openings through the sutures in the lateral corners of the ambulacral plates, but proximally a few alternate pores may gradually pass medially, when there are four columns of podial openings in each ambulacral furrow. Madreporite abactinal. Abactinal plates very numerous, generally small, either in distinct columns or rows or without either arrangement. The radial and supramarginal columns may be very distinct or may be obscured as such. Accessory ossicles always more or less abundantly developed."

Schuchert divides the family into the three subfamilies of Mesopalæasterinæ, Promopalæasterinæ, Anorthasterinæ.

Of these the Mesopalæasterinæ and the Promopalæasterinæ are related to the Hudsonasteridæ. One can clearly see the gradual development through the stages named in the table on p. 65, from the small simple "*Hudsonaster*" to the large complicated "*Promopalæaster*." This change is narrated in detail by Schuchert (85, p. 75) as follows: "*Mesopalæaster* apparently developed directly out of *Hudsonaster* in that the single axillary marginal plates [odontophors] are in the former genus in nearly all the species pushed inward (interbrachial) and their former place occupied by the proximal plates of adjoining inframarginal columns." . . . "Further, in *Hudsonaster* there are no abactinal accessory ray-plates, but in *Mesopalæaster* one or two more or less completely developed columns are inserted on each side of the radial columns, or in other words, between the radials and supramarginals. Between the inframarginal and supramarginal plates in *Mesopalæaster* there are also either a few incipient accessory plates, which in young specimens are wholly absent, or there is a complete column of these ambital plates. The accessory and axillary interbrachial plates are additions to the generic structure of *Hudsonaster* and *Palæaster*, and further distinguish *Mesopalæaster* from both. This progression toward a greater number of columns of abactinal plates attains its maximum in *Promopalæaster*, and is most marked in *P. magnificus*,

which has not less than twenty-eight columns at the base of a ray, and five interbrachial marginal plates in each interbrachial area. The ambulacral furrows, which are very narrow in *Hudsonaster*, are likewise so in *Mesopalæaster*, but are wide in *Promopalæaster*. Spinosity, which is practically absent abactinally in *Hudsonaster*, is developed in *Mesopalæaster*, and very pronounced in some forms of *Promopalæaster* (*P. spinulosus* and *P. dyeri*). This is apparently also true for the spines of the actinal area. The youthful plate structure of recent species seems to be retained to maturity in *Hudsonaster*, and somewhat so also in the genotype of *Mesopalæaster*, but in *Promopalæaster* the central area of the disc is occupied by numerous very small plates and no definite arrangement is discernible, though this is in large part due to their displacement through fossilisation. However, it is certain that the basal radials and interradials do not increase nor maintain a relative size as in *Hudsonaster* and in the genotype of *Mesopalæaster* (here radials only), but must have diminished to that of the accessory plates from which they are now not distinguishable. From *Hudsonaster* through *Mesopalæaster* into *Promopalæaster* the animals are constantly increasing in size, and this also continues in the species of the latter genus, attaining culmination in *P. magnificus* and *P. dyeri*."

Care must be taken, however, to avoid the conclusion that any of the known species of the Promopalæasterinæ descended from known species of the Mesopalæasterinæ. The Promopalæasterinæ appear among the earliest known Asterozoa as highly specialised forms, and die out at the end of the Ordovician period. The contemporaneous Mesopalæasterinæ are small and not highly specialised. It is not until we reach the Devonian that the largest and most highly specialised Mesopalæasterinæ appear. Nevertheless, the evidence is very strong that "*Promopalæaster*" passed through a "*Mesopalæaster*" stage.

We may also notice at this point the complication of the mouth-parts of certain species of *Promopalæaster*, *e. g. P. elizæ* (p. 95), and its parallel in *Mesopalæaster complicatus* (p. 88). This is a feature which appears peculiar to the subfamily, and in my opinion serves more than any other character to establish the close genetic relationship of the forms included in it.

The subfamily Anorthasterinæ is defined by Schuchert (85, p. 125) as follows: "Aberrant Promopalæasteridæ with the axillary and interbrachial areas composed entirely of adambulacral pieces." It contains one genus and one species, *Anorthaster miamiensis*, Miller. I am very doubtful if this form has any relationship with either the Mesopalæasterinæ or the Promopalæasterinæ.

### Sub-family Mesopalæasterinæ, Schuchert.

"Primitive Promopalæasteridæ with the interbrachial areas small, composed of one pair of inframarginals, single axillary interbrachials [an odontophor], and the adambulacral plates."

Schuchert places all the Ordovician and Silurian forms of this sub-family provisionally or finally in one genus, *Mesopalæaster*. He also recognises three Devonian genera—*Spaniaster*, Schöndorf, *Miomaster*, Schöndorf, and *Devonaster*, Schuchert.

As in the case of the Hudsonasteridæ (p. 68), the sub-family as defined probably contains diverse lineages which are at the same parallel stages of development. Thus—

(1) There are almost certainly amongst the Ordovician and Silurian "Mesopalæasters" the early stages of the "*Xenaster*" lineage.

(2) *Devonaster* may be a late stage of development of an offshoot lineage.

At present our knowledge of the forms is incomplete. Nevertheless, it seems necessary to separate the British forms known to Schuchert as *M. caractaci* from forms like the American *M. shafferi*, the holotype of the genus *Mesopalæaster*. I propose to name the new genus *Caractacaster*. Orally the species of *Caractacaster* are almost in the "*Hudsonaster*" stage (Text-fig. 41, p. 82), although apically accessory plates have been added. In the true "*Mesopalæaster*" the oral surface has advanced well beyond the "*Hudsonaster*" stage (Text-fig. 45, p. 85). British species very closely similar to *M. shafferi* are found in the Upper Ordovician (Ashgillian) of Scotland, but not in the British Caradocian or earlier strata. These facts suggest that the culmination and migration of this genus may have taken place in late Ordovician times (compare the corresponding details for *Promopalæaster*, p. 92).

## Genus **CARACTACASTER**, novum.

*Generic Characters.*—Odontophor scarcely enclosed by the proximal infero-marginalia. Plates of apical area only slightly swollen. Proximal supero-marginalia help to form boundary wall of disc. Madreporite present.

Genoholotype and only species, *C. caractaci*, from the Ordovician of Wales and the Welsh border.

Two American species, *Mesopalæaster intermedius*, Schuchert, and *Mesopalæaster* (*?*) *lanceolatus*, Schuchert, have the odontophor in the same position as *Caractacaster*. The apical surface of *M. intermedius* is unknown. The oral surface of *M.* (*?*) *lanceolatus* is very distinct from that of *C. caractaci* (see p. 98).

1. **Caractacaster caractaci,** Gregory sp. Plate II, fig. 4; Plate III, fig. 1; Text-figs. 40, 41, 42, 43.

1865. *Palæaster caractaci*, Salter, Cat. Foss. Mus. Practical Geology, p. 30 (nomen nudum).
1880. ,, ,, Nicholson and Etheridge, Mon. Silurian Foss. Girvan Dist., Ayrshire, fasc. 3, p. 321 (no description).

1899. *Palæaster caractaci*, Gregory, Geol. Mag., dec. 4, vol. vi, p. 344.
1910. „ „ Schöndorf, Jahrb. nassauisch. Ver. Naturk., Wiesbaden, vol. lxiii, p. 227.
1913. *Protopalæaster caractaci*, Spencer, Introductory Section to this Monograph, pp. 21, 30.
1914. *Mesopalæaster caractaci*, Schuchert, Fossilium Catalogus, Animalia, pt. 3, Stelleroidea palæozoica, p. 24.
1915. „ „ Schuchert, Bull. 88, U.S. Nat. Mus., pp. 92, 93, pl. 9, fig. 6; pl. 11, fig. 1.

*Material.*—There are four specimens in the Museum of Practical Geology, Jermyn Street (Nos. 4/30, 4/30*a*, 4/35*a*, 4/36), each possessing both imprint and counterpart. A fifth specimen, also consisting of imprint and counterpart, in the British Museum (Nat. Hist.) (No. E. 48206), is the holotype of the species.

*Apical Surface* (Plate II, fig. 4; Text-fig. 40).—Moulds taken from four specimens (Nos. 4/30, 4/30*a*, 4/35*a*, and E. 48206) show the apical surface. Unfortunately, the matrix in which the original fossils were embedded was somewhat coarse, and as the plates are not swollen one does not obtain sharp casts. In consequence it is only by careful examination and comparison of the different specimens that the structure can be elucidated.

The central portion of the disc at first sight appears to have been especially badly preserved. Possibly the want of evidence of clear-cut ossicles in this region is due to the fact that originally the disc was covered with a leathery skin in which the ossicles were somewhat loosely embedded. My restoration (Text-fig. 40) is based upon the assumption that there were three rather loose circlets of intermediate plates around the centrale, a view suggested by the first three specimens referred to above. The primary radialia and interradialia are also not very conspicuous ossicles, although both series are readily recognisable. The primary radialia are large compared with the succeeding radialia, but they are flat, and do not stand out. They have the usual breastplate-shaped form. The primary interradialia are small plates situated just proximal to the supero-marginalia. Just behind the primary interradial, on the left side of the figure, is situate a plate which must have been the madreporite. Unfortunately the coarse-grained sandstone has not preserved the madreporiform markings.

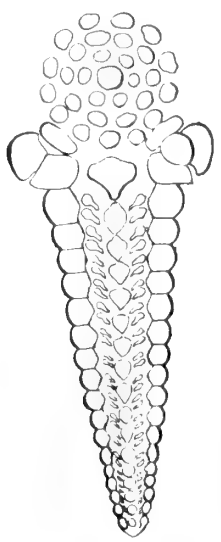
Nearly all the radialia are elongated and cut away at their edges. It is only at the extremities of the arms that they become irregularly polygonal in shape and closely touching.

There is a single row of adradialia on each side of the radialia, but the impressions of these ossicles are poor. One of the arms of 4/35*a* shows that in the proximal region the radialia and adradialia were equal in number. Several of the arms of the other specimens suggest that there were twice as many adradialia as radialia, as shown in Text-fig. 40. It is possible that the apparent doubling of the adradialia is due to weathering of the surface of the ossicles, but the appearance is so regular as to suggest that the arrangement was natural.

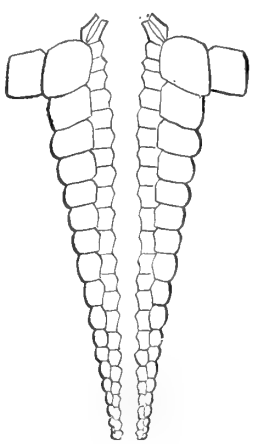
The supero-marginalia appear to form only a narrow margin to the arm. This appearance is partially because their inner extremities are covered by adradialia. When the adradialia have fallen away, inner finger-shaped processes may be seen, and the series looks much broader. The first pair of supero-marginalia are larger and more swollen than the remainder. Apart from this pair, there is little differentiation in the series.

*Oral Surface* (Plate III, fig. 1; Text-fig. 41).—The odontophor is large and almost pear-shaped. Its distal end is not quite enclosed by the neighbouring infero-marginalia. The species, therefore, can only be just passing out of the "*Hudsonaster*" stage. There is little differentiation among the infero-marginalia.

40



41



TEXT-FIG. 40 (on left).—Plan of the apical surface of the disc and an arm of *Caractacaster caractaci* (based on 4/30*a*). × 4.

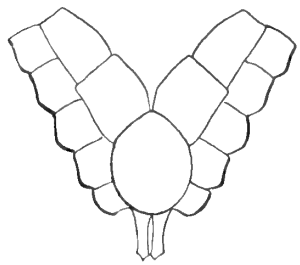
TEXT-FIG. 41 (on right).—Plan of the oral surface of one arm and the mouth-region of *Caractacaster caractaci* (based on 4/30). × 4.

The primitive condition of the species suggested by the position of the odontophor, and the form of the infero-marginalia, is further emphasised by the arrangement of the adambulacralia, which throughout the latter third of the arm (ten plates) correspond in number to the infero-marginalia. In the proximal portion of the arm there are fourteen adambulacralia corresponding to the first eight infero-marginalia.

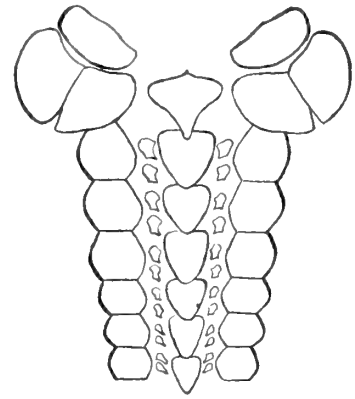
The ossicles of the mouth-region are not well defined. Schuchert states (p. 93) that "a peculiarity of this species is that the ambulacralia do not continue round the axillary interbrachials, but cease with the basal inframarginals. There are, therefore, in *M. caractaci* no adambulacral oral armature spines." The British Museum specimen examined by Schuchert presents this appearance, but the specimens at Jermyn Street show the form to have the normal Asteroid structure. The mouth-angle plates in these specimens are undoubtedly present

and are succeeded by the normal succession of adambulacralia. The condition of preservation of the plates, however, does not allow of complete description. I have restored the mouth-angle plates as if they were originally thin and triangular. Only the base of the plates, however, is preserved, with rather indistinct traces of their continuations into the mouth-cavity. The adambulacralia do not completely hide the groove, and the ambulacralia are consequently exposed. Fortunately, the British Museum specimen possesses ambulacralia still preserved in the original calcite. One or two of these plates came away from the specimen when I was making casts. These were distinctly oblong, with the usual ridge.

42



43



Text-fig. 42 (on left).—Plan of portion of disc and the base of an arm of *Caractacaster caractaci?* (based on E. 13531). × 12.
Text-fig. 43 (on right).—Plan of the apical surface of the base of an arm of *Caractacaster caractaci* (based on E. 13531). × 12.

*Measurements.*—
4/30. r is 4 mm. Width of arm at base is 5·1 mm.
4/30*a*. R : r : : 18·1 mm. : 4·8 mm. Width of arm at base is 6 mm.
4/35*a*. r is 3·5 mm. Width of arm at base is 4·2 mm.
4/36. r is 2·9 mm. Width of arm at base is 3·5 mm.
E. 48206. R : r : : 12·5 mm. : 3·8 mm. Width of arm at base is 4 mm.

*Horizon and Localities.*—All from the Ordovician (Caradocian) of the Welsh Border. 4/30 and 4/30*a* are from Marshbrook, Church Stretton, 4/35*a* is from Cynwyd (east of Bala Lake), 4/36 is from Nant Brain, 1½ miles south of Llandrillo. E. 48206 is from Soudley Quarry, Church Stretton.

One of the Asteroids from the Ruddy Collection, recently acquired by the British Museum (E. 13531), is apparently very nearly related to, if it is not identical with, *C. caractaci*. The fossil is preserved as an imprint on three fragments of rock which have broken apart from each other. The moulds obtained from the imprint are not very clear, but, so far as I understand them, are restored in Text-figs. 42, 43. They are seen to resemble *C. caractaci*. The arms,

however, appear to me to be somewhat shorter than in the holotype of that species, but there is no certainty that any of the arms is preserved throughout its entire length. Photographs of two of the fragments are given in Pl. II, fig. 8, and Pl. III, fig. 7.

The specimen (E. 13531) is from the Lower Bala rocks, in a lane to Gelli Grin Farmhouse, $2\frac{1}{2}$ miles south-east of Bala (see p. 75).

## Genus **MESOPALÆASTER**, Schuchert emend.

*Palæaster* (part) of Authors.
1868. *? Argaster*, Hall, Twentieth Rep. N.Y. State Cab. Nat. Hist., p. 287 ; rev. ed., 1868–1870, p. 329.
1914. *Mesopalæaster*, Schuchert, Fossilium Catalogus, Animalia, pt. 3, p. 24.
1915. „ Schuchert, Bull. 88, U.S. Nat. Mus., p. 74.

*Generic Characters.*—The odontophor well enclosed by the succeeding inferomarginalia. Plates of apical area often swollen and nodose. In the Ordovician species the proximal supero-marginalia help to form the boundary wall of the disc, but in the Silurian species they may be pushed inwards as in the Promopalæasterinæ and the Xenasteridæ. Madreporite unknown.

The genoholotype is *M. shafferi* from the Upper Ordovician of America. As already mentioned, the genus probably contains several lineages and will be split up when the forms are known in greater detail. The British species *M. primus* and *M. complicatus* are very similar to *M. shafferi* (for list of species of genus see p. 98).

### 1. **Mesopalæaster primus**, n. sp. Plate II, fig. 2; Plate III, fig. 8; Text-figs. 44, 45.

*Material.*—Imprints of two specimens are known, one (D. 70 and D. 70*c*) consisting of both imprint and counterpart, the other (D. 172) an imprint of the oral surface. Both are in the collection of Mrs. Gray, and are from the Starfish bed of Thraive Glen.

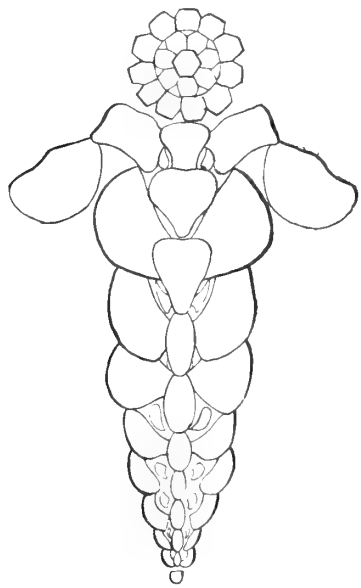
*Specific Characters.*—Central portion of disc covered with two distinct circlets of plates. Primary radialia and interradialia large and distinct. A single row of small adradialia. Adambulacralia about twice as numerous as the inferomarginalia.

The species in many respects approximates to *M. shafferi*, Hall (compare the figures given with Schuchert's figures, 85, pl. 8, figs. 1 and 2). The inferomarginalia, however, of the American species carry each a strong spine, and the two species differ in size. If I had only found one specimen of the British species I should have been inclined to place it as a young form of *M. shafferi*. Both

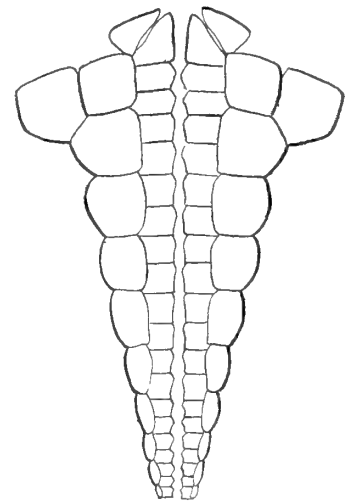
specimens, however, are small, and the specimens of the closely related species *M. complicatus* are also small. Together they form cumulative evidence that the British "true *Mesopalæaster*" were smaller and not so highly ornamented as their contemporaneous American brothers. (Compare also the account of the British species of *Promopalæaster*, p. 92.)

*Apical Surface* (Plate II, fig. 2; Text-fig. 44).—D. 70 is the only specimen which shows an imprint of the apical aspect of this species, but fortunately it yields very clear casts, which give the structure in almost complete detail. The central portion of the disc sunk somewhat during post-mortem change. Neverthe-

44



45



TEXT-FIG. 44 (on left).—Plan of the surface of the disc and one arm of *Mesopalæaster primus* (based on D. 70). × 12.

TEXT-FIG. 45 (on right).—Plan of the oral surface of one arm and the mouth-region of *Mesopalæaster primus* (based on D. 70*c*) × 12.

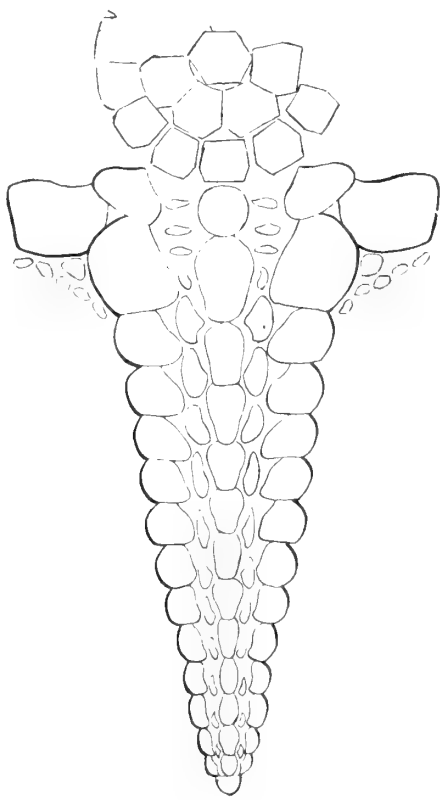
s, the ossicles are but little disturbed. A distinct centrale is seen, surrounded a circlet of seven plates. It is not clear that any of these plates were connected with an anal opening. The remainder of the sunk area of the disc is filled in by a second circle of small secondary plates.

Large primary interradialia are present. The proximal edge of these plates is convex, with a median nose. The distal edge is concave, and the two side edges slope together slightly in a distal direction. I have not been able to identify a madreporite with any certainty.

Between each interradial is situate a small radial. Just behind the small radial is a large primary radial. This is broader than long, and distinctly breast-plate-shaped. The remaining radialia are longer than broad, and alternate with the supero-marginalia throughout the greater part of the length of the arm.

A single row of small adradialia runs down each side of the radialia as far as the fifth supero-marginal.

Nearly all the supero-marginalia are finger-shaped, with the long axis of the finger pointing distalwards. They are large plates, especially conspicuous in the proximal region of the arm. The first four supero-marginalia occupy about two-thirds of the arm-length. All the apical plates possess granules which may have carried spine-pits.



Text-fig. 46.—Plan of the apical surface of the disc and one arm of *Mesopalæaster complicatus* (based on D. 74 and D. 133). × 12.

*Arm in Side View.*—Casts from D. 172 show a side view of the proximal portion of the arm. The supero- and infero-marginalia are seen to alternate. One or two scattered intermarginalia are present.

*Oral Surface* (Plate III, fig. 8; Text-fig. 45).—Both D. 70*c* and D. 172 give good casts of the oral surface. The odontophors are somewhat small, and have migrated proximalwards so far that the neighbouring infero-marginalia meet for about half their length along an interradius. The first six infero-marginalia are large and conspicuous. Beyond these there are a number of small infero-marginalia. Only three are drawn in the figure, but probably more could be seen if a clear view of the side of the distal portion of the arm could be obtained.

The mouth-angle plates are stout and triangular. They are succeeded by adambulacralia, which meet across the groove and completely hide the ambulacralia. There are two adambulacralia to each infero-marginal except at the extreme tip.

*Ornament.*—The ornament is of a rather coarse pustulose type.

*Measurements.*—R : r : : 6 mm. : 2·25 mm. Width of arm at base is 2·1 mm.

*Horizon and Locality.*—Upper Ordovician (Ashgillian) of Girvan, Ayrshire, Scotland.

2. **Mesopalæaster complicatus,** n. sp. Plate II, fig. 9; Plate III, fig. 5; Text-figs. 46, 47, 48.

*Material.*—Four specimens are known. Two are on one slab (D. 74), which has a counterpart. The third (D. 133) shows only an imprint of the apical surface. These are in the collection of Mrs. Gray, and are from the Starfish bed of Thraive Glen. The holotype is that nearest the margin of the slab possessing two specimens (D. 74). A fourth specimen from the same locality is in the collection of the British Museum (Nat. Hist.). It is registered as E. 13122, and shows the oral surface only.

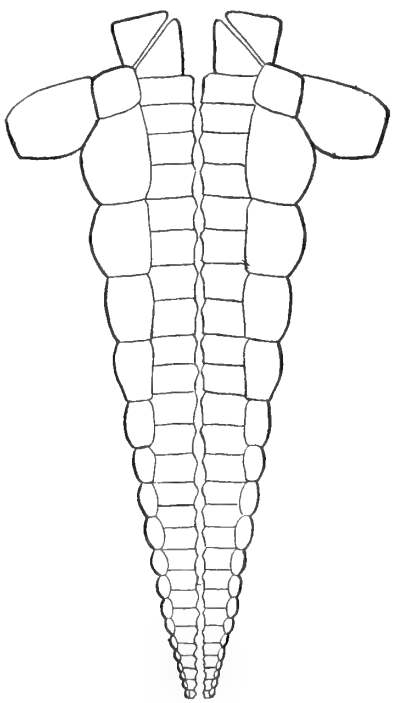
*Specific Characters.*—Forms somewhat more advanced than *M. primus.* The arms are more prolonged, the ossicles of the disc less distinct, the adradialia more prominent, and the intermarginalia better developed. There are also more adambulacralia in proportion to the infero-marginalia, and the mouth-parts are more complicated.

*Apical Surface* (Plate II, fig. 9; Text-fig. 46).—Neither the imprints on D. 74 nor that on D. 133 give complete casts of the apical aspect. A restoration can only be obtained by collation of the details presented by the three specimens. The central portion of the disc is, as usual, sunk because of post-mortem change, and the ossicles are in consequence somewhat disarranged. It is not quite clear whether there are two or three rings of intermediate plates round the centrale. The restoration (Text-fig. 46) shows two rings, and represents the appearance of the cast from D. 133. On the other hand, the cast from the holotype on D. 74 suggests that there may have been three rings of somewhat smaller ossicles in this specimen. The ossicles themselves are somewhat irregular in size and shape, and there is a strong suggestion that they were but loosely embedded in the covering skin.

The primary interradialia are of approximately the same shape as those of *M. primus*, but they are somewhat reduced in size. The primary radialia are large and, just as in *M. primus*, look as if they were the second member of this series. In two of the radii of D. 133 the primary radial is unusually large and distinctly tumid, with a stellate base. In other arms this ossicle is not so prominent. The

remaining radialia are of the usual type, that is, they are breastplate-shaped in the proximal region, and become polygonal distalwards.

With respect to the remaining structure of the arm, it is necessary to state that the arms in the specimen photographed (Pl. II, fig. 9) are somewhat flattened by post-mortem compression. The text-figure restoration gives the view as is shown by casts from the second specimen on D. 74, which has not been flattened in this way. The arm in consequence appears higher and narrower, and much more like that of *M. primus*.



Text-fig. 47.—Plan of the oral surface of one arm and the mouth-region of *Mesopalæaster complicatus* (based on D. 74). × 12.

The points noted in the specific characters given above are, however, quite clear in the photograph. The arm of *M. complicatus* is longer and the adradialia are more distinct than those of *M. primus*.

*Oral Surface* (Plate III, fig. 5; Text-figs. 47, 48).—At first sight there seem to be comparatively few points of essential difference between the oral aspect of *M. primus* and that of the species under description. I believe, however, that the possession by the latter of an increased number of adambulacralia in comparison to the infero-marginalia is a point of some importance. It was remarked that no view of the ambulacralia of *M. primus* could be obtained. Fortunately, the ambulacral groove of the holotype of *M. complicatus* is widely open in the mouth-region, and the structure thus presented is of great interest. It will be seen from Text-fig. 48 that the ambulacral ridges tend to form Vs, and the tube-feet would therefore be quadriserial rather than biserial in arrangement. Again,

the most proximal plate of the adambulacral series is obviously composed of a fused mouth-angle plate and a first adambulacral. This complication of the mouth-parts is a distinct approximation to that found in *Promopalæaster*, and shows the racial affinity of the two genera.

The plates of one of the interradial angles of the second specimen on D. 74*c* are slightly displaced, and show that there is a distal prolongation of the odontophor which fits in between the first infero-marginalia. This prolongation is usually hidden from view.

The specimen in the British Museum is interesting inasmuch as the odontophor is considerably larger than in the Thraive Glen specimen, and is not

Text-fig. 48.—Wash drawing of the mouth-parts of *Mesopalæaster complicatus* (taken from D. 74). × 16.

completely enclosed by the proximal infero-marginalia. In this respect the form is in the "*Hudsonaster*" stage. A row of very distinct intermarginalia is present, and there can be no doubt that the form belongs to the species under description.

*Ornament.*—Of a rather coarse pustulose type.

*Measurements.*—R : r : : 8·5 mm. : 2·4 mm. Width of arm at base is 2·5 mm.

*Horizon and Locality.*—Upper Ordovician (Ashgillian) of Girvan, Ayrshire, Scotland.

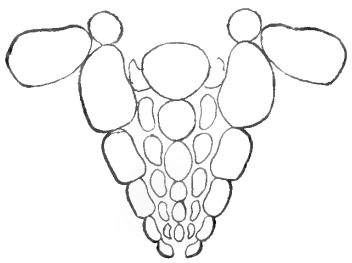
3. **Mesopalæaster (?) leintwardensis,** n. sp. Plate II, fig. 5; Text-fig. 49.

*Material.*—One specimen only is known of this species, an imprint in the British Museum (Nat. Hist.), No. E. 13153.

*Specific Characters.*—A small form with broad obtuse arms.

*Description.*—Casts from the imprint show the apical surface with the ossicles somewhat disturbed, and it is not easy to reconstruct the form. I believe, however, Text-fig. 49 to be a reasonable reconstruction and to give a fair idea of the species.

There are a few rounded disc-ossicles omitted in the drawing. The remainder



Text-fig. 49.—Reconstruction of apical surface of *Mesopalæaster* (?) *leintwardensis* (based on E. 13153). × 12.

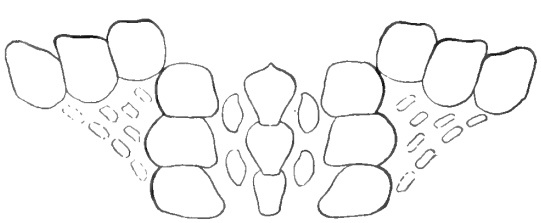
of the structure is obviously of a simple type. The noteworthy features are the large proximal supero-marginalia, the large rounded primary radialia, and the short broad obtuse arm.

The specimen may be the young of an unknown species.

*Horizon and Locality.*—Lower Ludlow mudstones of Leintwardine, Herefordshire.

4. **Mesopalæaster (?)** sp. Plate II, fig. 3; Text-fig. 50.

*Material.*—Among the numerous specimens in the Royal Scottish Museum, from the Scottish Silurian of Gutterford Burn, there is only one fragmentary imprint which can be referred to any member of this group of families. It is registered as 183.



Text-fig. 50.—Plan of base of arm (apical surface) of *Mesopalæaster* (?) sp. (based on Roy. Scott. Mus., no. 183). × 12.

*Description.*—The cast shows a very fragmentary view of the apical surface. The inner portion of the disc is entirely free from ossicles, and possibly was covered with a leathery skin which possessed few calcifications. The bases of the arms may be seen extending from the disc. There is a distinct intermarginal area, and in consequence the supero-marginalia are carried forwards well towards the centre of the disc. As is usual in such cases, the most proximal supero-marginal is a little smaller than the succeeding supero-marginalia. All these ossicles have the characteristic bent-finger shape. Radialia and adradialia of the usual form may also be recognised.

The form seems to be closely related to the Ordovician *Mesopalæaster*, but until more material is discovered it does not appear advisable to endeavour to give it an exact specific diagnosis. It may be noted that the American Silurian members of *Mesopalæaster* show a parallel development of a considerable intermarginal area, together with a thrust of the proximal supero-marginalia well towards the middle of the disc area.

*Measurements.*—r is 2·5 mm.

*Horizon and Locality.*—Silurian (Wenlockian) of Gutterford Burn, Pentland Hills, Scotland.

## Sub-family Promopalæasterinæ, Schuchert.

1914. Schuchert, C., Fossilium Catalogus, Animalia, pt. 3, p. 6.
1915. „ Bull. 88, U.S. Nat. Mus., p. 102.

"Progressive Promopalæasteridæ with the interbrachial areas complex and composed of the single axillary interbrachials [odontophors], more than one pair of interbrachial marginals, and adambulacral plates. Podial openings in each ambulacral furrow mainly in two columns, but proximally there may be two additional ones in a length never more than one-third the ray."

This sub-family contains one genus, *Promopalæaster*, Schuchert. The generic name is given (Προμος chief and αστηρ) because it includes the largest and chief Starfishes of the American Ordovician.

## Genus **PROMOPALÆASTER**, Schuchert.

*Palæaster* (part) of Authors.
1914. *Promopalæaster*, Schuchert, Fossilium Catalogus, Animalia, pt. 3, pp. 6 and 24.
1915. „ „ Bull. 88, U.S. Nat. Mus., p. 102.

*Generic Characters.*—See the definition of the Sub-family.

A statement as to the evidence for the evolution of *Promopalæaster* from a "*Hudsonaster*" through a "*Mesopalæaster*" stage is given on p. 78. It is also suggested there that *Promopalæaster* could not have evolved from any known *Mesopalæaster*. This is clear from the following argument. The earliest known *Promopalæaster*, *P. wilsoni*, is from the Middle Ordovician. In this form the adradialia are "small, convex, overlapping V-shaped plates, which are arranged with the point of the V directed towards the margin" (Schuchert, 85, p. 106). *P. magnificus*, the most advanced of the "Promopalæasters," is also described by Raymond as having the greater part of the apical surface "covered with smal

convex triangular plates," although according to Schuchert there are "spaces between the small triangular plates in this species" (p. 107). Very similar adradialia are found on the younger more distal portions of the arm in the British species, *P. elizæ* (Text-fig. 53). So far as I know, no adradialia of this type are found on any described species of *Mesopalæaster*, but *Urasterella primæva*, which has undoubtedly descended from a primitive Asterozoan stock, has similar plates. These facts are adverse to the conclusion of Schuchert (p. 106) that "it seems probable, from the mature material studied, that the most differentiated species of *Promopalæaster*, *P. magnificus*, passed through ontogenetic stages comparable to *Hudsonaster*, *Mesopalæaster granti*, and *Promopalæaster bellulus*." The "Mesopalæasters" and "Promopalæasters" appear to me rather to be divergent lineages which follow a more or less parallel course of evolution through certain of their earlier stages.

A table of the American species is given on pp. 98, 99. Although many are named, it seems as if the material really centres round a few forms. I could have distinguished several species among the British material, but it seems to me that the structure of the mouth-parts shows that really only one species is represented. The British forms are only half the size of the largest American species, but they are highly specialised. The want of real variety and the smaller size of the British forms suggest that they are immigrants from some other centre.

I have also to note that the specimen from which were drawn Text-figs. 18 and 20 of the Introductory Section to this Monograph, is a rather fragmentary example not of a *Uranaster* but of a *Promopalæaster*. "*Uranaster*" *elizæ*, therefore, is not simpler in structure than *Hudsonaster* (*Protopalæaster*) *narrawayi*, as stated by me on p. 21 of the Introductory Section, but is a highly modified form. There can be no doubt, however, that the ambulacralia and adambulacralia of the younger portions of the arm as figured (Text-fig. 54 A) are of a primitive type.

The genoholotype of *Promopalæaster* is given by Schuchert as *Palæaster granulosus*, Meek (not Hall, = *P. speciosus*, Meek).

1. **Promopalæaster elizæ**, n. sp. Plate IV, figs. 1–5; Text-figs. 51–58.

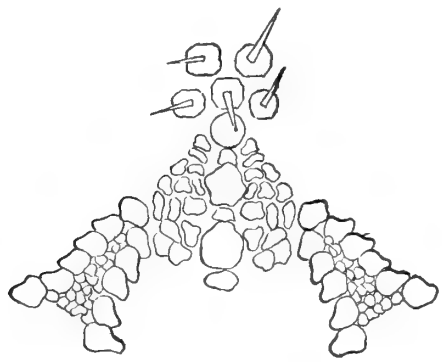
1914. *Uranaster elizæ*, Spencer, W. K., Introductory Section to this Monograph, pp. 20, 23; Text-figs. 18 and 20.

*Material.*—All the specimens known are in the collection of Mrs. Gray. There are fourteen imprints in all, and eleven of these possess counterparts. No specimen is perfect, but altogether they present such a variety of aspect that the species can be described in very considerable detail. The imprint D. 215, with its counterpart D. 215*c*, is taken as the holotype of the species. Casts of these imprints are figured, Pl. IV, figs. 1–5.

*Specific Characters.*—Interbrachial area consists of one pair of infero-marginalia and the odontophor.

*Apical Surface* (Pl. IV, figs. 1–4; Text-figs. 51–54).—Practically all the casts show considerable disturbance of the ossicles after entombment. Further, the best preserved specimen was collected in a fragmentary condition, and the pieces have been glued together. Unfortunately, some of the cracks go across the disc and add to the difficulties of study. In consequence of these many imperfections, I have not attempted to give a complete restoration of the form and have only figured those portions of the surface which appeared capable of reasonable interpretation. The ossicles of the disc have been least disturbed in the specimens D. 32 and D. 95*c*. The cast of D. 32 suggests that the centre of the disc was occupied by a circlet of five plates of medium size. Apparently each of these was

51



52

Text-fig. 51 (on left).—Diagram of disc and base of arm of *Promopalæaster elizæ* (based on D. 32 and D. 215). × 6.
Text-fig. 52 (on right).—Outline drawing of ossicles on apical surface of base of an arm of *Promopalæaster elizæ* (taken from D. 215).

surmounted by a single large spine, for two such spines may be plainly seen. These have fallen over and hidden the place where one might expect to find a centrale.

The second set of ossicles which help to guide the eye in the study of the apical region are the supero-marginalia. These are readily recognisable in the majority of the specimens. The most proximal members of the series do not margin the disc, but are thrust apexwards by the development of a very conspicuous intermarginal area. As is usual in such cases, the proximal supero-marginalia are rather smaller than the succeeding marginalia at the base of the arms.

Small but conspicuous primary interradialia are to be seen at the point of junction of the supero-marginalia of opposite arms. A large rounded madreporite (Text-fig. 54) is seen in D. 32 and D. 104. It is not visible in the remaining specimens, possibly because of post-mortem disturbance and loss. It is to be noticed that the development of the large intermarginal area has forced the primary interradialia well into the middle of the disc. The madreporite, which is associated by origin (see p. 40) with a primary interradial, has in consequence

also become more apical than marginal (see also the descriptions of species of *Promopalæaster* in Schuchert's work cited above). It is rather difficult to make out the exact arrangement of the intermediate plates lying between the primary circlet and the primary interradialia. Schuchert states in reference to the American species of *Promopalæaster* (p. 103) that these plates have no definite arrangement, a conclusion with which I am disposed to agree in respect to this English species. In the larger specimens these intermediate plates are irregularly arranged, but in the smaller specimens (*e. g.* D. 75) the plates are more polygonal.

The base of one of the arms of D. 215 is figured (Text-fig. 52). The ossicles appear at first sight to be scattered and displaced, but after careful investigation and comparison with the account of the American species, I am convinced that the irregular disposition of the plates is natural, and that in the genus there is a tendency to lose that symmetry of the apical ossicles which is so conspicuous in the more primitive genera.

53

54

Text-fig. 53 (on left).—Outline drawing of ossicles on right-hand side of the distal portion of an arm of *Promopalæaster elizæ* (based on D. 104). × 6.
Text-fig. 54 (on right).—Madreporite of *Promopalæaster elizæ*. × 25 (about)

The central portion of the arm shows no serial arrangement of the plates. Here and there larger plates, which are plainly radialia, may be seen. They are, however, slightly displaced from the central line and separated by smaller ossicles, which may represent the broken down intervening radialia. The remaining plates between the bordering plates are undoubtedly adradialia, but these also are not in definite series. The adradialia are present in considerable number and give pronounced width to the arm.

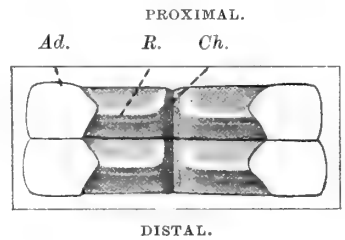
The supero-marginalia are larger than the remaining plates. When in position they look of irregular shape, but isolated ossicles show the finger-form with but little modification. The most proximal supero-marginal in the figure is the fourth member of the series. The ossicle is isolated from its proximal neighbour in the specimen, and in consequence its hollow articular face can plainly be seen.

The arrangement of the ossicles of the apical surface is more regular as the distal portion of the arms is approached, as seen in D. 104 (Text-fig. 53). This shows radialia in series bordered by small triangular adradialia arranged in rows. The appearance is strongly suggestive of that observed in *P. wilsoni* (Middle Ordovician of America) and *P. magnificus* (Upper Ordovician of America), and may

represent that typical of a primitive stage of the genus. No other specimen shows quite such a regular arrangement, but adradialia present on the distal extremities of several individuals occasionally show a distinct triangular shape. The inter-marginal area possesses four rows of ossicles at its widest point. It gradually narrows down to a single row, which persists as far as the sixteenth supero-marginal.

*Oral Surface* (Pl. IV, figs. 2, 3, 5; Text-figs. 54 A, 55, and 56).—The oral surface presents many interesting features. The interbrachial area is relatively simple, somewhat as in the American species *P. exsculptus*. Only the first two infero-marginalia touch one another on their outer edges. The bases of the next two infero-marginalia, however, closely approximate to one another. The odontophor has been forced inwards so that it is entirely proximal to the infero-marginalia (Text-fig. 55).

The mouth-parts, however, are very complex, and appear to be closely similar to those of *P. magnificus*. They are best shown in D. 51. Details are added




TEXT-FIG. 54 A.—Oral view of ambulacralia and adambulacralia of *Promopalæaster elizæ*. *Ch.*, ambulacral channel; *R.*, ambulacral ridge; *Ad.*, adambulacralia. (This figure is repeated from Text-fig. 18, p. 20, of the Introductory Section to this Monograph.)

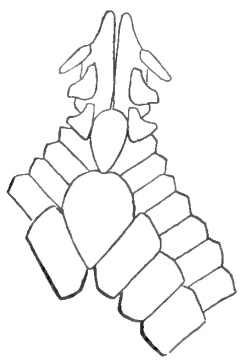
from D. 215*c* and D. 95. The mouth-angle plates are relatively stout, and not in series, as is usual, with the adambulacralia, for they themselves have adambulacralia attached to them (Text-fig. 55). Several ambulacralia fit on to the mouth-angle plates. A side view of these ambulacralia showing their mode of fitting on to the mouth-angle plate is given (Pl. IV, fig. 3), and may be usefully compared with fig. 1 of pl. xxiii in Schuchert's paper. A dissected oral view is also given (Text-fig. 54 A).

The first ambulacralia are short stout plates, quite unlike those seen in any other form. Their inner extremity is hollowed away, and this hollow is obviously a continuation of a hollow at the proximal edge of the mouth-angle plates. The two hollows together form a receptacle for the first tube-feet. The second ambulacral is also somewhat short. It fits on to a small triangular depression situated at the base of a ridge upon the mouth-angle plate which divides the depressions for the first and second tube-feet. The median ridge of the second ambulacral is almost parallel with that of the first ambulacral. The third and fourth ambulacralia are broad ossicles. Their median ridges form a V, as do the median ridges of each couple of succeeding ambulacralia up to the fifteenth member

of the series. The tube-feet in this portion of the arm were in consequence arranged in quadriserial rows. It is also noteworthy that the ambulacralia are high and thin.

From the fifteenth ambulacral onwards the tube-feet become biserial in arrangement, and the ambulacralia squarer in outline. The primitive appearance of the ambulacralia and adambulacralia in the more distal region of the arm is shown in Text-fig. 54 A. (See also p. 20 of the Introductory Section to this Monograph.) Pores for the passage of ampullæ are present between some of the ambulacralia of the proximal portion of the arm, and may be seen as small V-shaped slits on Pl. IV, fig. 3, at the upper extremity of the figure near the axillary interbrachial.

55



56

TEXT-FIG. 55 (on left).—Reconstruction in plan of mouth-region of *Promopalæaster elizæ* (based on D. 51). × 9.

TEXT-FIG. 56 (on right).—Wash drawing of the proximal region of the ambulacral groove of *Promopalæaster elizæ* (based on D. 51). × 12.

There are twelve adambulacralia to the first nine infero-marginalia. From that point the adambulacralia become equal in number and alternate in arrangement with the infero-marginalia. There are twenty-four infero-marginalia in the longest portion of an arm preserved.

*Interior View.*—D. 119 and D. 257 are both interesting as they show the form with the apical covering plates removed, so that one can look down into the body-cavity in the mouth-region. Both specimens show an unmistakeable Y-shaped odontophor in each of the interradial angles. Although one cannot be certain, I am almost convinced that this odontophor is merely the dorsal prolongation of the plate called by Schuchert the "axillary interbrachial." This view is supported by the observations made on *Girvanaster sculptus* (see p. 72).

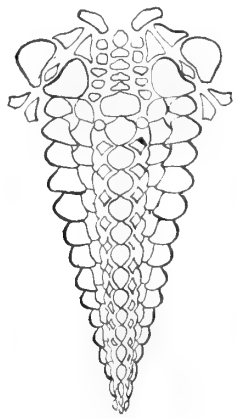
D. 257 is also interesting as it shows a cast of a Gasteropod shell inside the mouth-cavity. Even these older Asteroidea had their molluscan diet.

*Description of D. 26 and D. 26c* (Text-figs. 57 and 58).—At first sight casts from these imprints appear to belong to a distinct species, but the arrangement of the mouth-parts and the oral interradial areas is, so far as can be made out, that of the type. I am inclined therefore to regard the specimen either as a growth-

stage or as an individual variation which recapitulates ancestral characters more than is usual.

The specimen is much smaller than the type. The apical surface is figured. It is seen that the arrangement of the ossicles is much more regular than that in the larger specimens. The radialia retain their characteristic shape (Text-fig. 57) much more than do the radialia of the type, and the supero-marginalia are larger and more distinct. Again, the intermarginalia are fewer. The oral surface is not so distinct, but nevertheless the interradial areas can be seen. These show the odontophor in the same position as that in the type. The groove is closed and the ambulacralia consequently hidden from oral view. Some of the disc-plates, however, have fallen away from the apical surface and exposed long thin ambulacralia exactly as in the type (see Pl. IV, fig. 1).

57



58

Text-fig. 57 (on left).—Diagram of apical surface of young form of *Promopalæaster elizæ* (based on D. 26*c*). × 4.
Text-fig. 58 (on right).—Outline drawing of a portion of the apical surface of *Promopalæaster elizæ* (based on D. 26*c*). × 6.

*Ornament.*—The ornament is of a fine pustulose character. The large spines, so characteristic of very many of the American species of *Promopalæaster*, appear to be absent except on the circlet already described. It is to be noticed that a similar fine pustulose ornament is present on the infero-marginalia of American species, *e. g. P. exsculptus* (Schuchert, 85, pl. xx, fig. 2). The large spines of *P. dyeri* (Schuchert, pl. xx, fig. 6) are situate upon a perforate pustulose elevation very like that figured here, Text-fig. 33, p. 66.

*Measurements.*—D. 215 and D. 215*c*, R : r : : 29 mm. : 7 mm. Width of arm at base is 7 mm.

D. 26 and D. 26*c*, R : r : : 15 mm. (at least) : 4·8 mm. Width of arm at base is 5 mm.

*Horizon and Locality.*—Upper Ordovician (Ashgillian) of Girvan, Ayrshire, Scotland.

## Table of the English and American Species of the Mesopalæasterinæ and Promopalæasterinæ.

| | Formation. | R. | r. | Remarks. |
|---|---|---|---|---|
| *Caractacaster caractaci*, Gregory, sp. | Caradocian | 18·1 mm. | 4·8 mm. | — |
| *Mesopalæaster intermedius*, Schuchert | U. Ordovician | 14 „ (about) | 4 „ | Odontophor as in *C. caractaci*. About 20 infero-marginalia, but only 6 can be seen from the oral surface, while the rest pass on to the sides and distally even somewhat over to the apical surface. Apical surface unknown. |
| „ *shafferi*, Hall . | „ | 19 mm. | 3·5 „ | Holotype of the genus. |
| „ *primus*, n. sp. . | Ashgillian (U. Ordovician) | 6 „ | 2·25 „ | See p. 84. |
| „ *complicatus*, n. sp. | „ | 8·5 „ | 2·4 „ | See p. 87. |
| „ *finei*, Ulrich . | U. Ordovician | 7.5 „ | — | Not well preserved. |
| „ (?) *lanceolatus*, Schuchert | „ | 4·5 „ | 1·3 mm. | Large odontophor as in *Caractacaster*. Ambulacral groove wide and distinctly petaloid. |
| „ *proavitus*, Schuchert | „ | 18 „ | 4·5 „ | Akin to *M. granti*. |
| „ (?) *wilberanus*, Meek and Worthen | „ | — | — | Not well known. |
| „ (?) *dubius*, Miller and Dyer | M. Ordovician | — | — | Not well known. |
| „ (?) *antiquus*, Troost | „ | — | — | Not well known. |
| „ (?) *parviusculus*, Billings | L. Silurian | 6 mm. | 2·5 mm. | Apical surface unknown. Oral surface as in *M. primus*. |
| „ (?) *leintwardensis*, n. sp. | „ | — | — | See p. 89. |
| „ (?) sp. . . | „ | — | — | See p. 90. |
| „ (?) *cataractensis*, Schuchert | „ | 9 mm. | 3 mm. | Closely related to *M.* (?) *parviusculus*, but differs in being larger with more plates in the columns. Only the oral side known (Schuchert, p. 89). |
| „ *granti*, Spencer | „ | 16 „ | 5 „ | Supero-marginals carried well within the walls of the disc. |
| „ *bellulus*, Billings | M. Silurian | — | — | Related to *M. granti*. |
| „ (?) *acuminatus*, Simonovitsch | L. Devonian | 17·5 mm. | 8.5 mm. | Possibly an end member of a lineage. |
| „ (?) *Clarki*, Clarke and Swartz | U. Devonian | 24 „ (about) | 5·8 „ (about) | Schuchert remarks (p. 95): "This clearly determined species is a late survival of early Palæozoic primitive asterids. The characters, so far as determinable in the natural mould, are those of *Mesopalæaster*, but as the disc skeleton is not preserved, it is very probable that when this feature is known the form will be seen to belong to a new genus." |
| *Spaniaster latiscutatus*, Sandberger | L. Devonian | 11 mm | 4 mm. | — |
| *Miomaster drevermanni*, Schöndorf | „ | 35 „ | 8 „ | — |
| *Devonaster eucharis*, Hall . | M. Devonian | 40 „ (from Schuchert's fig.) | 11 „ | — |
| „ *chemungensis*, Schuchert | U. Devonian | 59 mm. (from Schuchert's fig.) | 11 mm. | — |
| *Promopalæaster wilsoni*, Raymond | M. Ordovician | 37·5 mm. | 10 mm. | See p. 91. |
| „ *prenuntius*, Schuchert | „ | 30 „ | 7 „ | Schuchert regards this species as ancestor of *P. speciosus*. |
| „ sp. undet. (see Schuchert, *op. cit.* p. 108) | U. Ordovician | 22 „ | 4 „ | Schuchert regards this as probably the young of *P. speciosus*. He remarks with respect to a still smaller specimen that "It has but a single axillary plate in each interbrachial area and about 15 adambulacrals in a column. It is interesting to note that in these young individuals of *Promopalæaster*, the smaller they are the more they approach *Mesopalæaster* and suggest *Hudsonaster*." |

| | Formation. | R. | r. | Remarks. |
|---|---|---|---|---|
| *Promopalæaster speciosus*, Meek, sp. | U. Ordovician | 44 mm. | 11 mm. | — |
| „ *granulosus*, Hall | „ | — | — | Not well known. |
| „ *bellulus*, Schuchert | „ | 36 „ | 10 „ | Somewhat similar to *P. speciosus*, except that the interbrachial areas in *P. bellulus* are much more elongated orally (Text-fig. 32, p. 62). Apparently also a plate similar to a torus may be present. |
| „ *spinulosus*, Miller and Dyer | „ | 38 „ | 7 „ | Somewhat similar to *P. exsculptus*. |
| „ *exsculptus* . | „ | 37 „ | 12 „ | — |
| „ *wykoffi*, Miller and Gurley | „ | 26 „ | 8 „ | It is apparently not at all certain that this species is really distinct from *P. exsculptus*. |
| „ *dyeri*, Meek . | „ | 75 „ (probably) | 22 „ (probably) | A very large form the relationship of which is with *P. spinulosus*. |
| „ *magnificus*, Miller | „ | 67 mm. | 17 mm. | See pp. 79, 93. |
| „ *elizæ*, n. sp. . | „ (Ashgillian) | 29 „ | 7 „ | See p. 92. |

## Family Xenasteridæ, Schöndorf.

1890. *Palægoniasteridæ*, Stürtz, Palæontographica, vol. xxxvi, p. 247.
1899. *Xenasterinæ*, Gregory, Geol. Mag., dec. iv, vol. vi, p. 346.
1900. „ „ Lankester's Treat. Zool., vol. iii, Echinoderma, p. 250.
1909. *Xenasteridæ*, Schöndorf, Palæontographica, vol. lvi, p. 105.
1909. „ „ Jahrb. nassauisch. Ver. Naturk., vol. lxii, p. 25.
1910. „ „ *Ibid.*, vol. lxiii, pp. 244, 250.
1914. „ Schuchert, Fossilium Catalogus, Animalia, pt. 3, p. 6.
1915. „ „ Bull. 88, U.S. Nat. Mus., p. 128.

The Xenasteridæ have been excellently described by Schöndorf in the volume of 'Palæontographica' which is referred to above. He defines the family as follows:

"Unterdevonische Seesterne mit deutlich entwickelten oberen und meist kräftigeren unteren Randplatten, von welchen letztere etwas zahlreicher als die oberen und infolgedessen mit diesen unregelmässig verbunden sind. Ambulacralfurchen mit zwei Reihen Ambulacralporen. Ambulacra unter sich und mit den Adambulacren korrespondierend. Mund adambulacral. Interradius ventral mit einer Gruppe von drei oder fünf besonders gestalteter Täfelchen. Interradialbogen dorsal zwischen den Armen allein von den unteren Randplatten gebildet. Zwischen diesen und den Anfangsgliedern der oberen Randplatten liegt ein von kleineren Täfelchen erfülltes Interbrachialfeld. Kleine Zwischenrandplatten zuweilen vorhanden. Scheitel schwach skelettiert, Scheitelplatten klein, rundlich, vorhanden sind das Centrale, die primären Radialia, primären Interradialia, zwei Centroradialia, ein Centrointerradiale. Die übrigen Dorsalplatten in drei Reihen, eine Mittelreihe und je eine obere Randplattenreihe jederseits, zuweilen durch kleinere Zwischenplättchen getrennt. Madreporit dorsal in einem Interradius."

Our knowledge of the Palæozoic Asteroidea has greatly increased since Schöndorf published his researches, and it is now possible to draw comparisons between these Devonian forms and the older Ordovician and Silurian genera. They resemble the more advanced species of the Promopalæasterinæ, inasmuch as on the apical surface the development of the intermarginal (interbrachial) area causes the first pairs of supero-marginalia to be situate well within the disc-area (see Text-fig. 29, p. 34, of the Introductory Section to this Monograph), whilst on the oral surface several pairs of infero-marginalia are enclosed in the disc (Text-fig. 4, p. 12). Schuchert (pp. 128—130) notes these resemblances, but points out that the Xenasteridæ have accessory interbrachials (ventrolateralia ?) whilst the Promopalæasterinæ have no such plates. He also points out the considerable resemblance between *Devonaster* (see above, p. 80) and *Xenaster*. According to Schuchert (85, p. 130): "If it were not for the accessory interbrachials, *Xenaster* would be closely related to *Promopalæaster*, which also has a number of inframarginals crowded into the interbrachial areas. It is the *Promopalæaster*-stock out of which *Xenaster* probably developed, while *Devonaster* apparently came through *Mesopalæaster*."

In my opinion, Schuchert is wrong here. The apparent similarity between the interbrachial structures in the two series of forms is brought about by parallel development. We have seen that the Promopalæasterinæ reach their maximum development in the Upper Ordovician, and even at this early period begin to show signs of degeneration. The specialised character of the mouth-parts of *Promopalæaster* is not repeated in *Xenaster*, which has mouth-parts of the Recent Asteroid type (Schöndorf, 'Palæontographica,' p. 89). Further, there is no known form from the whole of the Silurian which would serve to link up the two series. The Xenasteridæ are undoubtedly related to *Devonaster*, and this relationship suggests the derivation of both from a common *Mesopalæaster*-stock some time during the Silurian period.

The family of Xenasteridæ contains the following genera: *Xenaster*, Simonovitsch; *Agalmaster*, Schöndorf; *Rhenaster*, Schöndorf; *Eifelaster*, Schöndorf; *Trimeraster*, Schöndorf.

No member of the family has been found up to the present in either Britain or America.

### End Species of Undetermined Lineages.

Attention has already been called to the breaking down of the ossicles on the apical surfaces in advanced forms such as those of the *Promopalæaster* lineages. In the following forms this irregular subdivision of the ossicles has apparently gone still further, but unfortunately our knowledge is not sufficient for us to determine the exact lineages to which the species belong.

(1) The first of these species is a form found in the Wenlock (Middle Silurian) which I place provisionally in the genus *Mesopalæaster*.

**Mesopalæaster (?) ketleyi,** n. sp. Text-fig. 59.

*Material.*—Only one specimen is known, in the Museum of the Birmingham University (Ketley Coll., no. 220).

*Specific Characters.*—Primary radialia and interradialia large but irregular in form. Radialia broken down. Supero- and infero-marginalia alternating. Large intermarginalia apparently present.

The lineage to which this form belongs obviously branched off from the primitive stock before the primary radialia and interradialia lost their large size, primitive form, and primitive position, and before the proximal supero-marginalia were thrust apicalwards. Unfortunately there are no connecting links between it and any known Ordovician form. The oral surface is not known, but the form shows general resemblances to both "*Hudsonaster*" and "*Mesopalæaster*" stock.

*Apical Surface* (Text-fig. 59).—The specimen can best be orientated by the position of the madreporite, which is situated between arms I and II of the Text-fig. 59. Immediately proximal to the madreporite is a large irregularly shaped primary interradial bordered on each side by an irregularly shaped primary radial. The primary radialia and interradialia can be followed as a circlet of prominent plates round the disc at a point approximately median between the centre and the margin. They are all irregular in appearance, and can be recognised mainly by position. Here and there a few accessory plates are interspersed in the circlet.

Proximal to the circlet the disc is sunk and occupied by plates of very various size and shape. There is one large plate which occupies the centre which may be a centrale, but taken as a whole it is difficult to say that the plates in the sunk area have any definite arrangement. The sunk area is about 1·6 mm. in diameter. The arms vary considerably in appearance.

The key to the structure exhibited by the arms appears to be given by the interradius between arms V and IV. The ossicles on the extreme right side of arm V are clearly infero-marginalia with the supero-marginalia immediately above them. The outside ossicles of the left side of arm IV are also infero-marginalia. In the axil between the arms is a large plate which at first sight suggests the appearance of being a large odontophor which has been thrust somewhat upwards and outwards. If this were so, the form would obviously be akin to one of the Hudsonasteridæ. I do not think, however, that this ossicle really belongs to the oral surface. If it did, it would exhibit articulation, on its apical surface, for the fitting of the covering supero-marginalia. It certainly does not do this, and

the only other conclusion is that it is a large intermarginal. This conclusion seems to be borne out by examination of the other interradial areas, which appear to be filled up by somewhat smaller intermarginalia. There is another piece of evidence which suggests that the form has gone beyond the "*Hudsonaster*" stage. This is the appearance of the first pair of supero-marginalia which are thrust somewhat apicalwards, as in some of the Mesopalæasterinæ.

The infero-marginalia having been accurately determined, it is comparatively easy to orientate the remaining plates. The supero-marginalia on the right side of arm v are, of course, the ossicles which are above the infero-marginalia, and the corresponding series can be traced on the other side of the arm. Radialia and adradialia appear to be present, although the arrangement is not very regular. The supero-marginalia on both sides of arm iv can also be identified. Between these two series there is *only one row* of rather scattered ossicles.

The appearance of the apical surface of arm i also suggests that only broken-down radialia are present here, and that there are no adradialia. The supero-marginalia on the right side of the arm are somewhat scattered, because the row of the infero-marginalia, which are exhibited in full length, have been thrust upwards. A corresponding row of supero-marginalia may be seen on the left side of the arm. Between them there is but one row of small scattered plates. Arm ii, on the other hand, suggests that both radialia and adradialia are present, and the very varied aspect of the arms, and the want of regularity in the plates, show the form to have an unsettled structure, and to be in a critical stage in its lineage history.

A further interesting point is the passage of the infero-marginalia upwards to form the apical boundary of arm v as it is followed distalwards. The supero-marginalia tend to lose themselves in the mass of plates in the apical region. This arrangement is strongly reminiscent of that in *Uranaster* (*vide* p. 107).

*Measurements.*—R : r : : 9 mm. at least : 3·5 mm.

Width of arm i at base, 2·2 mm.

" " ii " 2·6 "

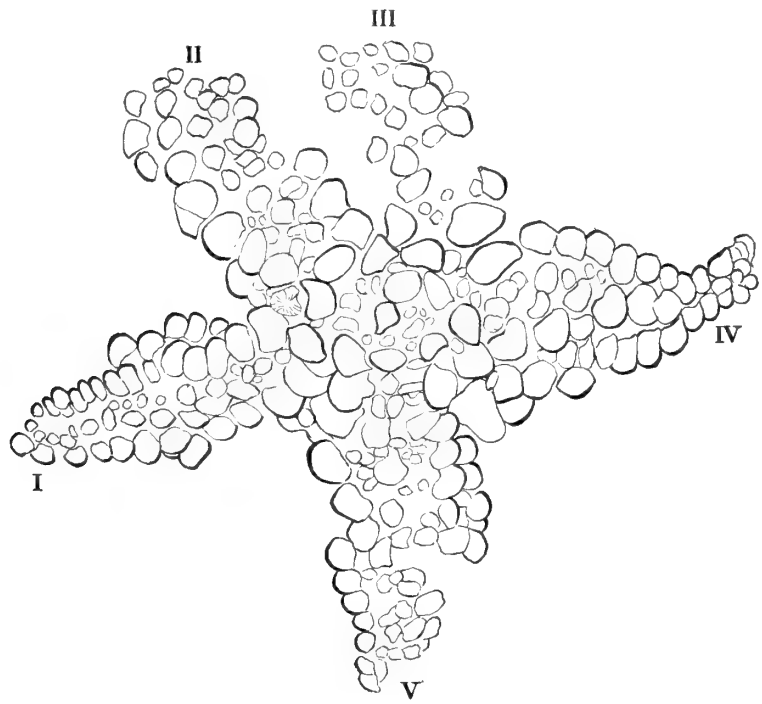
" " v " 3·2 "

*Ornament.*—The ossicles appear to be bare of ornament.

*Horizon and Locality.*—Middle Silurian (Wenlock Limestone) of Dudley.

(2) *Mesopalæaster* (?) *kelleyi* bears a general resemblance to *Neopalæaster crawfordsvillensis*, Miller, especially in the form and arrangement of the primary plates of the disc. It differs, however, in the fact that in the latter form "each supramarginal plate lies wholly and directly over an inframarginal, and the pieces appear as one consolidated plate with the abactinal side convex and the actinal nearly flat" (Schuchert, 85, p. 137). The two forms differ widely in horizon, *Neopalæaster crawfordsvillensis* being found in the crinoid beds of the Keokuk

group of the Lower Carboniferous at Crawfordsville, Indiana. Schuchert makes the species the genotype of a new genus *Neopalæaster*, for which he founds a new family, the Neopalæasteridæ. This family is defined (85, p. 134) as follows: "Progressive Phanerozonia without interbrachial arcs. The columns of supra- and infra-marginal ossicles wholly superposed. Madreporite abactinal. Well-developed ocular plates present. Ambulacrals alternating. Disc with a ring of large plates of basal, radial, and interradial ossicles." Schuchert states that "the origin of this family is uncertain, but it seems to be related to the Promopalæasteridæ, since its essential characters are those of the Mesopalæasterinæ." It




TEXT-FIG. 59.—Outline drawing of ossicles on apical surface of *Mesopalæaster* (?) *ketleyi* (drawn from specimen in the possession of the Birmingham University). × 6.

seems to be an end-species of one of the "Promopalæasterid" lineages, and the formation of a family for this single form appears to be an unnecessary complication of the classification of these Palæozoic starfishes.

(3) Schuchert, in his revision of the American Palæozoic genera, subdivides the genus *Palæaster*, Hall, and confines it to one species, *P. niagarensis*, Hall. The much reduced genus, with a new genus *Australaster*, founded from the two Australian species *Palæaster* (*Monaster*) *giganteus*, Etheridge jr., and *Palæaster* (*Monaster*) *stutchburii*, Etheridge jr., is made to comprise the family Palæasteridæ, Gregory (emend. Schuchert). This family is defined (85, p. 66) as follows: "Primitive, derived, five-rayed Phanerozonia with the ambulacrals slightly alternate or opposite. Interbrachial arcs incipient or somewhat enlarged,

and occupied by single axillary marginal plates. No accessory interbrachial or axillary interbrachial plates present, but there are developed accessory abactinal ray ossicles. Actinal plates consisting of ambulacrals, adambulacrals, and inframarginals. Madreporite abactinal."

Now, *P. niagarensis* is from the Silurian of America and is obviously related to the Hudsonasteridæ of that continent. It has no radialia, but in their place there is a double to a treble row of small polygonal plates. Radialia are such a constant feature in all really primitive forms that we are justified in assuming that these small polygonal plates represent broken-down radialia, and that this may be taken as a sign that *P. niagarensis* is an end-species of some "*Hudsonaster*" lineage.

*Australaster* is from a widely different horizon, the Permo-Carboniferous. Only the oral surfaces of the two species are known, and these show features of shape and ornament of the plates widely different from any species from Europe and America. Until we know more about the evolution of these forms from the Southern Hemisphere their exact systematic position must remain doubtful.

## Family Uranasteridæ, nova.

Schuchert (85, p. 138) amends the family Palasterinidæ, Gregory, and gives it the following definition :

"Progressive Phanerozonia developing large interbrachial arcs. Ambulacral plates more or less alternate. Madreporite abactinal. Disc large, pentagonal, and the rays separated by well-developed interbrachial arcs. The inframarginal plates bound the animal and are separated from the adambulacrals more or less completely by a varying number of interbrachial plates. Abactinal surface with longitudinal columns of radial, supramarginal, and accessory columns of plates, or the radial columns may be reduced or even replaced by transverse rows of small accessory pieces. The central region of the disc may retain a ring of larger basal radials and supramarginal pieces."

He places in the family the following genera : *Petraster*, Billings ; *Lindstromaster*, Gregory ; *Palasterina*, McCoy ; *Uranaster*, Gregory ; *Palæostella*, Stürtz ; *Pseudopalasterina*, Stürtz.

Many of the forms were only known to Schuchert from illustrations and descriptions, and fundamental redescription is required in some cases. I propose to give new descriptions in the following pages.

The first genus to be considered is *Uranaster*, and I propose to place it with forms to be dealt with later in a new family, the Uranasteridæ, defining this as follows :

Asterozoa with well-differentiated infero-marginalia which form both the apical and oral boundaries to the disc and arms. Supero-marginalia also apparently

differentiated in the disc and proximal regions of the arms. There is no visible odontophor, but there are well-developed ventrolateralia which fill out the interradial regions and cause the interbrachial arcs to be large and well rounded. Madreporite apical.

## Genus **URANASTER**, Gregory.

1899. *Uranaster*, Gregory, Geol. Mag., dec. iv., vol. vi, p. 348.

*Generic Characters.*—Disc comparatively small, arms long.

Genotype, *U. kinahani* (Baily), which is closely akin to the form described by Schuchert (85, p. 142) as *Petraster speciosus*, Miller and Dyer.

### 1. **Uranaster kinahani** (Baily). Plate V, figs. 1—5 ; Text-figs. 60—63.

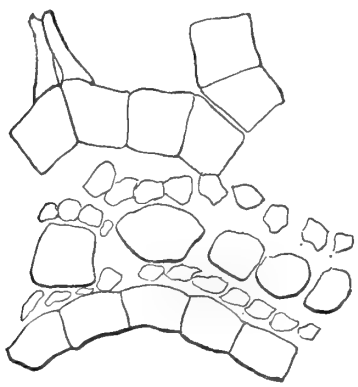
1878. *Palasterina kinahani*, Baily, in Kinahan, Man. Geol. Ireland, pp. xv, 26, pl. 2, fig. 1.
1879. „ „ Baily, Mem. Geol. Surv. Ireland, Expl. Sheets 169, 170, 180, 181, pp. 58, 59, g. 6.
1899. *Uranaster kinahani*, Gregory, Geol. Mag., dec. iv, vol. vi, p. 348.
1910. „ „ Schöndorf, Jahrb. nassauisch. Ver. Naturk., vol. lxiii, p. 225.
1914. „ „ Schuchert, Fossilium Catalogus, Animalia, pt. 3, pp. 7, 43.
1915. „ „ Schuchert, Bull. 88, U.S. Nat. Mus., p. 155.

*Material.*—Imprints of portions of four individuals in the British Museum (Nat. Hist.) (nos. E. 194, E. 13110) were regarded by Gregory as the topotypes of the species. There are also five specimens in the collection of the Geological Survey of Ireland (nos. S. 1443, S. 1439*a*, S. 1439*b*, S. 1441 and S. 1441[1], the last of these being an imprint of the specimen figured by Baily).

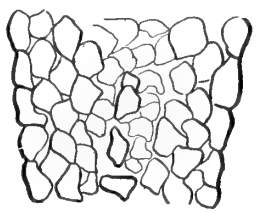
*Apical Surface* (Pl. V, figs. 2, 4; Text-figs. 60, 61).—The apical surface of the disc and arms is bounded not by supero-marginalia but by infero-marginalia. These are small and globular at the extremities of the rays (Pl. V. fig. 4) but soon become straight-sided and closely fitting, thus affording firm support to the body. As seen in apical view they always appear longer than broad. An oral view of the form shows, however, that in the interradii their breadth is really greater than their length (Text-fig. 63). Their surface, either in apical or oral view, is almost flat. There are no articulations for prominent spines as in *Petraster speciosus*. The apical plates inside the infero-marginalia differ considerably in arrangement in the various portions of the arm. Plates analogous to the supero-marginalia of the Promopalæasteridæ may be recognised in the proximal region (Text-fig. 60). They are highly convex with a rounded base which at times may be stellate. Similar plates are found in *P. speciosus*, where "at the apex of the rays the supramarginals are highly convex and nearly circular in outline but soon pass into

more and more distinctly stellate plates" (Schuchert, 85, p. 144). They are situate well within the margin, being separated from the infero-marginalia by several rows of inter-marginalia. In *P. speciosus*, as judged by the figures, one can recognise differentiated supero-marginalia throughout the length of the ray, although even in this species there is considerable similarity in the appearance of all the apical ossicles at the extremity of the ray. In *U. kinahani* it is very difficult to decide which are the true supero-marginalia of the distal half of the arm. An examination of Pl. V, fig. 4, shows that there are three rows of precisely similar ossicles interior to the infero-marginalia, and that it is not the row adjacent to the infero-marginalia which is in series with the ossicles described above as supero-marginalia, but the second row. We can suppose either that the supero-marginalia are not as yet completely differentiated throughout the arm, or

60



61



Text-fig. 60 (on left).—Outline drawing of ossicles on the apical surface of a portion of the disc of *Uranaster kinahani* (based on E. 194). × 6.
Text-fig. 61 (on right).—Outline drawing of the ossicles on the apical surface of the median portion of an arm of *Uranaster kinahani* (taken from E. 13110*a*). × 8.

that perhaps a differentiation already acquired is now in process of being lost. It is impossible to decide which of the two theories is correct until we know more of the ancestry of the forms.

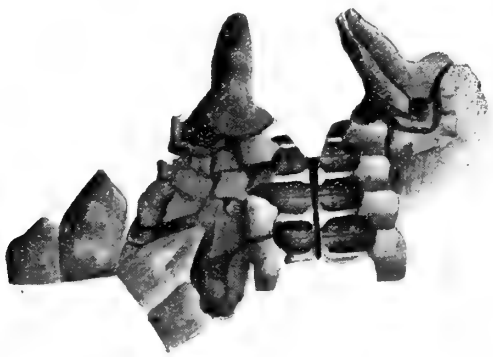
The middle of the arm is occupied by small irregularly shaped plates which probably represent radialia, for the greater part broken down. Only at the extremity of one arm of one specimen (E. 13110*b*) is there any suggestion of radialia in series such as are present in *P. speciosus*.

*Oral Surface* (Pl. IV, figs. 1, 5; Text-figs. 62, 63).—A noteworthy feature of the oral surface is the presence of numerous ventro-lateralia in the interradial angles of the disc, best seen in Text-fig. 63. They are numerous and almost granular in appearance. At the proximal apex of the ventro-lateralia may be seen a ridge to which the mouth-angle plates were attached. These latter plates are much longer than the succeeding adambulacralia and are much more Ophiuroid-like in character than Asteroid (compare the text-figure with Pl. I, fig. 10). The

proximal adambulacralia are smaller than those a little way down the arm, and thus the groove is slightly petaloid. Each adambulacral has the usual prominent nose and possesses pustules which undoubtedly carried small spines.

The ambulacralia are almost square, and the groove, except near the mouth, appears to have been shallow. Each ambulacral bears a prominent ⌊-shaped ridge, and appears to fit so closely with its neighbour that there are no pores for the passage of ampullæ. The groove is always found widely open. Between the ambulacralia of opposite sides of the arm there is a deeply excavate ambulacral channel.

The infero-marginalia in the interradii are paired, and the odontophor, if present, is not visible in external view as in the families already dealt with. These interradial marginalia are much broader than they are long (length is 1 mm.; breadth is 2 mm.). The disproportion between length and breadth is soon lost, for



Text-fig. 62.—Wash drawing of the ossicles in the mouth-region of *Uranaster kinahani* (taken from S. 1443). × 6.

the second infero-marginal is almost square. From the fourth ossicle onwards, the length is greater than the breadth. Except in the interradii the infero-marginalia adjoin the adambulacralia. At all the points at which the two series touch, that is almost throughout the length of the arm, the infero-marginalia are equal in number to, and alternate with, the adambulacralia. There are about thirty infero-marginalia reckoning from an interradius to the tip of the arm. The exact number is difficult to ascertain because of imperfections in preservation.

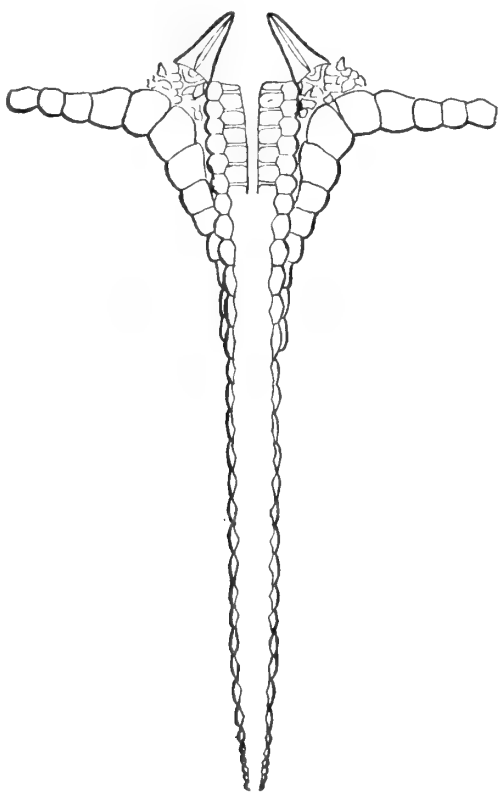
From about the middle of the arm the infero-marginalia pass over on to the lateral margin. The adambulacralia then bound the arms. This is another feature not observed in the Hudsonasteridæ and Promopalæasteridæ.

*Ornament.*—The ornament is not well preserved, but one or two infero-marginalia are covered with coarse contiguous pustules.

*Measurements.*—The two specimens which allow exact measurement give the following dimensions for the major and minor radius respectively:

S. 1443 R. : r : : 32·5 mm. : 7·5 mm.
S. 1439*a* R. : r : : 35 mm. : 8 mm.

I am indebted to Mr. W. B. Wright, the Senior Geologist of the Irish Geological Survey, for the following remarks upon the horizon and locality of this species: "Mr. Clark tells me that all the specimens of *U. kinahani* are from the same locality, namely the townland of Loftus-Acre, 700 yards west of Ballymadder Point, County Wexford. The whole townland has since been removed by the sea, and the rocks in which the fossils were found are no longer exposed. As regards the Ballymoney series, I cannot find any ground for supposing the rocks in question belong to this series, which is stated in the Memoir only to occur in the N.E.



Text-fig. 63.—Plan of the oral surface of one arm and the mouth-region of *Uranaster kinahani* (based on S. 1443). × 3.

corner of sheet 169. The following considerations may be of use in fixing the horizon: (*a*) The rocks on the shore in the neighbourhood of Loftus-Acre have a general westerly dip, and 700 yards to the east, at Ballymadder Point, they rest unconformably on metamorphosed Cambrians; *bb*) the locality also yielded *Glyptocrinus basalis?* and *Dicranograptus ramosus*. Mr. Clark tells me that the latter is a typical Lower Caradoc or Upper Llandeilo form, and on consulting Miss Elles's Monograph, pp. 518—527, I find that she refers this species to the same horizon." Mr. Wright also adds that the Survey originally possessed forty-four specimens of the species.

## PLATE II.

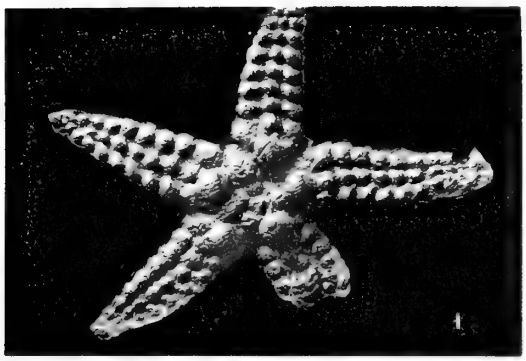
Photographs of Casts showing Apical Surface.

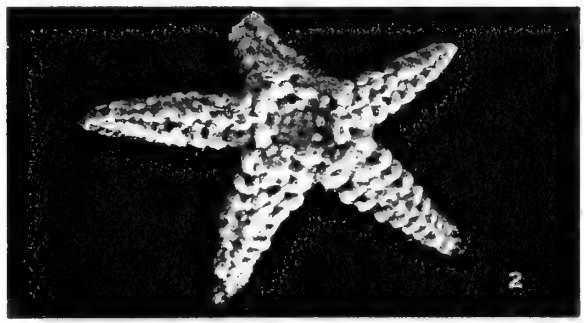
FIG. PAGE

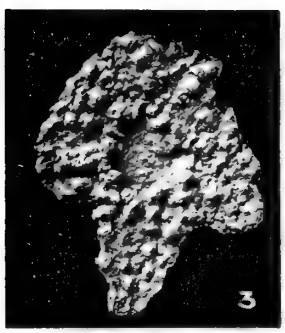
1. *Coccaster bulbiferus*, n. sp.—Upper Silurian (Lower Ludlow); Leintwardine, Herefordshire. ×4½. Royal Scottish Museum, Edinburgh, no. 65/158 *a*. 75.
2. *Mesopalæaster primus*, n. sp.—Upper Ordovician (Ashgillian); Thraive Glen, Ayrshire. × 4½. Mrs. Gray's Collection, no. D. 70. 84.
3. *Mesopalæaster?* sp.—Upper Silurian (Wenlock); Gutterford Burn, Pentland Hills. ×4. Royal Scottish Museum, no. 183. 90.
4. *Caractacaster caractaci*, Gregory sp.—Ordovician (Caradocian); Marshbrook, Church Stretton, Shropshire. × 2. Museum of Practical Geology, London, no. 4/30. 80.
5. *Mesopalæaster? leintwardensis*, n. sp.—Upper Silurian (Lower Ludlow); Leintwardine, Herefordshire. × 4. British Museum (Nat. Hist.), no. E. 13153. 89.
6. *Belaster ordoricus*, n. sp.—Upper Ordovician (Ashgillian); Thraive Glen, Ayrshire. × 3½. Mrs. Gray's Collection, no. D. 44. 73.

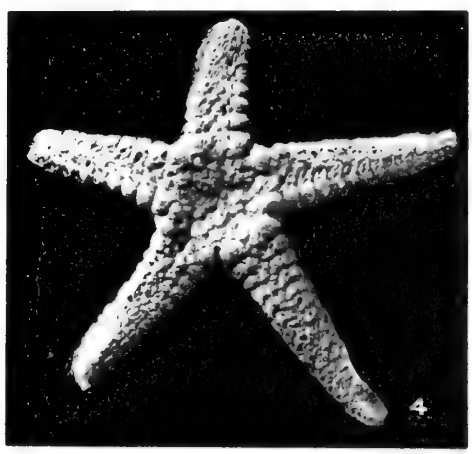
6 *a*. Ditto; extremity of arm of same specimen. × 7. 73.

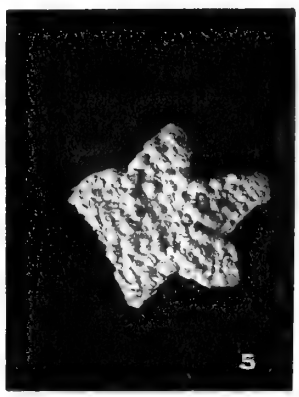
7. *Girvanaster sculptus*, n. sp.—Ibid. × 4. Mrs. Gray's Collection, no. D. 152. 70.
8. *Caractacaster caractaci*, Gregory sp. (?).—Upper Ordovician (Lower Bala); near Bala Lake, Wales. × 4½. T. Ruddy Collection, British Museum (Nat. Hist.), no. E. 13531. 83.
9. *Mesopalæaster complicatus*, n. sp.—Upper Ordovician (Ashgillian); Thraive Glen, Ayrshire. × 4. Mrs. Gray's Collection, no. D. 133. 87.

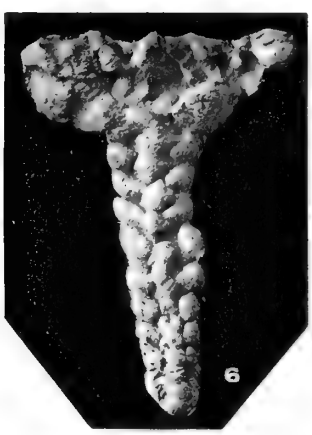

1


2

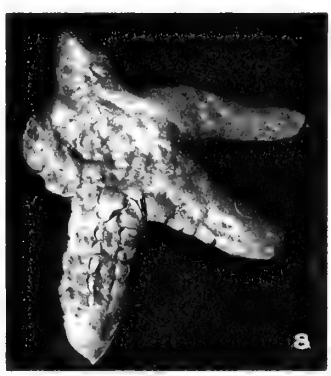

3


4

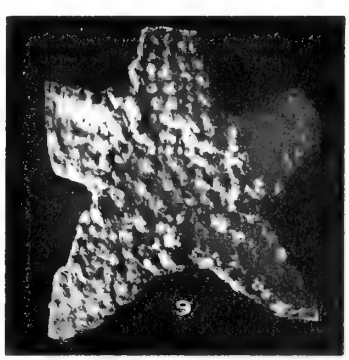

5


6


6A


8

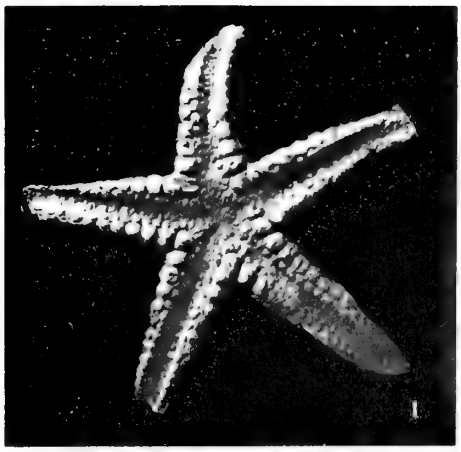

7

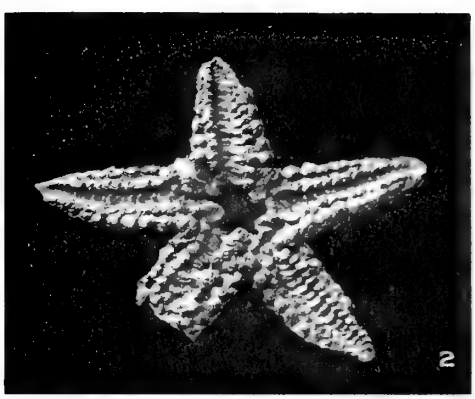

9

## PLATE III.

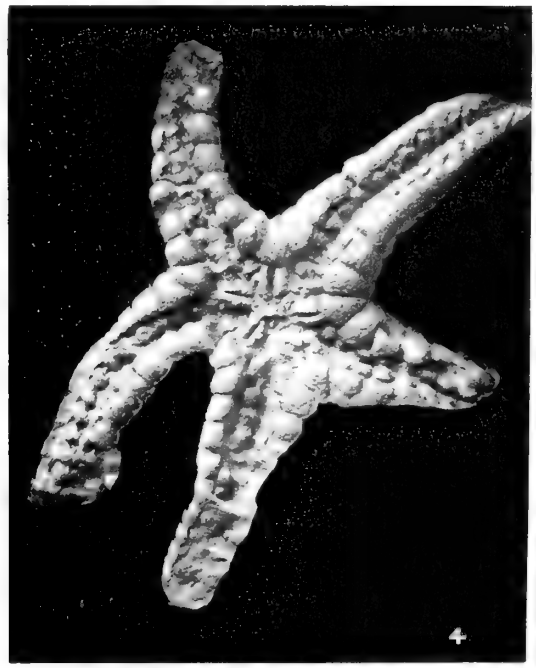
Photographs of Casts showing Oral Surface.

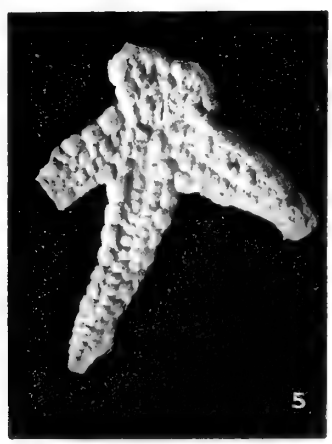
| Fig. | | Page. |
|---|---|---|
| 1. | *Caractacaster caractaci*, Gregory sp.—Ordovician (Caradocian); Marshbrook, Church Stretton, Shropshire. × 2. Museum of Practical Geology, London, no. 4/30. | 82. |
| 2. | *Coccaster bulbiferus*, n. sp.—Upper Silurian (Lower Ludlow); Leintwardine, Herefordshire. × 4. Ludlow Museum. | 76. |
| 3. | *Belaster ordovicus*, n. sp.—Upper Ordovician (Ashgillian); Thraive Glen, Ayrshire. × 4. Mrs. Gray's Collection, no. D. 44 *c*. | 73. |
| 4. | Ditto (?).—Upper Ordovician (Lower Bala); near Bala Lake, Wales. × $3\frac{1}{2}$. T. Ruddy Collection, British Museum (Nat. Hist.), no. E. 13532. | 74. |
| 5. | *Mesopalæaster complicatus*, n. sp.—Upper Ordovician (Ashgillian); Thraive Glen, Ayrshire. × 4. Mrs. Gray's Collection, no D. 74 *c*. | 88. |
| 6. | *Girvanaster sculptus*, n. sp.—Ibid. × $4\frac{1}{2}$. Mrs. Gray's Collection, no. D. 169. | 71. |
| 7. | *Caractacaster caractaci*, Gregory sp. (?)—Upper Ordovician (Lower Bala); near Bala Lake, Wales. × 7. T. Ruddy Collection, British Museum (Nat. Hist.), no. E. 13531. | 83. |
| 8. | *Mesopalæaster primus*, n. sp.—Upper Ordovician (Ashgillian); Thraive Glen, Ayrshire. × 4. Mrs. Gray's Collection, no. D. 70 *c*. | 86. |


1

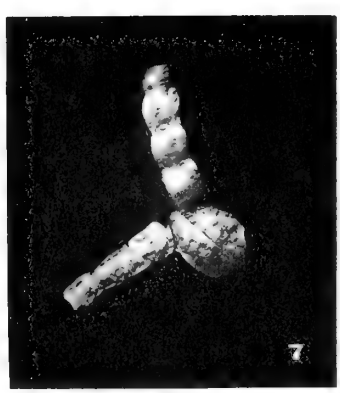

2


3


4


5

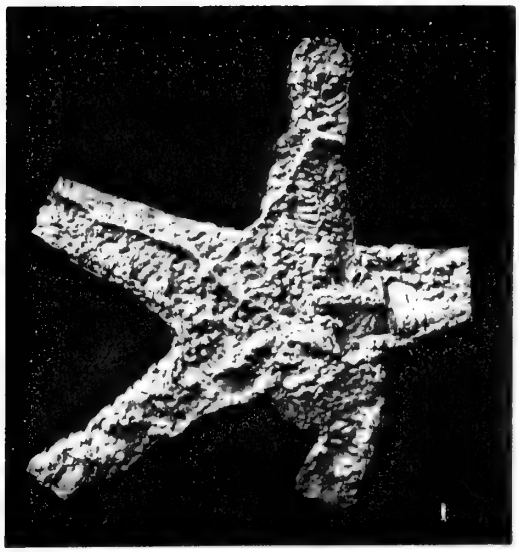

6

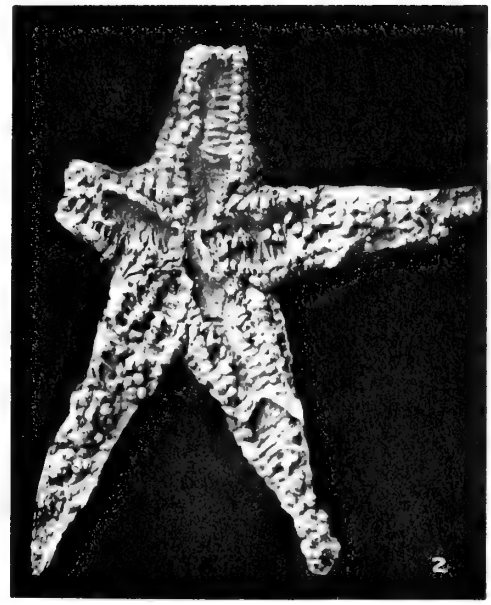

7

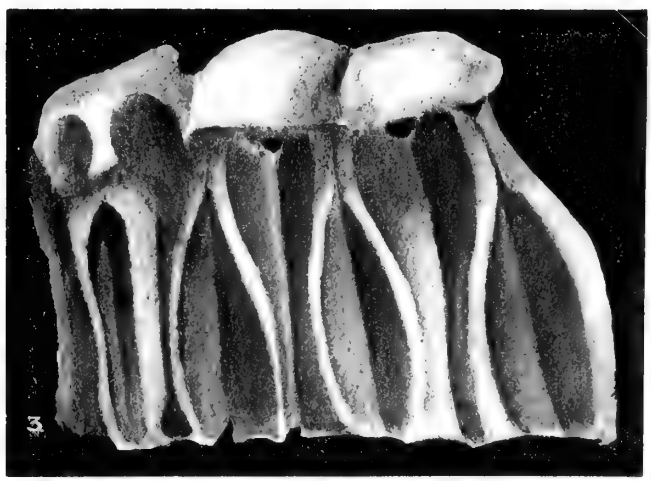

8

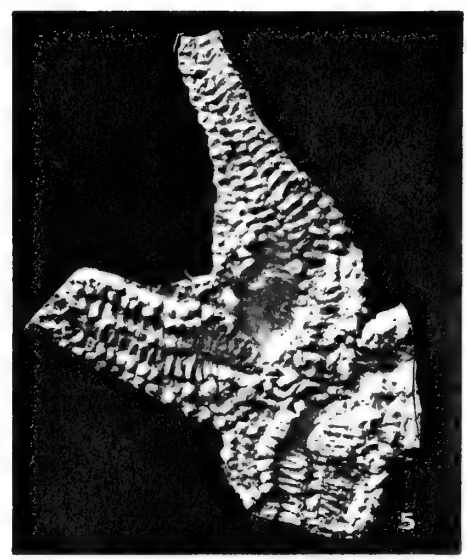
## PLATE IV.

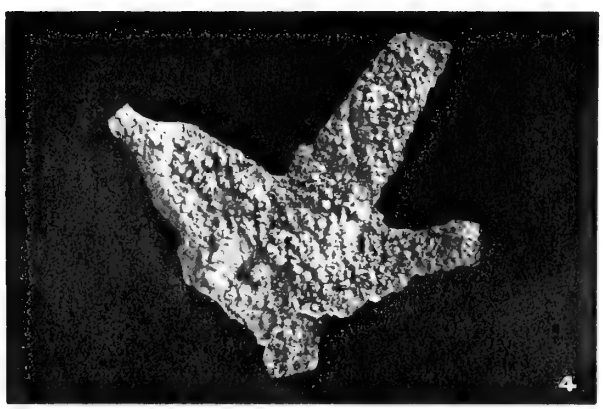
| Fig. | | Page. |
|---|---|---|
| 1. | *Promopalæaster elizæ*, n. sp.; photograph of apical surface, × 2.—Upper Ordovician (Ashgillian); Thraive Glen, Ayrshire. Mrs. Gray's Collection, no. D. 215. | 93. |
| 2. | Ditto; photograph of oral surface, × 2.—Ibid. Mrs. Gray's Collection, no. D. 215 *c*. | 95. |
| 3. | Ditto; wash drawing of ossicles in the right of a groove, including the mouth-region, × 30 (approx.).—Ibid. Mrs. Gray's Collection, no. D. 51. | 95. |
| 4. | Ditto; photograph of apical surface, × 2.—Ibid. Mrs. Gray's Collection, no. D. 104 *c*. | 93. |
| 5. | Ditto; photograph of oral surface, × 2.—Ibid. Mrs. Gray's Collection, no. D. 32 *c*. | 95. |
| 6. | *Palasterina primæva*, Forbes; photograph of extremity of one arm, nat. size.—Upper Silurian (Lower Ludlow); Leintwardine, Herefordshire. British Museum (Nat. Hist.), no. 40301. | |


1


2


3

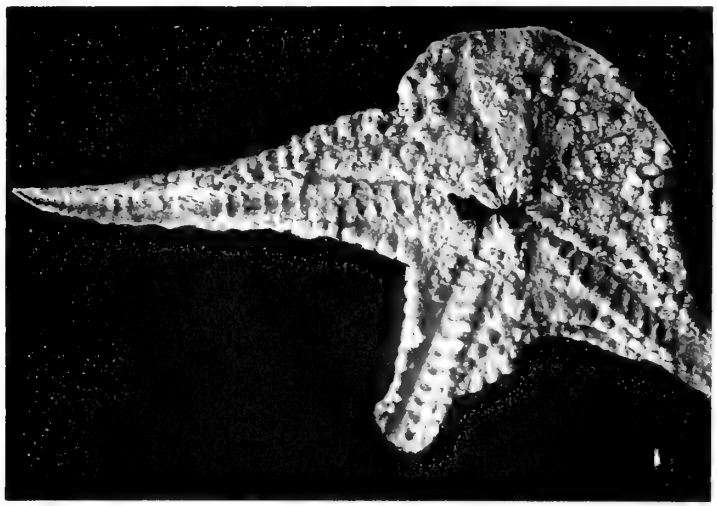

5

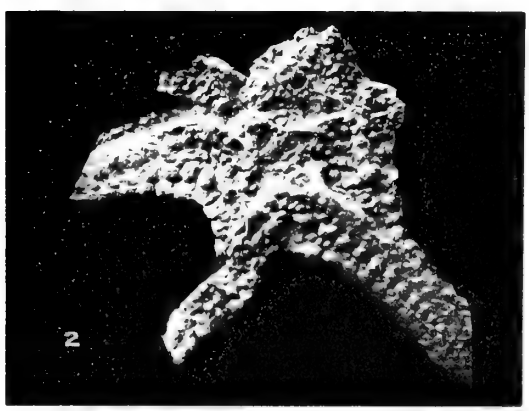

4

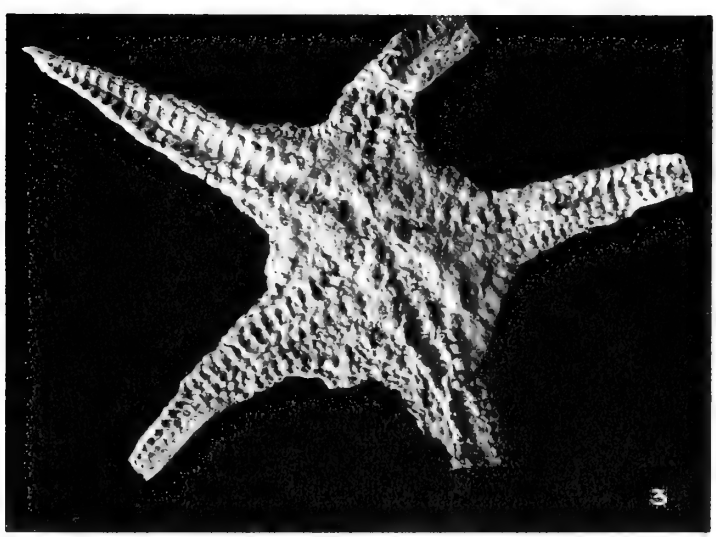

6

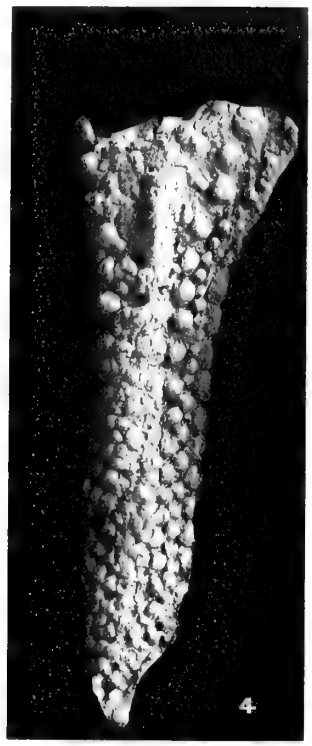
## PLATE V.

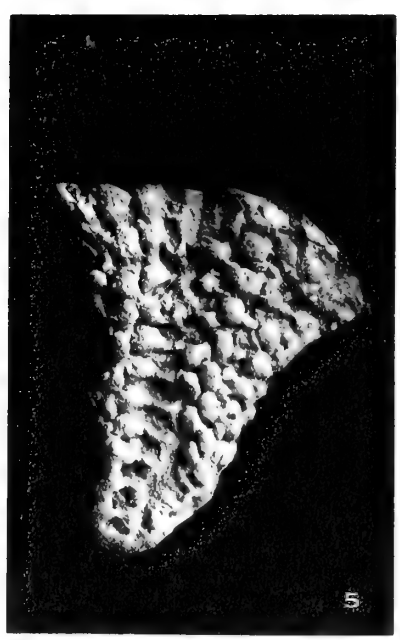
| Fig. | | Page. |
|---|---|---|
| 1. | *Uranaster kinahani*, Baily sp.; photograph of cast of oral surface, × 2.—Ordovician; seven hundred yards west of Ballymadder Point, Co. Wexford, Ireland. National Museum, Dublin (Geol. Surv., no. S. 1443). | 106. |
| 2. | Ditto; photograph of cast of apical surface, × 2.—Ibid. British Museum (Nat. Hist.), no. E. 194. | 105. |
| 3. | Ditto; photograph of cast of oral surface, × $1\frac{1}{2}$ (approx.)—Ibid. National Museum, Dublin (Geol. Surv., no. S. 1439 *a*). | 106. |
| 4. | Ditto; photograph of cast of the apical surface of the greater portion of one arm, × 4.—Ibid. British Museum (Nat. Hist.), no. E. 13110. | 105. |
| 5. | Ditto; photograph of cast of oral surface of base of one arm of same specimen, × 4. | 106. |


1


2


3


4


5