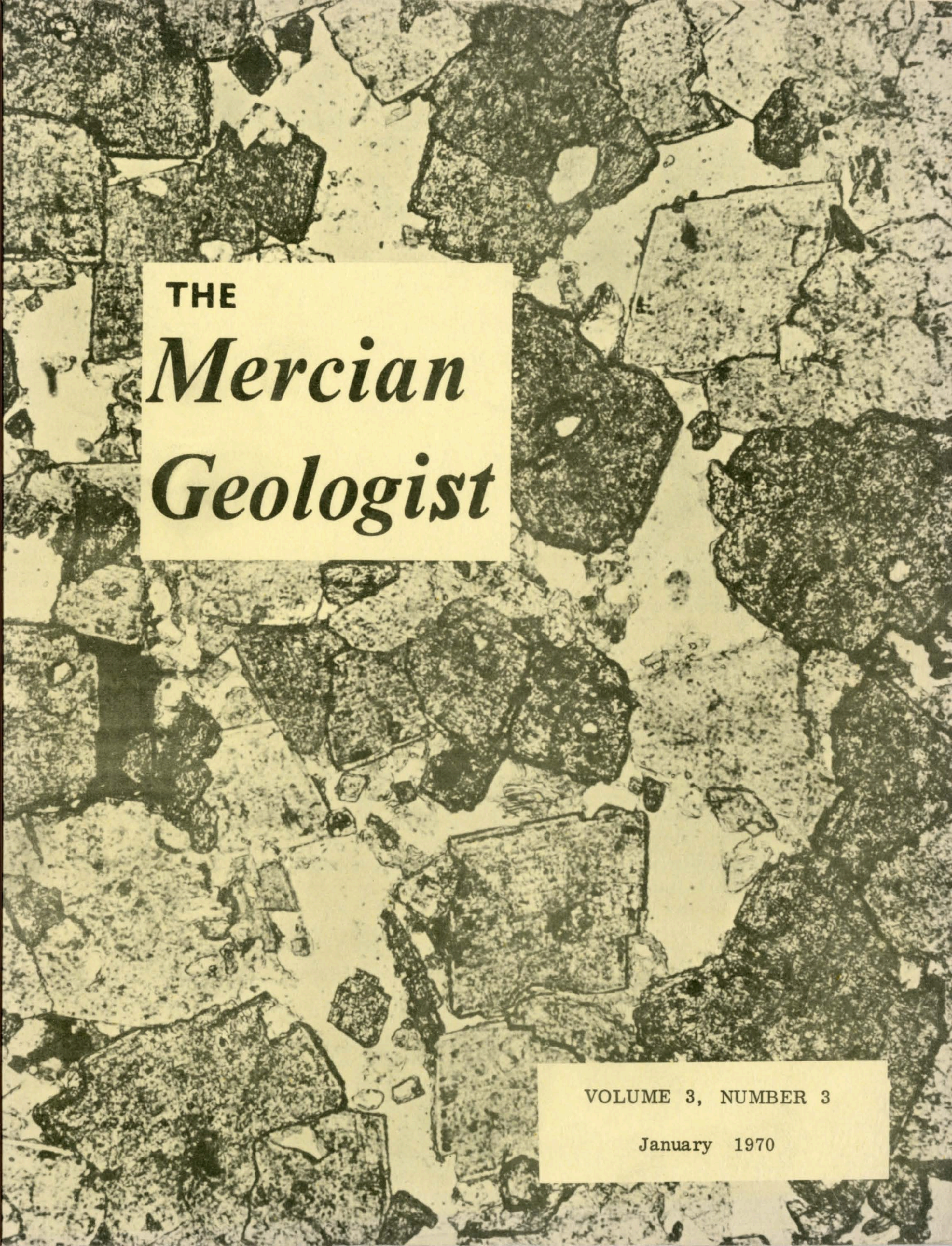

THE

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THE MERCIAN GEOLOGIST

JOURNAL OF
THE EAST MIDLANDS
GEOLOGICAL SOCIETY

VOLUME 3. NUMBER 3.

JANUARY 1970

EAST MIDLANDS GEOLOGICAL SOCIETY

Due to changes made at the A.G.M. on the 14th. February 1970, all correspondence, membership forms and Bankers Orders should now be sent to the following address:

Mrs. D.M. Morrow,
Secretary, E.M.G.S.,
54, Cyprus Road,
Mapperley Park,
Nottingham NG3 5EB.

Will you please delete any other addresses in your records.

The Editorial Board wish to apologise for the late appearance of the Mercian Geologist, Vol. 3 No. 3 which was unavoidable delayed through a printing error. The correct publication date for Vol. 3 No. 3 is March 2nd. 1970.

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Address for correspondence:

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Nottingham NG7 2RD,
England.

Price of this issue: 15/-

Subscription rates and other information may be obtained from the Secretary.

The Front Cover:

Bulwell Stone; the common building stone of Nottingham - with well-formed rhombohedral dolomite crystals and an open texture. Superficially, it resembles a sandstone, for which it is often mistaken. It is quarried around Bulwell, Linby and Kirkby-in-Ashfield; farther north, it changes character, and the famous "Mansfield Red Rock", which paves Trafalgar Square, is a lateral equivalent.

Horizon: Lower Magnesian Limestone, Upper Permian (Zechstein).

(Section and photo: R.B. Elliott)

GEOLOGY IN EAST MIDLANDS MUSEUMS

by

David A.E. Spalding

Summary

Details of the collections and services available to geologists in East Midlands Museums are presented.

Introduction

Earlier papers by the writer (1964, 1967) have discussed the relationship of the provincial museum and the amateur geologist and summarised various sources of information available. Mention has been made of the services that may be available, and of ways in which the geologist can in turn help the Museum. The co-operation of the respective Museum officials now makes it possible to present a detailed breakdown of the services and collections available in the Museums of the East Midlands. Very little of this information is available elsewhere.

The data was gathered in 1967 by means of a circular letter and questionnaire to all the Museums concerned and subsequent correspondence. Information was up-to-date to the summer of 1967, but some later information has been incorporated. It is regretted that the writer's removal to Western Canada has prevented earlier completion of this paper, and it is hoped that its usefulness will not be seriously affected by not being fully up-to-date. All the Museums listed in the 'Museums Calendar' for the counties covered by the East Midlands Geological Society were approached and most replied.

Of 54 museums circularised, 39 sent back the questionnaire or gave a nil return. 34 Museums are listed in the appendix as having geological material, for 3 of which no further details were available. The questions asked and a summary of the replies for the remaining 31 museums follows:

1. Name and address of Museum, name of official in charge, and normal opening hours.
   Replies are detailed in the appendix. Opening hours quoted are for weekdays/Saturdays/Sundays, except where otherwise indicated.
2. Names of staff with geological experience or qualifications.
   Museums with such staff numbered 18 (total staff 20). Of these, two were Consultant or honorary staff, sixteen were able to devote part of their time to geology, and two (at Leicester) are full time geologists.

3. Do the collections include: Local Fossils/Minerals/Rocks?
British (other than local) Fossils/Minerals/Rocks?
Foreign Fossils/Minerals/Rocks?

(Local was specified as the East Midlands Region, as defined above).

As might be expected, most of the Museums possess local and British material. In this century, museums have generally reacted against the old 'everything welcome' policies, and stressed their own region sometimes to the exclusion of all else. In this context it is interesting to note that only a small proportion (under one-third) indicate the presence of any foreign material at all. Ths indicates a surprising degree of active dispersal (presumably to suitable bodies) of irrelevant material. Details of replies are given in the Appendix, using the abbreviations
F (Fossils), M (Minerals), R (Rocks).

Name any specific collections of importance.
Details are given in the appendix.

Are reference collections accessible to students?
22 Museums specifically replied affirmatively, though some with qualifications. Some of the replies ('accessible, but not sorted or catalogued') indicate ways in which the amateur could be of assistance.

Is additional material welcome; if so should it be preferably Local/British/Foreign?
The results of the trend towards a local collecting policy are clearly shown here, where selectiveness will affect the future content of collections. Only four Museums were willing to take any sort of material, and these are mainly institutions building a geological collection from scratch. One is interested in foreign material where it illustrates basic geological structures not in the collection. Nine are interested in British material, and 20 are interested in local specimens.

4. Please indicate roughly the extent and range of material normally on display.
Fifteen museums display fossils, twelve display minerals, and eleven rocks. A further five have displays of which details were not given, and four are without geological display.

5. Enquiries. Are you able to identify Local/British/Foreign Fossils, Minerals and Rocks?
Four Museums were able to identify local material, three British material and only two foreign material. Here again is clearly a field in which the amateur can be of assistance.
Roughly how many geological enquiries are answered per year?
Of the six who keep records, one museum answers under ten, two under one hundred, one over two hundred, and two answer over five hundred enquiries a year.

6. Library. Do you have books and maps related to geology for consultation?
Four museums mention libraries specifically. Many others are adjacent to, or in the same building as, a public library and do not maintain a separate collection.

7. Records. Do you have available for consultation unpublished maps/sections/field notes/ borehole data/photographs/letters/personalia relating to geologists?
Six museums mention unpublished data, 2 specify maps, 2 sections, 3 field notes, 2 bore-hole data, and one each photos, letters and personalia.

Do you maintain a local bibliography/index of exposures/other relevant records?
Four museums maintaon local records, 2 a bibliography and one an exposure index.

8. Publications. Do you publish or have on sale any relevant handbooks, guides etc. ?
Two have geological publications; and a further four sell other relevant publications. Titles are mentioned in the Appendix.

9. Assistance. Is there any way in which the amateur geologist is assisting or could assist your Museum?
Four museums mention active assistance, and others would welcome it.

Acknowledgements

I am very grateful to those Museum officials who have kindly supplied the information listed in the Appendix; and I wish to apologise to them for the length of time this paper has been in preparation. My thanks also to the patient editor, who originally suggested this study and has himself made a transatlantic tour and returned to office before receiving it.

D.A.E. Spalding, B.Sc., F.G.S., F.M.A.,
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Provincial Museum and Archives of Alberta, Edmonton,
Alberta, Canada.

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APPENDIX: EAST MIDLAND MUSEUMS WITH GEOLOGICAL COLLECTIONS

DERBYSHIRE

BIRCHOVER (HEATHCOTE MUSEUM)

1. Private Museum, J.P. Heathcote (Hon. Curator).
3. Some fossils and rocks.
7. Lead mining maps and letters.

BUXTON

1. Terrace Rd., Buxton. 10-6/10-5/Closed. I.E. Burton (Librarian in Charge).
2. Dr. J.W. Jackson, F.S.A. (Hon. Consultant - Geology).
3. Stalactites and Stalagmites from local caves. Blue John. Black Ashford Marble. Limestone fossils. Accessible to students; local additions welcome.
5. 500 enquiries p.a.
6. Books and maps, which may be consulted whenever Museum is open.
7. Unpublished data available, and local records maintained.
9. Local material is added to the collection.

DERBY

1. Strand, Derby. 10-6/10-5/Closed. A.L. Thorpe (Curator).
2. Curator and Assistant Curator.
3. Accessible to students; local additions welcome.
4. General collection of M and British F. Minerals used in jewellery. Local economic geology.
5. Local F, M, R can be identified.
9. Local and British collections could be made more comprehensive.

HEREFORDSHIRE

HEREFORD

Has geological material.

LEICESTERSHIRE

LEICESTER

1. New Walk, Leicester. Oct. - Mar. 10-5, Apr. - Sept. 10-6. May-Aug. 10-7 (week & Sat.), 2-5 (Sun.); T.A. Walden (Director).

2. Miss J.B. McKellar, B.Sc., A.M.A. (Keeper of Geology). M.D. Jones (Assistant Keeper).

3. Local FMR, British FMR, Foreign MR.

Beeby Thompson Collection of about 200 Jurassic F from East Midlands.

Bennett, Gregory & Lowe collections of 600 British FMR.

Horwood collection of 450 Coal Measure Plants.

Lowe collection of 305 R from Mountsorrel, Leics.

Trelease collection of 1300 M.

Willoughby Ellis collection of 300 M.

Reference collections accessible and Local and British material welcome.

4. One gallery shows various geological themes, a long free-standing case with large mineral specimens and five 4' x 6' cases on local geology. A second gallery is being re-displayed and will be entirely devoted to fossils, with a Plesiosaur as centrepiece.

5. Local, British and foreign FMR can be identified. 600 per year.

6. Library available on weekdays on request or by arrangement.

7. Unpublished field notes, borehole data, photographs, and a local bibliography.

8. Lowe E.E. (1926): Igneous Rocks of the Mount Sorrel District.

Appleby R.M. (1958): Catalogue of Ophthalmosauridae in the collections of the Leicester and Peterborough Museums.

Sizer C.A. (1962): Catalogue of cited and figured specimens in the Department of Geology of Leicester Museum.

Also offprints of Leicestershire geology from Leicester Literary and Philosophical Society.

9. Reports and records of temporary sections welcome.

LINCOLNSHIRE

BOSTON (Guildhall Museum)

1. South Street, 9.30-12. 1.30-4.30/ mornings only 1 Oct. - 30 April/closed. Miss B.E. Robinson (Librarian-in-charge).

3. Local FMR. Additional local material welcome.

4. One or two local specimens.

5. Identification referred to Lincoln. Less than 10 per year.

GRANTHAM

1. St. Peter's Hill. 9.30-7.00/9.30-5.30/closed. D.E. Hayward F.L.A. (Librarian-in-charge).

3. Local FMR. Reference collections accessible, local additions welcome.

4. Due to recent changes in the use of the Museum, displays are related to local history and archaeology. All the geological material is in storage, but access to this is granted to

amateurs and students provided they are prepared to tolerate the existing conditions, which are far from good.

5. More common items, without any degree of authority. 65 per year.

6. Library available for consultation when Museum is open.

7. Unpublished maps, sections and fieldnotes available, and records maintained.

9. The majority of identification, cataloguing, indexing, etc. has been carried out by voluntary assistance and serious amateur geologists. Until such time as the authorities are able to appoint a qualified member of staff, this will continue to be the case; amateur assistance is, however, limited by the lack of space to examine and display exhibits.

GRIMSBY (Doughty Museum)

1. Town Hall Square. Tues., Fri., Sat., 10-12.30, 2-5.30. Wed., Thur., 10-12.30, 2-8. Closed Sunday and Monday. E.H. Trevitt, F.L.A. (Librarian-in-charge).

9. Members of the local branch of the Geographical Association prepared an exhibit of local geological specimens for a fortnight in June 1967, and in the near future it is hoped that we shall house a reference collection of Local/British specimens.

10. Space is extremely limited and there is no immediate prospect of an adequate Museums Service being provided.

LINCOLN (City and Country Museum)

1. Broad Gate. 10-5.30/10-5.30/2.30-5. F.T. Baker, M.A., F.S.A., F.M.A., A.L.A. (Director).

2. M. Johnson.

3. 12 drawers of general specimens. 2 cases local rocks. Accessible to students; local additions welcome.

4. Four cases, Lias fossils, plesiosaur, quartz, metallic minerals.

5. Local and British FMR identified. 50 enquiries p.a.

SCUNTHORPE

1. Oswald Road. 10-5/10-5/2-5. M. Kirkby M.A., A.M.A. (Curator).

2. R.B. Walker, A.I.S.T., A.R.P.S., F.Z.S., M.B.O.U., Asst. Curator and Head of Department of Natural History and Geology.

3. Local and British FMR, foreign M.

   Rev. J.E. Cross Coll. (177 local F); Rev. S. Cutts Coll. (mainly local); Harold Dudley Coll. (2,000 local F, some non-local FM); A.L. Sich Coll. (500 local and British FM); A.M. Cobban Coll. (Lincolnshire Limestone and Great Oolite); Greaves Coll. (Australian MR); Standerline Coll. (Lake District M); Reference collections accessible, Local and British material welcome, also foreign material demonstrating basic geological structures not in collection.

4. 7 cases in room 16' square. General background of geology, with simple geology of N. Lincs. Jurassic fossils, cleaning fossils, dating rocks. Materials of geology, time scale, minerals and man. Geological Maps.

5. All identified, using University & BM for more difficult material. Hundreds of local enquiries, plus many specialised ones.

6. Local and British books and maps available whenever Museum is open.

7. Few sections, fieldnotes, and borehole data. A local bibliography and exposure index is being built up.

8. Doughty, P.S. (1965): Trace fossils of the Liassic Rocks of North West Lincolnshire (1/8d). Reprint from "Mercian Geologist".

9. Amateur geologists helping with collections.

STAMFORD

1. High Street, 10-1, 2-5, 6-8/10-1, 2-6/ closed Sun., Thurs. L. Tebbutt (Librarian & Curator).

2. Curator.

3. Small collection of local FMR, accessible. Additional local material welcome.

4. Small collection from construction works.

5. Local FMR identified roughly. 25 enquiries p.a.

6. Books and Maps on local and British geology available when Museum is open.

7. Sections, fieldnotes, borehole data and photographs available, and local bibliography maintained.

NORTHAMPTONSHIRE

KETTERING (Westfield Museum)

1. West St., 10-5 (10-8 Wed. & Fri. summer) /10-5/2-6. J.S. Burden (Librarian-in-charge).

2. F.V. Lyall.

3. Local FMR, accessible to students.

4. One room, six cases.

5. Local FMR identified.

6. Books and maps relating to local geology available when Museum is open.

7. Local bibliography at Public Library.

9. Assistance by collection of specimens welcome.

NORTHAMPTON

Has geological material.

NOTTINGHAMSHIRE

NOTTINGHAM (Natural History Museum, Wollaton Park)

Has geological material.

WORKSOP

1. Memorial Avenue. 10-4/10-4/closed (& Thurs.) D. Inger, A.L.A. (Librarian-in-charge).

3. Local material welcome.

9. Presentation of identified specimens/collections and advice on items brought in welcome.

10. Opened as a Museum April 1, 1967, and no qualified staff.

SHROPSHIRE

CLUN

1. Town Hall. 2-5 Tues./on request or by appointment at other times.
T. Beardsley (Hon. Curator).

2. Curator.

3. Local FMR. Accessible, local additions welcome.

4. One case, Longmyndian, Caradocian, Costonian, Cordan R., Shelve, Snailbeach M, Ordovician, Silurian, Old Red Sandstone F.

5. Local FMR identified. Some assistance from Birmingham University.

6. Books and Maps by arrangement.

7. Photographs and exposure records.

10. Frequent visits from Training Colleges and Schools. No paid staff.

LUDLOW

1. Butter Cross. Easter to 30th Sept. 10.30-12.30, 2-5/10.30-12.30, 2-5/ closed Thurs. & Sun.
W.J. Norton, F.G.S., F.R.E.S. (Curator).
1st Oct. to Easter 2-5/ 10.30-12.30, 2-5/ closed Thurs. & Sun.

2. Curator.

3. Local, British and Foreign FMR. c.20,000 specimens. Reference collection accessible, Local and British additions welcome.

4. Introduction of fossils, succession of life, local geology, evolution of mollusca, classification of trilobites, Old Red Sandstone fishes.

5. Local and British F, Local M and R identified; over 1000 enquiries p.a.

6. Books and Maps on local and British geology available when Museum open.

7. Unpublished maps, sections, field notes and personalia available, and exposure index and other records maintained.

8. Ludlow Museum Bulletin 1 (Geology).

9. Many fossils donated by amateur geologists and children.

10. School loan service, and lectures given to parties. Collection originally that of Ludlow Natural History Society in mid-19th century, considerably enlarged in last 8 years.

SHREWSBURY

1. Castle Gates and Rowley's House, Barker St. M.F. Messengler F.L.A. (Librarian-in-charge). 10-1/2-5/closed.

3. Local and British FMR, including Coalbrookdale Coal Measures ex-Anstice Collection. Accessible, and local additions welcome.

4. Complete range of Shropshire geology, and representative collection of general minerals and rocks.

5. Local and British FMR and foreign M identified; 40 enquiries p.a.

8. Introduction to the collection in "Guide to Rowley's House Museum".

9. Fieldwork and collecting would assist.

10. Within 12 months, geological collection will be moved to a new Museum at Clive House.

STAFFORDSHIRE

BURTON-ON-TRENT

1. Guild St. 11-6/11-5/closed. K.F. Stanesby, F.L.A. (Librarian-in-charge).

3. Miscellaneous specimens in store.

5. 20 enquiries p.a. answered by local Society.

9. Would always be grateful for any assistance.

SHUGBOROUGH HALL (Staffordshire County Council Museum).

1. Shugborough, Great Haywood. 11-5.30/11-5.30/2-5.30.
G. Wilding, C.Eng., A.M.I. Mech.E., A.C.T. (Curator).

2. F.J. Beasley, M.A. Assistant Curator (Geology and Natural History).

3. Collections are being built up from scratch; local and British material welcome.

4. Token displays at the moment.

5. Local and British FMR identified.

7. Local records will be built up.

9. Photographic records, notification of exposures welcome.

STAFFORD

1. The Green. 10-7/10-5/closed. H. Dyson, A.L.A. (Librarian-in-charge).

3. "Nothing to speak of".

5. Few enquiries passed to Area Museums Service.

9. Collection and identification of local material welcome.

STOKE-ON-TRENT

1. Broad St., Hanley. 10-6/10-6/2.30-5. A.R. Mountford, F.M.A. (Director).

3. Local fossils (Ward collection of Coal Measure fossils on loan to Keele University). Reference collections accessible and local and British material welcome.

4. No material on display.

5. Local and British FMR (more common specimens). 100 enquiries p.a.

6. Books and Maps may be consulted on weekdays when the Museum is open.

9. Geological material will be required for forthcoming extensions, and assistance in the collection of material would be welcome.

TAMWORTH (Castle Museum)

1. November-February 10-4 (not Fri.) /10-4/2-4. Miss C.F. Tarjan, B.A. (Curator). March-October, Mon.-Sat. 10-1hr. before sunset or 8 p.m., 2-1 hr. before sunset or 8 p.m.

3. Collections accessible but not sorted or catalogued. Additional local and British material welcome.

4. No geological displays at present.

5. Identifications not practicable.

WARWICKSHIRE

BIRMINGHAM

1. Congreve St. 10-6/10-6/2-5.30. J. Lowe, M.A., F.S.A. (Director).

3. Local, British and Foreign FMR, including Bragge Collection of gemstones. Reasonably accessible to students, and local and British additions welcome.

4. Gemstones, formation of rocks, mineral collection, radio-active and fluorescent rocks, stratigraphic fossils, Irish Elk, Triceratops, Ichthyosaur.

5. Local and British FMR, Foreign MR can be 'reasonably' identified (fossils to genera). 200 enquiries p.a.

6. Books and Maps on local and British geology may be consulted on weekdays.

10. Shortage of staff prevents even adequate cataloguing of collections.

COVENTRY (Herbert Museum)

1. Jordan Well. 10-6 (8 Tues., Wed.)/10-6/2-5. C. Scott, F.M.A. (Curator).

2. K.C. Davies, B.Sc., Grad. Cert. Ed.

3. Local and British FMR, including Hippopotamus skull and fragment of Barwell Meteorite. Collections accessible and local additions welcome.

4. Local FR, geological time scale.

5. Local and some British FMR identified, 100 enquiries p.a.

6. Books and Maps on local geology may be consulted by arrangement.

9. Local fieldwork and collection would be welcome.

10. Great interest in increasing local material to build up a comprehensive collection for Vice-County 38.

NUNEATON

1. Riversley Park. 12-7/10 - 7/10 - 7. F.L.Fawcett, F.R.A.E., F.S.A. (Scot.) (Curator). Winter 12-5/10-5/10-5.

2. Curator.

3. Few local FMR, British FM, foreign MR. Accessible, all additions welcome.

4. Display planned when enough material available.

5. Identifications of non-specialist material. 25+ enquiries p.a.

6. Few books and maps on local and British geology accessible when Museum is open.

7. Unpublished field notes and maps relating to 'Manganese' and other mining. Local records will be developed in future.

9. A few F and R supplied, and further assistance would be very welcome.

10. Opened with a permanent Curator in 1960, when a specialisation in geology was considered. Previously, good material had been disposed of, and attempts are now being made to build up this aspect of the collections again.

WARWICK (County Museum)

1. Market Place. May-Sept. 10-5.30 (closed Fri.)/10-5.30/2.30-5. Miss J.M. Morris, F.S.A. (Curator).

2. B.R.P. Playle, M.Sc.

3. Local FR, British FMR, foreign FM. Warwick Natural History and Archaeological Society collection. Collections accessible, and all additions welcome.

4. 1200 sq. ft. containing 4 cases on Warwickshire geological history, 3 desk cases on a succession of fossils, 17 cases on various geological topics including soils, minerals and fossils.

5. All identifications; enquiries 250 specimens and 100 information p.a.

6. Books and Maps on local and British geology available by arrangement.

7. Unpublished borehole data and photographs available, and local records maintained, including bibliography and exposure index.

9. Collection of specimens and observation of temporary exposures would help.

WORCESTERSHIRE

DUDLEY

1. St. James Road. 10-6/10-6/closed. A. Wilson (Director).

3. Local, British and Foreign FMR. Upper Silurian from Wren's Nest and Castle Hills, Dudley. Carboniferous from South Staffordshire Coalfield. Collections accessible and offers of any additional material of interest.

4. New geological gallery opened January 1965 - Silurian and Coal Measure Fossils: some minerals and general paleontology.

5. Local fossils identified. Few identifications required, but many requests for information on local geology.

7. Unpublished maps, sections and photographs. Bibliography and other records available.

8. "Wren's Nest Geological Nature Reserve" (Dudley): handbook published by the Nature Conservancy, 1967.

9. At present no geologist on staff. Most collections come from mining, now discontinued.

10. Hope to lend FMR to schools this year.

HARTLEBURY CASTLE (County Museum)

1. Nr. Kidderminster. 10-8/1-8/1-8. Mrs. D.J. Bullard (Keeper).

2. Education Officer, B.J.R. Blench.

3. FMR of Worcestershire.

6. Local books and maps available. Weekdays by arrangement.

9. Hoped that local natural history society will help build up collection, and a collection scheme with local schools will be organised.

10. Geological collection only just begun, but plans are being made for displays of local geology and geological background to local industry.

WORCESTER

1. Foregate St., Worcester. 10-1, 2-6/10-6/closed. C. Phipps (Librarian-in-charge).

2. M. Fendall.

3. General collections, including Strickland collection of fossils, purchased 1909, accessible; additional local and British material welcome.

4. Local geology, with particular reference to Severn Valley region. Also displays relating to practical, industrial and economic use of local geological material are to be erected.

5. Local and British FMR can usually be identified.

6. Local and British Books and Maps available, whenever Museum is open.

9. Assistance and advice relating to use of local geological material to illustrate local trades, industries and other activities.

YORKSHIRE

DONCASTER

1. Chequer Rd. 10-5.30/10-6/1-5.30. J. Barwick (Curator).

3. Local, British and Foreign FMR. Collections from Scarborough, Kilmanoch, Worksop, Smalldale (Derbys.), Local Carboniferous accessible; all additions welcome.

4. Systematic, MR. Stratigraphical - British Paleontology. Structural - General, British, Local. Economic MR.

5. Some Local, British and Foreign FMR. Enquiries 100 p.a.

6. Books and Maps on Local, British and Foreign available, whenever Museum is open, by arrangement.

7. Unpublished Maps, Sections, field notes, borehole data, photographs.

9. Systematic recording and collection in area valuable.

10. Geology section yet to be developed; a large increase in display area and subject matter is envisaged. Geology may eventually be a separate Department.

KINGSTON-UPON-HULL

1. 23/24 High Street. 10-5/10-5/2.30-4.30. J. Bartlett (Director).

2. B. Latham, B.Sc. (Keeper of Natural History).

3. Local, British and Foreign FMR. T.B. Parkes. General geol. N. Lincolnshire. Local, Foreign and British Shillito collection. Holocene Molluscs from N. Lincolnshire. (v. Hull Museum Publication 218). Reference material available, all material welcome.

4. Very limited display of East Yorkshire and N. Lincolnshire fossils, pending rebuilding of Central Museum destroyed in 1943.

5. Local, British and Foreign FMR can be identified. c.70 enquiries p.a. (400 specimens).

6. Books and Maps on Local, British and Foreign geology may be consulted weekdays and some Saturdays, and borrowed by accredited libraries through Hull and ER under lib. co-op. scheme.

7. Local bibliography, index and records, all available.

8. Occasional geological papers in Hull Museum Publications, including 214 (out of print). 218 P.J. Boylan: 'The geological material in the T.B. Parkes collection'.

9. Assistance with collecting and local recording welcome. Information about collections for disposal.

ROTHERHAM (Municipal Museum)

1. Clifton Park, Rotherham. 10-5 (except Friday)/10-5/2.30-4.30 Oct.-Mar. 10-6 (Except Friday)/10-6, 2.30-5 (April-Sept.). L.G. Lovell (Librarian-in-charge).

3. Gemstones. Reference collections not at present accessible, local material welcome.

4. Gemstones.

5. Identifications not possible.

SHEFFIELD (City Museum)

1. Weston Park, Sheffield, S10 2TP. 10-5/10-5/1-4 Sept.-May. 10-8.30/10-8.30/1-4 June-August. G.D. Lewis (Director).

2. T.H. Riley, B.Sc., F.G.S., A.M.A. (Keeper of Natural History).

3. Local, British and Foreign fossils, rocks and minerals. Notable collections include:

Bateman, Thomas (1821-1861), well-known Derbyshire archaeologist; large collection of fossils came to Museum in 1893. Uncatalogued.

Blaydes, John Alfred (- 1884?), local naturalist, whose collection of c.5000 local fossils (inc. Derbyshire Pleistocene material) was purchased in 1884.

Bragge, William (Alderman). Collections purchased in 1875, 1877 and 1881, containing 100+ fossils (inc. Glyptodon and Megatherium) and 300+ minerals.

Dawkins, William Boyd. Collection of Pleistocene Mammalia from Creswell Crags, donated in 1878.

Fitzwilliam (Earl). Collection of fossils, largely Corallian of Yorkshire. Partly catalogued.

Hemingway, W. Paleobotanist of Derby and Barnsley. Material in Museum from 1910 onwards. The bulk of his collection of Coal Measure plants, recently donated, is awaiting cataloguing.

Moore, E.F. Collection from Coralline and Red Crags (c.200 specimens).

Pennington, Rooke. A collection from Derbyshire 'bone caves' was acquired in 1876. Ref: 'Barrows and bone caves of Derbyshire', Pennington 1877.

Puttrell, J.W. (1869-1939). Pioneer of cave exploration. Large collection of minerals bequeathed in 1939. Refs: Obit. in Bull. Peak District Mines H.S., 1, 2, 7, &8, and Trans. Hunter Arch. Soc. 5, 159.

Rimmington. Collection of c.500 minerals purchased in 1892.

Smith, Urban (Rev.) Cleric at Stoney Middleton. Collection of 1500+ specimens (inc. many Lower Carboniferous fossils) acquired in 1888.

Vine, G.R. Fossil and recent Bryozoa. Uncatalogued.

All collections are amalgamated and catalogued unless otherwise stated.
Reference collections are reasonably accessible; local and British material welcome.

4. Local, British and Foreign FMR. Local stratigraphic collection, Jurassic vertebrates.

5. Local, British and Foreign FMR can be identified.

6. Extensive library includes many classic works, Palaeontographical Society monographs etc., accessible weekdays, weekends by special arrangement.

7. Extensive unpublished data; bibliography and index of exposures available.

8. 'An introduction to local Natural History'.
'Rivelin Nature Trail'.
Other publications on sale include:
'Lead mining in the Peak District' ed. T.D. Ford and J.H. Rieuwerts.
Peak Park Planning Board, 1968.
'The geological column', Manchester Museum.
'Sorby Record' and special jubilee issue (on behalf of Sorby Natural History Society).
Peak Park Planning Board and nature trail brochures.
Transparencies: 'Stalactitic barytes'
'Ashford marble inlaid vase'.

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PSEUDAMUSIUM ELLIPTICUM LIMESTONE: A NEW LITHOSTRATIGRAPHIC UNIT IN THE LOWER CARBONIFEROUS AT CASTLETON, DERBYSHIRE

by

K. Robert Shaw

Summary

Certain limestones at Castleton, Derbyshire, containing the pectenid *Pseudamusium ellipticum* (Phillips), show a strong uniformity of character among themselves, but are markedly distinct from other limestones in the vicinity. Observations on the condition and distribution of the fossils suggest features of the depositional environment. Considerations of the distribution of the limestone indicate that it belongs to an isochronous unit of rock, and with further study it may prove to be a useful marker horizon in this district.

Introduction

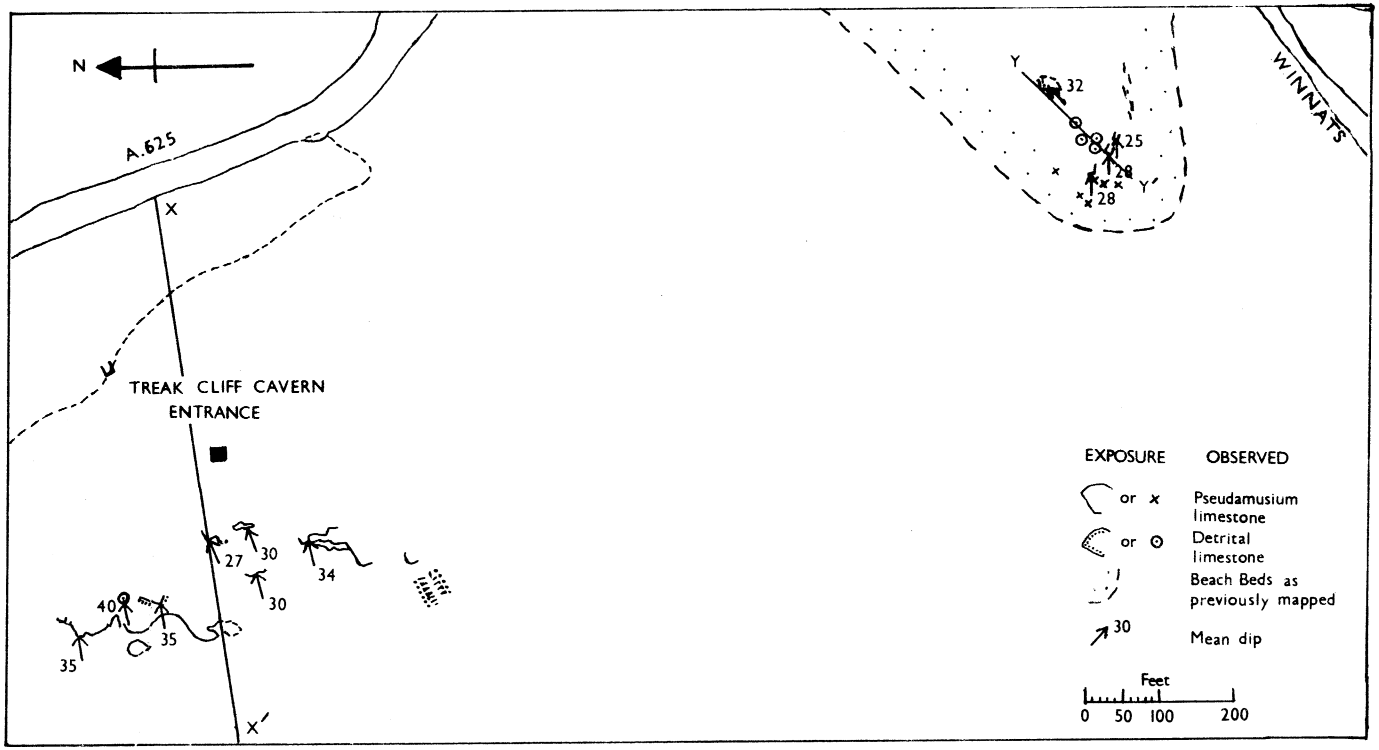
Since 1896, when Barnes and Holroyd wrote a paper "On the occurrence of a sea-beach at Castleton, Derbyshire", the lower Carboniferous rocks of this region have been studied intensively. The limestones which have received the greatest attention in recent years are those of the reef-complex. Bedding is usually obscure in these; and individual beds often show rapid lateral variation in petrology and fossil content. This makes it difficult to recognise or to trace laterally any significant features of the limestone sequence in this district.

Recently a limestone containing abundant *Pseudamusium ellipticum* (Phillips) was discovered in exposures on the eastern side of Treak Cliff hill. Subsequent study has suggested that this limestone might serve as a marker horizon in the vicinity of Castleton.

Serious work on this topic has now had to end because of other commitments. Insufficient data has been collected to allow a comprehensive examination of the *Pseudamusium ellipticum* limestone; this paper should therefore be regarded as a preliminary account which outlines some of the limestone's basic characteristics, and some of the methods considered suitable for its study.

The nature of Pseudamusium ellipticum limestone

Within the area shown on the map (Text-Fig. 1) two types of limestones were distinguished. These will be referred to as *Pseudamusium ellipticum* limestones and non-*Pseudamusium ellipticum* limestones. The former either contain large, concentrated pockets of *Pseudamusium ellipticum* (Phillips) (often with 50 valves per litre of rock) or lie visibly at the same horizon as such pockets.



TEXT-FIG. 1 Sketch map indicating the distribution of exposures of Pseudamusium ellipticum limestone on Treak Cliff, Derbyshire.

The latter contain only occasional P. ellipticum (rarely 2 valves per litre of rock).

A comparison was made between the faunas seen at different exposures in P. ellipticum limestone. The abundance of each species was seen to be similar at all of the localities where it was found and no species was common at one locality and absent from the others.

A comparison was also made between the faunas of the P. ellipticum limestones and those of other limestones in the area. In non-P. ellipticum limestones, pelecypods were found to be subordinate in number to brachiopods and rarely made up 25% by number of the pelecypod-brachiopod fauna. In P. ellipticum limestones, pelecypods are the most common bivalve shells. A sample of $8\frac{1}{2}$ litres of this limestone was collected from an exposure above Treak Cliff Cavern, and 233 bivalve shells were extracted. 75% of these were Pseudamusium ellipticum (Phillips), 10% were other pelecypods and 15% were brachiopods. Eighteen common species of fore-reef brachiopods, including Pleuropugnoides pleurodon (Phillips), Pugnax spp. etc. were absent from all P. ellipticum limestones examined. At least 100 other fore-reef species that have been seen locally in B_2 non-P. ellipticum limestones (see Wolfenden, 1958, pp. 894-898) were not represented. Eight species were restricted to P. ellipticum limestones.

Thus, the faunas observed at different exposures in P. ellipticum limestone are markedly similar. They differ, however, from the faunas of the other limestones exposed in the vicinity.

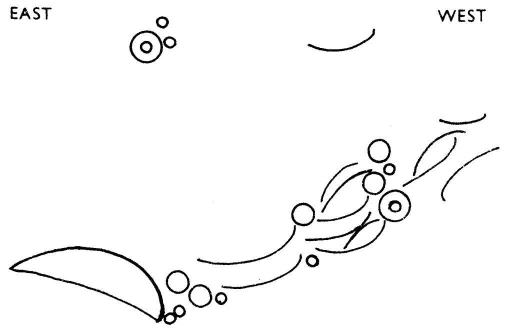
Some elements of the sedimentary environment of P. ellipticum limestone

From what has been written above, it seems reasonable that similarities may exist between the sedimentary environments of the P. ellipticum limestones in different exposures. As far as they were taken, studies made at the individual localities support this view.

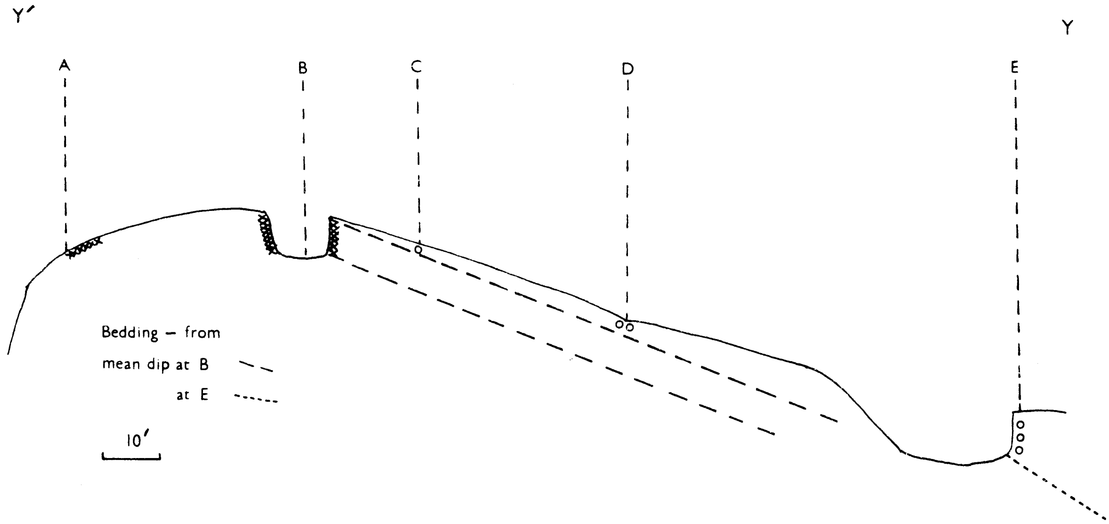
The condition and mode of distribution of the fossils were used to indicate factors in the depositional environment of the P. ellipticum limestones.

Completeness was one of the major criteria which was used to describe the condition of the fossils: it depends on their degree of fragmentation and, in the case of bivalves, their articulation. Little damage was seen in any parts of the fauna. Damaged or fragmentary shells are uncommon, typically about 10 pelecypod fragments were seen to every 100 entire P. ellipticum (Phillips) in a sample of the limestone. Most pectenids and all P. ellipticum (Phillips) observed were disarticulated. The only peleypods that were commonly found articulated were Edmondia primaeva (Portlock) and Aviculopinna mutica (McCoy), and those specimens of the borer Lithodomus which were found in vertical or near vertical positions. Most of the brachiopods seen were articulated. This evidence suggests that the pectenids, including P. ellipticum (Phillips), are not in their life positions and that their transportation did not have a strongly abrasive action.

Perhaps the most notable feature of the fossil distribution was its unevenness. Often fossils would be seen locally concentrated and elsewhere very scarce. The structure of the high concentration areas was of special interest. They were often in the form of thin lenses of limestone embedded in less fossiliferous limestone and predominantly had an easterly dip. In the majority of cases, the shells in these pockets appeared to be in contact with one another. Often individual shells showed a probable direction of origin, which was predominantly from the west (see Text-Fig. 2). Accumulations of crinoid columnals were often seen on the western sides of large shells. This evidence suggests that many of the fossils have been transported from the west, and that they came to rest against obstacles, such as large shells, with which they are still in contact. (Text-Fig. 2).



TEXT-FIG. 2 Diagram to indicate common features of shell pockets: crinoid columns and Pseudamusium ellipticum (Phillips) valves are seen to the west of an articulated Buxtonia, which appears to have obstructed their movement down the submarine slope.



TEXT-FIG. 3 Section near the Winnats (see Text-Fig. 1) suggesting the superposition of the Beach-Beds (circles) on the P. ellipticum limestones (cross-hatched).

Two major agencies that might have been responsible for the transportation of the fossils are westerly flowing currents and gravitational forces acting down an easterly dipping slope. It seems unlikely that a current which was strong enough to drag shells along the sea floor would have a small abrasive action. The fine intermediate sediment of shell "piles" suggests that currents were weak in the deposition zone. It seems unlikely that the thin shelled pectenid Pseudamusium ellipticum (Phillips) would have lived in a region typified by strong, abrasive currents. For these reasons, the importance of current action was dismissed as being negligible.

The present evidence may be explained if transportation and deposition occurred on an easterly dipping slope. The presence of such a slope was first suggested by Shirley and Horsfield (1940) to explain the dip pattern of the Castleton area, and has subsequently received support from a study of geopetal infillings of fossils (Broadhurst and Simpson, 1967).

The original slope may be responsible for the pockety distribution of fossils. It seems likely that once a pile began to accumulate, then its first members would naturally afford new obstacles and would hinder or terminate the movement of other shells down the slope. It would thus grow, in contrast with the surrounding sediments which would not afford many places where shells could become lodged.

Finally, some comments may be made on the rate of sedimentation. It was clearly slow enough for the soft parts of the pectenids to disintegrate sufficiently to allow the valves to drift apart before they were entombed: also, the common occurrence of bryozoan colonies between layers of shells in pockets, and their presence throughout whole pockets, suggests that individual areas were free from disturbance over periods long enough to allow the growth of these colonies.

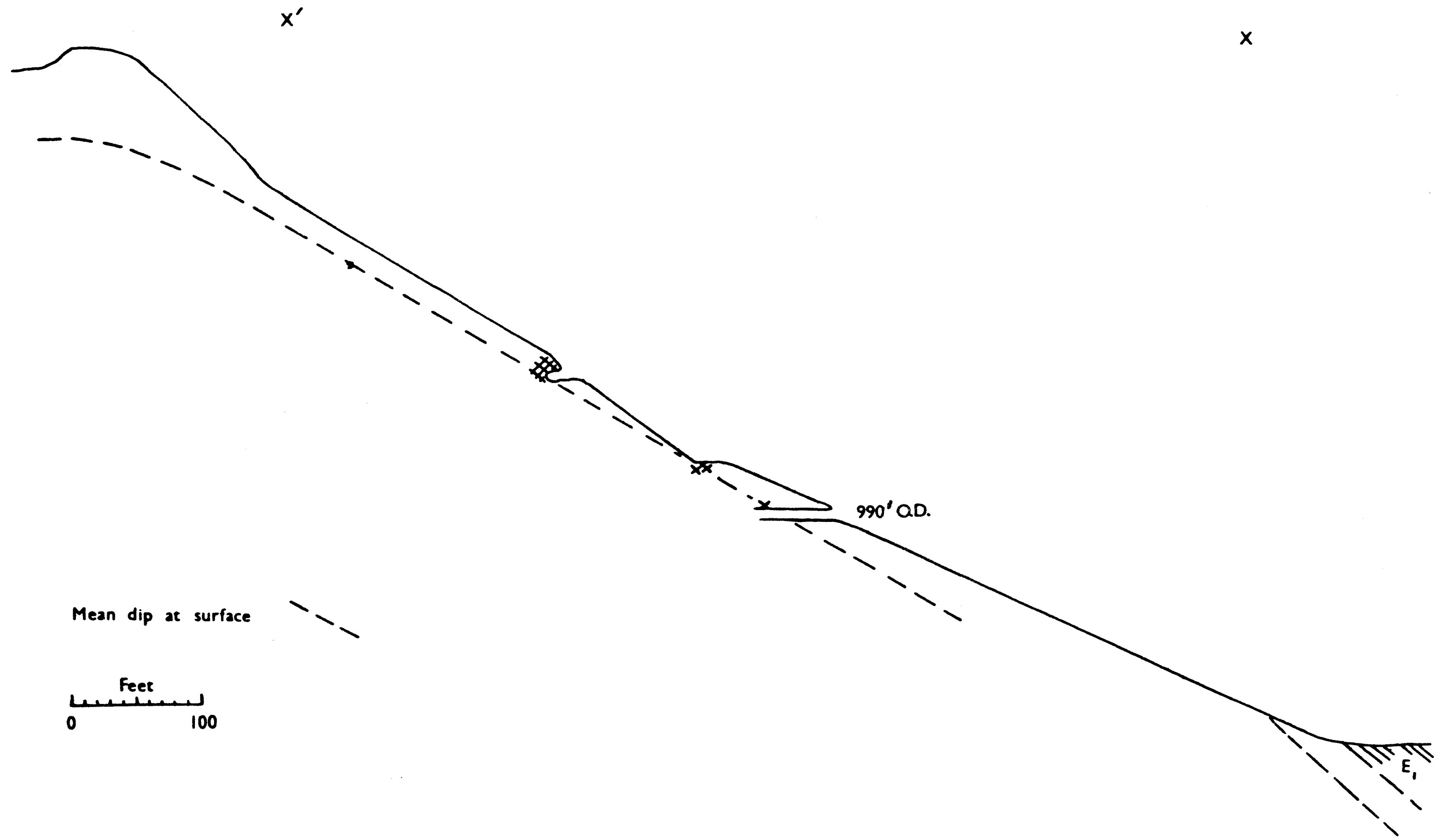
Stratigraphical relationships between the exposed sections of Pseudamusium ellipticum limestone

Having shown, above, that locally on Treak Cliff Pseudamusium ellipticum limestones form a distinct class of rocks, it is now convenient to examine the field relationships of their exposed sections, with a view to elucidating the stratigraphy.

At this point it should be noted that the limestones contain joints which show a preferred orientation, suggestive of true bedding. The spread of values of dips seen in these joints suggests that their interpretation as true bedding is not wholly satisfactory. At most exposures, structures such as shell pockets were examined to help in interpreting the data from joints, and on this basis a figure was arrived at for the dip. The inaccuracies of such figures, and the possibility that local unevennesses in true dip may be present, make any large scale interpretations uncertain.

Consider the section Y - Y' (Text-Figs. 1 and 3). If the local dips have been correctly interpreted, then the P. ellipticum limestones at B lie below the "Beach-Beds" at E. Also, large blocks of "Beach-Bed" limestone have been seen in the deep subsoil at C, and at D small exposures in "Beach-Beds" - almost certainly not loose rocks - are present. Within this section there is no evidence to suggest faulting or rapid local change of dip: and so it appears that the P. ellipticum limestones here lie below the "Beach-Beds". Unfortunately their relationship cannot be determined at present, since their contact is not exposed. The limestones exposed below A have not yielded any P. ellipticum (Phillips). In this section, upper and lower stratigraphical limits to the P. ellipticum limestone seem to be present.

P. ellipticum limestones also seem to have upper and lower limits in the exposures above Treak Cliff Cavern. The following two sections illustrate this:



TEXT-FIG. 4 Section near Treak Cliff Cavern indicating the relationship of the exposures of P. ellipticum limestone (cross hatched) to the dip.

			Thickness
A.	(i)	grey limestones with Pseudamusium ellipticum (Phillips) pockets locally; also pockets of brachiopods and shell fragments.	1 foot
	(ii)	typical P. ellipticum limestones; shell fragments rare.	20 feet
	(iii)	P. ellipticum limestones with a high percentage of pelecypod fragments.	3 feet
	(iv)	pale brown crinoidal limestone.	3 feet
B.	(i)	white limestone containing limestone pebbles, rolled shells, crinoid ossicles etc.	3 feet
	(ii)	brown, coarse grained limestone containing crinoids, shell fragments, corals etc.	8 feet
	(iii)	fine grained grey limestone containing productids, smooth spiriferids etc.	1 foot

Section (B) appears to be faulted down from its original position above a section in P. ellipticum limestone. Section (A) was measured very close to section (B), and judging from the character of the beds (Ai) and (Biii) there is a strong possibility that sections similar to (B) lay on top of (A). If this is so, then non-P. ellipticum limestones of a detrital character lay vertically above the P. ellipticum limestones at (A). Non-P. ellipticum limestones lie at the base of (A).

Other comprehensive sections in this area show non-P. ellipticum limestones with reef brachiopods and shell fragments above the highest P. ellipticum limestones. In Treak Cliff Cavern, no examples of P. ellipticum limestone have been seen in any of the sections vertically below surface exposures of the limestone; this clearly establishes lower limits to the P. ellipticum limestones at these localities. In fact, at all sufficiently large sections above Treak Cliff Cavern, there appears to be a vertical limitation of the exposed P. ellipticum limestones to an individual unit of rock, though the top or base of this unit is not always exposed.

An attempt will now be made to explain the field observations in terms of a stratigraphical theory. Clearly the period and localisation of deposition of the P. ellipticum limestone will have a control over its distribution, and these will play an important part in any stratigraphical theory.

At all localities, P. ellipticum limestones were encountered in a restricted layer. Above Treak Cliff Cavern, sections in the limestone lay in one plane, which was parallel to the apparent dip.

The suggestion of ubiquitous deposition over all of Treak Cliff hill over a long period may be dismissed immediately because of the restricted extent of P. ellipticum limestone. Prolonged deposition at one location may also be dismissed because of the vertical limitation of the limestone in many exposures. No definite decision may be reached on whether the limestone was deposited over a prolonged period in different parts of Treak Cliff hill at different times. It should be mentioned that there is no evidence to suggest such a method of deposition, and the planar exposure pattern of the P. ellipticum limestones, parallel to the apparent dip, and the absence of P. ellipticum limestone in Treak Cliff Cavern, make this theory seem unlikely.

It seems likely, therefore, that deposition did not occur over a prolonged period; it must therefore have occurred over one or more short periods. The planar pattern of outcrops suggests that deposition occurred over a single period.

Evidence of localisation of deposition has been observed above Treak Cliff Cavern - i.e. in the larger area of outcrop. In some of the higher exposures, P. ellipticum limestones passed laterally into coarser grained limestones, containing brachiopods and shell fragments but no Pseudamusium ellipticum (Phillips).

There still remains the question of whether the P. ellipticum limestone exposed near the Winnats was deposited at the same time as that near Treak Cliff Cavern. Though no conclusive evidence has yet been found on this question, certain features suggest that the two limestones are isochronous. For example, there is a marked similarity between the sequences in the two areas. (High percentage of pelecypod fragments at the base, followed by a larger thickness of limestones with fewer fragmentary shells, and capped by limestones in which brachiopods are rapidly becoming abundant). The two faunas are closely similar, yet distinct from all neighbouring faunas.

Thus it seems very likely that all P. ellipticum limestones encountered to date belong to one isochronous unit.

The age of the Pseudamusium ellipticum limestones

It was suggested in a previous section that all examples of Pseudamusium ellipticum limestone may have a similar age; and it seems reasonable that their period of deposition should be placed in an already existing zone. The goniatite Beyrichoceras rectangularum Bisat occurred in Pseudamusium ellipticum limestone at many localities. Goniatites of the Goniatites maximus Bisat group were collected near the Winnats at C (Text-Fig. 2) and other indeterminate goniatites were seen from all localities in Pseudamusium ellipticum limestone. Ford (1952) noted Posidonia becheri Bronn and a goniatite "probably of the Goniatites maximus group" from "Fairyland" in Treak Cliff Cavern, in limestones below the Pseudamusium ellipticum limestone.

The fossils cited above suggest that the Pseudamusium ellipticum limestones are of B_2 age, as might be expected from consideration of previous theories on the age of Treak Cliff's limestones (see Parkinson 1953 and 1965). The present state of theories on the B_2 subzones, and especially on the range of the species mentioned above (see Parkinson, 1965 pp. 162-164), seems unsettled and no reliable verdict on the age of these limestones can be reached at present.

Conclusions

From present evidence it appears that the Pseudamusium ellipticum limestones form a uniform class of rocks at Treak Cliff which are quite distinct from all other rocks on the hill. They were probably deposited slowly on a quiet, easterly dipping underwater slope, and most of the fossils probably reached their present positions after a short slide down this slope.

It appears that all examples of P. ellipticum limestone were deposited in one short period, in particular areas on the depositional slope: these limestones form a unit that is usually 25 feet thick. It should be remembered that non-P. ellipticum limestones were being deposited at the same time as P. ellipticum limestones.

Acknowledgements

I wish to thank Dr. W.H. Ramsbottom and Dr. M. Mitchell of the Institute of Geological Sciences and Mr. S. Turner of Leeds University for their help in identifying some of the specimens used in the faunal studies. Thanks are also due to Mr. A.M.S. Guthrie for his company and invaluable help in the field, and to the staff of Treak Cliff Cavern (particularly to Mr. P. Harrison) for their help during the course of field work. Photographic work, which played an important part in the study, was carried out by Mr. C.H. Porter.

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THE STRATIGRAPHY AND PALAEONTOLOGY OF THE RHAETIC BEDS (RHAETIAN: UPPER TRIASSIC) OF BARNSTONE, NOTTINGHAMSHIRE

by

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Summary

The history of previous geological work carried out at the Barnstone Railway Cutting is reviewed. The Rhaetic beds at this locality are recognised and delimited. They are measured at a series of equally spaced exposures and examined in detail. The Rhaetic fauna is described, figured and analysed palaeoecologically. The fauna includes molluscs, branchiopods, ophuiroids and fish and reptile remains. The Scymnorhynid teeth described herein are the first specimens of this family to be recorded below the U.Cret. The much confused teeth of the fishes Gyrolepis albertii Agassiz, Birgeria acuminata (Agassiz) and Saurichthys longidens Agassiz are clearly differentiated and fully described.

Introduction

The name "Rhaetic" was for long applied to a separate, small geological system, placed between the Triassic and the Jurassic. It has now, by international agreement, been reduced to a stage (the Rhaetian) and placed into the uppermost Triassic. However, in this country it remains a convenient name for a group of beds laid down in the shallow waters of an encroaching sea, which spread from West Europe over the previous Triassic landscape as a prelude to marine Jurassic conditions. These beds consist of a comparatively thin series of rocks and are persistent at the junction of the Triassic and the Jurassic rocks from Dorset to Yorkshire. Their thickest development is in the South, and near Watchet in Somerset the following composite sequence has been described by Arkell (1933, p. 99).

Watchet Beds	8'
Langport Beds	20'
Cotham Beds	5-7'
Westbury Beds	46'
Sully Beds	14'

In the Midlands the highest and the lowest of these beds are absent. There are very few natural exposures and the rocks are only rarely seen in quarries. They usually form a small but distinct scarp which overlooks the Triassic plains. The spreading of the railways in the 1860's and 70's opened up a number of cuttings through the Rhaetic rocks, which had hardly been known in this area before that period. These cuttings were recorded at the time though were soon grassed over. Since that time, the Newark section has been reinvestigated (Johnson 1950) and various minor sections described. The long road section at Bunny has been measured in detail and the general variation of the Rhaetic over the whole East Midlands area worked out from borehole data (Kent, 1953 and 1968).

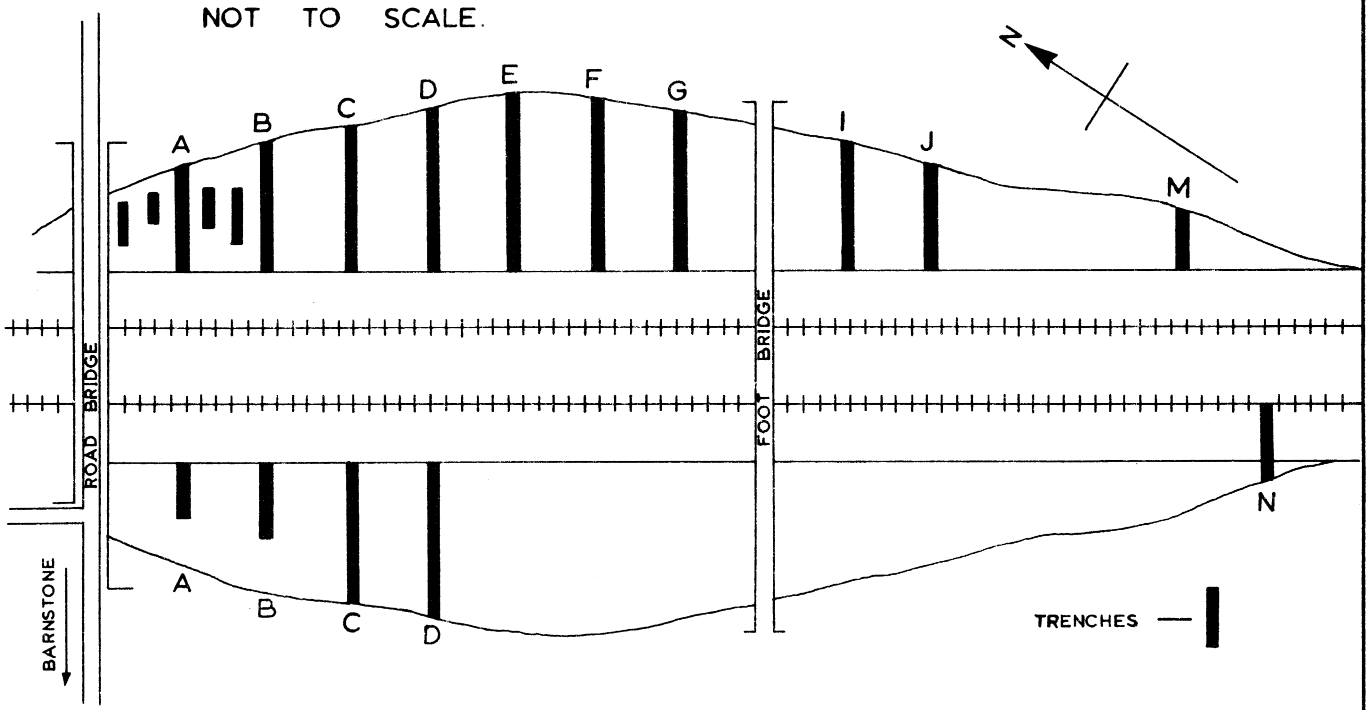
In 1876 the new Bingham branch line of the Great Northern and London and North-western Railway Companies opened up a section of the Rhaetic and Lower Lias rocks in a cutting at Barnstone, approximately ½ mile East of the village (SK 739358). The exposure was examined at the time by Wilson (1877), who sent a letter to the Geological Society of London in which he made brief notes on the succession and said that he hoped to make a full report later. In the thickness of the Rhaetic beds he noted about 15' of "paper shales" and, on top, an estimated 18-19' of dark blue earthy shales. Brodie (1876, p. 7) identified a collection of fossils from the Bone Bed at Barnstone and stated (on information received from Wilson) that all the rest of the beds were unfossiliferous. Wilson's next reference to the cutting (1882) added no further information, but this time stated the same thickness for the beds without the ambiguity of the words "about" and "estimated" in their description. It is evident that his proposed further investigations had not been carried out. Further work, however, was done by Wilson on the Liassic rocks (Jukes-Browne, 1885, p. 24).

Jukes-Browne (1885) reported that the cutting was then obscured by grass. He gave the following section and a fossil list which summarised all the information given by Wilson and Brodie with the addition of a list of bivalves. (The fossils recorded by Jukes-Browne are included in the synonymies given in the following fossil descriptions, with the exception of the following species which were not found in the present study:
Ceratodus altus Agassiz, Nemacanthus filifer Agassiz, Saurichthys sp.

LIAS	Thin-bedded blue limestones and brown clays, at the base a compact or concretionary bed of limestones from 3" to 7" thick.	10'	0"	
WHITE LIAS	Layer of limestone nodules.		6"	
	Thick-bedded, earthy, dark-blue shales with frequent nodules of limestone.	3'	0"	
	Similar shales with occasional nodules near the centre	15'	0"	about
AVICULA CONTORTA BEDS	"Paper shales" (Avicula contorta zone) with thin, variable sandstones in the upper part	13'	0"	
	Bone bed, with the usual fish remains		2"	
	Paper shales, sharply divided from	1'	6"	
KEUPER	Hard, light blue marls			
	Red Keuper Marls with thin gypsum bands.	12'	0"	

Lamplugh (1908, p. 58) gave exactly the same description. Johnson (1950) investigated the section, specifically examining the bivalve fauna. He stated that Pteria (= R. contorta) only occurs high in the succession (ibid., p. 117) and suggested that Barnstone lay just beyond the limits of a lagoonal area to the North West.

In the early 1960's the railway line was closed and the rails were taken up. Eventually it was realised that an excellent opportunity was available for the re-examination of the cutting and this was taken on as a project by the East Midlands Geological Society. In April 1968 work was started and this paper is the outcome of the activities by members participating in the project.



TEXT-FIG. 1. SKETCH-MAP OF BARNSTONE CUTTING.

Description of beds

The Barnstone cutting lies almost at right angles to the scarp face and therefore exposes the whole succession of the Rhaetic, some of the underlying Keuper, and the lowermost Liassic. After the cutting was excavated a thick layer of clay was placed on the exposed shales to protect them and prevent seepage of water. Now the whole of the sides are completely covered with grass. Trenches were dug into both sides of the cutting at 100ft. (30.5 m) intervals measured from the road bridge (Text-fig. 1). A Surveyors' Level was used to measure the relative heights of the main beds. The dip of the beds was found to be 1 deg. 9 mins. in the direction S.34 degs. E., which is also the direction of the cutting. Much of the section near the bridge was found to have been built up when the cutting was made and, as that end is also the scarp face, it probably accounts for the more extensive weathering of the rocks which is to be found there. The beds are named and their contents summarised in Table 1.

Trias

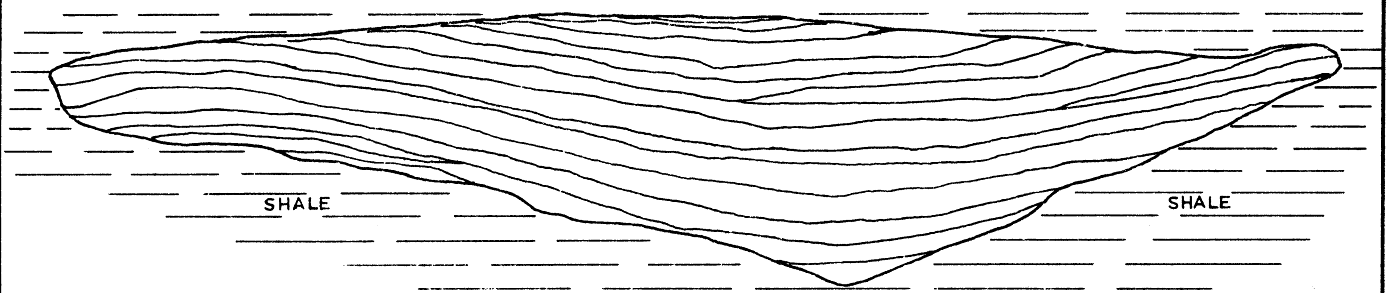
The Tea Green Marl (More than 2 ft. (.6 m.))

The Tea Green Marl which underlies the Rhaetic is a grey green, non-calcareous mudstone which easily breaks down into mud when broken in water. It is unfossiliferous. A 3 lb. sample was carefully cleaned, processed in water and washed through sieves of 18, 60 and 240 mesh. The residue left in the sieves was approximately 1.4% of the whole and consisted of clean quartz sand, with a sprinkling of grains of nodular pyrite. Only a few grains were found in the coarsest sieve (pyrite up to $2\frac{1}{4}$ mm. across and quartz up to $1\frac{1}{4}$ mm. across) and the finest sieve held about 65% of the residues. The quartz grains are well rounded and most of them have a scored surface; a few of them are coloured rose-pink, brick-red or green.

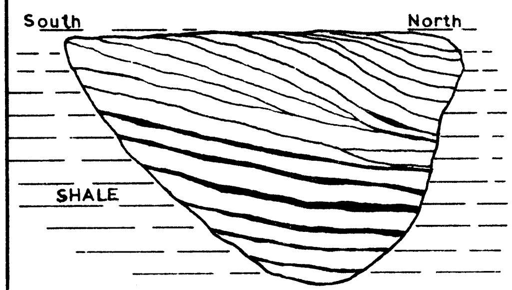
The Pre-Bone Bed Black Shale (1 ft. 6 ins. (0.4 m.))

At the base of the Rhaetic there is a sharp break from the grey-green marl to black shale; however, a close examination shows that the lowest $\frac{1}{2}$ in. (13 mm.) or so contains small patches of black shale isolated in the underlying marl. The greater part of the lowermost shales contain a fair amount of coarse quartz grains, occasionally up to about 1/8 in. (3 mm.) across, though some of the shale is laid directly on the Tea Green Marl without this content. These lowermost shales also contain small fragments of Tea Green Marl, patches of pyrite, phosphatic material, selenite crystals and circular green patches of (?) chamosite. They also contain scattered teeth, scales and finrays of fish, some of which are found flat on the contact plane.

Though superficially the shales of these beds appear to be all alike, slight but significant changes take place in their composition from the bottom upwards. The lowest beds have sandy partings of fine quartz and also coarser quartz grains and fish remains scattered through the rock. Between approximately 3 to 7 ins. (76 to 178 mm.) above the base, there is more sandiness with some thin patches of coarser deposits. At one horizon there is an impersistent layer of sandy rock up to $\frac{1}{2}$ in. (13 mm.) thick. Many more fish remains are present, generally associated with the quartz, and these shales could be classed as an incipient bone bed. Near the middle of the Pre-Bone Bed Shales there are fewer sandy partings and less quartz generally. The fossils are fewer and more conspicuously associated with the coarse sandy patches. Approaching the top the conditions change and the coarse content is only present in a few small patches, the fish remains found with these being only fin rays and occasional *Gyrolepis* scales. The shale is more fissile with an increasing amount of mica. The upper beds are devoid of sandy partings or quartz and fish remains are rare.



A. Longitudinal section of a sand-filled channel, showing the shallowing of the extremities, the flattened top, and the concentric bedding, which roughly follows the base of the channel. Length of channel 127 mm.



B. Cross-section of a sand-filled channel, showing the dip of the bedding towards the steeper wall. Width of channel 39mm.

C. a broken piece of shale with sandy partings, showing distortion of the bedding. Length 79mm.

TEXT - FIG. 2. STRUCTURES FROM THE SANDY BEDS.

The Bone Bed (Up to 3 ins. (76 mm.))

The Bone Bed is accessible at the surface for about 250 ft. (76.2 m) along the cutting, and in this distance it varies considerably, though it is difficult to assess just how much of this is accounted for by weathering. It is first found about 50 ft. (15.2 m.) from the road bridge as a thin layer of sandy material with a few fossils. At exposure A it has changed to a pyritous Bone Bed with a thin crumbly layer on top, though much of its phosphatic material is in a weathered condition. Along the cutting the fossil content of the bed improves, and where it is found just below the water table at exposure C, it is in the best state of preservation and also the most prolific in fossil specimens. Here the Bone Bed is between 2 and 3 ins. (50 to 76 mm.) thick; the bottom half is solid with a pyrite matrix and the upper part is a friable mudstone with patchy layers of shale. Apart from the shale patches, the whole bed is crowded with vertebrate bone and teeth, coprolites, phosphatic nodules, fine and coarse quartz sand grains together with pebbles up to 1in. (25 mm.) across. Some of the quartz grains are coloured. Parts of the Bone Bed are slightly calcareous and the rare closed bivalves which have been found there are filled with calcite. In the lowest inch or two of the succeeding Black Shales, where the bivalves are absent, there are slight signs of continued Bone Bed deposition. Small patches of coarse deposits are found, either locally concentrated or scattered on a bedding plane. Associated with these are sparse Bone Bed fossils.

The Black Shales (6 ft. 1 in. (0.9 m.))

These beds are a remarkably constant lithological unit consisting of finely laminated black shales. They are thinly bedded except for about 2 ft. 6 ins. (0.8 m.) above the base where they are flaggy in beds up to 3 ins. (76 mm.). These beds, however, soon weather down, either to paper shales or to unevenly bedded shales. The shale on the south west side of the cutting is less weathered than that on the north east side. Water drains through the south west side and probably inhibits the weathering, as it does below the water table which is just below the base of the cutting. When weathered the shale contains masses of tiny selenite crystals, often arranged in rosettes, on the bedding planes. Some bedding planes are covered with a rust-coloured iron deposit and on some partings there is some sulphurous yellow clay. These secondary products are probably formed from the decomposition of pyrite to iron oxide and sulphuric acid. The sulphuric acid reacts with calcareous material in the ground water to produce selenite.

In the unweathered shale there is evidence of pyrite. Small nodules occur here and there, and 4 ins. (101 mm.) above the Bone Bed there is a $\frac{1}{4}$ in. (7 mm.) bed of solid pyrite associated with many flat, circular pyrite nodules. There is not very much silty material in the shales; thin layers of fine, silty quartz found near the Bone Bed become rare higher up.

Fossils are difficult to find in the unweathered shales because they are difficult to split, though if they are allowed to weather naturally, the fossil layers become exposed. The fossils are chiefly thin-shelled bivalves (Text-fig. 4). Nothing but their moulds remain upon the bedding planes. They are spread sparsely through the rock, though some bedding planes are covered with innumerable specimens. The shells vary randomly in size but sometimes a whole bedding plane will have specimens of a limited size range, usually small. Many of the Eotrapezium and Protocardia are found with their shells open and joined together; some are upright in the sediments only partly open, a few are closed.

The Sandy Beds (4 ft. 6 ins. (1.4 m.))

Though these are well defined beds, the contents vary along the cutting. The base of the beds is recognised by a change of the weathering colour, by the appearance of strong sandy partings or by a sandstone at the base. The weathering changes from a 'rusty' reddish-brown to an ochrous yellow-brown. The main mass of the rock is black shale, though most of it contains many partings and layers of sandy material. The thicker layers constitute thin sandstones, a few of which are up to 4 ins. (0.1 m.) thick and occur either in lenses or impersistent beds. Some of the thicker ones are current bedded. On fracture, some of the sandstones are white whilst others are black, although both weather to an ochrous yellow-brown colour. Selenite does not occur, but pyrite is found in both the shales and the sandstones.

On both sides of the cutting at exposure C, many horizons show slight disturbance of the sediments leaving striations and ripple-like markings. Some of these are emphasised and sand filled, leaving isolated channel fillings (Text-fig. 2). All these phenomena are orientated in the same general direction of 5 deg. S of E. The channel fillings differ in length and depth but characteristicly are approximately $6\frac{1}{2}$ ins. (160 mm.) long and 1 in. (25 mm.) deep near the middle, tapering in depth towards each end. Some are curved, all are flat topped. A section across them shows that the wall on the northern side is steeper than the wall on the southern side. When cut along their length, the bedding is roughly horizontal but curves up towards the ends of the channel (Text-fig. 2). Across their breadth the bedding is either almost horizontal or dipping to the north (the channels being filled up last on their northern side), this being shown best in the deepest ones. At this exposure some of the beds are curved in association with a minor fault which strikes about E.-W.

At exposures D, E and F, the upper part exhibits contorted bedding, varying from fine plications of the sandy partings, through folds and overfolds, to completely distorted sediments. These tie in with the previously described phenomena, since they show horizontal bedding on an E.-W. line.

Small specimens of Eotrapezium are the only fossils found in these beds. In the shales they are rare and scattered, except in two layers 1 ft. 2 ins. (0.4 m.) and 1 ft. 4 ins. (0.4 m.) above the base which are crowded with specimens. In the sandstones the bivalves are larger and, apart from those found on the base of a sandstone, all the specimens have their valves closed. These are sometimes spread plentifully through the rock, though (apart from rare pyritised ones) they are poorly preserved, being filled with a white, fibrous, non-calcareous mineral. About 1 ft. 6 ins. (0.5 m.) above the base the shales become calcareous. This is a general boundary at Barnstone, the exception being the Bone Bed below which is slightly calcareous in parts.

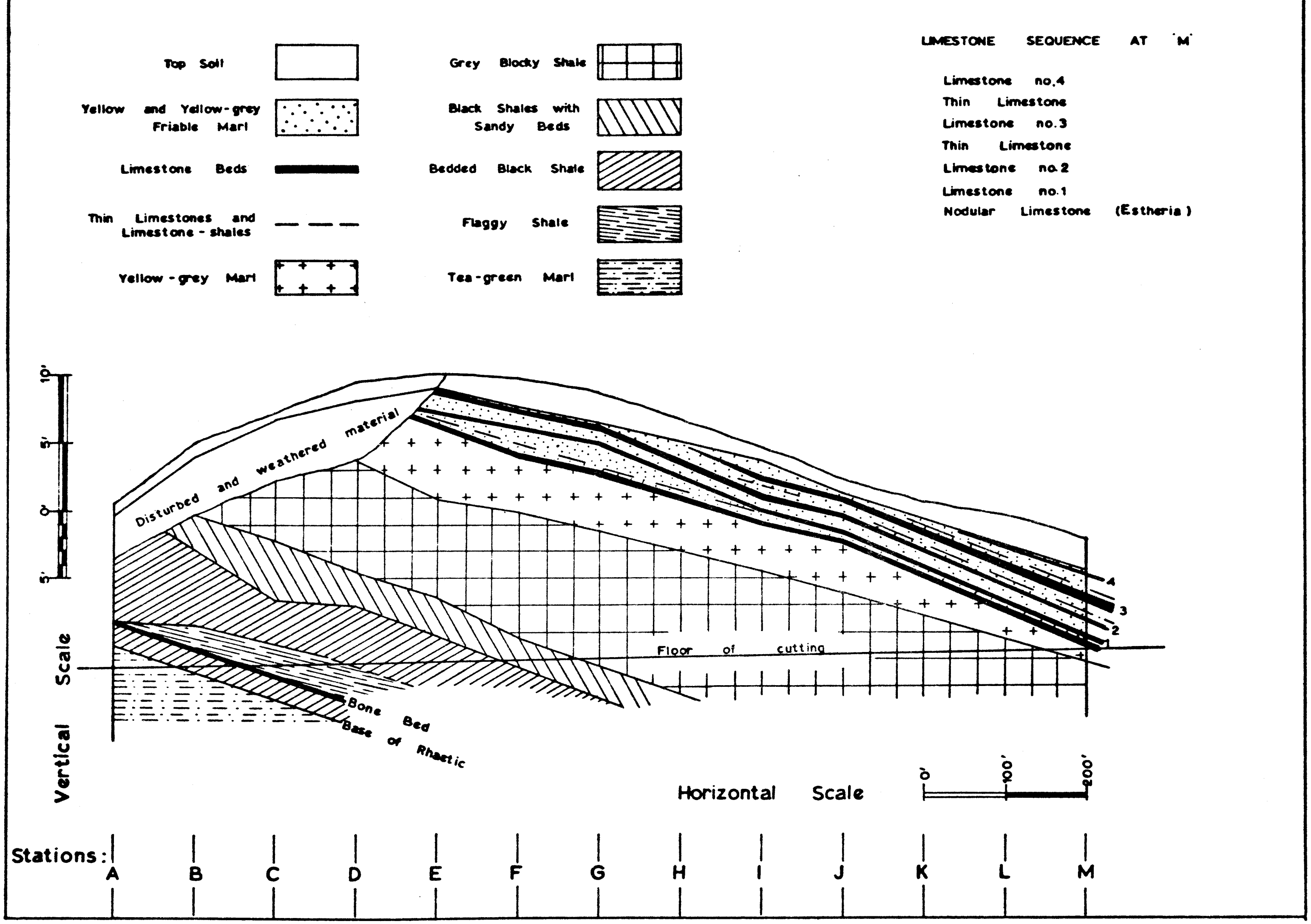
The Blocky Beds. (9 ft. (2.7 m.))

These beds consist of black to grey calcareous shales and siltstones which vary in lithology and fossil content from the base to the top, though a characteristic 'blockiness' of the material is present throughout. The basal beds have some thin partings of white sand and the black shale weathers to light grey without any iron staining. There are beds of undisturbed sediments alternating with distorted beds showing folding and plication of sandy streaks. Although these basal beds will split along their bedding, they will just as easily break into blocks. The only fossils present are occasional single valves of Eotrapezium.

Towards the middle of the Blocky Beds the bedding becomes less noticeable and the rock breaks naturally into sub-cuboidal pieces, some of which are rounded and smooth like cobbles. Eotrapezium occurs as rare isolated valves.

In the upper part the marine bivalves are absent and rare; indeterminate fossils have been found which may be insect remains. The rock is either completely unbedded or with very faint bedding, and also breaks into blocks which tend to be smaller than those below. In the

TEXT - FIGURE 3. SECTION - BARNSTONE CUTTING



upper part the blackness of the rock fades progressively upwards to where the unweathered rocks are light grey in colour. These middle and upper beds are siltstones and sieved residues leave granules of light grey material with quartz grains, mica, small nodules of pyrite and pieces of cemented sandy material.

The boundary between the Block Beds and the Cotham Marls above is an indeterminate one, there being a gradual change from one to the other. The change is characterised by a transition from blocky to shaly bedding, from a grey to a yellow-grey colour and by an increase in the calcareous content.

The Cotham Marls (6 ft. (1.8 m.))

These beds consist chiefly of grey marls which turn yellow on weathering. Most of the material exposed was weathered to some extent, the yellowness first appearing in patches. Much of these beds has bands of hard crumbly shale alternating with layers of softer rock. Some of the marl is almost a whitish grey, due to an increase of calcareous material. Scattered through the marl, but particularly in the upper part, there are many pieces of white and light buff coloured calcitic material which ranges in size from extremely minute up to about one inch (25 mm.) across. The larger ones are found only at exposure J. They have internal hollows and bizarre shapes. At exposures E and F, about 1 ft. 9 ins. (0.5 m.) from the top of the marl, there is about 10 ins. (0.3 m.) of light grey calcareous shales. At the base of these shales there is a ½ inch (12 mm.) layer of flattened, buff-coloured, calcareous nodules, many being sub-circular in shape with rounded, radially cracked edges. In the Cotham Marls at various horizons, there are occasional nodules of limestone up to 2 ft. (0.6 m.) across. These are of a similar rock to that of the limestone bed above and they contain rare branchiopods (Euestheria minuta). E. minuta has also been recorded in the Rhaetic beds of the Barnstone quarry (Kent, 1937, p. 165).

The Nodular Limestone (3 to 6 ins. (76 to 152 mm.))

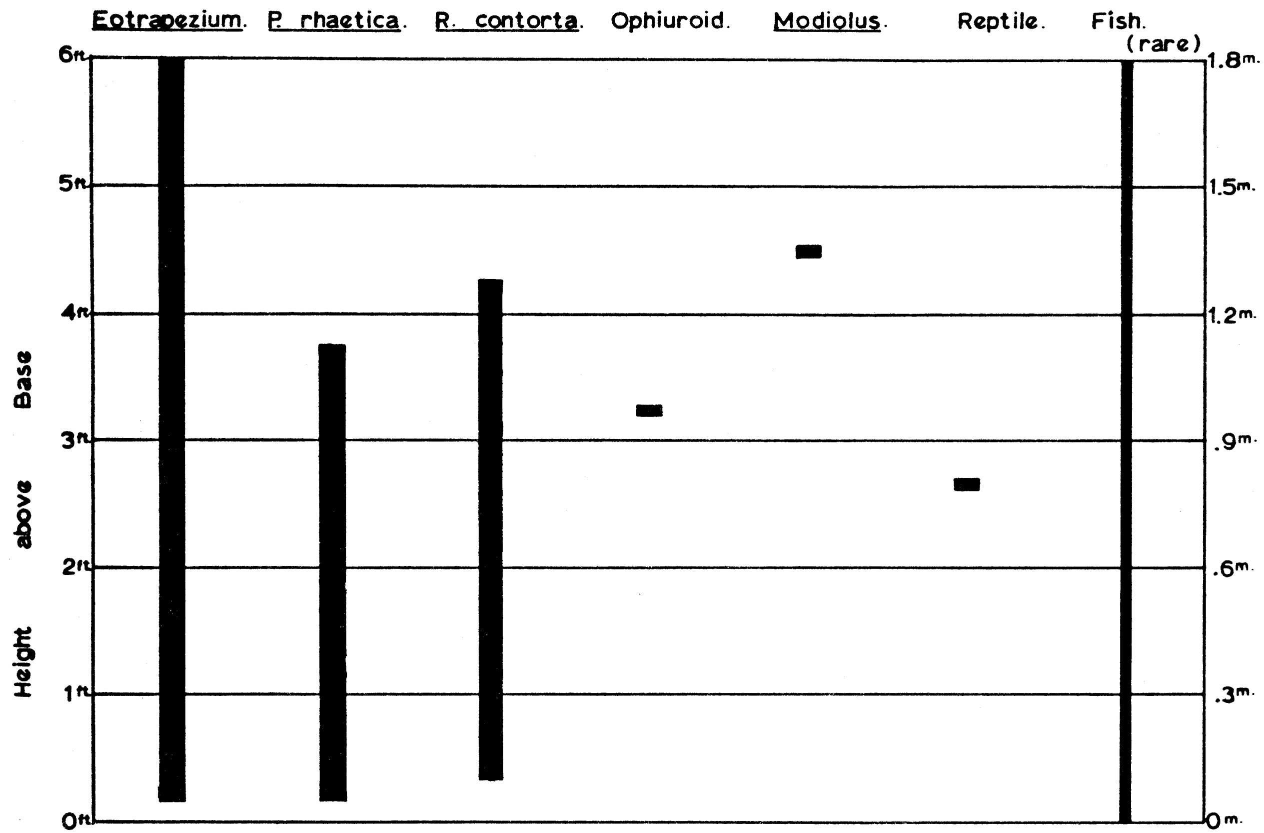
The Nodular Limestone occurs at the top of the Cotham Beds and is sporadic in its development. In one place it is found as a solid 6 ins. (0.2 m.) bed of limestone but mostly it is in the form of a layer of separate nodules 2 to 3 ins. (50 to 75 mm.) thick which are sometimes rather scattered. The limestone has a conchoidal fracture, is fine grained, light grey, weathering creamy and is unbedded. There is much calcite in the form of veins and layered tufa on the outer surfaces. Rare Euestheria minuta are the sole fossils found.

Jurassic

The Pre-Planorbis Beds (5 ft. 5 ins. (1.6 m.))

The beds above the Nodular Limestone consist of thin limestones, limestone shales and marls. The lowest bed comes in at the top of the cutting just N.W. of exposure E and the highest bed is just below ground level at exposure N (Text-fig. 3). The beds are fairly consistent along their length with the exception of the lowest. This is separated from the Nodular Limestone by 3 ins. (75 mm.) of marl, except between exposures E and J where the marl thickens up to 1 ft. 10 ins. (0.6 m.) and contains a minor limestone bed. The lowest limestone has a lumpy undersurface. The marls are grey to buff and range from shales to clays. Between these and the limestones there are sometimes some hard, transitional limestone shales. The limestones are thinly bedded, being medium grey with bluish centres and occasionally purple stained, one exception being the top 1½ ins. (38 mm.) layer of the third which is brown and sandy.

These beds have a distinctive fossil suite which is found, either fully represented or in



TEXT-FIG. 4. THE OCCURRENCE OF FOSSILS IN THE BLACK SHALE BEDS.

part, in each separate bed. The marls have sparse, poorly preserved foraminifera and occasional ostracods. The limestone shales are similarly poorly fossiliferous, though also with occasional bivalve impressions. The limestones are much more fossiliferous. Modiolus minimus J. Sowerby is found mostly in the first and second limestones. Modiolus sp. is found in them all, though most abundantly in the brown, sandy upper bed of the third limestone. This is a type intermediate between M. hillanus J. Sowerby and M. minimus (Kent, 1953, p. 136). Liostrea hisingeri (Nilsson) is rare throughout, whereas echinoid spines increase from being rare in the first limestone to abundant in the fourth. Pleuromya tatei (Richardson and Tutcher) is found in all the limestones but is only abundant in the purple-stained lower part of the third limestone. Ostracods and foraminifera (Cornuspira sp.) are scattered in the limestones, though these also become abundant in the top bed of the third limestone.

Palaeoecological Discussion

At Barnstone there is no fossil evidence to suggest that open marine conditions were present before the deposition of the Rhaetic Beds. The transition from the Tea Green Marl to the lowermost shale of the Rhaetic is suggestive of a gentle invasion by the sea, causing little disturbance to the previous deposits. It must be considered, however, that the incursion occurred after a long period of peneplanation, and that the supply of material available for deposition will have come from the surrounding low-lying Triassic plains. At Barnstone this material may have possibly been laid in a pre-existing body of water. The sedimentology of the Tea Green Marl shows that it has a comparable composition to that of the Rhaetic shales above, so that they were probably derived from a common source. However, the sediments are more sorted in the Rhaetic, where partings of current concentrated, white sandy quartz are characteristic of much of the shales. The multi-coloured grains of the Tea Green Marl can also be found matched in the Bone Bed.

With the first deposition of black shale we find that a variety of fishes were living in the open water, but locally there is no evidence of a benthonic fauna. It is only higher up the succession, above the Bone Bed, that bivalves appear. As all the shales have broadly the same lithology it is suggested that bivalves were slow to migrate into the area.

The presence of concentrations of vertebrate remains in bone beds is the outstanding feature of Rhaetic rocks, and many widely differing theories have been advanced to explain them. These theories may be divided into three categories:-

1. That mass deaths of vertebrates provided an enormous amount of material for preservation.
2. That concentrations were formed by the lack of deposition of any associated sediments.
3. That any sediment deposited with the bones was subsequently winnowed away.

Throughout this country the Rhaetic Bone Beds differ lithologically, but all appear to contain coarse sand and sometimes pebbles. This is the case at Barnstone, where there seems to be a special relationship between coarse sediments, phosphatic nodules and vertebrate remains. Phosphatic remains occur in association with coarse deposits in patches within the black shales below the Sandy Beds. It would appear that the conditions which produced one also produced the other. The presence of unfossiliferous lenses of fine sediment within the fossil-packed Bone Bed emphasises that vertebrate remains and fine sediments are not usually associated. The presence of rare and randomly scattered fish and reptile remains, together with the absence of coarse quartz

STRAT. DIVS.	BEDS	LITHOLOGY	FAUNA	THICKNESS ft.	ins	metres
HETT-ANGIAN	PRE-PLANORBIS BEDS	Blue-centred, grey limestones with light grey L/st. shales, yellow-grey marls and clays between. 3rd limestone with purple-stained base and sandy top.	Pleuromya tatei, Modiolus minimus, Modiolus sp., Liostrea hisingeri, Echinoid spines, Ostracods, and Foraminifera.	5	5	1.6
UPPER RHAETIC	NODULAR LIMESTONE	Light grey limestone, weathering creamy	Rare Euestheria minuta		3-6	0.1
	COTHAM MARLS	Light grey shaley marl, weathering yellow, with calc. nodules and limestone boulders	Rare Euestheria minuta in the boulders.	6	0	1.8
LOWER RHAETIC	BLOCKY BEDS	Black, blocky shales and siltstones becoming grey towards the top.	Eotrapezium in the lower part.	9	0	2.7
	SANDY BEDS	Black shales with thin sandstones, also many sandy partings and layers.	Eotrapezium concentricum and Eotrapezium sp.	4	6	1.4
	BLACK SHALE BEDS	Bedded black shales, flaggy towards base.	Protocardia rhaetica, Rhaetavicula contorta, Eotrapezium concentricum, E. sp., ?Modiolus, Ophiuroid, rare fish and reptile remains	6	1	1.9
	BONE BED	Crumbly mudstone with shale patches on a layer with pyritic matrix. Pebbles, quartz grains and phosphatic nodules, etc.	Fish and reptile remains with rare bivalves and many coprolites. (All the fish and reptile specimens described are from the Bone Bed).		3	0.1
	PRE-BONE-BED BLACK SHALE	Black shales with sandy partings, occasional quartz grains and phosphatic nodules.	Fish remains	1	6	0.5
KEUPER	TEA-GREEN MARL	Grey-green indurated marl.	More than	2	0	0.6

TABLE 1. STRATIGRAPHICAL COLUMN WITH CONTAINED FAUNA

concentrates, shows that vertebrates were being continually deposited in the black shales overlying those just above the Bone Bed. In the Bone Bed there was obviously increased water movement in bottom currents to transport the coarse material and to roll, break up, and abrade the bones deposited. In considering the origin of the Bone Bed, one of the main problems to be explained is how such a thick concentration of vertebrate remains came to be formed contemporaneously over such a wide area. It is possible, however, that the Bone Bed exposed at different localities does not belong to one continuous bed. This is supported by its variable occurrence at Barnstone, its absence at Cotham (in Lincolnshire, not the famous locality) and Bunny, and also its occurrence at more than one horizon at such places as Gainsborough and Aust. If the bed is not continuous but occurs as discrete lenses at slightly different levels, it makes the depositional theory of coarse transported sediments more feasible. Variations in the lithology and horizon of the Bone Bed and the diverse theories of its origin are more fully discussed by Kent (1968).

Apart from the Bone Bed the Black Shales are the most fossiliferous Rhaetic rocks, containing mostly thin-shelled marine bivalves. Near the base of the Black Shales occasional slight increases in water movement produced silty layers, although higher up, quieter conditions are indicated by the absence of silt and by bedding planes covered with bivalves. Some small groups of shells are found broken up in the Black Shales, yet on the layers containing numerous specimens they are mostly undamaged and many of them are still joined together. These crowded layers often contain individuals of a small size range and may have been sorted by short distance transport, which would not have broken or dissociated the valves. The blackness of the shales and the contained pyrite indicates that anaerobic conditions were probably present within the sediments. The bottom conditions, however, must have been fairly saline and oxygenated, because ophiuroids which occur in these beds require these conditions.

After the quiet conditions of the Black Shales, the overlying Sandy Beds contain disturbed sediments which indicate greater current action. The black shale within the Sandy Beds has a similar lithology to that in the beds below which shows that the same anaerobic influences were still active. When bivalves are present within this shale, a few still have their valves joined and open. However, these conditions were periodically disturbed by increased water movement bringing in an influx of a new type of sandy deposit. The sandstones were probably deposited quickly because the bivalves are scattered indiscriminately and occur with their valves closed. Further evidence is the current bedding of some of the sandstones. There is also evidence of contemporaneous movement of the sediments after deposition, as demonstrated by the alternating layers of disturbed and undisturbed sediments. At exposure C, some black shale horizons show a 'rippled' surface, although, according to Twenhofel (1950, p.567) ripple marks cannot be formed in muds. In addition the sides of some of the sand-filled channels are too steep to be ripple marks. The orientation of all these structures is in the same general direction. It is therefore concluded that these phenomena are not depositional features but are due to lateral pressure on the sediments. The structures figured (Text-fig. 2) show that these channels were filled from the South. Regionally, the Rhaetic thickens to the North and thins towards the South (Kent, 1968, p.179) and movement of material from the South to the thicker beds of the North is consistent with the deposition of these channels. Exposures at D, E and F show distorted beds, which are due to the same influences as described above, since they orientated in the same direction. The folding here could have been caused by slumping due to slight local tilting which also gave rise to the lateral pressures. Flat-lying beds are found laid on top of distorted beds, which could indicate slight pauses in deposition whilst the distortion was taking place. The transition to calcareous conditions is found widely in the Rhaetic, and this transitional horizon occurs about one third of the way up these beds.

The outstanding character of the Blocky Beds is their development of jointing and their general paucity of bedding. Pressure or tension on rocks results in jointing and, on partly indurated muds, causes splitting into well defined blocks, some of which become rounded by movement and abrasion (Boswell, 1961, p.102). The definitely calcareous nature of these beds could influence their fracture on weathering. They were, however, probably affected by stress a short time after their deposition, producing the many smoothly rounded blocks. Near the base, these sediments show sorting and the fact that they have alternate deformed and undeformed layers indicates that the same influences were in operation as in the beds below. Silty layers are not present higher up, although silt grains are still present in the sieved samples. When the supply of sediment is much greater than can be carried by the transporting agent, the sorting of silt and sand does not take place. This would imply that these beds were laid down fairly rapidly. This is supported by the progressively greater rarity of the marine bivalves upwards, caused either by their aversion to rapid silt deposition or by their sedimentological dilution. Near the top of the Blocky Beds a marine fauna is absent, and this suggests a transitional period to the conditions of the beds above. The presence of paler sediments near the top is possibly due to a lessening of the previously existing anaerobic conditions.

No distinct line can be drawn between the Blocky Beds and the Cotham Marls, for one merges slowly into the other. However, a progressive change in lithology is shown by the residues, which contain an increasing quantity of shale fragments, pyrite and calcite granules, becoming yellow rather than grey. There is no unconformity or non-sequence at the top of the Blocky Beds. Although Wilson (1877) placed them in the Upper Rhaetic, these beds are here placed in the Lower Rhaetic because of their continuity with the fauna below and their lithological difference from the Cotham Beds here and in other parts of the Midlands. These are possibly a set of rapidly accumulated, localised deposits.

The Cotham Marls at Barnstone have yielded few fossils. It has been suggested that Midland equivalents of these beds show a return to conditions approaching those found in the Keuper (Kent, 1968, p.178). The branchiopods (Euestheria) which have been found near the base and at the top of these beds helps to bear this out, since they are considered to have lived in fresh or brackish water (Jones, 1862; Thompson, 1966).

There are some indications of a non-sequence at the top of the Rhaetic. The lowest of the Pre-Planorbis Beds varies in thickness and the overlying limestone seems to have been laid down on an eroded surface. Above the Nodular Limestone a new suite of fossils appear which are characteristic of the Pre-Planorbis Beds. These are very sparsely represented in the lowest marls, but are fully represented in the lowest limestone. Only the lower part of the Pre-Planorbis Beds is present in the Barnstone cutting. The bivalve Pieuromya tatei is the main fossil found there and it is the dominant fossil of this horizon elsewhere in this country (Tutcher, 1917, p.281). A full sequence of the Pre-Planorbis Beds is described by Kent (1937). The specimens of the bivalve Modiolus sp. found associated with these beds are thought to occupy a definite horizon in this area and have been considered as a possible indicator of the White Lias (Kent, 1953). However, at Barnstone they are found only in association with the Pre-Planorbis Beds.

Fossil Descriptions

The fossil descriptions have selected synonymies only. The figured specimens have been deposited in the Department of Palaeontology, British Museum (Natural History).

Phylum Mollusca

Class Bivalvia

Rhaetavicula contorta (Portlock)
(Pl. 18, Fig. 12)

1962 Rhaetavicula contorta (Portlock): Cox, 4, pt. 4, p.594, fig. 1.
MATERIAL: Numerous detached left valves and a few right valves.
DESCRIPTION: An adequate and easily obtainable description of this species is available (Cox, 1962).

Protocardia rhaetica (Merian)
(Pl. 18, Fig. 14)

1853 Cardium rhaeticum Merian in Escher v.d. Linth, p.19, pl. 4, figs. 40-41.
MATERIAL: Many crushed, discrete or associated valves.
DESCRIPTION: The valves are rounded in outline, with fairly prominent umbones situated a little anterior of the centre. The anterior margin is concave near the umbo and sweeps round in a convex curve to the gently rounded, rather flattened, ventral margin. The dorsal margin is short and straight and is separated from the posterior margin by a distinct angle. The posterior margin is nearly straight and steeply inclined, and is separated from the ventral margin by a rounded angle. The posterior portion of the valve is gently folded on a line from the umbo to the postero-ventral corner. The posterior area is ornamented by an average of thirteen low radial ribs, four of which are anterior to the fold. The surface of the shell is ornamented with faint concentric rugosities which are impressed on the radial ribs.

Eotrapezium concentricum Moore
(Pl.18, Fig. 11)

1861 Axinus concentricus Moore: Moore, pl. 15, figs. 19-21, p. 503.
1969 Eotrapezium concentricum (Moore): Ivimey-Cook and Elliot, p. 145.
MATERIAL: Numerous specimens with separate or joined valves.
DESCRIPTION: The valves are moderately inflated, ovate, with the umbones a short way anterior of the centre. The anterior margin is concave near the umbo and sweeps round in a convex curve to the gently rounded ventral margin. The dorsal margin behind the umbo is gently inclined, straight, and produced to give an obtuse angle with the very gently rounded posterior margin. The posterior margin is almost vertical and has an angular junction with the ventral margin. There is a sharp carina from this angle to the umbo. The posterior area is inclined at an angle to the rest of the valve. The surface of the valve is ornamented with very fine striations which follow the margin.

? Eotrapezium sp.
(Pl. 18, Fig. 13)

MATERIAL: Several solid phosphatic specimens and a few crushed moulds in shale.
DESCRIPTION: (Based on phosphatised specimens). The valves are slightly inflated, ovate, with the umbones about one third of the length from the anterior margin. The margins are gently rounded, there being no posterior truncation.
REMARKS: It has not been possible to accurately determine this species and it is only tentatively allocated to Eotrapezium.

Phylum Arthropoda

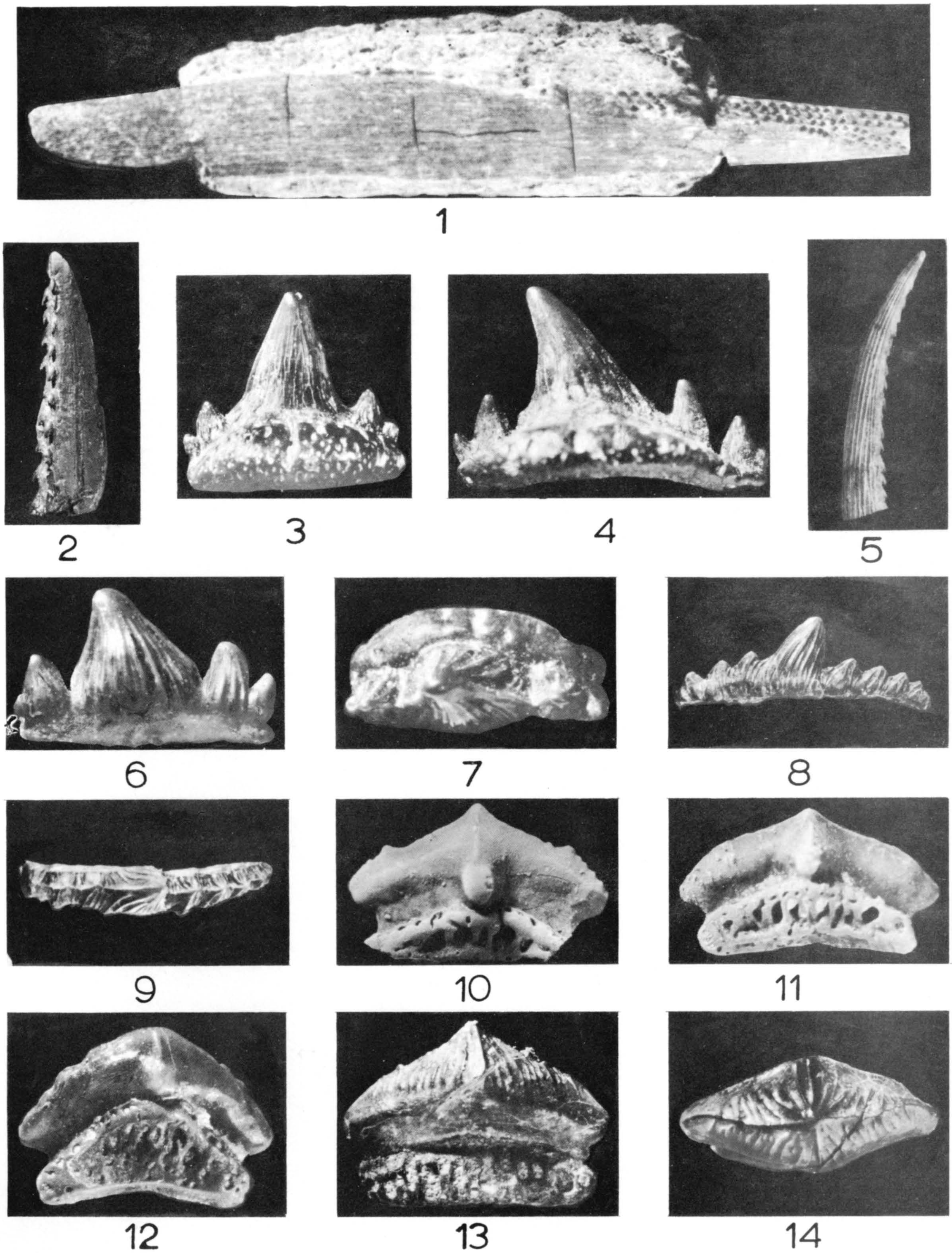
Class Crustacea
(Pl.18, Fig. 10)
Euestheria minuta (Alberti) var. brodieana Jones

1862 Estheria minuta var. brodieana, Jones: Jones, p. 67, pl. 2, figs. 8-15.
MATERIAL: A few carapaces.

EXPLANATION OF PLATE 15

Figs. 1 & 2	Nemacanthus monilifer Agassiz.
Fig. 1	Lateral view of fin spine. (18.6 x 151.6 mm.)
Fig. 2	Lateral view of tip of fin spine. (17.6 x 4.7 mm.)
Figs. 3-7	Hybodus minor Agassiz.
Fig. 3	Inner view of anterior tooth. (5.3 x 6.3 mm.)
Fig. 4	Inner view of lateral tooth. (2.3 x 3.5 mm.)
Fig. 5	Lateral view of fin spine. (51.7 x 9.1 mm.)
Fig. 6	Outer view of posterior lateral tooth. (1.5 x 2.9 mm.)
Fig. 7	Apical view of same. (1.5 x 2.9 mm.)
Figs. 8 & 9	Hybodus cloacinus Quenstedt.
Fig. 8	Outer view of lateral tooth. (4.8 x 14.8 mm.)
Fig. 9	Apical view of same. (2.6 x 14.8 mm.)
Figs. 10-14	Acrodus minimus Agassiz.
Fig. 10	Outer view of posterior lateral tooth. (1.8 x 2.8 mm.)
Fig. 11	Outer view of posterior lateral tooth. (1.8 x 3.4 mm.)
Fig. 12	Outer view of anterior tooth. (3.1 x 4.8 mm.)
Fig. 13	Inner view of lateral tooth. (4.0 x 5.0 mm.)
Fig. 14	Apical view of same. (2.6 x 5.5 mm.)

All quoted measurements are of the heights and widths respectively in each of the given views.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DESCRIPTION: The carapace of this branchiopod is ovate, moderately inflated, with the maximum inflation about half way down the carapace below the umbo. The hinge border is straight and just over half the length of the carapace. It curves downwards at the posterior end into a rounded, rather oblique, posterior margin. The rounded umbo is situated about one quarter of the length from the anterior end. The anterior border is straight and inclined for a short distance before forming a gently, more acute curve than the posterior margin. The ventral margin is slightly curved. The carapace has a small smooth area around the umbo and the rest is ornamented with a series of fourteen concentric rugosities.
REMARKS: These specimens compare well with Jones (1862) description.

Phylum Echinodermata
Subphylum Eleutherozoa
Class Stelleroidea
Indeterminate Ophiuroid
(Pl.18, Fig. 9)

MATERIAL: One complete specimen and a few fragmentary arms.
DESCRIPTION: The complete specimen consists of a roughly pentagonal central disc and five long, narrow, radiating arms. The disc shows the bases of the arms converging inwards towards a central mouth. This is suggestive of an under surface of a disc. The arms are gradually tapering and originate at the angle of the disc. Some of the fragmentary arms clearly show the shield plates.
REMARKS: This ophiuroid is strictly indeterminate but on stratigraphical grounds may be referable to *Ophiolepis damesii*, which has been found in Leicestershire (Harrison, 1876).

Phylum Chordata
Class Chondrichthyes

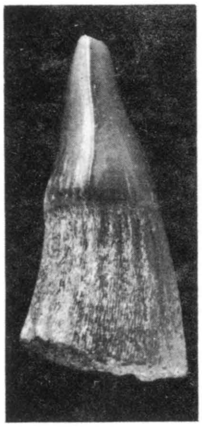
Nemacanthus monilifer Agassiz
(Pl.15, figs. 1-2, text-fig. 5, fig. 3)

1837 *Nemacanthus monilifer* Agassiz: Agassiz, 3, p. 26, pl. 7, figs. 10-15.
1858 *Desmacanthus cloacinus* Quenstedt: Quenstedt, p. 34, pl. 2, fig. 13.
1872 *Nemacanthus monilifer* Agassiz: Etheridge, p. 64, pl. 2, fig. 1.

MATERIAL: One nearly complete spine and many isolated fragments.
DESCRIPTION: The spine is elongate, solid, and laterally very compressed. The anterior margin is gently convex and bears a distinct, rounded enamel keel whereas the posterior margin is straight and has a rounded, longitudinal, median furrow. It is roughly triangular in cross section, with an anterior acute angle and a posterior narrow face with rounded edges. It has an acutely pointed tip bearing two rows of downwardly directed tubercles on the posterior face. The spine is very finely striated throughout its full length. The distal half of the spine is mostly ornamented with regular, rounded enamel tubercles. These are absent near the tip and extend to about one third the way to the proximal end on the anterior margin, producing an oblique boundary with the rest of the spine. None of the specimens shows a clearly defined insert portion.

EXPLANATION OF PLATE 16

Fig. 1	Birgeria acuminata (Agassiz). Lateral view of tooth. (10.5 x 5.2 mm.)
Figs. 2 & 3	Saurichthys longidens Agassiz.
Fig. 2	Lateral view of tooth. (13.3 x 6.3 mm.)
Fig. 3	Inner view of same. (13.3 x 6.3 mm.)
Fig. 4	Gyrolepis albertii Agassiz. Lateral view of tooth. (2.8 x 1.1 mm.)
Fig. 5	?Sargodon tomicus (Plieninger.) Lateral view of tooth. (5.4 x 1.9 mm.)
Figs. 6 & 7	Birgeria acuminata (Agassiz).
Fig. 6	Outer view of jaw fragment. (7.1 x 10.3 mm.)
Fig. 7	Inner view of jaw fragment. (7.1 x 10.3 mm.)
Figs. 8 & 9	Saurichthys longidens Agassiz.
Fig. 8	Inner view of jaw fragment. (20.5 x 25.6 mm.)
Fig. 9	Lateral view of jaw fragment. (20.5 x 16.2 mm.)
Figs. 10-13.	Gyrolepis albertii Agassiz.
Fig. 10	Outer view of anterior scale. (4.6 x 6.6 mm.)
Fig. 11	Outer view of dorsal scale. (5.2 x 5.4 mm.)
Fig. 12	Outer view of posterior flank scale. (1.1 x 3.2 mm.)
Fig. 13	Outer view of flank scale. (5.1 x 10.0 mm.)
Fig. 14	?Sargodon tomicus (Plieninger.) Lateral view of tooth. (1.8 x 1.8 mm.)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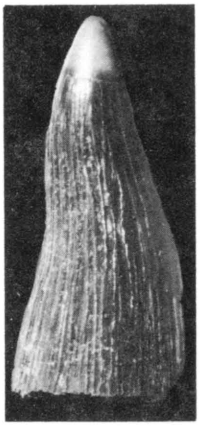
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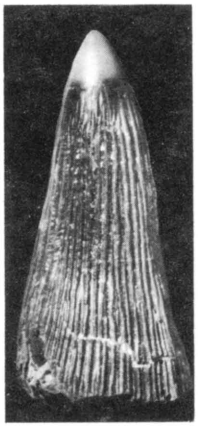
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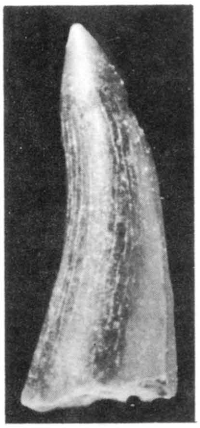
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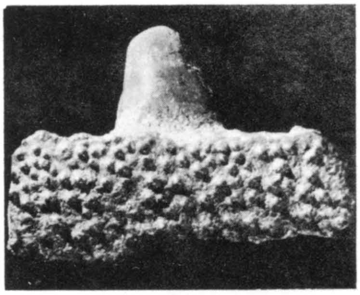
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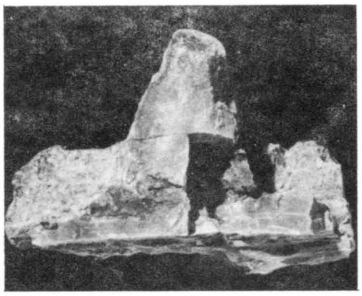
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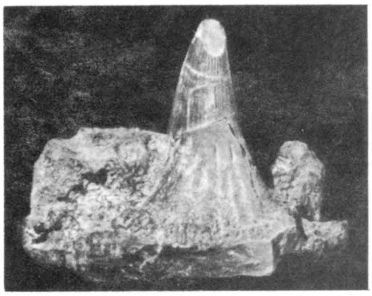
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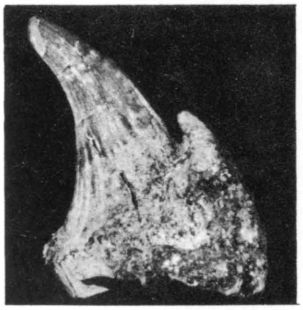
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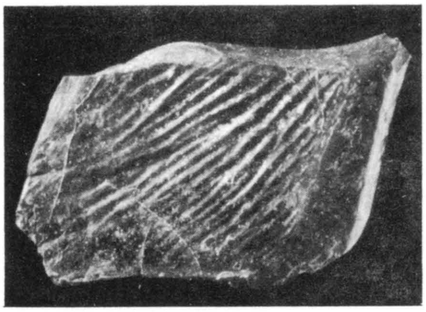
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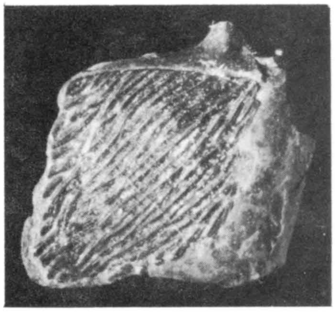
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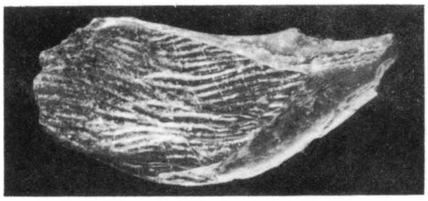
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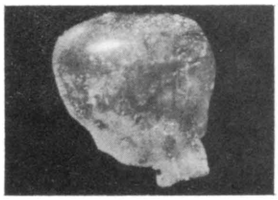
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Hybodus minor Agassiz (Jukes-Browne, 1885)
(Pl.15, Figs. 3-7, text-fig. 5, figs.4-b)

1843 Hybodus minor Agassiz: Agassiz, 3, pp. 48 and 183, pl. 8, figs. 2-3, pl. 13, figs. 21-24.
1858 Hybodus cloacinus Quenstedt: Quenstedt, p. 34, pl. 2, fig. 14.
1872 Hybodus minor Agassiz: Etheridge, p. 64, pl. 2, figs. 12-14.
1889 Hybodus minor Agassiz: Woodward, 1, p. 250.

MATERIAL: Numerous isolated teeth and three fin spines, one complete.
DESCRIPTION: The teeth consist of a central crown generally with one to three lateral crowns on each side rising from an interiorly extended root platform. The central crown rises from the aboral margin of the root, curves slightly inwards, and is upright or inclined posteriorly. It is broadly to moderately conical, has two cutting edges and is coarsely ribbed. The lateral crowns also rise from the aboral margin of the roots and resemble the main crown with respect to ribbing and shape. They decrease in size away from the centre, and occasionally the outermost have an incipient crown which is developed as a lateral protruberance. The root is basically a flat, semi-circular platform with the crowns rising at about a right-angle from the straight aboral margin. The roots are regularly perforate and vary from thin to bulbous forms.

The spines are elongate, hollow for approximately half their length, the distal portion being curved posteriorly. They are laterally compressed and oval in cross section. They have strong, broad, rounded ribs on each side, which increase by bifurcation from four near the apex to a maximum of nine. One of these ribs is situated along the anterior margin. There is a narrow area either side of the posterior angle which is pitted and lacks ribbing. The posterior margin possesses a row of downwardly directed denticles for about half the length of the spine. The upper end of each denticle is extended and wraps around the side of the one above, alternatively to the right and the left. The insert portion is distinguished from the exsert portion by its lack of ribbing and also its finely striate and pitted surface. The junction between the insert and exsert portions is diagonal, at an angle of about 45° to the posterior margin.
REMARKS: The fin spine figured by Agassiz (1843, pl. 8, figs. 2-3) is incomplete and lacks the distal end, which is the largest part of our figured specimen. This specimen differs only from those found at Barnstone in being more inflate.

Hybodus cloacinus Quenstedt
(Pl.15., Figs. 8-9)

1839 Hybodus reticulatus Agassiz: Agassiz, 3, pl. 24, fig. 26. (Jukes-Browne, 1885).
1858 Hybodus cloacinus Quenstedt: Quenstedt, p. 34, pl. 2, fig. 15.
1872 Hybodus reticulatus Agassiz: Etheridge, p. 64, pl. 2, fig. 11.
1889 Hybodus cloacinus Quenstedt: Woodward, 1, p. 256.

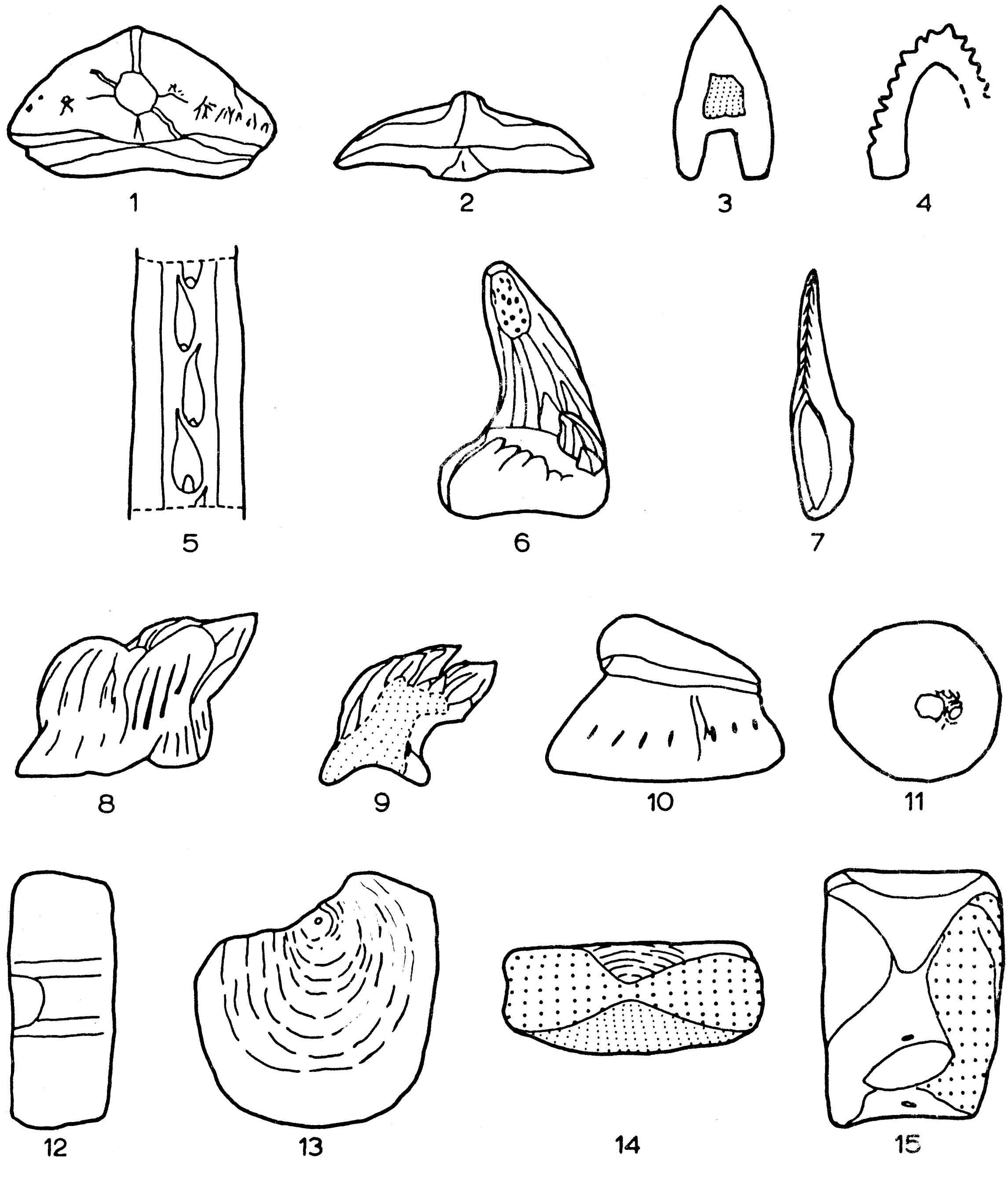
MATERIAL: A few isolated teeth, none with roots attached.
DESCRIPTION: The tooth, minus its roots, consists of an arched band of enamel with upright posteriorly inclined crowns which are low and coarsely striate. The centre crown is higher than the rest, there being about four lateral crowns on either side. Unlike H. minor, where the root forms an integral part of the tooth, no specimen has been found with root attached.
REMARKS: The teeth, although similar to those of H. minor, may be easily distinguished by their lateral extension, curved shape, low central crown and larger number of lateral crowns. The root attachment also differs; the under surface is concave and inclined upwards to the oral side because the tooth is longer aborally than orally, this is not the case in H. minor.

EXPLANATION OF TEXT-FIGURE 5

Figs. 1-2	Acrodus minimus Agassiz.
Fig. 1	Upper view of anterior tooth (same specimen as that figured on pl.15, fig. 12). (2.8 x 4.8 mm.)
Fig. 1	Upper view of posterior lateral tooth (same specimen as that figured on pl.15, fig. 11). (1.7 x 3.4 mm.)
Fig. 3	Nemacanthus monilifer Agassiz. Cross section of fin spine. (19.1 x 11.4 mm.)
Figs. 4-6	Hybodus minor Agassiz.
Fig. 4	Cross section of proximal part of fin spine. (15.7 x 11.0 mm.)
Fig. 5	Diagram showing details of denticles on posterior edge of fin spine (same specimen as that figured on pl.15., fig. 5). (9.8 x 4.3 mm.)
Fig. 6	Lateral view of anterior tooth (same specimen as that figured on pl.15, fig. 3). (5.3 x 3.5 mm.)
Fig. 7	Scymnorhinidae gen. undet. Lateral view of tooth (same specimen as that figured on pl.17, fig. 8). (4.3 x 0.7 mm.)
Figs. 8-9	Indeterminate Hybodont.
Fig. 8	Lateral view of type D dermal denticle. (1.2 x 1.9 mm.)
Fig. 9	Lateral view of type E dermal denticle (same specimen as that figured on pl.17, fig. 5). (1.3 x 1.8 mm.)
Fig. 10	Indeterminate Selachian. Lateral view of dermal denticle (same specimen as that figured on pl. 17, fig. 6). (1.7 x 2.4 mm.)
Fig. 11	?Sargodon tomicus Plieninger. Upper view of tooth (same specimen as that figured on pl. 16, fig. 5). (1.9 x 2.0 mm.)
Figs. 12-14	Indeterminate Ichthyosaur.
Fig. 12	Lateral view of type 1 vertebra centrum (same specimen as that figured on pl. 17. fig. 14). (35.3 x 14.7 mm.)
Fig. 13	Anterior view of type 2 (caudal) vertebra centrum). (75.1 x 73.2 mm.)
Fig. 14	Upper view of same. (32.0 x 70.4 mm.)
Fig. 15	Indeterminate Plesiosaur. Lateral view of vertebra centrum (same specimen as that figured on pl. 17, fig. 10). (60.9 x 43.0 mm.)

All measurements quoted are of the heights and the widths respectively in each of the views given.

TEXT - FIGURE 5



Acrodus minimus Agassiz (Jukes-Browne, 1885)
(Pl. 15, Figs. 10-14, text-fig. 5, figs. 1-2)

1839 Acrodus minimus Agassiz: Agassiz, 3. p.145, pl. 32, figs. 6-12.
1872 Acrodus minimus Agassiz: Etheridge, 3, pt. 2, p.64, pl. 2, figs. 15-17.
1889 Acrodus minimus Agassiz: Woodward, 1, p.282.

MATERIAL: Numerous isolated teeth, mostly detached from the roots.
DESCRIPTION: The teeth consist of an elongate low crown which is attached to a narrow elongate root. From above they are straight to slightly incurved, and sometimes possess an angular curve towards the ends. The crown consists of a central cusp with one to three minor cusps on each side. They may be broadly conical to depressed and rounded. Most cusps are radially, coarsely to finely striate from their apices; some have striations arranged in a 'herring bone' pattern. Cutting edges on the crowns join up to form a continuous edge passing through the apices. There is a centrally placed tubercle, sometimes accompanied by a row of minor tubercles at the base of the outer face of the crown. The crowns curve under to the roots. On the inner side there is a smooth, flattened area which extends obliquely below the crowns to the root contact. The teeth are inclined inward at an angle to the roots which are perforate and when detached leave a concave undersurface to the rest of the tooth.
REMARKS: By comparing these teeth with those of Liassic hybodonts, it is possible to refer the triangular shaped ones to the symphyseal area of the fishes mouth, the more elongate ones to the lateral region and the simplest teeth to a rear lateral position.

? Indeterminate Hybodont
(Pl.17, Figs. 1-5, text-fig. 5, figs.8-9)

MATERIAL: Many minute dermal denticles.
DESCRIPTION:
Type A - This resembles the minute teeth of Hybodus minor, with the typical root, nearly cylindrical crown, and inconspicuous lateral denticles.
Type B - The blunt, strongly fluted crown is round or oval when viewed from above and narrows near the flat root.
Type C - This type is similar to the last, but differs in possessing two to six closely-packed crowns and in being often more depressed.
Type D - This type is again similar to the preceding, but possesses one or more rear crowns which are laterally extended and bent to the rear.
Type E - This type is laterally elongate and consists of flattened and bent crowns.
REMARKS: These denticles bear a strong resemblance to those of Liassic hybodonts and may therefore be assigned to this group. The type A denticles probably came from the mouth area and the type E denticles from the flank. Those in between come from intermediate positions.

Scymnorhinidae gen. undet.
(Pl.17, Figs. 8-9, text-fig. 5, fig. 7)

MATERIAL: Several teeth.
DESCRIPTION: The teeth consist of a roughly triangular crown situated on a rectangular root. The crown is very compressed, pointed at the top and has pronounced serrated edges. The crown is slightly incurved either upright or laterally inclined, and usually rises from almost the full width of the root. It thins towards the edges, on which are three to nine upwardly directed, strong serrations. The serrations increase in size towards the apex, which is prominent. The root

has two upright lateral grooves which are either both on the inner side or on opposite sides. There is sometimes a transverse thickening below the lateral grooves, beneath which are two small circular canals near the middle of the root which are inclined inwards. The tooth is covered with parallel crack-like striations in its enamel.
REMARKS: These teeth compare closely with those of the Recent Scymnorhinus licha (Bon.) [see Casier, 1961, pp. 7-61, figs. 7-9.] None of the teeth recoverd from Barnstone is complete, however, and the best appear to lack the lower half of the root. Even so, the similarity with the Recent species leaves no doubt that they can be referred to the family Scymnorhinidae. They differ from Scymnorhinus particularly in the coarse serrations of the crowns and in the presence of two(not one) foramens in the root. They may well prove to belong to a new genus.

? Indeterminate Selachian
(Pl. 17, Fig. 6, text-fig. 5, fig. 10)

MATERIAL: A few minute dermal denticles.
DESCRIPTION: These denticles consist of a rounded to sub-quadrate base surmounted by a smooth rounded cap with undercutting sides. The base narrows sharply upwards and is radially grooved. The cap is more elongate than the base is inclined lengthwise and possesses a depressed upper surface.
REMARKS: These denticles are very similar to those of Hypolophus sylvestris White from the lower Eocene (White, 1931, p.72, figs. 109-112) but they differ in their smaller size and relatively larger caps. They presumably belong to a similar type of fish so far unrecorded.

Class Osteichthyes

Gyrolepis albertii Agassiz
(Pl. 16, Figs. 4 & 10-13)

1835 Gyrolepis albertii Agassiz: Agassiz, 2, p. 173, pl. 19, figs. 1-6.
1888 Gyrolepis albertii Agassiz: Dames, 4, p. 143, pl. 1, fig. 1.
1891 Gyrolepis albertii Agassiz: Woodward, 2, pp. 510-512.

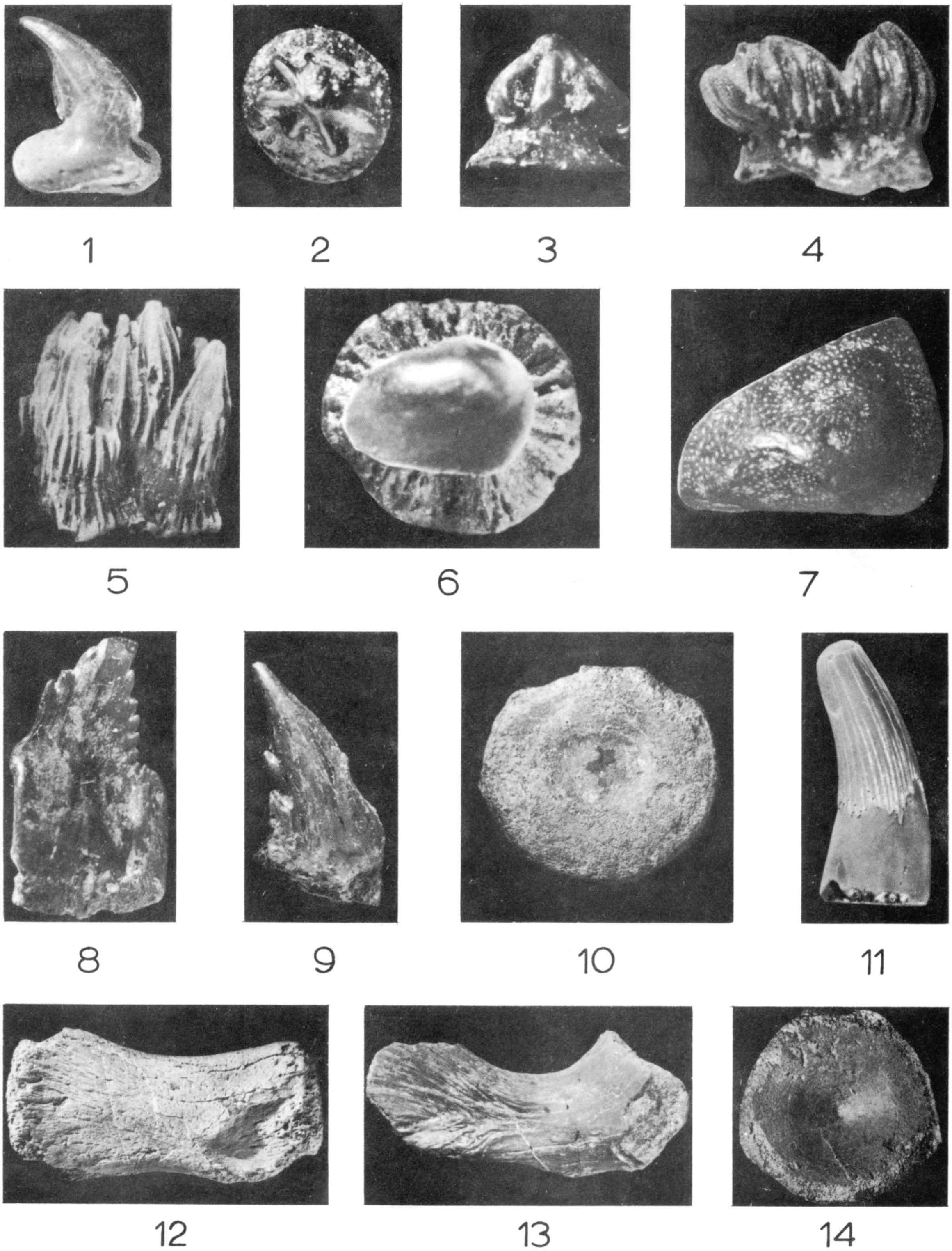
MATERIAL: Many isolated teeth and scales.
DESCRIPTION: The teeth are conical and gently tapered with a small, distinct cap. They curve inwards sometimes with a rather angular bend and they also incline slightly to the rear. The cap is smooth, sometimes translucent, and is directed upwards, i.e. not inwards. The rest of the crown is fairly smooth but the enamel is covered with parallel cracks. Some specimens are broadly striated at the base of the inner face.

The scales are quadrilateral in shape, varying widely from nearly square forms to types which are nearly rectangular, rhomboidal or elongate parallelograms. The outer surface is characterised by an enamel area which is variable in relative size. The under surface of the enamel possess low concentric ridges, which are clearly impressed on the outer face of worn scales which lack enamel. The enamel is ornamented by fine, diagonal, wavy striations. The enamel is made up of numerous thin layers which can be seen on worn specimens. The insert portion of each scale is wedge shaped and fits under the scale or scales anterior to it. The more rectangular and square types have one insert edge on the antero-ventral margin, which is often prolonged upwards to a varying degree. This type sometimes possess a small locking peg on the antero-dorsal margin and a corresponding notch on the under surface of the postero-ventral margin. The rest of the scales conform basically to this type but may possess two insert edges on the anterior margin.

EXPLANATION OF PLATE 17

Figs. 1-5	Indeterminate Hybodont.
Fig. 1	Lateral view of type A dermal denticle. (2.2 x 1.5 mm.)
Fig. 2	Upper view of type B dermal denticle. (1.4 x 1.1 mm.)
Fig. 3	Lateral view of same. (1.2 x 1.1 mm.)
Fig. 4	Lateral view of type C dermal denticle. (1.5 x 2.9 mm.)
Fig. 5	Upper view of type E dermal denticle. (2.0 x 1.8 mm.)
Fig. 6	Indeterminate Selachian. Upper view of dermal denticle. (2.2 x 2.4 mm.)
Fig. 7	?Ceratodus latissimus Agassiz. Upper view of dental plate fragment. (9.1 x 12.5 mm.)
Figs. 8-9	Scymnorhinidae gen. undet.
Fig. 8	Inner view of tooth. (4.3 x 2.5 mm.)
Fig. 9	Inner view of tooth. (3.5 x 1.8 mm.)
Figs. 10-12	Indeterminate Plesiosaur.
Fig. 10	Anterior view of vertebra centrum. (60.9 x 66.0 mm.)
Fig. 11	Lateral view of tooth. (22.8 x 9.2 mm.)
Fig. 12	Lateral view of paddle bone. (19.5 x 40.0 mm.)
Fig. 13	Indeterminate Archosaur. Upper view of ?pelvic bone. (18.2 x 40.9 mm.)
Fig. 14	Indeterminate Ichthyosaur. Anterior view of type 1 vertebra centrum. (33.2 x 35.3 mm.)

Plate 17



Fin rays of the tail are composed of a series of minute, discrete elements, each with the typical ornament found on the enamel of the scales described above.
REMARKS: Agassiz (1835) based this species on scales alone, which were said to be prevalent in the Trias and Rhaetic. It is possible to allocate the position of different scale shapes by comparison with articulated specimens of G.albertii from the Muschelkalk of Germany (Dames, 1888), and with the modern ganoid Lepisosteus. The scales of the rectangular type come from the neck region and those more square in shape come from behind these in the dorsal region. The trapezoidal elongation increases along the flank and in the ventral area, becoming extremely elongate in the tail region.

By these more complete fishes it was possible to associate the Rhaetic scales and teeth of the above form (Dames, 1888).

Birgeria acuminata (Agassiz)
(Pl. 16, Figs. 1 & 6-7)

1844 Saurichthys acuminatus Agassiz: Agassiz, 2, p. 86, pl. 55a, figs. 1-5.
1872 Saurichthys apicalis Agassiz: Etheridge, 3, p. 64, pl. 2, figs. 5-6.
1921 Birgeria mougeoti Hogard: Stensiö, p. 151, pl. 24, figs. 1-2.
1929 Birgeria mougeoti Hogard sp.: Corroy, p. 99, pl. 12, figs. 16-19.
1966 Birgeria acuminata (Agassiz): Savage and Large, 9, pt. 1, p. 135, pl. 20.

MATERIAL: Numerous isolated teeth and several jaw fragments.
DESCRIPTION: The teeth are broadly conical with a well defined cap which is often more than half the length of the shaft. They are upright and gently curved inwards; the crown is covered with enamel, which is often transculent near the apex. The cap has two cutting edges and is coarsely striated from the base to near the apex on the inner face; these striations are restricted to near the base on the outer face. The base of the cap is emphasised by a raised collar. The lower half of the crown is finely striated and broadly oval or round in cross section. A few specimens possess a short sub-cylindrical root which is smooth throughout and widens towards the base. The root shows no trace of a strongly infolded surface.
REMARKS: This is a well characterised species recorded from most Rhaetic Bone Bed exposures in this country. The isolated teeth figured by Corroy (1929) appear to be conspecific with acuminata.

Saurichthys longidens Agassiz
(Pl. 16, Figs. 2-3 & 8-9)

1844 Saurichthys longidens Agassiz: Agassiz, 2, p. 87, pl. 55a, figs. 17-18.
1929 Birgeria acuminata (Agassiz): Corroy, pl. 12, figs. 20-23.

MATERIAL: Numerous isolated teeth and several jaw fragments some with teeth attached.
DESCRIPTION: The teeth have a broad to elongate conical shape with a small distinct cap. They are upright with a moderate curvature inwards, some of the more curved ones being sigmoidal. The crown is covered with enamel which is often translucent at the apex. The cap is smooth and has an acute to obtuse tip which tapers more than the rest of the crown. The crown is circular in section and is coarsely striate between the cap and root, especially on the inner face. The hollow roots broaden widely to their base which is attached to a flat shelf of bone on the inside of the jaw. The walls of the root have a deeply infolded structure of labyrinthine type, giving externally a shallow ribbed surface.
REMARKS: More than a thousand teeth of the class Osteichthyes, from Aust Cliff, Somerset, were examined by Dr. J. Griffiths (unpublished MS.) who placed them into three groups:-

1. Teeth without striations or only light ones Gyrolepis albertii Agassiz .
2. Strongly striated teeth with distinct edges (Birgeria acuminata) (Agassiz).
3. Strongly striated teeth but round in section. These latter ones he named as Saurichthys longidens Agassiz, the type teeth having come from Aust Cliff.

The teeth from Barnstone also fall into these three types. Much confusion has occurred in the past over the two latter types. However, in the present work it has been possible to show that the root of S. longidens differs from that of B. acuminata and also that the ornamentation of their respective jaws is not the same.

Some jaw fragments, complete with roots only, resemble presumed labyrinthodont specimens labelled 'Metoposaurus ?' in the British Museum (Natural History) [Catalogue No. R2722] (Miall, 1875; Brodie, 1876). Some of the specimens recovered from Barnstone are very similar to these but undoubtedly belong to Saurichthys on the basis of the associated teeth. We therefore consider that all these jaw fragments belong to Saurichthys.

? Sargodon tomicus (Plieninger) (Jukes-Browne 1885)
(Pl. 16, Figs. 5 & 14, text-fig. 5, fig. 11)

1847 Sargodon tomicus Plieninger: Plieninger, J.H., p.165, pl. 1, figs. 5-10.
1889 Sargodon sp. Plieninger: Woodward, 1, pt. 11, p.20.
1895 Sargodon sp. Plieninger: Woodward, 3, pp. 67-68.

MATERIAL: Several tritorial teeth, mostly fragmentary.
DESCRIPTION: The crowns are minute and have a smooth shiny surface. From above they are oval, often almost circular. Laterally they widen from the root to a depressed dome, sometimes with a naturally worn surface. A few of the specimens have a small chisel-shaped tubercle on top of the crown. One specimen still possesses a straight cylindrical root.
REMARKS: Sargodon tomicus Plieninger was described from its front incisive teeth, which are chisel-shaped. These teeth are common at many Rhaetic Bone Bed exposures and have been found at Barnstone, though not by the present authors. Woodward (1895) considered the teeth with a depressed dome to be the tritorial teeth on the inner bones of the mouth of Sargodon. The few possessing tubercles are transitional in shape between those with the depressed domes and those definitely belonging to S. tomicus. This strongly supports the suggestion that these types are conspecific.

? Ceratodus latissimus (Agassiz)
(Pl. 17, Fig. 7)

1838 Ceratodus latissimus Agassiz: Agassiz, 3, p.131, pl. 20, figs. 8-9.
1889 Ceratodus latissimus Agassiz: Woodward, 1, pt. 11, p.21.

MATERIAL: One tooth fragment.
DESCRIPTION: The specimen consists of a roughly triangular domed fragment with a broken under surface. A series of minute parallel pores pass through the bone which has a pitting effect on the outer surface.
REMARKS: The fragment is identifiable by it shape and distinctive pore structure. It is the tip from a ridge on a dental plate. Its rounded dome suggests that it came from C. latissimus rather than more laterally compressed ridges of C. parvus.

Class Reptilia

Indeterminate Ichthyosaur
(Pl. 17, Fig. 14, Pl. 18, figs. 3-4 & 7-8, text-fig. 5, figs. 12-14)

MATERIAL: Several teeth and vertebrae, a paddle bone and possible jaw fragments.
DESCRIPTION: The teeth consist of a roughly cylindrical root surmounted by a broadly conical crown, which is about a third the length of the tooth. The rather stubby crown is slightly incurved and is moderately striate throughout, with fine striations superimposed. There is no distinct cap and the enamel is usually worn off the tip, leaving an oval exposure of dentine. The oval cross section of the crown is accentuated by two lateral cutting edges. The crown is often round at the base and is gently angled inward from the root. The hollow root is somewhat wider than the crown, is straight and narrows towards the base. The walls are deeply infolded longitudinally in a labyrinthine manner, externally forming broad shallow ribs. The crowns do not break cleanly from the roots, which are sometimes completely flattened.

The vertebrae are represented by only a few flattened, roughly circular centra. These are biconcave, with the centres of concavity near the centre of the concentrically striated posterior and anterior surfaces. The shape varies somewhat, depending on which part of the animal they come from. The dorsal vertebrae (Pl. 17, fig. 14) are equidimensional and roughly pentagonal, whilst the caudal vertebrae are more elongate (Text-fig. 5, figs. 13-14). The dorsal surface has two lateral raised regions for the articulation with the discrete neural arch. The dorsal vertebrae also possess two similar processes for the attachment of the ribs.

The paddle bones are flattened and polygonal usually elongate hexagonal though sometimes pentagonal. They are slightly concave on all surfaces. One of the specimens is slightly worn and shows an elongate pitting on the upper and lower surfaces which is radially orientated.

The jaw fragments consist of short regular lengths of bone with a characteristic cross section. In section they consist of an upright wall which is thickened at the base producing an upward-facing groove on the inner side.
REMARKS: Fragmented remains such as these are not sufficient for accurate determination beyond a statement that they are ichthyosaurian. The jaw fragments are only tentatively placed here as they possess a tooth groove similar to that of ichthyosaurs but not so pronounced (compare with that figured by Zittel, 1932, p. 275, fig. 379).

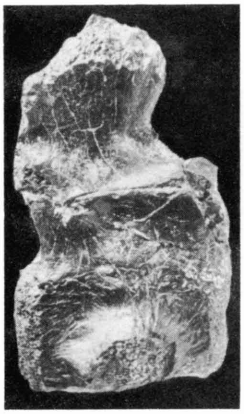
Indeterminate Plesiosaur
(Pl. 17, Figs. 10-12, text-fig. 5, fig. 15)

MATERIAL: One paddle bone definitely referable to a plesiosaur, and two centra, a few teeth and rib fragments, possibly plesiosaurian.
DESCRIPTION: The paddle is elongate and flattened; in outer view it is roughly quadrilateral and concave on both the anterior and posterior margins. In anterior view it is nearly straight, although it appears to be slightly sigmoidal.

Only one of the centra is here described. This centrum is moderately flattened and is roughly equidimensional, being slightly wider than high. The depth of the centrum is about two thirds the height and the anterior posterior surfaces are slightly concave. The base of the neural canal is preserved and forms a raised, flattened ridge across the dorsal margin. On either side of this the surface is excavated down as far as the widest part of the centrum. The ventral margin is roundly angled, with two prominent pores, one on either side of the ridge. Half way between the ventral margin and the widest portion of the centrum, on either side, there is a slightly

EXPLANATION OF PLATE 18

Figs. 1 & 2	Rhysosteus oweni Owen.
Fig. 1	Lateral view of type 1 (dorsal) vertebra. (27.5 x 16.2 mm.)
Fig. 2	Anterior view of same. (27.5 x 12.3 mm.)
Figs. 3 & 4	Indeterminate Ichthyosaur.
Fig. 3	Lateral view of tooth. (24.6 x 7.1 mm.)
Fig. 4	Possible jaw fragment. (33.1 x 13.0 mm.)
Figs. 5 & 6	Rhysosteus oweni Owen.
Fig. 5	Lateral view of type 2 vertebra centrum. (9.1 x 16.8 mm.)
Fig. 6	Anterior view of same. (9.1 x 8.2 mm.)
Figs. 7 & 8	Indeterminate Ichthyosaur.
Fig. 7	Upper view of paddle bone. (12.2 x 17.3 mm.)
Fig. 8	Lateral view of same. (12.2 x 7.0 mm.)
Fig. 9	Indeterminate Ophiuroid. (23.0 x 42.0 mm.)
Fig. 10	Euestheria minuta (Alberti) var. brodieana Jones. (2.1 x 3.2 mm.)
Fig. 11	Eotrapezium concentricum Moore. (5.1 x 4.2 mm.)
Fig. 12	Rhaetavicula contorta (Portlock) Left valve. (8.3 x 9.6 mm.)
Fig. 13	?Eotrapezium sp. (6.4 x 9.0 mm.)
Fig. 14	Protocardia rhaetica (Merian). (11.5 x 11.5 mm.)



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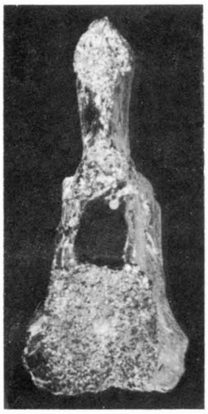

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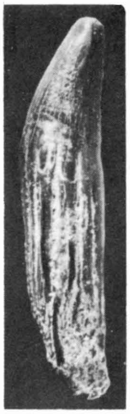

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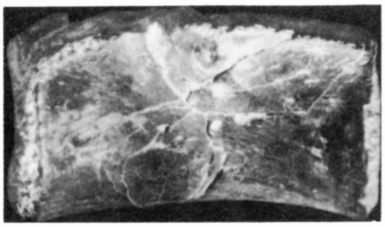

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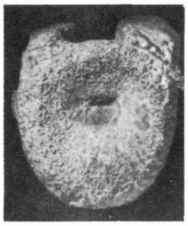

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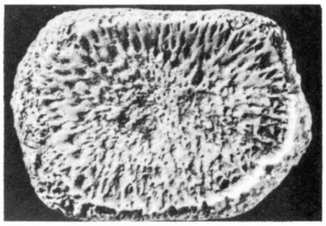

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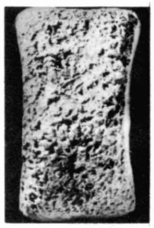

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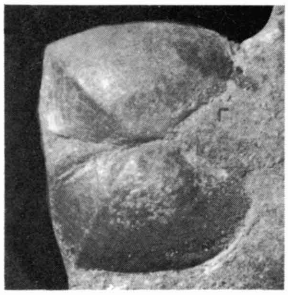

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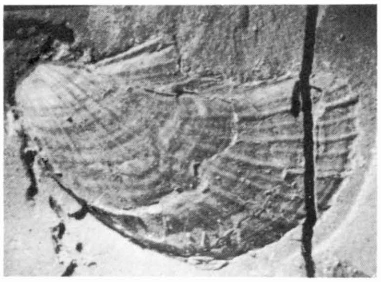

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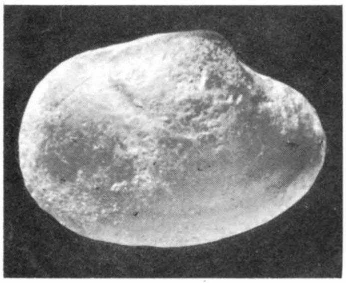

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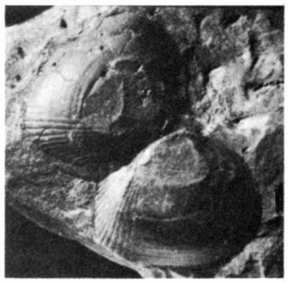

14

oblique oval pit for the articulation of the ribs.

The teeth, which all lack their roots, are conical and curve strongly inwards. They are very worn but appear to possess strong striations throughout. The crown is moderately oval in section, becoming circular towards the base. The only specimen with the top preserved is flattened by wear.

The rib fragment consists of the articulatory end and the majority of the shaft. The articulation surface is concave and elongate oval, comparing fairly closely with the corresponding area on the centrum. The shaft is narrow and strongly curved, becoming sharply inflated towards the articulatory end and broader near the ventral end. In cross section it is roughly oval with a keel down one side.
REMARKS: Small fragments such as these cannot be determined, beyond a tentative allocation to the plesiosaurian type.

Indeterminate Archosaur
(Pl.17, Fig. 13)

MATERIAL: Several fragmentary limb and ? pelvic bones.
DESCRIPTION: All the Archosaur remains recovered from Barnstone are too imperfect to be worthy of description. The limb bones include two proximal ends of tibias. The rest of the remains are only tentatively ascribed to this group of reptiles. It may be worth noting here a large indeterminate limb bone fragment (4 ins., 95 mm. across) which has also been recovered from Barnstone.

Rhysosteus oweni Owen
(Pl.18, Figs. 1-2 & 5-6)

1841 Rhysosteus oweni Owen: Owen, pp. 60-204.
MATERIAL: Several vertebrae.
DESCRIPTION: Two types of vertebrae were recovered which presumably come from different regions of the vertebral column. Type 1 (Pl.18, Figs. 1-2) is a dorsal vertebra of indeterminate position. The centrum is elongate, about twice as long as high, and is roughly rectangular in anterior view. The articulating surfaces are both badly eroded, but were probably slightly concave. The ventral surface is somewhat excavated. Each side is nearly flat and is dominated by the central, ventrally placed, broken end of the transverse process. The neural arch is high, with broad, thin walls which are nearly parallel but converge slightly upwards. The canal is roughly equidimensional in anterior view and becomes slightly laterally constricted posteriorly. Although the zygopophyses are missing, the orientation of the vertebra is given by the positions of their worn bases. The neural spine is broad, laterally compressed and directed forwards. It is somewhat constricted at the base and widens and thickens towards the top, where it is very worn.

Type 2 (Pl.18. figs. 5-6) is also a dorsal vertebra, and is probably a cervical. It is represented by six specimens from Barnstone, all but one of which are badly worn, and all lack the neural arch. The centrum is about twice as long as high and is broadly oval in end view, varying from narrow laterally to narrow vertically. The articulating surfaces are concave. The ventral surface is rounded and narrows towards the middle. The dorsal surface has a deep median longitudinal channel (floor of the neural canal) which deepens in the middle. This is bounded on each side by evenly raised ridges (base of walls of neural arch) which projects outwards in the middle and are ornamented by obscure broad, radial hollows radiating from points at the middle of the inner margins. In lateral view, the centrum is deeply excavated and the ventral margin is slightly concave.

Two specimens of discrete neural arches show additional details to those given above. These possess an elongate, laterally compressed neural spine which widens slightly upwards and is inclined

slightly posteriorly. The dorsal surface of the spine is flattened and has fine transverse rugosities. The sides are ornamented with downward oblique ridges in the upper half. The base of the spine widens considerably to form the broad roof of the neural canal. Both specimens have one of the posterior zygppophyses preserved,which project slightly posteriorly from the base of the neural spine and are directed downwards and outwards. The anterior zygopophyses are missing. On the right side of the larger specimen there is the broken end of a transverse process, just anterior of the centre of the specimen.
REMARKS: The type 2 vertebrae described above are closely comparable with those originally described by Owen as Rhysosteus oweni. The types of this species have their neural arches preserved, and compare closely with those described above. The also conform to that type 1 vertebra, which is therefore here allocated to this species.

Class uncertain
Indeterminate Coprolites

MATERIAL: Numerous coprolites.
DESCRIPTION: These are generally roughly cylindrical, sometimes curved, with irregular transverse furrows caused by the individual faecal pellets. In thin section they are not homogenous, and sometimes contain undigested fish remains, such as teeth and scales.
REMARKS: The coprolites recovered from Barnstone are very variable in shape and preservation. They are typically like the ones described by Pollard (1968). It is not possible to allocate these to the organisms that formed them, both reptiles and fish being probably responsible.

Conclusions

The Rhaetic rocks at Barnstone show that, after a quiet invasion of the sea, fine black muds were deposited in fairly quiet marine conditions. Within this environment, concentrations of coarse sand grains, phosphatic nodules and vertebrate remains were formed by current action. The influx of more sand from a different source resulted in slight movements of the deposits and possibly slightly intermittent deposition. This was followed by more rapid deposition of mud and silt, associated with conditions transitional to brackish water. Possibly a pause in deposition occurred at the end of Rhaetian times, after which the incursion of the Jurassic sea brought new sediments and a new fauna.

The prolific Bone Bed has yielded representatives of most Rhaetic species of fish and reptile previously recorded in this country.

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CYLINDRICAL TAPERING STRUCTURES IN THE ALLUVIAL SANDS OF THE TRENT VALLEY

by

Charles W. Claxton

Summary

Some structures produced by growth and decay of plants, and modified by percolating groundwater, are described. These structures provide a further method by which the way up of deformed strata may be determined.

Introduction

During the summer of 1968, examination of the gravel pits at Holme Pierrepont, Nottinghamshire (SK 625395) revealed that, overlying the gravels, there are 2-4 metres of loose friable sand, in turn overlain by silt up to 1 metre thick. At a number of localities in the sands, bright red, iron stained and cemented vertical cylindrical tapering structures are developed. These structures are absent from the overlying silts and also from the gravels below.

Description and Origin of the Structures

In all the exposures examined, the cylindrical structures were discontinuous. The observed sections are 2-8 c.m. long, but several short lengths are frequently seen to be aligned vertically through the sand faces; it is evident that they are parts of once continuous structures up to a maximum of 3 metres long.

The thickness of the structures is very variable. The maximum diameter observed was 14 mm. and the minimum was 4 mm. In all cases, the structures taper downwards, and they terminated with a conical point (Plate 19). In many cases, the structures are solid and are made up of the normal sandy deposit of the area, which has been cemented by a secondary iron oxide cement, giving rise to the bright red. colour. The iron oxide is present as a coating to the grains and does not render the material non-porous by filling in spaces between the grains. In fact, the structures at present exposed are extremely friable and it is very difficult to extract them from the sand. In other cases, the iron cemented structures have a central hollow core, which tapers downwards in the same way as the external form of the structure does. When there is a central hollow, it often contains traces of black carbonaceous material. The structures do not branch in any way.

The tubular structures are not evident in the silt above the clay; however, in these silts there are often dead roots of thistles and these are, in many cases, in alignment with the tubular structures developed in the sands below. The roots have not been observed extending into the tubular structures, though living roots can be seen at several localities extending down into the sands. The black carbonaceous material inside some of the hollow tubes is considered to be the decay products of long-dead roots.

The origin of the tubular structures is considered to begin with downward penetration of a major root, probably of the thistle (Cirsium lanceolatus), which is the plant around the gravel pits that produces the deepest-penetrating observable roots. During growth, this root structure produces and fills a hole, but after death of the plant, the root first shrinks and contracts away from the hole that it has forced in the sand, and then decays to give the black organic residue observed. As the root contracts, the sides of the progressively fall in after it; and at the same time, iron-bearing ground waters can enter the hole. Where decay of the root is rapid after shrinking, the hole becomes filled with sand before cementation. However, if the root shrinks and then persists without immediate decay, iron cementation from the percolating ground waters may sufficiently consolidate the sand to prevent further collapse into the hole after the root does decay, thus producing the structures with a central hollow. It is considered that the biochemical action of the decaying plant root is a possible factor which causes the precipitation of iron materials from the ground water: this is perhaps combined with evaporation due to the fact that the intergranular water of the sands is entering comparatively large open spaces around the roots, which may be in free access with the air when the root decays. Iron oxide deposition extends outwards for several millimetres beyond the original limit of the root. The tubular iron cemented structures are absent from the silts above the sands because these sediments are above the general level of the water table in this area; they are absent from the gravels below because the original roots did not penetrate to the gravels.

Conclusions

Fossilised roots and stems have long been used as way up criteria in areas of deformed sedimentary rocks and descriptions of in situ fossil trees with root systems are common. A selected bibliography of occurrence of this type from rocks of widely different ages is given by Shrock (1948, p.293). Almost exclusively these examples involve fossil remains in which the original botanical features are preserved by carbonisation or silicification, or by the formation of a cast after the original material disappears. Barrell (1913, p.462) has described and illustrated (op.cit. p.462, fig. 4) rootlet impressions on fracture surfaces in Upper Devonian argillaceous sandstones from the Appalachian Mountains. In this example, no trace of the original material is preserved but very clear impressions are present. Jenkins (1925, p.241) has described carbonaceous rootlets with calcareous linings, from lacustrine sands in the valley of the Pende Oreille River in Washington: he concludes that the dead rootlets acted as open channelways along which lime changed waters passed, precipitation of calcium carbonate taking place by evaporation during the drier season. There is no clear indication of the precise form of the structures, but in all of them the original rootlet is still present as a solid central core, and the calcite lining is a thin marginal structure.

In the example described here from the Trent Valley, a structure is developed which is dissimilar from the examples quoted above; it is larger than a cast or mould of the rootlet would have been, and it is not a thin sheath down the side of where the rootlet was originally, nor is it an impression. None of the structures of the roots are preserved, except for their tapering nature, and it is this latter factor which is of significance because it means that both the hole produced by the root, and the subsequent area of secondary iron cementation both taper downwards. This might be used in determining the way up of deformed strata in which similar structures are present.

PLATE 19 Cylindrical tapering structures from the alluvium of Holme Pierrepont, near Nottingham.

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The Hoveringham Gravel Company gave permission for a number of visits to their Holme Pierrepont quarries. In addition, the efforts of Mrs. S. Worth and Mr. W.J. Newman in searching the gravel pits for examples of these structures are gratefully acknowledged.

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FOSSIL FOOTPRINTS FROM THE MIDDLE TRIASSIC OF NOTTINGHAMSHIRE AND THE MIDDLE JURASSIC OF YORKSHIRE

by

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Summary

A vertebrate footprint from the Keuper Waterstones of Mapperley Park, Nottingham, is redescribed and made the type for a new ichnospecies: ?Otozoum swinnertoni ichnosp. nov; it is considered to be probably the footprint of a bipedal saurischian dinosaur, perhaps a prosauropod. A vertebrate footprint from a new locality in the Middle Jurassic (Lower Deltaic Series) near Ravenscar, Yorkshire, is described; it is compared with a Lower Cretaceous ichnospecies, Satapliasaurus dsocenidzei Gabouniya, but probably represents an ichnospecies as yet undescribed. It is considered to be the footprint of an ornithopod dinosaur.

Introduction

In an earlier paper redescribing fossil vertebrate footprints collected by the late Professor Henry H. Swinnerton (Sarjeant, 1967), it was noted that no footprints according with Swinnerton's "type A" had been located. A specimen considered by the author to accord with this type of track has now been found; it is here described and illustrated, and its taxonomic assignation is considered.

In addition, a vertebrate footprint from a new locality near Ravenscar, Yorkshire, is described; this was collected during the summer of 1969 by a Nottingham University student, Robert D. Boutell. It is compared with specimens recorded earlier from the "Inferior Oolite" of Saltwick, Yorkshire.

1. FOOTPRINT FROM THE MIDDLE TRIASSIC OF NOTTINGHAMSHIRE

In 1912, Swinnerton recorded the track of a vertebrate from the Keuper Waterstones of Mapperley Park, which he described in the following terms (pp., 66-7):-

> "Its foot was nine inches long and had at least four toes with a span of five inches. The toes were short as compared with the sole and were widely spread. The presence of the impression of the sole as well as of the toes indicates that it walked, as a man does, upon the flat of the foot, and was therefore plantigrade. The same print is repeated a yard in front, and halfway between but not in quite the same line is an imperfect impression of the other hind foot. There was no trace of the impression of the front feet, so that it evidently progressed easily on its hind feet alone.

This conclusion is substantiated by the discovery on another slab, and in association with a print made by a closely similar if not identical animal, of the imprint of a fore foot. This was only two and a half inches long with a span of three inches. The hind feet were therefore much larger than the fore feet and evidently carried the major portion of the weight of the body. The length of the stride and the size of the feet indicate an animal about four feet high."

In an earlier restudy of Swinnerton's material (Sarjeant, 1967), footprints of this type (his Type A) were not located. A large single print of a hindfoot, considered to be the right hind foot, has since come to light, labelled as from this locality and of the correct dimensions. It is described below:-

Class REPTILIA

Order SAURISCHIA

Ichnofamily Gigandipodidae Lull 1904

Ichnogenus OTOZOUM Hitchcock 1847

1847 Otozoum HITCHCOCK, p. 34.
1858 Otozoum Hitchcock. HITCHCOCK, p. 123.
1904 Otozoum Hitchcock. LULL, p. 513.
1915 Otozoum Hitchcock. LULL, p. 122.
1953 Otozoum Hitchcock. LULL, pp. 187-8.
1954 Otozoum Hitchcock. BAIRD, p. 185.
1958 Otozoum Hitchcock. KUHN, p. 23.
1959 Otozoum Hitchcock. SCHMIDT, pp. 21, 107.
1963 Otozoum Hitchcock. KUHN, p. 85.

Diagnosis. Bipedal. Manus rarely present in the trackway. Pes plantigrade, functionally tetradactyl, hallux non-rotated. Digits broad, with well marked phalangeal pads; claws more or less rounded. Manus apparently pentadactyl, relatively small. Occasional trail trace.

Type Species. Otozoum moodii Hitchcock, 1847, Upper Triassic, Connecticut, U.S.A. (Text-fig. 3).

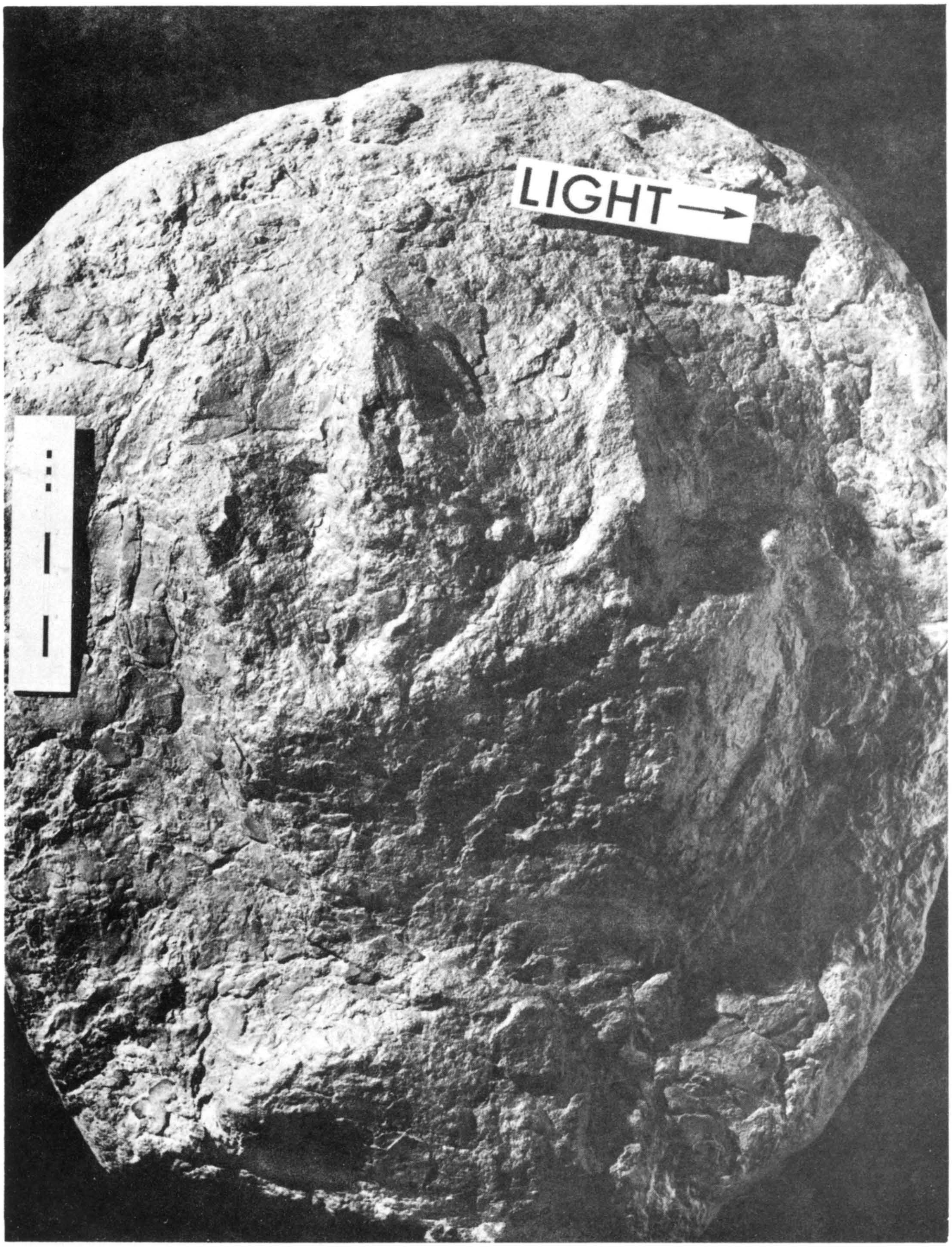
? Otozoum swinnertoni ichnosp. nov.

Plate 20, Text-figures 1, 2B.

1912. Vertebrate tracks, type A. SWINNERTON, pp. 66-7, pl. 4 fig. 3.
?1949 Vertebrate footprint. CHARLES, p. 10, text-fig. 1.

Diagnosis. Pes, considered to be of a bipedal reptile. Plantigrade, with the digits and front and hind parts of the sole deeply impressed, the central part of the sole not being impressed. Four digits (I-IV) are represented, the first being reduced. The fifth digit is not impressed (either non-functional or lacking). The digits are not markedly divergent; the phalangeal pads are poorly marked and the claws are not very acute.

Supplementary Notes. The author believes that this imprint, which is certainly from the same locality and exhibits comparable dimensions, corresponds to Swinnerton's "type A" (1912). From his description (quoted earlier), this was the track of a plantigrade animal; his illustration (1912, pl. 4 fig. 3) shows that the digits and front and hind parts of the sole of the pes were impressed, but that the central part of the sole was not impressed. Unfortunately, he illustrates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the mould, not the cast, making direct comparison impossible; unfortunately also, the photograph is over-reduced and of poor quality. For these reasons, certain identification is impossible and the identity of his "type A" with the specimen here figured cannot be established beyond doubt. If it is accepted, the following additional information can be supplied:-

> Typically bipedal, sometimes quadrupedal. Manus impression about one-third the size of that of the pes, with four (or five?) digits. Length of stride in bipedal gait about four times the length of the pes.

Holotype. Specimen PC4238 (cast of pes), collections of the Department of Geology, University of Nottingham. Type locality and horizon. Keuper Waterstones (L. Ladinian; Middle Triassic), Mapperley Park, Nottingham.

Dimensions. Pes (holotype); maximum length 215 mm., maximum breadth 145 mm., length of digit II c. 50 mm., digit III c. 63 mm., digit IV c. 50 mm., digit V 24 mm. Interdigital angles: I - II, 6.5^{o}, II - III, 8^{o}, III - IV 8^{o} (see Text-fig. 2B).

Supplementary Measurements. Manus not available for measurement; according to Swinnerton (1912, p.67) length c.62.5 mm., breadth c. 71.5 mm. Length of stride in bipedal gait (according to Swinnerton, 1912, p.66) c. 915 mm.

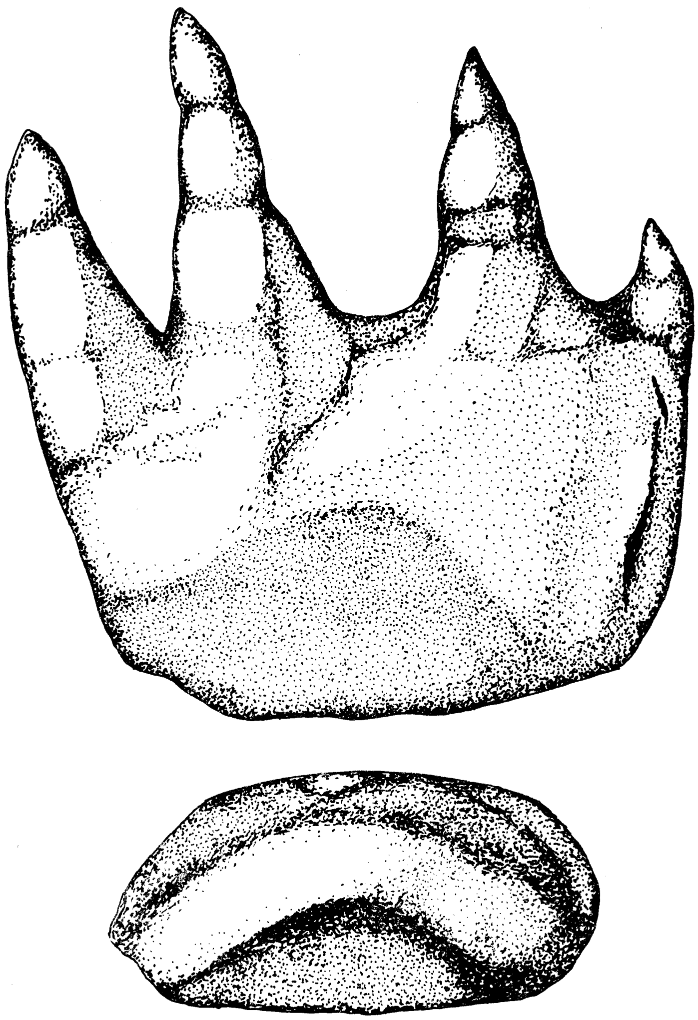
Derivation of Names. After the late Professor Henry Hurd Swinnerton, a pioneer of footprint study in Nottingham and Derbyshire.

Remarks. So far as has been determined from an extended examination of footprint literature, the imprint here recorded represents an undescribed type, without close morphological similarity to any described ichnospecies (bipedal or quadrupedal). For this reason, a new name is confidently assigned to it.

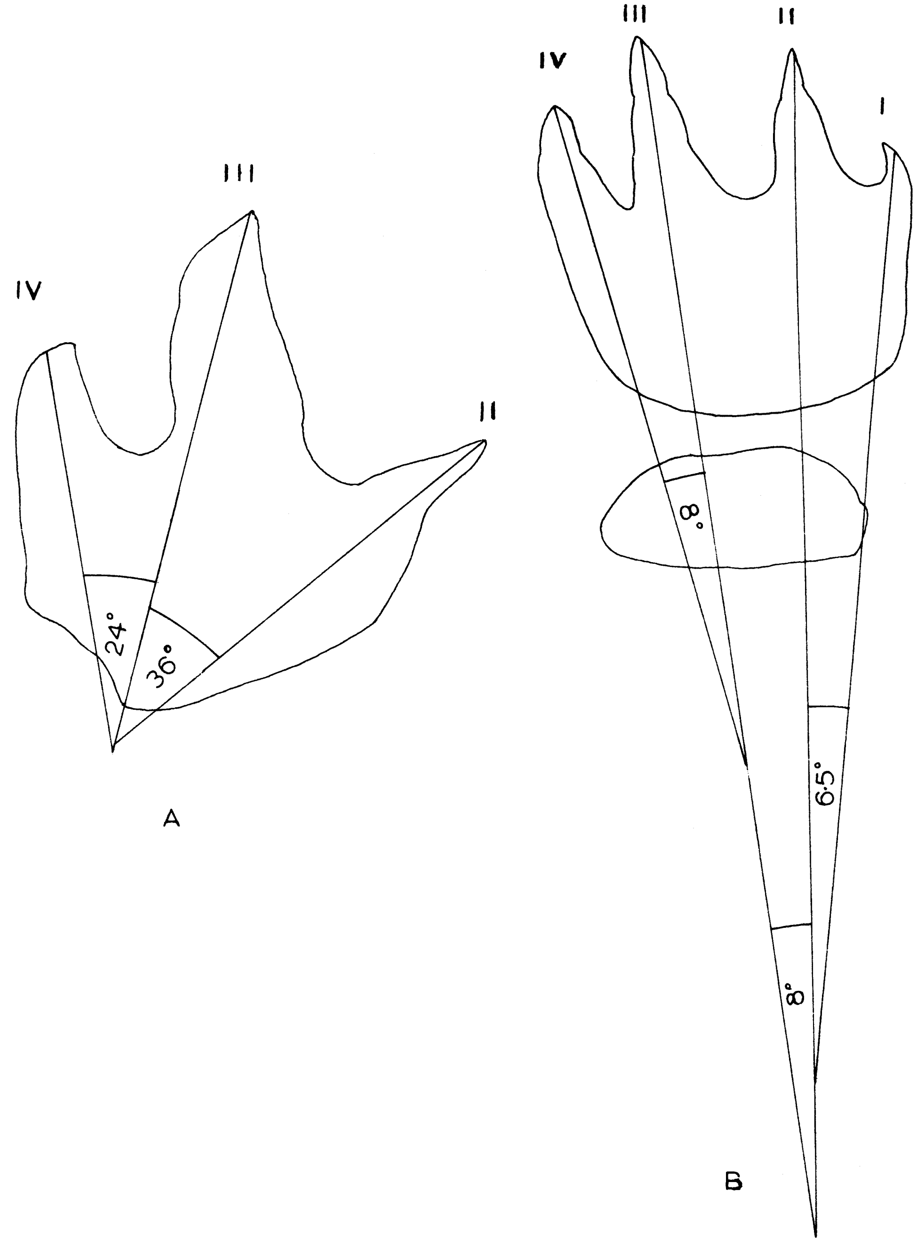
Although I recognise that final confirmation is impossible, I believe that this print is identical with "type A" of Swinnerton. If this is accepted, then these are the tracks of a basically bipedal and plantigrade, occasionally quadrupedal animal, with manus much smaller than pes and with pes blunt-clawed, the sole being clearly impressed. On these bases, it is attributable to the ichnogenus Otozoum, from which it differs only in that the phalangeal pads are poorly marked.

Swinnerton commented on the absence of claws (1912, p.67) and believed these to be amphibian tracks: however, his photograph of a mould (ibid., pl. IV fig. 3) indicates that claws were indeed present and his conclusion, that the gait of this creature was normally bipedal, scarcely favours an amphibian affinity. The marked difference in size of manus and pes strongly suggests a diapsid reptile. It should be noted, however, that the disparity in size between manus and pes is less great than the measurements suggest, for the sole of the pes is impressed and included in the length, whereas the palm of the manus is not. The rather blunt claw impressions do not suggest a carnivorous reptile, since in most bipedal carnivores the hind feet were very definitely "weapons of offense"; they suggest rather an omnivorous or a herbivorous mode of life.

Lull (1915, 1953) concluded that the Otozoum footprints were those of a prosauropod, a group on the evolutionary line that was to lead to the giant quadrupedal, herbivorous sauropod reptiles of the Jurassic. The typical prosauropods, such as Plateosaurus, are known to be both bipedal and quadrupedal at different times and, when bipedal, to be plantigrade. In such forms, the manus and pes are not very markedly different in size. In Yaleosaurus, which is considered to be an early prosauropod, the size difference is about 1 to 2. Allowing for the absence of a



TEXT-FIG. 1 ? Otozoum swinnertoni Sarjeant, ichnosp. nov.; pes. Keuper Waterstones (M. Triassic), Mapperley, Nottingham. (For dimensions, see text).



TEXT-FIG. 2 Sketches of footprints, showing how the angles of divarication of the digits were taken. A. *Satapliasaurus* cf. *dsotsonidzei* Gabouniya. B. ?*Otozoum swinnertoni* Sarjeant, ichnosp. nov.

palm imprint, the prints here described would suggest an animal whose limbs were of comparable relative proportions (an attempt at a reconstruction is made in Text-fig. 3A). It thus seems feasible, though by no means certain, that ?Otozoum swinnertoni ichnosp.nov. represents the track of an early prosauropod; however, it should be noted that skeletal remains of prosauropods have been only doubtfully recorded to date as early in the Triassic as the Ladinian.

If Lull's conclusion on affinity is accepted, then his numbering of the digits, which he designates II-V, requires revision; in the prosauropods, it is the fifth digit of the pes, not the first, that is reduced and non-functional. The digits are accordingly here numbered I-IV. (See Text-fig. 2B).

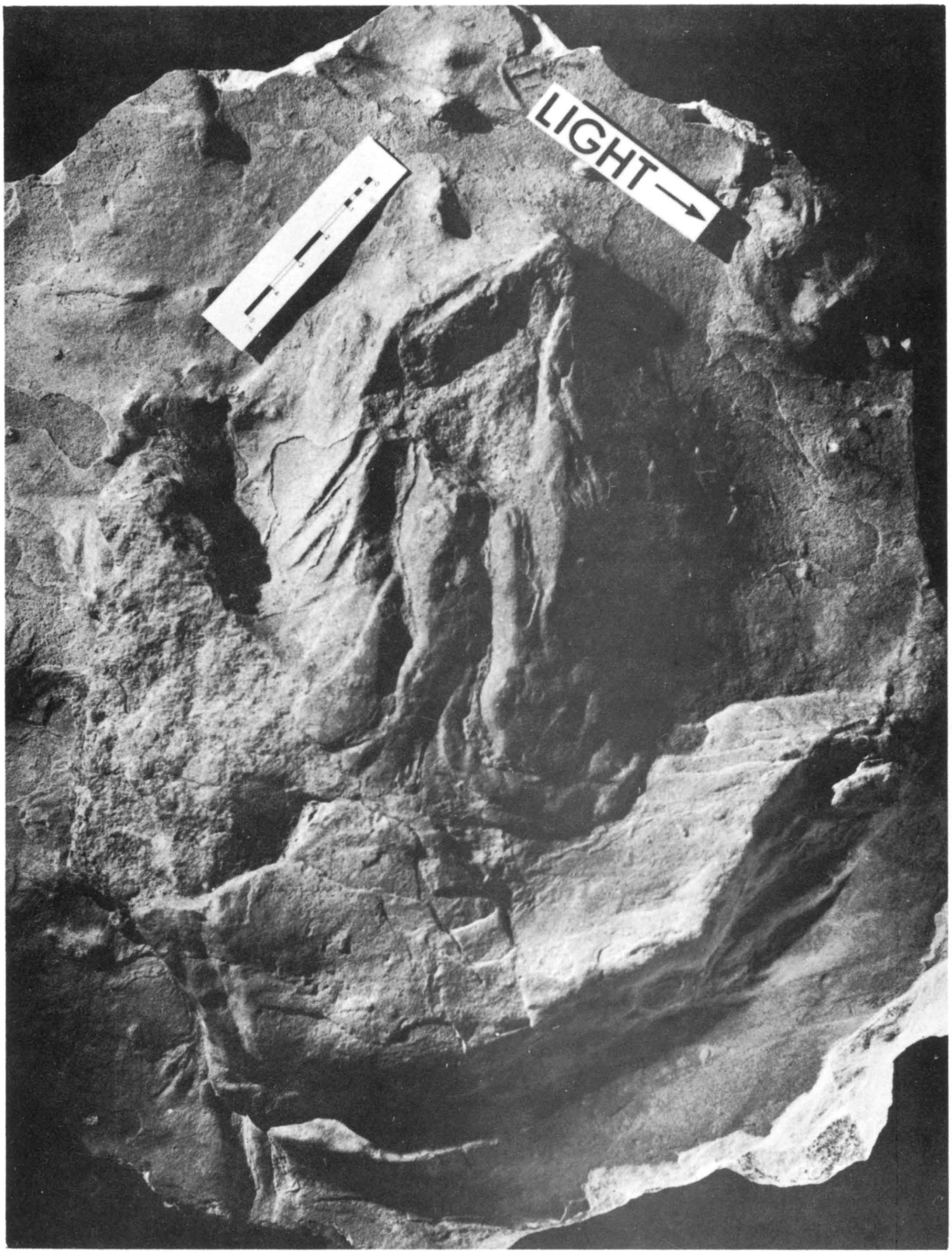
Only one form at all comparable to ? Otozoum swinnertoni ichnosp.nov. has been previously figured, to the author's knowledge. This is an unnamed imprint from the Triassic of Provence, France, figured by Charles (1949, text-fig. 1): it accords closely with the Nottingham print in the form of the digits and front part of the sole, but the diagram does not show an impression of the hind part of the sole. It thus may be the footprint of a digitigrade biped, perhaps related to this new ichnospecies, perhaps not.

II FOOTPRINT FROM THE MIDDLE JURASSIC OF YORKSHIRE

Footprints from the Middle Jurassic of northeast Yorkshire were first described by Harold Brodrick (1907), who found casts of three-toed prints in two fallen blocks of sandstone on the foreshore at Saltwick, Yorkshire and described them in a brief article arrestingly entitled "A Find!!! " This article was noted by "T.S." (probably Thomas Sheppard) in "The Naturalist" (1908, pp. 300-1), who commented caustically that its title savoured "of a Patent Medicine advertisement"; he concluded, from an examination of the specimens, that the blocks were derived from the Estuarine Series. Brodrick wrote a follow-up note on his original find (1908 a) for the British Association, then reported the finding of a further block, apparently from the same sandstone, with some thirteen prints of a number of different types (1908 b). He gave a definitive account of these footprints in a longer article published in 1909, in which some 17 prints are depicted, of at least three basic types. In 1915, Fox-Strangways and Barrow reported that the position of the footprint bed within the Lower Estuarine Series had been identified by P.F. Kendall, and gave details of its position (p.31); they also reported the finding of footprints in the Upper Estuarine Series near Burniston Fields, about half a mile south of Long Nab (p. 44).

The footprint here described was collected from the disused Peak Alum Quarries (NZ/45. 969 016), near Ravenscar, Yorkshire. It was found in a loose block of material from the base of the Lower Deltaic Series (ex: Lower Estuarine Series), considered to be derived from a stratum about 21 feet above the top of the Dogger.

Jurassic footprints have attracted only slight attention from palaeoichnologists; the number of works dealing with them is slender, contrasting strikingly with the vast literature on Triassic tracks. (Kuhn, 1958, pp. 25-6, lists only about fourteen references to Jurassic tracks; though his list is certainly incomplete, published references to date probably do not exceed fifty). For this reason, it was considered desirable to give a full description and illustration of the footprint.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Class REPTILIA

Order ORNITHISCHIA

Ichnofamily Anomoepodidae Lull 1904

Ichnogenus SATAPLIASAURUS Gabouniya 1951

1951 Satapliasaurus GABOUNIYA, p. 917.
1955 Satapliasaurus Gab. PIVETEAU, p. 900.
1955 Satapliasaurus Gab. LESSERTISSEUR, p. 115.
1958 Satapliasaurus Gab. KUHN, p. 28.
1963 Satapliasaurus Gab. KUHN, p. 107.

Diagnosis. "Small, slender, functionally biped, digitigrade dinosaurs. The pes has three functioning digits, equipped with sharp claws. The digits are rather close-set, giving the pes a narrow shape. The weakly developed first digit left little trace in the footprint. The tail balanced, or lightly touched the ground when walking". (Transl.)

Remarks. The generic diagnosis presents several points of difficulty. Of three species originally placed in this genus by its author, only S. tschabukianii (the type species) shows indication of the presence of the first digit and can be said to have a narrow-shaped pes. In the other two species (S. dsocenidzei and S. kandelakii), only three digits are represented and, in the latter especially, the pes has quite a broad spread. The size can scarcely be said to be "small" when the quoted footprint lengths range from 220 to 250 mm. - small for a dinosaur, maybe, but many footprints of diapsid reptiles are very much smaller! A revision of the generic diagnosis, possibly involving removal of the two latter ichnospecies to a separate ichnogenus, appears urgently necessary: a clarification of the features distinguishing Satapliasaurus from the older ichnogenus Anomoepus Hitchcock, 1848, would also be helpful.

Satapliasaurus dsocenidzei Gabouniya 1951
Text-fig. 5b

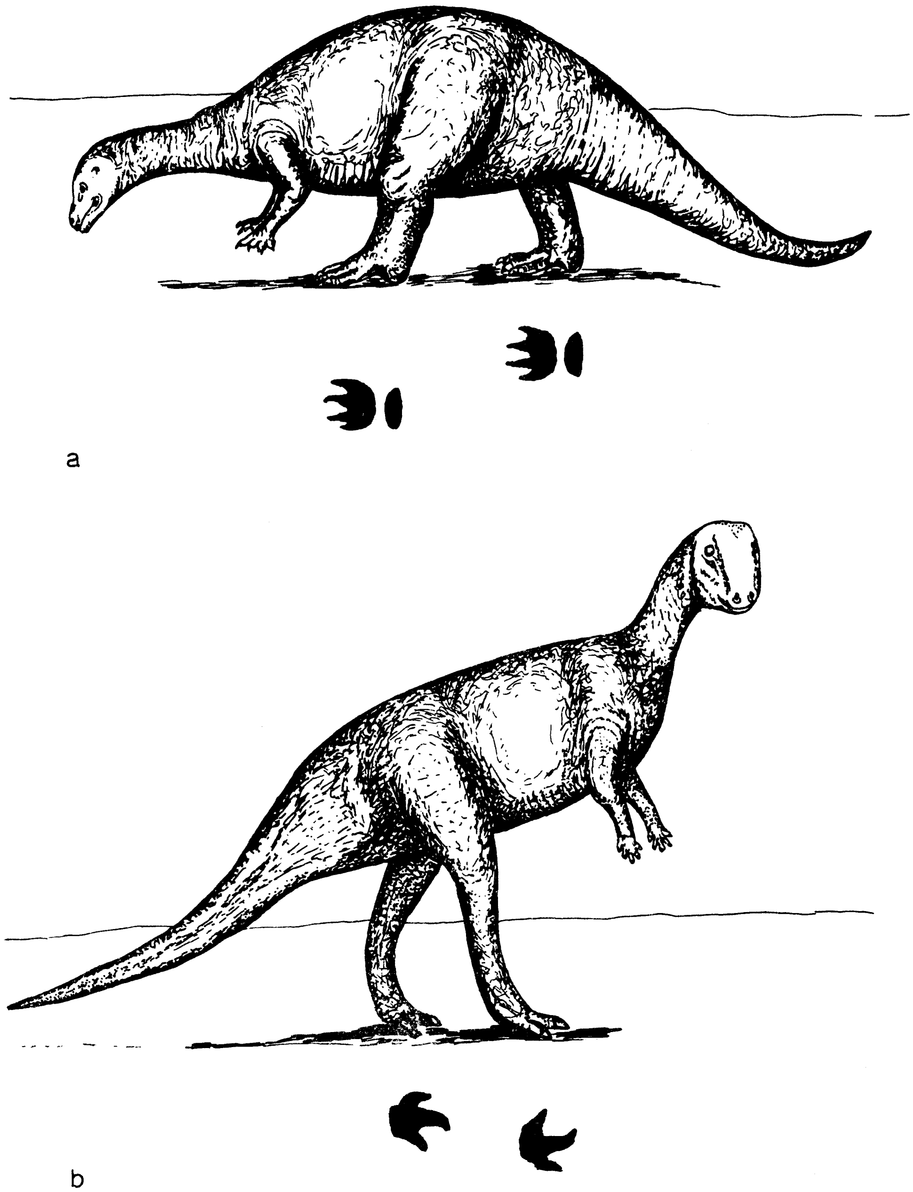
1951 Satapliasaurus dsocenidzei GABOUNIYA, p. 918, Text-fig. 1c.
1952 Unnamed footprints GABOUNIYA, p. 122, text-fig. 2.
1958 S. dsocenidzei Gab. KUHN, p. 28, pl. 12, fig. 14.
1963 S. dsocenidzei Gab. KUHN, p. 107.

Diagnosis. "Small, biped, digitigrade dinosaurs. The pes has a narrow shape and comparatively short digits, with strongly developed claws. On the imprint of the pes is a well-marked footprint (of the post-phalangeal section of the "heel"). Prints of the first digit and tail are lacking.

"Length of footprint 220 mm. Width of footprint 155 mm. Length of pace 600 mm." (Transl.)

Satapliasaurus cf. dsocenidzei Gabouniya. 1951
Plate 21, Text-figs. 2a, 4

1899 Saurischia div., gen. indet. MARSH, p. 231, fig. 1a, pl. V.
?1907 Footprint, type 1. BRODRICK, p. 8.
?1908 Footprint, type 2. "T.S.", p. 301, text-fig. 1.
?1908a Footprint, type 1. BRODRICK, p. 707.
1908b Footprints, type F and ?G. BRODRICK, p. 7.
1909 Footprints, type F, ?G. BRODRICK, pp. 330, 333-4, text-figs. F, G, pl. III.



TEXT-FIG. 3 The probable nature of the track-makers. a. A bipedal diapsid reptile, possibly an early prosauropod related to Yaleosaurus. (Redrawn after Lull, 1953). b. An ornithopod reptile, comparable with Camptosaurus. (Based on a restoration by J.C. Germann).

Description. Footprint of a bipedal digitigrade reptile with three functional digits (II - IV), spreading quite widely. Digits broad, with blunt claws; phalangeal pads not distinguishable. Digit III is longest; digits II and IV are of similar length. Front part of sole impressed quite deeply: back part apparently raised well clear of the ground, since it is not indicated at all.

The specimen is considered to represent the right pes and the digits are numbered accordingly.

Figured Specimen. Specimen PC 4237 (cast of pes), collections of the Department of Geology, University of Nottingham. Type locality and Horizon. Lower Deltaic Series c.21 feet above base (U.Aalenian: Middle Jurassic), Peak Alum Quarries, near Ravenscar, Yorkshire.

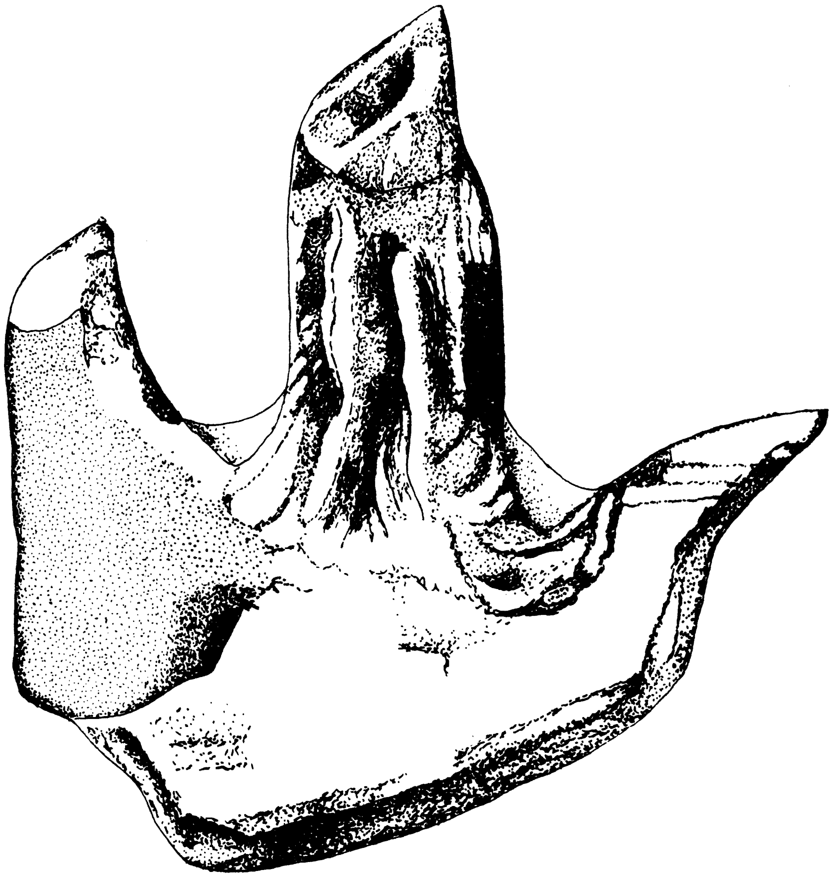
Dimensions. Pes (figured specimen): maximum length 240 mm., maximum breadth c.230 mm., length of digit II 70 mm., digit III 130 mm., digit IV 65 mm., interdigital angles II-III 36^{o}, III-IV 24^{o} (see Text-fig. 2a).

Discussion. In his earliest reports of the Saltwick footprints, Brodrick (1907, 1908a) gave no figures. The photograph included in the note by "T.S." (1908, Text-fig. 1) suggests a similarity of one of the prints with the type here described; the dimensions are comparable (length $8\frac{1}{2}$ inches) but the print appears more elongate. In his fuller account, Brodrick (1909, p. 334, pl. III) names this as "Type P": his figure again suggests some differences from the type here described, the print being more elongate and with longer digits.

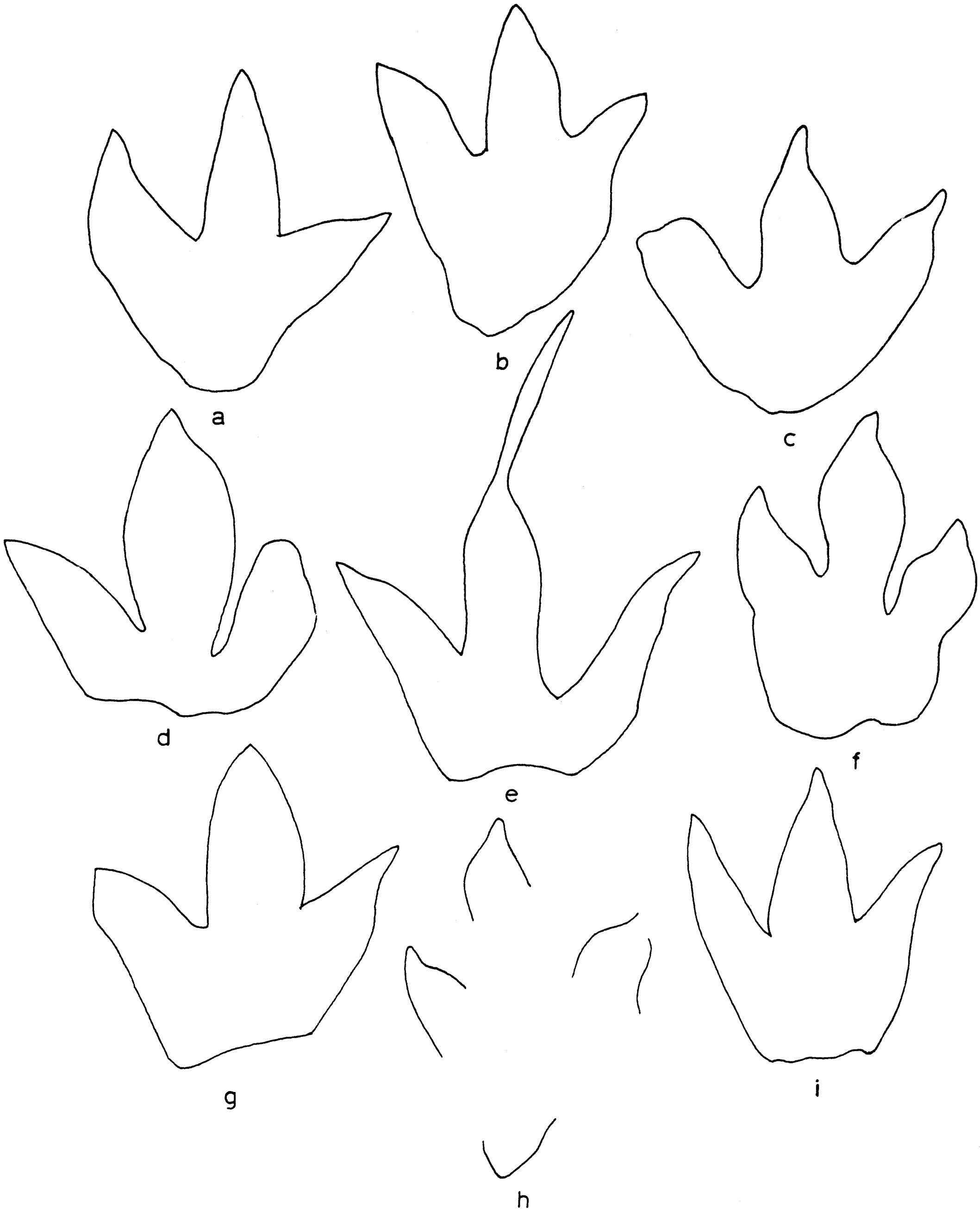
In contrast, one print on the second slab found by Brodrick (1908b p.7: 1909, p.333, text-fig. F; herein, Text-fig. 5d) appears identical in morphology with that here described, though it is markedly smaller in size (length 170 mm., breadth 180 mm.). A second print (Brodrick, 1908b p.7; 1909 p. 330, text-fig. G; herein, Text-fig. 5e) is comparable in general morphology, but shows an immense elongation of the central digit which may well represent a superimposed tail-drag mark; its size appears similar, but the measurements quoted are not helpful. A re-examination of the type material (lodged in Whitby Museum, Yorkshire) will be needful before these comparisons can be confirmed or otherwise.

Footprints apparently identical with the one here described were recorded by Marsh (1899) from the Upper Jurassic of the Black Hills, Dakota (Text-fig. 5g). Footprints from the Lower Lias of La Vendée, France, described as Saltopoides igalensis ichnogen. et sp. nov. (Lapparent & Montenat, 1967), have a comparable outline, but are somewhat more elongate and only the tips of the digits and heel are impressed (Text-fig. 5h). Much more closely comparable are two species described from the Lower Cretaceous of Russia, described by Gabouniya (1951). In overall shape, Satapliasaurus kandelakii Gabouniya is closely similar: however, the digits bear narrow, sharp claws (see Text-fig. 5c). A second ichnospecies, S.dsocenidzei, is similar in general shape and has less markedly acute claws than S.kandelakii (see Text-fig. 5b). However, it differs in that the hind part of the heel is clearly impressed. The Yorkshire prints probably represent an undescribed ichnospecies; until further specimens become available, however, it is proposed that they be named Satapliasaurus cf. dzocenidzei Gabouniya.

Other comparable ichnospecies include ?Coelurosaurichnus schlehenbergensis (Rehnelt, 1950) Kuhn, 1958, from the Triassic of Germany, which differs in that the digits show a marked terminal thickening (Text-fig. 5f); Coelurosaurichnus moeni Beurlen, 1950, also from the German Triassic, differing in that the digits are more equal in length (Text-fig. 5i); Sinoichnites youngi Kuhn, 1958, from the Jurassic of China, differing in that its digits lack claws; unnamed footprints from the Cretaceous of Algeria (Bellair & Lapparent, 1949, pl. 5), closely similar but with lateral digits slightly more angular in outline and size markedly smaller (Text-fig. 5a); and Gypsichnites pacensis Sternberg, 1932, from the Lower Cretaceous of Canada, differing in its larger size, more rounded heel and broader central digit III.



TEXT-FIG. 4 Satapliasaurus c.f. dsotsenidzei Gabouniya; pes. Lower Deltaic Series (M. Jurassic), nr. Ravenscar, Yorks. (For dimensions, see text).



TEXT-FIG. 5. Outline drawings, at approximately constant size, of some Mesozoic tridactyl footprints comparable with Satapliasaurus cf. dsotsenidzei.

a. Unnamed footprint from the Cretaceous of Algeria (Bellair and Lapparent, 1949).
b. Satapliasaurus dsotsenidzei Gabouniya 1951. L. Cretaceous, Georgia, U.S.S.R.
c. Satapliasaurus kandelakii Gabouniya, 1951. L. Cretaceous, Georgia, U.S.S.R.
d. Footprint type F, from the Middle Jurassic of Yorkshire (Brodrick, 1909).
e. Footprint type G, from the Middle Jurassic of Yorkshire (Brodrick, 1909).
f. ?Coelurosaurichnus schkehenbergensis (Rehnelt, 1950) Kuhn, 1958, Triassic, Germany.
g. Unnamed footprint U. Jurassic, Dakota, U.S.A. (Marsh, 1899).
h. Saltopoides igalensis Lapparent & Montenat, 1967, Lower Jurassic, France.
i. Coelurosaurichnus moeni Beurlen, 1950, Triassic Germany.

This footprint is considered to be that of a bipedal, herbivorous ornithopod dinosaur (see Text-fig. 3b). This interpretation differs from that of Gabouniya, who considered her prints to be those of carnivorous dinosaurs; it is based simply on the relatively blunt character of the claws, an important weapon of offense in carnivorous dinosaurs and therefore usually sharp and pronounced. Ornithopod footprints have long been known from the Upper Triassic: and recently, skeletal remains have also been discovered. In the Jurassic, remains of ornithopods are only sparsely known; much is still to be learned about the early history of this group of reptiles.

Acknowledgements

The author acknowledges with thanks the generosity of Mr. R.D. Boutell, in presenting the Jurassic footprint to the University of Nottingham; helpful discussions with Mr. A.J. Rundle; photographic assistance from Mr. B.M. Logan; translation of relevant Russian passages by Mr. Stephen Henley; and the critical reading of the manuscript by Mr. A.M. Honeyman. Dr. Hartmut Haubold, of the Martin-Luther-Universität, Halle, Germany (D.D.R.) courteously permitted reading of his unpublished manuscript on Triassic footprint classification.

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BORING ALGAE IN BRACHIOPOD SHELLS FROM LOWER CARBONIFEROUS (D_1) LIMESTONES IN NORTH DERBYSHIRE, WITH SPECIAL REFERENCE TO THE CONDITIONS OF DEPOSITION

by

Helen E. Sadler

Summary

Microscopic tubes now infilled with cryptocrystalline calcite were found penetrating the shells of brachiopods, crinoid ossicles and some ooliths, in the Cyrtina septosa Band and associated limestones in the 'Beach Beds' at Castleton, and from the Back-Reef facies of Windy Knoll, all of D_1 age.

Brachiopod shells accumulating in quiet waters were found to have algal tubes mainly on their upper surfaces, while both sides of shells accumulating in more turbulent waters possessed these tubes.

The tubes of boring algae were found to be more abundant in limestones of the shelf facies than in the fore-reef facies. In the 'Beach Beds', shells containing algal tubes are thought to have been washed down a submarine channel from the warmer waters of the shelf above.

Introduction

The presence of penetrative or boring algae in the calcareous tests of molluscs, brachiopods, corals and other algae has been known since the middle of the last century. Boring algae were recognized in 1845 by Carpenter, who described them from modern seas, while tubes of fossil boring algae were first noted in 1855 (Rose).

Nadson (1927) described their presence in many warm and cold seas on a world-wide basis and came to the conclusion that they were very abundant. Ten species were known to him, none of which were found below 50 metres depth. He believed them to be very important in the destruction of coral reefs, where they had been found boring into corals and the alga Lithothamnium.

Johnson (1946) briefly described perforating algae from limestones in Kansas, noting that the fine algal threads had an average diameter of 0.0027 to 0.0036 mm., and that they coated and penetrated fragments of shells, echinoderms, and the larger foraminifera. Where the algal threads were abundant, they appeared to have caused a chemical alteration and disintegration of the fossil fragments.

In a paper by Hessland (1949), details are given of boring algae from the Ordovician of the Siljan area of Sweden. He suggested that their presence indicated shallow, rather stagnant water, such as shallow bays of warm seas in waters not deeper than 20 metres. He thought the action of boring was solution by organic acids. The relationship was probably a symbiotic one, the algae producing oxygen for the animal and using its excretory products in photosynthesis. In the Siljan district, the majority of the algal tubes had a diameter of 5 μ ; they varied from gently tortuous and fine to straight and thick. Sometimes the tubes were seen to follow the structure of the shell and sometimes they ran irregularly across the shell. The canals could even penetrate right across the shell, cutting it in two. He concluded that penetrative algae belonged to the classes Cyanophyceae, Chlorophyceae and Rhodophyceae.

Wolfenden (private communication) described the presence of boring algae from the standard, reef and fore-reef facies of the Derbyshire massif. He noted an increase towards the centre of the shelf region and a decrease towards the reef and fore-reef. He found remains of boring algae in 30% of his limestone specimens from the standard (shelf) facies and only 6% from the fore-reef and reef facies. He described the tubes left behind by the algae as having diameters of 5-20μ, some of them curved and others branched. The best ones were seen in brachiopod shells, where they ran across the shell structure. Crinoid ossicles, too, were often attacked, but here the tubes were not so distinct. Some corals and molluscs also showed the remains of boring algae.

In 1957, Wanless, Ziebell, Ziemba and Carozzi recorded the presence of tubes of boring algae on shells; this feature was thought to show that there was probably interrupted sedimentation, with exposure on shallow sea bottoms for a time before burial.

Hallam (1963) recorded boring algae in lamellibranch shells from the Lower Jurassic ironstones of Frodingham. The borings consisted of a ramifying network of fine tubes averaging 5 μ in diameter, which were infilled by cryptocrystalline siderite. He described the tubes as straight or slightly sinuous, occasionally branching and mostly normal to the shell margin, with no relationship to the structure of the shell even when recrystallized.

Swinchatt (1965) described the importance of boring algae in the breakdown of mollusc shells. Extensive boring weakened the outer part of the shell, which became abraded off by current action. This was repeated until the shell was reduced in size. The process only took place in fairly quiet conditions. In very turbulent water abrasion was mechanical.

Bathurst (1966) described the presence of micrite envelopes round many skeletal grains from Bimini lagoon, Great Bahama Bank. They were formed by algae boring into the shell wall; the filaments then died and decayed, the tubes infilled with micritic aragonite. Later the shells dissolved away leaving the micrite envelope intact.

Field Evidence

Algal borings, represented by tubes of approximately 0.008 mm. in diameter, some of which were tortuous and some of which cut straight across the shells, were found in brachiopod fragments and crinoid ossicles at a number of localities in Carboniferous Limestones of D_1 age in North Derbyshire. The localities are described below under the headings:- standard (shelf), back-reef, reef and fore-reef facies, and 'Beach Beds', an unusual group of beds in the fore-reef facies west of Castleton (Sadler, 1964a).

Shelf facies

Ten localities in the standard (shelf) facies were found to contain brachiopod shells and crinoid ossicles attacked by boring algae. Of these ten localities, eight were in the Cyrtina septosa Band (described in detail by Sadler, 1964b, and Sadler and Merriam, 1967). This band occurs 25 feet below the Lower Lava flow in the D_1 subzone and is found quite widely spread over North Derbyshire. It varies in thickness from about 1 foot to 7 feet and the shells may either be

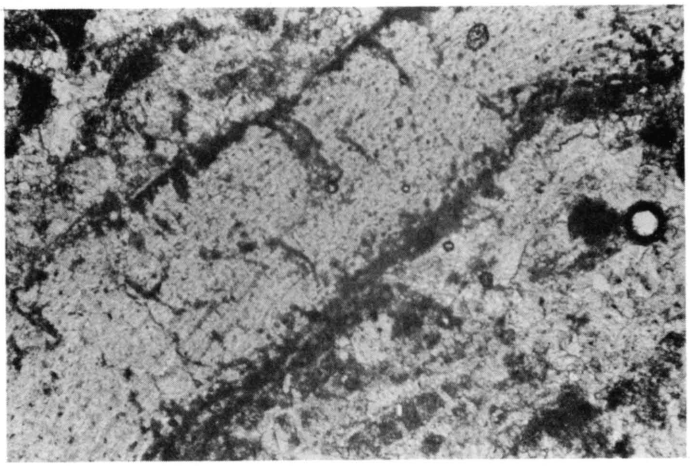


PLATE 22. Photomicrographs of sections of shells showing boring algal tubes.

Fig. 1. Netherlow Farm. Section of brachiopod shell showing tubes of boring algae on both upper and lower surfaces. x100.

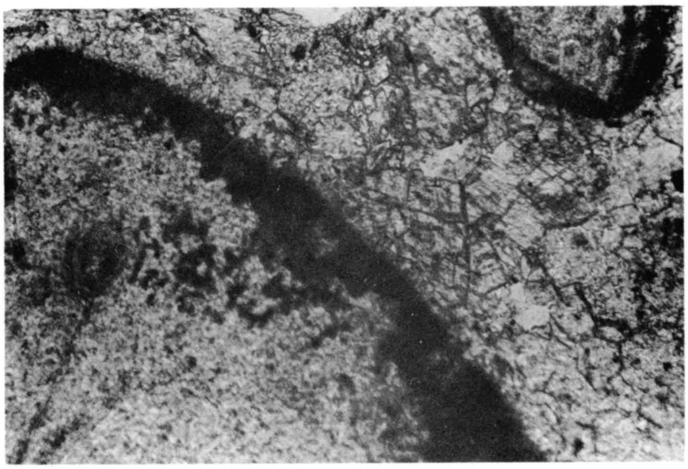


Fig. 2. Section of brachiopod shell showing tubes of boring algae penetrating into it. Shell set in sparite matrix. Windy Knoll. x150.

fairly close together, sometimes forming poorly developed ripple marks, or they may be widely scattered. Numbers of specimens of Davidsonina (Cyrtina) septosa (Phillips) vary from one locality to another, and there is also variation in the orientation, size, distribution and disarticulation of the brachiopods.

The limestones of the Cyrtina septosa Band are fairly massive, light-grey, pinkish grey or yellowish grey, and are classified as medium to coarse calcarenites (Folk, 1959).

The following localities provided specimens which showed good examples of boring algae tubes:-

1 Netherlow Farm (10456973)[see Plate 22 fig. 1.]
2 Wheeldon Trees Farm (10356620)
3 Outcrop above Earlsterndale village (10256671)
4 Monksdale House (13207533)
5 Jericho (08556750)
6 Via Gellia (24115762)
7 Chelmorton Flat (10667130)
8 Waterswallows Quarry (08667511)

For locality map see Sadler (1964b).

Fossil horizons are rare in the D_1 Limestones and this accounts for the fact that boring algae are found mostly in the Cyrtina septosa Band.

Algal tubes have also been found attacking shells at two limestone localities situated stratigraphically above the Cyrtina septosa Band. These are:-

1 Twenty two feet below the D_1/D_2 boundary in the large Station Quarry at Miller's Dale (13207335).

2 Seventy five feet above the Cyrtina septosa Band on the roadside from Brierlow Bar to Jericho (08256795).

The Miller's Dale locality consists of light-grey, fine-grained, very massive limestone with abundant stylolites. Some specimens of D. septosa were recorded, together with Productid fragments and small crinoid stem fragments. Near Jericho a six-inch band of thin Productid shells and fragments was found in light-grey, fine-grained limestone. One of the shells showed very well defined algal tubes.

Back Reef facies

From a small outcrop of limestone at Windy Knoll, Castleton (12658265) came specimens of oolitic limestone thought to be in the back-reef facies. The beds are light-grey in colour. It was found that the brachiopod shells and crinoid ossicles were attacked by boring algae and the ooliths composed of two or more concentric rims were also attacked (see Plate 22 fig. 2).

Fore-Reef and Reef facies

No examples of boring algae were found in limestones from the fore-reef or reef facies. Wolfenden (private communication) noted only a very small percentage from these facies.

'Beach Beds'

An examination of fifty slides from the Castleton 'Beach Beds' was made, but only five showed tubes of boring algae. Three of these were from limestones found on the fore-reef slope on the west side of the Winnats Pass (13808270), where the 'Beach Beds' extend nearly up to the 1000 foot contour. The other two localities were found much lower (topographically) on the fore-reef slope. The first of these is a limestone behind the Speedwell Mine, on the east side of the Winnats (13988265), and the second is an outcrop of limestone immediately to the west of the Speedwell Vent (14258255). Two of the three localities on the west side of the Winnats Pass contain limestones which are brownish-grey and rubbly, with many brachiopods, some of which are rounded and waterworn. Most of the fragments are broken and crushed shells, nearly all of which are orientated parallel with the bedding. The third locality on the west side of the Winnats contains a very fine-grained, putty coloured limestone which is thinly bedded and consists of abundant broken brachiopod shells; these still retain some of their ornamentation but show no preferred orientation.

Behind the Speedwell Mine are very rubbly beds consisting of many waterworn brachiopod shell fragments, all of which are oriented parallel with the bedding with very little matrix in between them. It was the presence of these beds which led earlier writers (Barnes & Holroyd 1896, Jackson 1943, Parkinson 1947 & 1953) to believe they were laid down on an old sea beach. These very rubbly beds are seen to pass down into black basin limestone, through a narrow band of transitional beds which consist of water worn shells in a black matrix. It is from near the boundary of the transitional beds with the black basin limestone that one waterworn, rounded shell fragment was found which showed good evidence of boring algal tubes.

On the west side of the Speedwell Vent is an outcrop of massive limestones, very fine-grained and containing very small shell fragments and occasional small crinoid stem fragments. Tubes of boring algae are seen attacking many of the crinoid ossicles, but they are not very well defined (see Text-Figure 4).

General environment of the Derbyshire massif

The conditions of deposition of the Carboniferous Limestone of North Derbyshire were described by Wolfenden (1958) and Sadler (1964a). Wolfenden suggested that the shelf area was one of shallow warm water which was quite often turbulent. The presence of Dasycladacean algae in the limestones, recent forms of which are most abundant at depths of 9 to 15 feet and never below 90 feet (Cloud 1952), and of calcarenites containing grains of a type which at present form in waters less than 30 feet deep, both indicate shallow sun-lit waters over the shelf. The overturning of corals and brachiopod shells to their more stable position of rest (convex side uppermost) and the sorting of shells into ripple marks (Sadler 1964b) indicate that turbulent waters with strong current action must, at times, have been present.

The reef and back-reef limestones were probably formed also in shallow wave-agitated waters. The fossils in these two facies are often fairly well-preserved.

In several areas (e.g. the Winnats), horizontal limestones of the shelf facies are seen resting on steeply dipping fore-reef beds, showing that the dip is depositional and that the fore-reef beds probably dipped down into deeper water, forming a submarine slope of at least 400 feet.

The 'Beach Beds', which are found near the foot of the fore-reef slope and in one place extending up it, are thought to have been laid down at the foot of a submarine channel cutting through the reef complex, the site of which is now the Winnats (Sadler 1964a).

On the lower slopes of the fore-reef the waters would probably have been too cold and dark for algae to live and photosynthesise, and therefore any shells attacked by algae found low on this slope, such as those in the 'Beach Beds', must have been brought down the submarine channel from the shallow, warmer waters of the shelf above.

Evidence from thin sections

Thin sections were studied in detail from localities where boring algae tubes were found. From two localities of the Cyrtine septosa Band (Monksdale House [see Text-Fig. 1] and Netherlow Farm), where field evidence indicates fairly quiet water conditions, several large brachiopod (Productid) shells show very well-developed tubes of boring algae on their upper surface only. This probably indicates that the shells rested in one position for a considerable length of time and were not turned over and over by currents. It is unlikely that boring algae would accumulate on the under surfaces of shells which were not exposed to sunlight. At the second locality, occasional shells do show algal tubes on both upper and lower surfaces (see Plate 22 fig. 1).

Where water conditions were more turbulent, it is found that tubes of boring algae are present on both sides of the shells and all round the crinoid ossicles, indicating that the fragments were turned over and rolled about by water movement. Specimens of such fragments can be seen from the Via Gellia, above Earlsterndale, at Jericho (see Text-Fig. 3), Wheeldon Trees Farm and Chelmorton Flat.

At Waterswallows Quarry, a specimen containing a section of D. septosa shows very well defined algal tubes on the outside and upper surface only, while the lower surface and inside remain unattacked (see Text-Fig. 5).

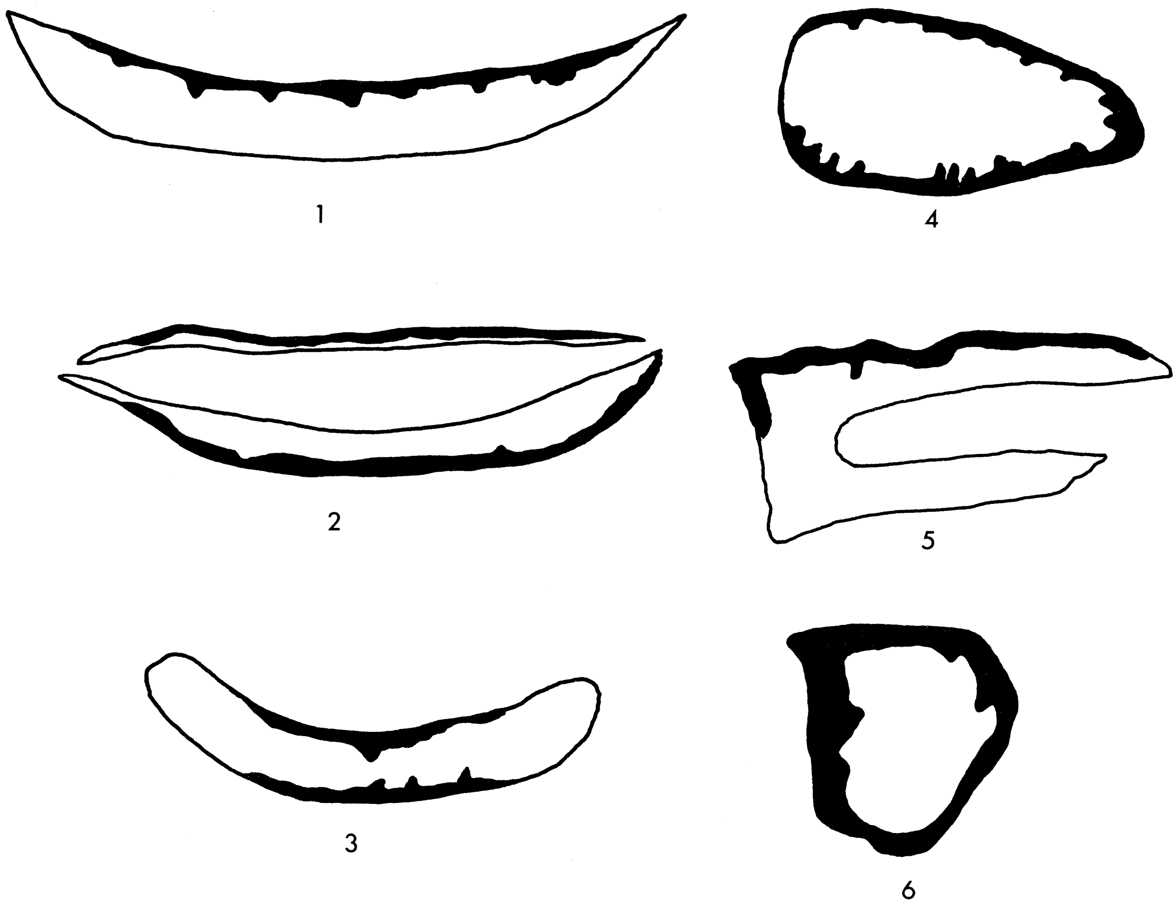
In the Station Quarry, Miller's Dale (22 feet below the D_1/D_2 boundary), and on the road-side near Jericho (75 feet above the Cyrtina septosa Band), all evidence shows that water conditions were fairly quiet. Disarticulated Productid shells containing tubes of boring algae on their upper concave surfaces only are present, indicating that they have not been turned over by turbulent water. Very well preserved tubes are seen in shells from Jericho.

In the back-reef facies, oolitic limestones from Windy Knoll are evidence of water movement; the ooliths were accumulated and rolled about in shallow turbulent water. Many of the shell fragments and crinoid ossicles are also rounded. The outer oolitic rims show tubes left by boring algae. One ribbed shell exhibits an interesting feature, in that the boring algae have attacked it on both sides in the depressions between the ribs rather than on the ribs themselves, suggesting that the ribs received more intense erosion than the depressions, the latter being quieter areas more favourable to the accumulation of boring algae. Boring algae tubes are not common in the 'Beach Beds' (see Plate 23); of nearly 50 slides studied, only 5 showed evidence of algal attack. It seems probable that water in this environment was too swift-flowing, cold and deep, for the algae to have lived there. The shells which do contain remains of boring algae are thought therefore to have been brought down the submarine channel by strong currents of water which crushed and abraded them.

Wolfenden noted some boring algae on the upper fore-reef slopes, but on the lower slopes and in the deeper waters of the basin it was again probably too cold and dark for algae to live.

Conclusions

Tubes left behind by boring algae are seen in greatest numbers in the shallow water shelf limestones, particularly in the Cyrtina septosa Band, the deposition of which may mark a considerable period of time to allow fragments to be rolled about and accumulate algae. Evidence of boring algae also comes from the back-reef where the shallow warm turbulent waters were ideal for the algae. Any evidence of boring algae in the 'Beach Beds' is accounted for by the



TEXT-FIGS. 1-6. Photomicrographs of sections of brachiopod shells and crinoid ossicles, showing evidence of boring algae.

1. Ventral valve of Productid (x3), showing tubes of boring algae on upper surface of shell only. Monksdale House.
2. Articulated Productid (x3.75), showing evidence of boring algae on upper surface of dorsal valve and lower surface of ventral valve. Netherlow Farm.
3. Slightly abraded brachiopod valve (x18), with boring algae on upper and lower surfaces. Jericho.
4. Crinoid ossicle (x 27) attacked by boring algae. Adjacent to the Speedwell Vent.
5. Fragment of <u>Davidsonina (Cyrtina) septosa</u> (x 4.5), showing boring algae on upper surface only. Waterswallows Quarry.
6. Crinoid ossicle (x 33) attacked by boring algae. Chelmorton Flat.

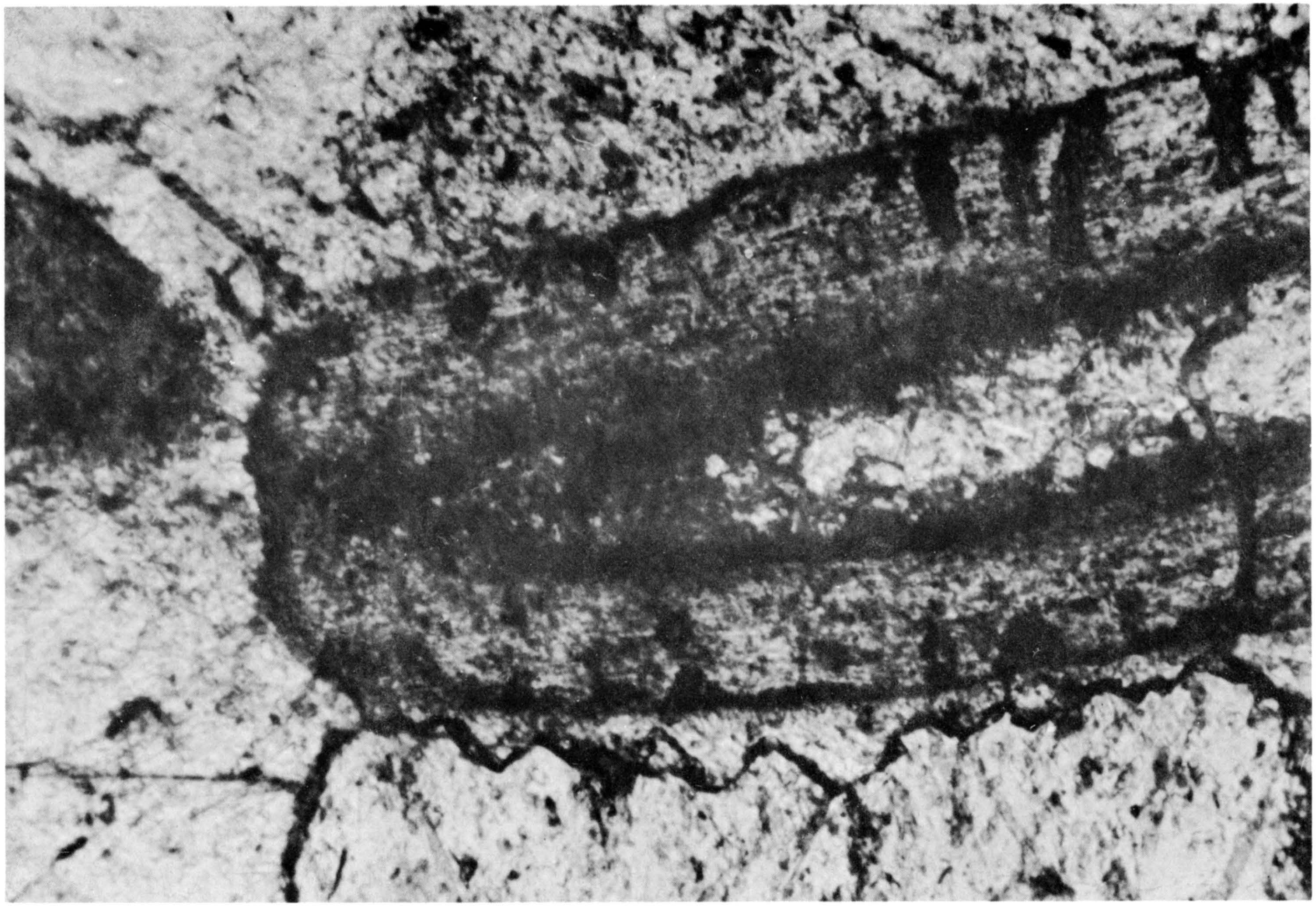


PLATE 23. Photomicrograph of section of brachiopod spine showing boring algal tubes. The tubes are wider than was normally found, being about 0.02 mm. in diameter. They are found on the outer surface of the spine section only. Above the Speedwell Cavern. x250.

fact that the fossils which have been attacked lived in the shallow shelf seas and were washed down to their present position through the submarine channel. Boring algae are not found elsewhere on the lower fore-reef slopes or in the basin facies.

Acknowledgements

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EAST MIDLANDS GEOLOGICAL SOCIETY
EXCURSION REPORTS, 1969

WEEKEND EXCURSION TO SHROPSHIRE

Leaders: Dr. I.D. Sutton & Dr. W.A.S. Sarjeant — Fri. 2nd - Sun. 4th May, 1969

The county of Shropshire is of exceptional geological interest for the wide variety of strata to be seen at outcrop. Its rocks range in age from Pre-Cambrian to Lower Jurassic and in character through the whole gamut of sediment types, plus a wide variety of igneous rocks. Its tectonic history has been complex. At least four major phases of earth movements have affected the region - in descending order, Armorican (Carboniferous - Permian), Caledonian (Silurian - Devonian), Taconian (Ordovician) and one or more phases of movement in the Pre-Cambrian.

The effects of the Caledonian phase of movements have been the most striking. They have imposed a strong N.E. - S.W. trend to the geology of the county, as a result of compression from west and north against the Pre-Cambrian basement. The county is thus divisible into three broad structural regions. The northern area forms part of the Cheshire - North Shropshire Basin, a broad syncline (the Prees Syncline) modified by two N.E. - S.W. faults (the Hodnet and Ercall Mill Faults) and bounded to the southeast by the great Church Stretton Fault and its northward continuation, the Brockton Fault. On the southern margins of this basin lie three minor coalfields: the Oswestry, Shrewsbury and Leebotwood Coalfields. All these fields have been productive in the past, though mining has now generally ceased.

The southern part of the county presents a less straightforward structural picture. Two broad divisions are recognisable: the Long Mynd - Wrekin anticlinal uplift to the west, separated by the Church Stretton fault axis from the East Shropshire-West Staffordshire Syncline to the east. However, the structure of each of these areas is complicated by further faults and folds, producing lesser structural divisions which obscure the broad, general picture. The Long Mynd - Wrekin area consists, in its northern part, of a succession of synclines and anticlines, each with a N.E. - S.W. axis: the Long Mountain Syncline, the Shelve Anticline, the Ritton Castle Syncline and the fault-bounded anticlinal Longmyndian Massif and Wrekin area. The southwestern part consists of a general syncline, the Clun Forest Basin. The southeastern region of the county, the Clee Hills Basin, forms part of the overall East Shropshire - West Staffordshire syncline. It is bounded on its western margin by the irregular line of the Stretton Hills, Pre-Cambrian basement brought to the surface by movements along the Church Stretton Fault, and its structure is complicated by the Ludlow Anticline, whose trend swings in an arc from south to west, separating the Brown Clee Syncline from the Titterstone Clee Basin. Faulting on a general east - west line further complicates the picture in the southernmost part of the county.

The area was intensively glaciated during the Pleistocene, but the ice was largely confined to the valleys and was stagnant or slow-flowing. As a consequence, its action was rather depositional than erosional. There are considerable spreads of boulder clay and fluvio-glacial deposits and many features of glaciated lowland topography - kettle-holes, moraines, kames and perhaps eskers - can be recognised.

The drainage pattern, as would be expected in a region of such structural and lithologic variety, is complex. This is a watershed region, the rivers of north Shropshire flowing north to the Irish Sea by way of the Dee and Mersey estuaries, while those of central and south

Shropshire are collected by the Severn and poured into the Bristol Channel.

The resultant landscape is one of great variety and scenic interest, to the tourist as well as to the geologist. The area of the Wrekin was the subject of an earlier Society one-day excursion. On this occasion, the party was based at the Denehurst Hotel, Church Stretton, and, after arriving on the Friday evening, spent two days in visiting areas of south and west Shropshire. 29 members and friends attended.

SATURDAY 3rd MAY

The Onny River Region

Having left Headquarters the party made their way south along the main A.49 road to a point about one mile north of Craven Arms. Here the Bishop's Castle road (A.489) branches off to the northwest, and just over a quarter of a mile along the road we disembarked at a road junction called Cross Way.

During the visit to the Onny River area the party were able to examine rocks of Silurian (Wenlockian and Llandoverian) and Ordovician (Caradocian) age.

The rocks were examined in a descending stratigraphical order and the first exposure was in the lane 100 yards or so northeast of Cross Way. Here in the bank on the eastern side of the lane (431853) was a small outcrop of the Wenlock Shales. The lithology consisted of very weathered, decalcified, yellowish-brown siltstones with mudstones. Fossils were relatively abundant and members collected fragments, particularly pygidia, of trilobites (Dalmanites caudatus), and also graptolites (Monograptus sp.) and ostracods (Beyrichia sp.).

The party then retraced their steps, crossed over the Bishop's Castle road and took the path down to the footbridge over the Onny River. 350 yards upstream from the bridge is an excellent cliff section (426853) on the left bank of the river, displaying the unconformable junction between the U. Llandovery (the Hughley or Purple Shales) and the youngest of the Caradocian rocks in the Onny River, the Onny Shales (Trinucleus Shales). It proved very difficult to trace the unconformity, as the angular discordance between the Ordovician and Silurian at this particular horizon is small. From the southeast end of the cliff section the Hughley Shales could be seen to consist of green and purple shales but nearer to the junction with the Ordovician they have a much browner tinge, similar in fact to the weathered Onny Shales, thus making the unconformity even more difficult to detect. Although little time was spent collecting from the Hughley Shales, as the party was going to see more productive beds later in the excursion, a number of small brachiopods typical of the Hughley Shales were found.

The Onny Shales underlying the Hughley Shales were found to be a series of weathered greenish-brown micaceous shales and siltstones, although in the river bed the lower part of the section exposed blue-grey mudstones and siltstones. Most members of the party were able to collect specimens of the trinucleid trilobite, Onnia sp., the brachiopod Onniella sp. and a number of indistinguishable fragments of other trilobites and graptolites.

200 yards or so further upstream, just past the tributary stream, Batch Gutter, is a small, poor exposure of the Acton Scott Beds (423854). The lithology was found to be largely of grey, rubbly micaceous mudstones and siltstones. A number of shell fragments of brachiopods, especially Onniella sp., were found.

The party then crossed to the south side of the river and slightly further upstream from the previous exposure another small outcrop revealed the uppermost beds of the Longville Flags (422855). Specimens of the brachiopods Kjerulfina sp. and Wattsella sp., typical of this horizon, were collected from the weathered yellow sandstones. To the south of the old Bishop's Castle railway, at the north end of Burrells Coppice (421855), a much larger and better outcrop of the Longville Flags was examined. The beds here are exposed in an old river cliff, and at certain levels were found to be particularly fossiliferous. The brachiopods Kjaerina sp., Dolerorthis duftonensis and the large lamellibranch Modiolopsis obliqua were particularly abundant, while certain bedding planes were found to be crowded with Tentaculites sp. (incertae sedis, but referred by some people to the Scaphopoda).

Having spent some time at the latter exposure the party walked along the old railway cutting where in one or two places (especially at 418857) the base of the U. Longville Flags, in the form of the Alternata Limestone, was found. The Alternata Limestone is a bed consisting of thin lenticular grey limestones packed with specimens of Heterorthis alternata and Sowerbyella sericea, separated by greenish siltstones and calcareous mudstones.

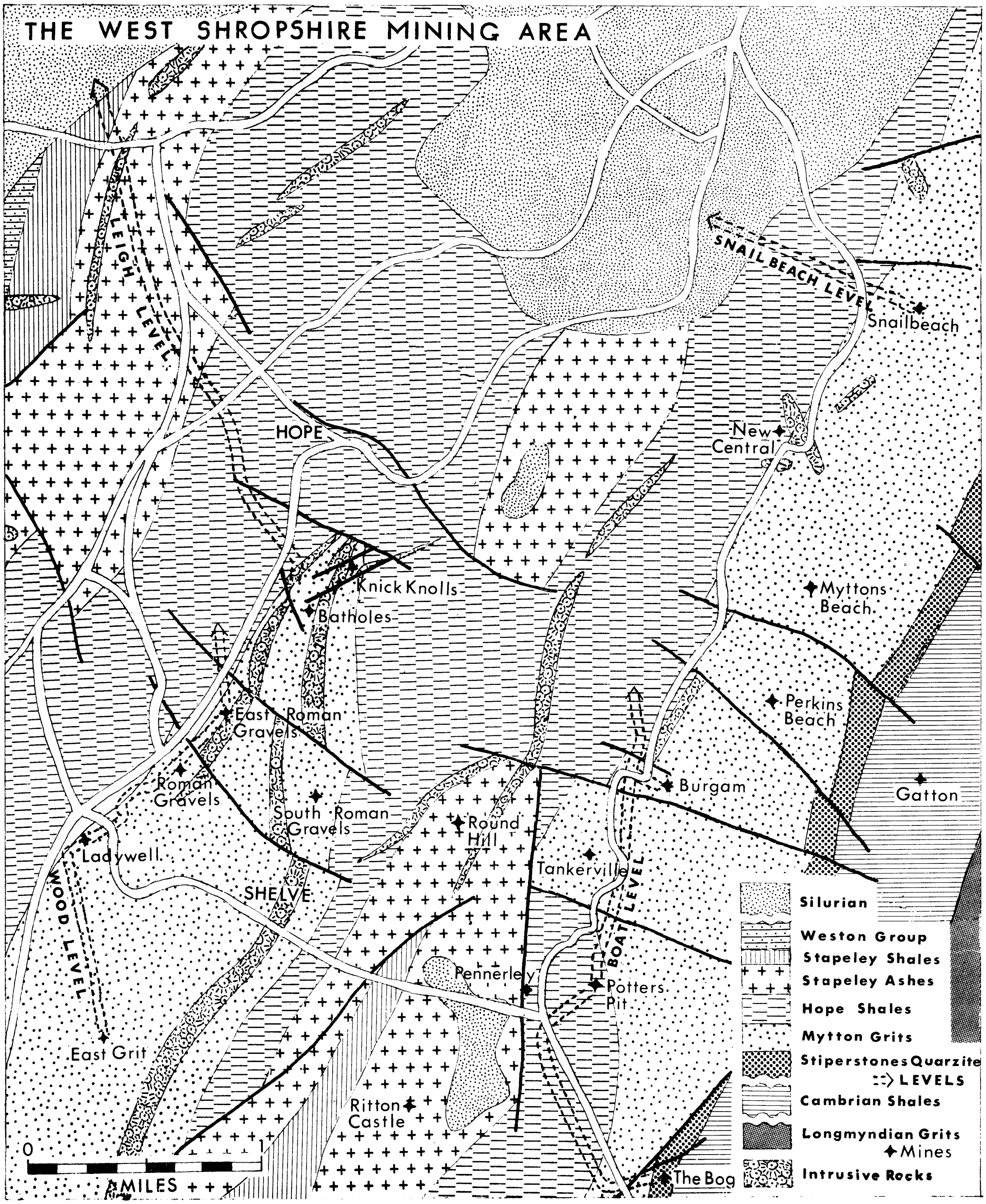
The best exposure of the next beds in the sequence, the Horderley Sandstone (≡ the Chatwall Sandstone), is found in the large disused quarry on the north side of the Bishop's Castle road and the party crossed the road up to this locality (415859). The sandstones dip very gently to the east and show colourful variations of green and purple banding. The banding enabled members to see quite clearly the excellent current bedding structures. At one or two levels thin bands of shelly limestone occur. Surface weathering has decalcified these shelly bands, which contain a variety of brachiopods but predominantly Sowerbyella sericea, Wattsella horderleyensis, Resserella sp. and Kjaerina jonesi. It was rather fortunate that another small road-side quarry in the sandstone about 100 yards northwest of the larger quarry was so completely overgrown to make access impossible. In this quarry the dip of the strata is nearly vertical, due to the close proximity of the most easterly of the main faults of the Church Stretton disturbance.

The last sub-division of the Ordovician sequence in the Onny River section is the Hoar Edge Grit and this was examined in the small quarry (419861) on the south side of the river near to Rock Cottage. The buff, coarse-grained gritstones are inclined very steeply and on the western side of the quarry is the junction with the Wentnor Series (Longmyndian). Much discussion has been aroused as to the nature of the junction. Whittard (1958, p.16) has suggested a fault junction but Mitchell (in Greig et al., 1968, p.119) infers an unconformable junction with a possible movement along the unconformity. Although a search for fossils proved fruitless the members were able to inspect the cavernous weathering at various places in the gritstone, which has been suggested as a result of the solution of bryozoan colonies. On the extreme eastern part of the section a small outcrop of the overlying Harnage Shales was seen.

After a morning of warm sunshine the party retreated to the Red Lion at Horderley for lunch.

The West Shropshire Mining Region (Text-fig. 1).

Lead mining in west Shropshire has a history spanning around two thousand years. The finding of pigs of lead bearing the stamp of the Emperior Hadrian (A.D. 117-138) in workings on Roman Vein at Roman Gravels Mine testifies to working of the mines during the Roman occupation of Britain and strongly suggests still earlier working, since the Romans seem never to have initiated mining in Britain, but always to have taken over control of existing mines. Active working of this mine and also of Snailbeach, Tankerville and East Grit Mines is known to have been taking place in the 12th and 13th Centuries and mining appears to have continued intermittently throughout the ensuing centuries, though records are remarkably sparse. In the early 19th Century,



TEXT-FIG. 1 The West Shropshire mining area. (Sketchmap based on Smith, 1922, but utilising additional information from Adams, 1963–4).

nine mines are known to have been working - Batholes, Roman Gravels, East Roman Gravels, East Grit, White Grit, Snailbeach, Ladywell, Pennerley and The Bog - and mining reached its peak during the fifty years that followed, a maximum of 7932 tons of lead in 1875. The working of zinc commenced about 1858, the record year for production being 1882 (914 tons); and working of barytes commenced at about the same time. Water problems were encountered in some mines and a number of drainage levels were driven: the largest of these were the Wood, Boat and Leigh Levels. The Wood and Boat Levels each drained several mines: their history is obscure. The Leigh Level was begun about 1825 and designed to drain the East Roman Gravels Mine. Work was abandoned in 1835, restarted almost a century later, in 1920, but abandoned again in 1923 without ever achieving its purpose (see Adams, 1963, p.107). A decline had begun to set in by around 1900, as a result of falling world prices and the exhaustion of the more accessible deposits. The great Roman Gravels Mine closed in 1912, after some nineteen centuries of intermittent working and, by 1913, only 3 mines (Snailbeach, East Roman Gravels and Perkins Beach) were working on any significant scale. The First World War brought a brief revival and some mines (e.g. Rorrington, The Bog and Burgam) reopened briefly but this proved ephemeral. Ridge Hill Mine (off map) was opened for barytes in 1919 and remained open until 1931. This was the only new mine in the postwar period, working generally ceasing around 1920, though Burgam Mine was intermittently worked, on a very small scale, until as late as 1961. The total output, considered even on a national scale, is not especially impressive: 235,650 tons of lead were produced between 1845 and 1913; 18,994 tons of zinc, between 1858 and 1913; and 271,397 tons of barytes, between 1860 and 1913.

The mineral deposits of this region occur within Ordovician rocks; the general sequence is as follows (Dines, 1958, p.3):

Whittery Shales (with some grits)		900 ft.
Whittery Volcanic Group (tuffs)	}	800 ft.
Hagley Shales		
Hagley Volcanic Group (tuffs)		
Aldress Shales		700 ft.
Spy Wood Grit		175 ft.
Rorrington Shales		400 ft.
Meadowtown Shales (with flags and limestones)		800 ft.
Betton Shales and Flags		200 ft.
Upper Weston Grit	} Weston Group	500 ft.
Weston Shales		
Lower Weston Grit		
Stapeley Shales	}	900 ft.
Stapeley Volcanic Group (andesites interbedded with tuffs, grits and shales.)		
Hope Shales		800 ft.
Mytton Grits (flags with shales)		1,500 ft.
Stiperstones Quartzite		250 ft.

The ore-bearing solutions, rising from below, were generally prevented from upward migration in the Shelve anticline by the Hope Shales, which would expand as a result of the effects of moisture to close up fault planes. The greatest concentration of minerals is thus in the Mytton Grits. To the west of the region covered by the sketch map (Text-fig. 1), however, a through-passage was found. Workable veins of lead and barytes occur at Rorrington in the Upper Weston Grit, of barytes at Ridge Hill in the Hagley Volcanic Group and at Wollerton as high as the Whittery Volcanic Group, the overlying Whittery Shales preventing further upward migration. The distribution of ore minerals suggests an arrangement into primary depth zones, related to temperature of precipitation from solution, so familiar in other ore fields, with zinc lowest, lead next, and barytes penetrating highest. There is no true copper zone and most records of copper minerals in Shropshire mining literature appear to have resulted from misidentifications of the green lead ore, pyromorphite (see Sarjeant, 1967).

After lunch, the party travelled west along A489, following the valley of the River Onny to Eaton, at which point we turned along a secondary road following the valley of the East Onny northwards through Wentnor. Good views were obtained of the western flanks of the Long Mynd, a rolling plateau formed by late Pre-Cambrian sediments (sandstones, silts and mudstones). We left this valley about a mile southwest of Bridges, following a second minor road through the hamlets of Kinnerton and Coldyeld and across the southern flanks of the STIPERSTONES, a striking ridge formed of Ordovician quartzites weathered into bizarre shapes (approx. SO/368987). A brief pause was made for photographs.

As we descended the hill, we passed the ruins and tipheaps of THE BOG MINE (SO/357977), originally worked for lead and later for zinc and barytes, opening before 1845 and being intermittently worked until about 1915. The road then swung northward along the western flanks of the Stiperstones. The engine house of the NEW CENTRAL (or SOUTH SNAILBEACH) MINE (SJ/369016) was noted. Little is known of this mine which only worked lead and closed about 1872.

The first stop was made at the SNAILBEACH MINE (SJ/375022). This was one of the largest mines in Shropshire. A pig of lead of Roman date has been found here, but this was not found in the workings, so that Roman working cannot be considered proven. However, it appears to have been in operation during the 12th, 18th and 19th centuries, eventually closing around 1920. Ore was conveyed by narrow-gauge railway, the Snailbeach District Railway, to the main line at Pontesbury; the tracks of the old light railway are still to be seen.

"Beach" or "batch" are Shropshire terms for small valleys on the flanks of hills and the Snailbeach Mine occupies such a valley. The ore deposits occur in a series of east-west fissures in the Mytton Grits, a series of beds consisting of hard flags or grits with interbedded shales. There are three main veins (Main, Black Tom, and South), worked from four shafts. Extensive spoilheaps now conceal one of these (Old Shaft), but Black Tom Shaft, marked by a derelict headgear on the north side of the valley, close to some mine cottages, and Engine Shaft, with its crumbling engine house hidden among trees on the south side of the valley, were both seen, and Chapel Shaft, covered over by concrete slabs, can still be found near the head of the valley.

Tubs full of lead ore (galena) have been left under a shelter near to the mine reservoir. The tips yielded good specimens of galena, blende, calcite and barytes; specimens of bitumen, in part in pseudocrystalline form (asphaltum), witherite, pyromorphite, fluorspar and quartz were also found.

We then returned south along the same road to visit two further mines. BURGAM MINE (SO/358996) is now marked only by a spoilheap, with a derelict level and run-in shaft. It was working in 1867 for lead, subsequently also for zinc and later still for barytes. Working for the latter mineral continued intermittently until about 1961. The apple-green lead ore, pyromorphite, occurs in quantity here and was said to be "abundant underground" (see Sarjeant, 1967, p.175) but it was mistaken for copper and never worked. Small specimens of this mineral were collected by most members.

A nearby exposure of the Hope Shales (SO/357997) situated alongside a fault and containing a dolerite intrusion, was briefly examined.

We then followed a track for about quarter of a mile on the west side of the road to visit the TANKERVILLE MINE (SO/355995), where a fine array of mine buildings survive. Working here was taking place in the 12th and 13th centuries, but the most recent phase of activity was between about 1865 and 1894; together with the neighbouring Potters Pit and Pennerley mines, this formed a group known as "Tankerville Great Consols"; it yielded some 17,948 tons of galena, 3,049 tons of zinc blende, 1,157 tons of barytes and 10 tons of witherite during this period. All these minerals were found on the tips; especially excellent specimens of blende and barytes were collected. In addition, calcite, pyrite, chalcopyrite, fluorspar and quartz were obtained.

Back to the cars and south to the road junction near where overgrown tips mark the site of the PENNERLEY MINE (SO/353988). Then west along another minor road, to visit the classic fossiliferous exposure in the Mytton Flags beside the church at SHELVE (SO/336990). Here, a rich fauna of dendroid and extensiform graptolites, including Dictyonema, Clonograptus and Glyptograptus, was collected before rain drove us from the outcrop.

We continued west to join the main north-south road (A.488). Here an engine-house marks the site of the LADYWELL MINE (SO/327994), which closed around 1880. A fine prospect of Corndon Hill, just over the Welsh border into Montgomeryshire, could be seen at this point. This prominent landmark is a dolerite laccolith. We turned north past the extensive spoil heaps and crumbling buildings of the ROMAN GRAVELS (SO/333999) and EAST ROMAN GRAVELS (SJ/334002) MINES. Working here has proceeded intermittently since Roman times, ceasing in 1912 and 1901 respectively. Shortly after, we left the main road and travelled by a series of minor roads to MEADOWTOWN.

At Meadowtown is the type locality of the Meadowtown Beds (Llandeilo Series) in a small quarry (311013) in the village. At one time this quarry was famous for the fossils it contained, especially specimens of Ogygia sp., but recently little of note has been found there. Due to the atrocious weather conditions members did not spend any time at this locality, but made their way along the Rorrington road to the point where the Lower Wood Brook crosses the road. In the stream section on the north side of the road the black shales of the Meadowtown Beds were found to be very prolific in trilobites (Ogygia sp.) and, despite the torrential rain in the heart of a thunderstorm, most of the party were able to collect good specimens.

SUNDAY 4th MAY

The Lawley - Wenlock Edge District

In this region, the general succession is as follows (thicknesses based on Dean, 1960; Greig, et al., 1968; and on mapping by the authors):

		thickness in feet,
PLEISTOCENE	Boulder clay, fluvoglacial deposits, etc.	variable
	~ unconformity ~	
CARBONIFEROUS	Upper Coal Measures (Coed-Yr-Allt Group)	c.100 to 200

	~ unconformity ~	
SILURIAN LUDLOW	Upper Ludlow Shales (siltstones with occasional thin limestones)	100 to 400
	Aymestry Limestone: nodular limestone with siltstone bands.	80 to 210
	Lower Ludlow Shales (mudstones and siltstones with occasional thin limestones)	600 to 850
WENLOCK	Wenlock Limestone	0 to 140
	Tickwood Beds (alternating argillaceous limestones and calcareous siltstones)	50 to 180
	Wenlock Shales (siltstones and silty mudstones, in part calcareous)	1000
LLANDOVERY	Hughley Shales	0 to 250
	Pentamerus Beds (siltstones and mudstones, with some thin shelly limestones and sandstones)	0 to 225
	Kenley Grits (coarse sandstones, grits and conglomerates)	0 to 75
ORDOVICIAN CARADOCIAN	Onny Shales	up to 400
	Acton Scott Beds (mudstones with impure limestones and sandstones locally)	200 to 500
	Cheney Longville Flags (flaggy sandstones and shales)	300 to 750
	Alternata Limestone (thin shelly limestones intercalated into sandstone/shale sequence: mapped with Chatwall Sandstone in Text-fig. 2)	20 to 30
	Chatwall Sandstone	c. 25 to 40
	Chatwall Flags (with some shale bonds)	? 300 to 500
	Harnage Shales (mudstones with thin sandstones)	? 600 to 1,000
	Hoar Edge Grit (coarse sandstone and conglomerate, with thin limestones locally)	300 to 400
	~ unconformity ~	
TREMADOCIAN	Shineton Shales	? 1,000
CAMBRIAN UPPER	Black Shales	? 10
	Orusia (Grey) Shales	? 10

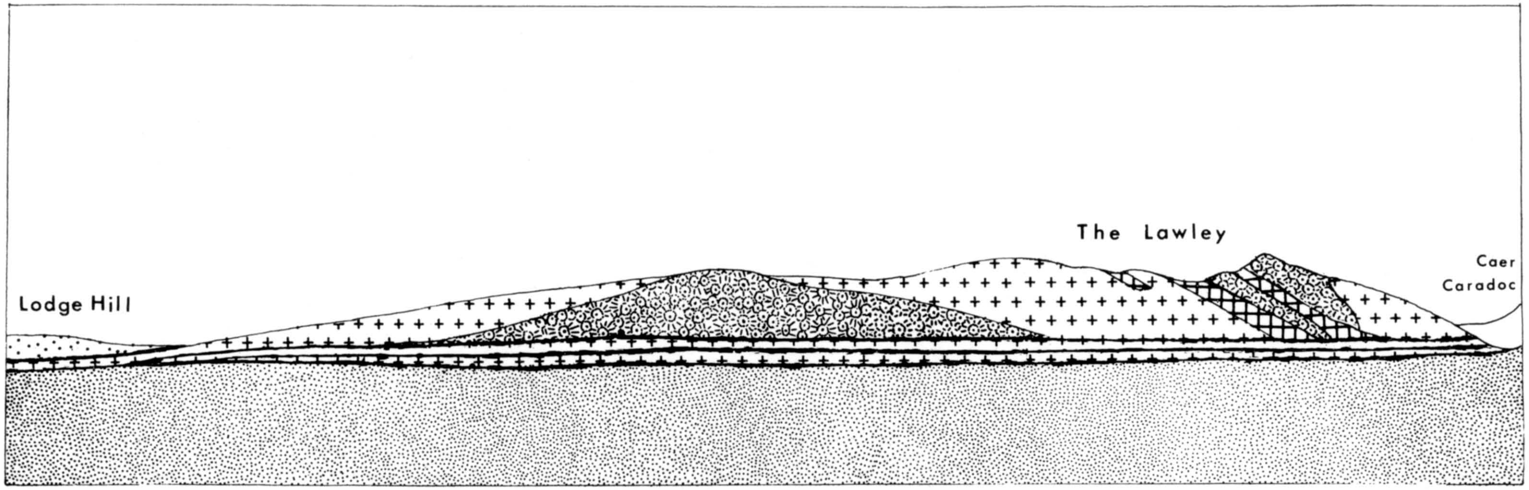


PLATE 24. The Lawley, Shropshire, viewed from a point $1\frac{1}{2}$ miles N.E. of Leebotwood. Photograph, accompanied by an interpretative geological sketch with shading as in Text-fig. 3. (Photo. and sketch: W.A.S. Sarjeant).

unconformity

MIDDLE	Upper Comley Series (sandstones with some shales)	300 +
LOWER	Lower Comley Series	
	Comley Limestone	0 to 6
	Lower Comley Sandstone	500
	Wrekin Quartzite	150

unconformity

PRE-CAMBRIAN URICONIAN	Dolerites (locally intrusive)	0 to c.750
	Andesites, rhyolites and tuffs	1,000 +

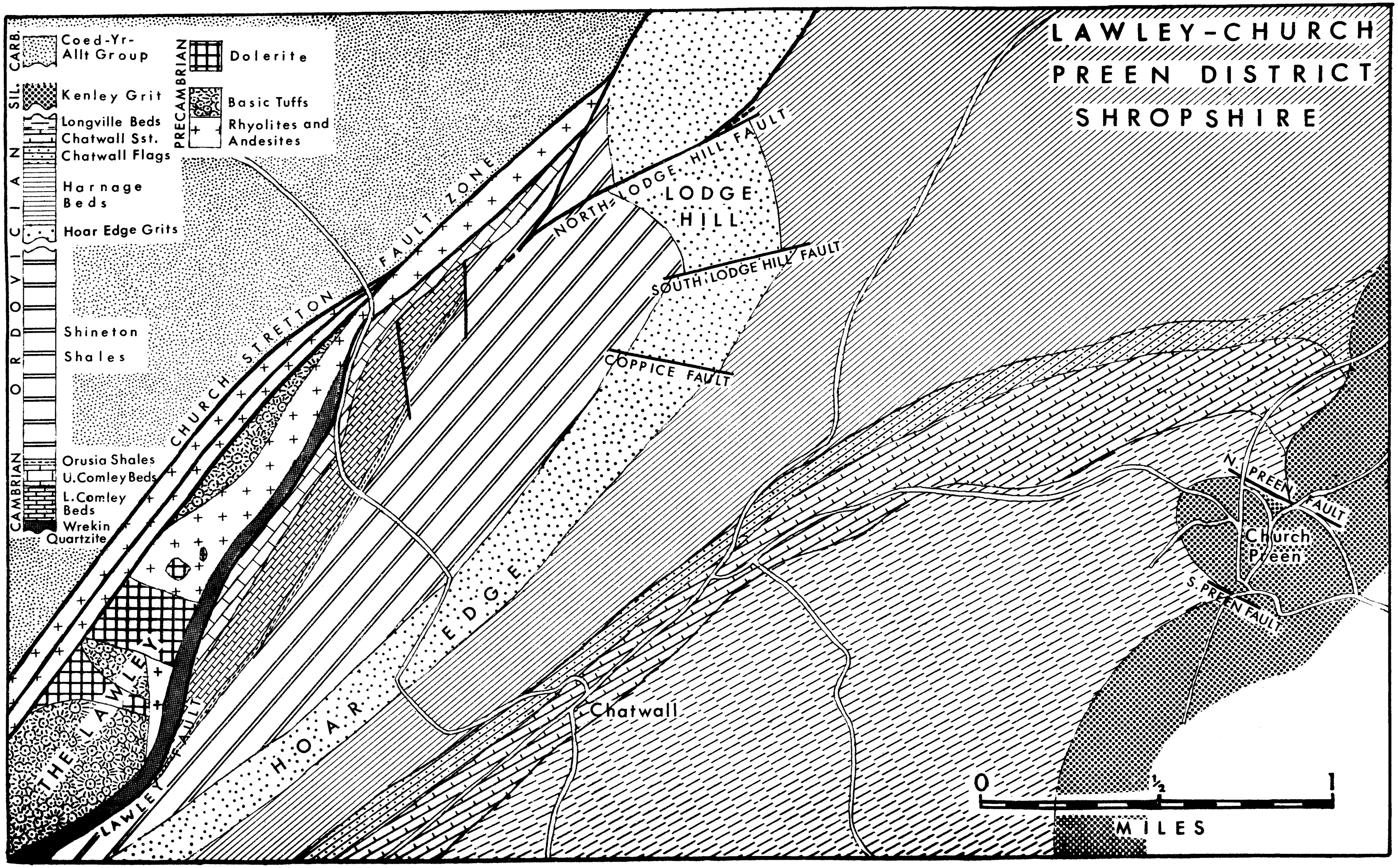
After heavy overnight rain, Shropshire was enshrouded in thick, wet mist when we left the hotel. We travelled northeast from Church Stretton, initially on the A.49, then along an old Roman road and through two very wet fords, leaving this at Longnorgreen and stopping at a point about $1\frac{1}{2}$ miles northeast of Leebotwood (SO/0997). Under normal conditions, this affords an excellent view of The Lawley, the topography of the hill accurately mirroring variations in rock types. However, this view was spoined and our halt was brief. (In belated compensation, it is illustrated in Plate 24 .

At the northern end of The Lawley, the Church Stretton fault complex throws Uriconian against the Coed-Yr-Allt Series (Upper Coal Measures). Unfortunately, the point (SO/506992) at which the LAWLEY BROOK crosses the fault corresponds to the position of a road-bridge, and the stream bed has been cemented, obscuring the fault plane from view. However, massive yellow sandstones of the Coed-Yr-Allt Group, almost horizontal, are exposed in the stream bed to the west of the bridge and, to the east, a good exposure is afforded of the Uriconian beds, to a total width of about 100 yards. Nearest to the bridge, purplish fine-grained tuffs are seen, overlying a coarser, brownish-grey tuff of more rhyolitic character. These in turn overlie fine-grained, grey tuffs, of probably andesitic character. The brownish tuffs then reappear, suggesting an anticlinal structure. (Such a structure is eminently possible, since the Church Stretton faults, bordering The Lawley on its western flanks, and the Lawley faults, bordering its eastern flank, are here converging).

G.H. Mitchell (in Greig et al., 1968) has interpreted the sequence at the southern end of The Lawley as comprising:

Basic Tuffs
Upper Andesites
Rhyolite
Lower Andesite

However, in terms of the exposures in the northern end of the hill, it is considered that a more complex sequence of events must be envisaged. Rhyolitic tuffs are certainly present. One of the authors (W.A.S.S.) has collected a typical, spindle-shaped volcanic bomb from the downfaulted rhyolitic tuffs on The Lawley's western flanks. Although this was not in situ, it strongly indicates the local presence of coarser, agglomeratic material and the proximity of a vent.



TEXT-FIG. 2 The geology of The Lawley – Church Preen district, Shropshire. (Based on mapping by W.A.S. Sarjeant)

The party then followed the road over the northernmost tip of The Lawley and down its eastern flanks, examining roadside exposures of rhyolites and rhyolitic tuffs en route. As we descended the hill, we crossed onto the lowest Cambrian unit, the Wrekin Quartzite, a greyish-white sediment consisting of coarse quartz grains set in a cement that is typically siliceous, in part ferruginous. It is very poorly exposed in the road verges (SO/506988). The Lawley Fault follows the junction between the Wrekin Quartzite and the Lower Comley Series. The former horizon is faulted out within a few yards of the exposure, so that the Lower Comley Beds are thrown against the Uriconian. Exposures of the Lower Comley Beds are equally poor. Medium grained, glauconitic sandstones in a roadside bank near Blackhurst (SO/504985), probably represent a sandy horizon in the lower part of the Comley Limestone. No fossils were noted.

The Wrekin Quartzite forms a well-marked bench along the western flank of The Lawley. Two further features, much less well marked, were noted on its lower flanks, marking the top of the Comley Limestone and of the Upper Comley Beds, overlain by shales. Unfortunately, no outcrop of the Upper Comley Beds could conveniently be visited and the three shale units that follow are largely concealed beneath drift, not being exposed in the valley of the Lawley Brook. We therefore crossed the valley by car, the next stop being made at some abandoned quarries at BIRCH COPPICE (SO/509978), near the foot of Hoar Edge.

Hoar Edge is a cuesta formed by the Hoar Edge Grits, the lowest division of the Caradocian (Ordovician). At its northern end, it is affected by three faults (here named the Coppice and South and North Lodge Hill faults). The first two of these alter the trend of the ridge and reduce its dip, the third obliterates it, so that the Grits form lowlying ground north of Lodge Hill. Lithologically, they typically consist of coarse to medium grained, yellowish sandstones with occasional conglomeratic horizons, containing pebbles of quartz and of Uriconian volcanic rocks. False-bedded horizons are present and the fossil foraging tracks of invertebrates were noted on some bedding planes; poorly-preserved moulds of brachiopods were collected, but Harknessella, typical of these beds, was not recognised with certainty.

We then crossed Hoar Edge and the drift-filled Causewaywood valley, floored by the Harnage Shales. These are poorly exposed in a roadside bank on the south flank of the valley, but, since the outcrop appears entirely unfossiliferous (one of the authors, W.A.S.S., having spent four days in an unsuccessful search), no stop was made here. Instead we proceeded directly to CHATWALL HALL (SO/514975), where the upper Chatwall Flags and lower Chatwall Sandstone are exposed in roadside banks and a small abandoned quarry. A full account of the stratigraphy and palaeontology of these beds has been given by Dean (1958, 1960). Fossils collected included crinoid ossicles (Rhaphanocrinus sp.) and brachiopods (Dinorthis aff. flabellulum, Rafinesquina expansa, Sowerbyella soudleyensis, Horderleyella corrugata, etc.) graptolites (Orthograptus sp.), trilobites (Broeggerolithus sp. plur., Brongniartella sp.) and bryozoa (Diploclema sp.).

We next drove northeast, following the Chatwall Beds cuesta, noting a roadside outcrop of the Alternata Limestone (SO/522981), then descended the dip slope to cross the valley formed by the Cheney Longville Flags to CHURCH PREEN (SO/542979), to visit a small quarry exposing the Kenley Grits (Silurian), which inconformably overlie the Ordovician. The line of the unconformity is locally modified by two small faults (here named the North and South Preen Faults) of uncertain throw. Lithologically these are a sequence of pebble conglomerates and coarse sandstones, interbedded with lenticular sandstones and sandy mudstones. Their colour is generally a rich brown, indicating a high ferruginous content. False-bedding, indicating derivation from the west or southwest, was noted.

To the northeast of the Kenley Grits, stretching to the base of the Wenlock Edge escarpment, is the low-lying area occupied by the argillaceous sediment of the U. Llandovery and

Wenlock Shales, both of which are largely obscured by a covering of drift. However, in a few of the strike streams running across this area a limited number of exposures can be found.

After having had lunch in the village of Longville in the Dale members drove to the hamlet of HUGHLEY. To the west of the bridge crossing Hughley Brook in the village the party found an exposure of the Hughley Shales in the left bank of the stream (564978), and also in a small left bank tributary a few yards further upstream. Despite the inclement weather and the necessity of wading in the stream to get at the exposure, members spent a considerable and worthwhile time at this locality. The beds consist of greenish and purplish shales with a few thin limestone bands and are extremely fossiliferous. Among the fossils collected were the corals Heliolites sp., Halysites sps., Favosites sps., Calostylis sp., Cantrillia prisca, Phaulactis sp.; the brachiopods Atrypa reticularis, Dicoelosia biloba, Camarotoechia sp., Cyrtia exporrecta, Pentamerus sp., Plectodonta spp., Strophonella sp.; the trilobites, Encrinurus sp., Phacops sp.; and also Tentaculites sp. and numerous crinoids and bryozoans. In some of the shales collected from this locality and taken back to Nottingham the denticle of an early Silurian fish was found. This possibly belongs to the genus Birkenia.

From the village of Hughley members were able to get an excellent view of the striking escarpment feature of Wenlock Edge. Two or three irregular knobs of limestone could be seen as upstanding masses on the ridge. These are examples of the reef structures or "ballstones", common features in the Wenlock Limestone.

The next locality to be visited was in the Wenlock Limestone itself. Recent extensive working of the limestone has resulted in a number of old, disused quarries becoming amalgamated with the working ones. The quarry we visited is known as LEA QUARRY (598983) and over the last two or three years this has been extended enormously. Members were able to see excellent examples of the reef structures and their relationship with the normal bedded limestone. The uppermost 15 feet or so of the Wenlock Limestone in the Wenlock area consists of closely bedded. fragmentary crinoidal limestones and these could be seen in the quarry-face at Lea Quarry. One feature of the Wenlock Limestone is that the best fossils can be found in weathered blocks of the limestone and at the above locality members spent a considerable time collecting the diverse fauna. The fossils include the corals Acervularia sp., Kodonophyllum sp., Phaulactis sp., Favosites gothlandicus, Palaeofavosites asper, Heliolites megastoma, H. interstinctus, Propora sp., Halysites catenularius, H. sp., Syringopora fascicularis and Thecia swinderniana; the brachiopods Atrypa reticularis, Camarotoechia sp., Leptaena rhomboidalis, Rhipidomella sp. and Plectodonta sp.

The next exposure visited was in another Wenlock Limestone quarry, this time in SHADWELL QUARRY (626007) just to the north-northeast of Much Wenlock. In this quarry a similar lithological sequence was found and the faunal list for the previous exposure indicates the main fossils.

From Much Wenlock we crossed over the Aymestry Limestone outcrop and down into Corve Dale. Behind the school in the village of BROCKTON (578939) we were able to see a good exposure of the Upper Ludlow Shales, some bands of which were extremely fossiliferous with two brachiopods, Camarotoechia nucula and Protochonetes ludloviensis and also a few fragments of orthoceratid nautiloids. The lithology of the Upper Ludlow Shales at this locality is mainly of buff-coloured siltstones with a few thin, coarser sandstone bands and also a number of clayey partings.

The last exposure of the day was seen in a very quick visit to the sand beds at BUILDWAS (646044). Here the glacial sands, gravels and clays, well described by Wedd (in Pocock et al., 1938, p. 197) were briefly examined.

I.D.S. & W.A.S.S.

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THE JURASSIC ROCKS BETWEEN ANCASTER AND LINCOLN

Leader: A.M. Honeyman Sunday, 8th June, 1969

The purpose of the excursion was to examine the Jurassic succession exposed in quarries in the vicinity of Ancaster and northwards towards Lincoln. The stratigraphical divisions are as follows:-

GREAT OOLITE SERIES	GREAT OOLITE LIMESTONE UPPER ESTUARINE SERIES		Feet 5+ 25 - 30
INFERIOR OOLITE SERIES	LINCOLNSHIRE LIMESTONE	Lincoln area / Ancaster area	
		Ancaster Rag (Ancaster area)	8 - 18
		Hibaldstow Beds = Ancaster Beds (coral bed) Ancaster Freestone	15 - 20
		Crossi Bed (absent at Ancaster)	12 - 0
		Cementstones	12 - 20
		Silver Beds - Little Ponton Beds) Blue Beds)	10 - 20
	LOWER ESTUARINE SERIES NORTHAMPTON IRONSTONE		0 - 7 6 - 12
LIAS	UPPER LIAS	Upper Lias clays and shales	100
	MIDDLE LIAS	Marlstone Rock-bed (South of Leadenham)	0 - 15
		thin ironstone beds at Lincoln Middle Lias Clays	35 - 60
	LOWER LIAS	Upper Clays of Lower Lias	50+

For further detail of the various divisions the reader is referred to the relevant chapters in Sylvester-Bradley and Ford (1968) and to the excellent review by Kent (1966) of the Lincolnshire Limestone.

The excessively wet weather which had made a quagmire of much of the countryside during May had at last given way to a dry sunny spell. On the journey from Nottingham via Grantham to Ancaster, advantage was taken of the exceptionally good visibility to make a few brief stops to view the main topographical features and their relationship to the geology, in particular the prominent escarpment formed by the Marlstone Rock-bed in the vicinity of Grantham.

In the area just south of Ancaster quarries were visited as follows:-

Gregory's Quarry (SK 992410), about 2 miles south of Ancaster, is the only quarry in this area at present working the Lincolnshire Limestone as a building stone. The stone is quarried after removal of an overburden of clays belonging to the lower part of the Upper Estuarine Series. Members first examined the Ancaster Beds and noted the contrast between the massive oolitic freestones, the true Ancaster stone, and the overlying strongly cross-bedded shelly limestones known as the Ancaster Rag, here about 8 feet thick. Formerly the Rag was not used, being removed and dumped on spoil heaps, but it is now sold for building purposes although less valuable than the freestone. In places the blue colour of the unweathered stone was observed and an additional colour effect was given by the patchy pink staining of the upper layers of the limestone. This was seen to be due to the presence of irregular nodular lumps of haematitic ironstone, which overlie the limestone and mark the base of the clays of the Upper Estuarine Series. Much of the detail of the clay succession was obscured by sludge and slipped material. Fossils found were mainly bivalves, *Liostrea hebridica* being abundant.

The party then walked to the nearby Thompson's Quarry (SK 992409) now disused and much overgrown, to examine the highest beds of the Upper Estuarines and basal beds of the Great Oolite Limestone. Near the top of the clays is a prominent hard band with *Liostrea hebridica*. The few feet of rubbly limestones and marls exposed along the top of the quarry belong to the Great Oolite Limestone; these are highly fossiliferous but collecting in situ involved finding and retaining a foothold on the steep quarry face. Fallen blocks in the floor of the quarry provided a less hazardous means of collecting. The commonest fossils are bivalves, e.g. *Liostrea*, *Modiolus* and *Pholadomya*, and the brachiopods *Epithyris* and *Kallirhynchia sharpi*, the latter being diagnostic of the base of the Great Oolite Limestone.

The next locality visited was Copper Hill Quarry (SK 979427), about half a mile south of Ancaster, which exposes a succession from the Cementstones to the Ancaster Rag. The upper level of the quarry was examined first and the coach delivered the party directly on to its most striking feature, namely the hard, almost white and slightly undulating erosion surface which marks the top of the Ancaster Freestone. Quarrying operations are facilitated by the hardness of this surface and it has been laid bare over a considerable area by the scraping off of the overlying Ancaster Rag. The Rag here is seen to a thickness of about 15 feet; it is strongly cross-bedded and contains much shell debris and spines of the echinoid *Cidaris*. In the southwest corner of the quarry fossils were collected from the hardened top of the freestones; these included *Liostrea*, *Plagiostoma*, small terebratuloid brachiopods and *Cidaris* spines. The beds beneath this level were then examined in the lower part of the quarry; the 5 feet of thinly bedded pale coloured limestones seen at the base presumably belong to the Cementstone division of the Lower Lincolnshire Limestone. These are succeeded abruptly by the oolitic Ancaster Freestones, here too thinly bedded and closely jointed to be used as a building stone. The Crossi Bed (named from the spinose rhynchonelloid *Acanthothyris crossi*), which occurs at the top of the Cementstones in other areas, is missing at Ancaster probably as a result of local erosion. The coral bed mentioned in the table above is seen only in the Castle Quarry (SK 987434), which was not visited on this excursion.

From the roadside near the entrance to Copper Hill Quarry, a good view was obtained northwards across the broad valley of the Ancaster Gap, now without any through drainage. The origin of the gap as a pre-glacial west to east course of the Trent River, and its abandonment at some time during the complex glacial history of the region, were briefly outlined.

Lunch was taken at the Railway Inn, Ancaster, recently renovated inside and providing amenities and comfort hardly hinted at by its rather drab exterior. Our feet were clean on this occasion; excursion leaders are apprehensive of the reaction of landlords to the advance of forty or so pairs of muddy boots over carpets and polished floors.

A pleasant after-lunch drive a few miles northwards along Ermine Street brought us to the Leadenham Stone Quarry (SK 962522) in which the Lower Lincolnshire Limestone is worked for limestone aggregate. Here, in the early 1920's, the Northampton Ironstone was extracted by open cast working, but little can now be seen of the beds beneath the Lincolnshire Limestone. At the western end of the quarry a cutting through the woods marks the route by which ironstone was transported some quarter of a mile to the railway at Leadenham. In the cutting, the base of the limestone was seen above 6 feet of sands and clays of the Lower Estuarine Series. The ironstone is not exposed, but blocks showing the characteristic box structure were found at the western end of the cutting. At this spot, the party enjoyed superb views along the Lincoln Cliff to Lincoln Cathedral and westwards over Leadenham to Newark and the Trent Valley, the course of which northwards to the Humber was clearly indicated by the line of distant power stations.

In the main quarry the sequence in the Lower Lincolnshire Limestone was examined, in ascending succession Blue Beds, Silver Beds and Cementstones. The Blue Beds (so called from the colour of the fresh unweathered stone) are brown weathering ferruginous limestones, contrasting with the paler oolitic Silver Beds. The Cementstones, light coloured fine-grained limestones with scattered ooliths and marly partings are well exposed in the present working faces in the higher level of the quarry. A varied fauna is present, but fossils have to be sought for assiduously and it is not easy to make an extensive collection during a brief visit. Bivalves are the commonest fossils, *Gervillella acuta* in the Silver Beds, *Pholadomya* and *Pinna cuneata* in the Cementstones, the latter occurring in bands and in their life attitude, pointed umbones downwards. Gastropods also occur, the commonest being high-spired nerineids.

The excursion continued northwards towards Lincoln to see the Liassic rocks exposed in the well known brick pits at Waddington and Bracebridge, both still actively worked by the Lincoln Brick Company. The Waddington Station Pit (SK 967652) displays the upper part of the Lower Lias (*Prodactylioceras davoei* Zone), here consisting of stiff dark clays with bands of septarian nodules. In the clays the fossils are usually crushed and difficult to collect but the large tip of discarded nodules near the entrance to the pit provided good hunting for ammonites. Species of *Androgynoceras* are the commonest; *Liparaceras*, *Oistoceras* and the zonal fossil *P. davoei* also occur. Belemnite guards are common and phragmocones may be found in an excellent state of preservation. The tip heap also contains lumps of shelly limestone crowded with bivalves, e.g. *Liostrea*, *Oxytoma* and *Plagiostoma*.

The highest beds now visible at Waddington belong to the Middle Lias, which is more fully exposed in the Bracebridge Pit (SK 971672) on the southern outskirts of Lincoln. This vast pit is now being used as a refuse dump, but fortunately it is still being extended and deepened at its northern end. In recent years clays for brick-making have been dug intermittently from three different levels which conveniently correspond approximately to Lower, Middle and Upper Lias. Time permitted only a rapid examination of these divisions. In the lowest level clays with *Androgynoceras*, similar to those at Waddington, were seen. The Middle Lias may be recognised by the presence of thin beds of brown ironstone which provide a striking colour contrast with the blue-grey clays and shales. It was noted that the Middle Lias hereabouts reveals no sign of the Marlstone Rock-bed, which is present south of Leadenham. Small crushed amaltheid ammonites were found in the clays. Howarth (1958) showed that almost the whole of the Middle Lias at Bracebridge is in the *Amaltheus margaritatus* Zone, the higher *Pleuroceras spinatum* Zone (which further south includes the Marlstone) possibly being present but no more than a foot or so thick. A final scramble up the steep slope at the top of the quarry was required to reach the lowest beds of the Upper Lias, which here consist mostly of very fissile paper shales. The parting planes of these shales are crowded with tiny crystals of selenite showing radiating habit. The commonest ammonite at this horizon is *Tiltoniceras acutum*.

The party then rejoined the coach and returned to Nottingham via Newark. The excursion was attended by 43 members and on their behalf the leader wishes to thank Mr. Lee of Quarry Farm, Ancaster, The Castle Lime Company, Messrs. C.A.E.C. Howard and the Lincoln Brick Company for permission to visit the various localities.

A.M.H.

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EXCURSION TO THE GYPSUM DEPOSITS OF NOTTINGHAMSHIRE

Leader: Dr. J.H. James — Sunday, 7th September, 1969

Members of the Society left Nottingham at 9.30 and travelled via Bottesford to Hawton, just south of Newark. At the Jericho Quarry of British Gypsum Limited (grid reference 480710 339120), an introduction to the succession was given. This was followed by a description of the methods of working by Mr. J. Alker, the Quarry Manager.

The party then made their way via the Hawton Works (480150 350580), where members were able to collect specimens of blue Anhydrite, to Hawton Quarry (479650 348680). Here the party were able to examine the Upper Gypsum beds and collect specimens of satin spar and massive gypsum. Attention was paid to the main divisions of the succession, in particular the nodular masses of gypsum set on blocky green and red marls, associated with numerous satin spars. Further, that this was constantly underlain by approximately twenty feet of blocky red marl with an almost absence of satin spar veining, but containing four recognisable gypsum horizons. It was further pointed out that while these four gypsum horizons varied in thickness from point to point, they would be readily recognisable in the quarries we visited later in the day.

The above horizons are underlain by other gypsum-bearing marls, which in general, in the next ten to twelve feet below, contain well developed green "fish-eyes" or spots. It was at this point that some discussion was held on the question of the coloration of the marls. We also took the opportunity for Mr. A.Z. Aljubouri, a research student at Nottingham University, to demonstrate the presence of Uranium minerals coating some of the gypsum nodules.

The next quarry to be visited was the Staunton Quarry of Bellrock Gypsum Industries Limited (480150 344640). Here the change of distribution of the green marls, normally associated with some of the upper gypsum beds, was pointed out and examination was made of large gypsum blocks to show the dendritic inclusions of red and green marl within the larger masses. The party was able to observe in this quarry water coming upwards from the base of the gypsum layers, after having made its way downdip.

The next stop was at the Manor Arms Hotel for lunch. In the afternoon, the party proceeded to Cropwell Bishop to a British Gypsum Quarry (467465 336090), where the various layers of gypsum were discussed and the opportunity was taken to point out the changes in quarry-mens' names for similar beds within the Vale of Belvoir. In this quarry, a short time was devoted to discussing what was likely to be the mode of origin of the gypsum, in particular whether the sabhka concept of D.J. Shearman could be applied to this type of deposit.

The party then left the Vale of Belvoir and proceeded to Bunny on the Nottingham-Loughborough road (458110 328600), where, by kind permission of H. Baldwins, we took the opportunity of looking at gypsum exposed just above the working Tutbury horizon of the East Leake/Gotham areas. However, time was short and the party proceeded to Gotham, where Mr. J. French, the Mine Manager, had arranged to escort the party down the Glebe Mine (4353870 328955). During the visit to the mine, the mode of occurrence of the gypsum in this horizon was demonstrated. The effect of faulting on mine workings was shown and the method of working was explained by Mr. French.

A vote of thanks was given by Dr. R.J. Firman to the leader and to Mr. M.J. Evans and Miss L.M. Bates, who assisted with the excursion.

J.H.J.

REVIEWS

ALAN MOOREHEAD, 1969. Darwin and the Beagle. London: Hamish Hamilton. 280 pp, many illustrations. 75s.

Books on Darwin and Darwinism are legion and, when yet another appears, one might well ask if there be any justification for it. Following the publication of the "Origin of Species", Darwin (so he tells us in his "Autobiography") made an attempt to collect all that appeared on the book, "excluding newspaper reviews", but the volume grew so great that he "gave up the attempt in despair".

The author of "Darwin and the Beagle" is not known for his scientific work; however, he is the highly accomplished - and successful - author of several interesting non-fiction works and has the ability to make what could be a rather boring subject very readable. Editions of Darwin's own account of the voyage of the "Beagle" are not uncommon; however, to many would-be readers they have a somewhat Victorian appearance which does not lend itself to easy reading. What Moorehead does, in effect, is to rewrite Darwin and pad the account with information culled from other works. The whole process produces a highly interesting and very readable account of an important voyage.

Not unnaturally the methods utilised by Moorehead cannot escape criticism, particularly regarding what he manages to leave out. Darwin stressed the importance of geological observation, but Moorehead pays scant attention to this aspect of the voyage and even refers to the giant ground sloth Mylodon as "an extinct elephant", while indexing another ground sloth, Megatherium, as appearing on page 81 when it does not. Nevertheless such defects are of minor importance; a palaeontologist would note them, but most general readers will not. A more debatable procedure is to present certain of Darwin's later formulated opinions as dating from the period of the voyage; however, once again it will be the specialist to whom this is jarring, not the general reader for whom the book seems primarily to cater.

The last chapter concerns the historic meeting of the British Association at Oxford in 1860. It was here that Bishop Samuel Wilberforce sought to "slay the evolutionary infidels", but was himself "slain" by the redoubtable T.H. Huxley. This was also a public condemnation of his scientific "advisor", the anatomist Richard Owen, who seems to have been more peeved at the publicity Darwin was receiving than the bitter opponent of evolution as which history has branded him. Huxley and Owen had crossed swords before; and while "Soapy Sam" Wilberforce took the public drumming, in reality it was Owen who went off to sulk.

It had not been Huxley's intention to attend the British Association meeting but, as Moorehead notes, a chance meeting in the street with an old friend had brought about the change of heart. The old friend, who Moorehead does not name, was in fact Robert Chambers, author of an earlier and equally controversial evolutionary work, "Vestiges of the Natural History of Creation" (Leicester University Centre for Victorian Studies have, through the University Press, recently republished this once famous book). The fact that it was a bishop who led the attack on Darwin's theories illustrates the bitterness to which they gave rise in religious circles, though it should be noted that hostility was not unanimous (as witness the Reverend Charles Kingsley's welcome of the theory). Darwin seems to have been rather puzzled by it all and noted in his "Autobiography" that "considering how fiercely I have been attacked by the orthodox it seems ludicrous that I once intended to be a clergyman". When the invitation to join the "Beagle" as naturalist reached Darwin, one of the objections to his accepting which his father raised was that it would be "disreputable to (his) character as a clergyman". As it turned out, Darwin's intention to take Holy Orders died a natural death on his joining the ship. Another objection made by Dr. Robert Darwin to his son taking on the job was that the voyage "would be a useless undertaking". How wrong he turned out to be.

"Darwin and the Beagle" is a book which makes the famous voyage come alive; for those who know little about it in detail but want to fill this gap in their knowledge, this book will be welcome. It is well printed and contains a wonderful range of illustrations, many in full colour. The price is high, which is a pity as I feel there are many people who would like to own this book but who may think twice before paying 75/-.

ROBERT W. MORRELL

Geology: Journal of the Association of Teachers of Geology, vol. 1, 1969, Ashstead, Surrey: Association of Teachers of Geology. 68 pp. (obtainable from Dr. J.R. Harpum, Secretary of the A.T.G., St. Paul's College, Cheltenham, Glos.: Price not stated).

The teaching of geology in Britain has had a varied history. At the university level, it may be said to have begun in Scotland, where John Walker, Professor of Natural History in the University of Edinburgh, was already giving a remarkably sound course in geology between 1779 and 1803 (as is indicated by his "Lectures", published for the first time in 1966 by the University of Chicago Press). His successors included the arch-Wernerian Robert Jameson, an influential teacher (although Charles Darwin found him "distressingly dull") and Edward Forbes, a versatile naturalist who was arguably the founder of palaeoecology. Not until 1871, however, was a specific Chair of Geology founded (its first holder was Archibald Geikie, succeeded by his brother James in 1882). In England, the commencement was almost as early: John Kidd, primarily a chemist, introduced geological courses at Oxford during the years 1805-10 and William Buckland, who succeeded him as Reader of Mineralogy in 1813, greatly expanded this aspect of his teaching, becoming the first Professor of Geology in 1819. Although the Woodwardian Chair of Geology at Cambridge had existed since 1731, none of its incumbents did anything in the way of teaching (indeed, only two of them, John Michell and John Hailstone, can even have been said to have done any geology!) until 1818, when Adam Sedgwick was elected and poured his considerable energies into the task of learning to be a geologist, since he had done no geology beforehand! The year 1838, when Charles Lyell commenced lecturing at King's College, London, marks the beginning of a greater expansion: geology had become sufficiently "respectable" to be included in the curricula of all subsequent University foundations of Victorian times, and its progress as an academic discipline has since been steady.

Outside the Universities, the development of geology presents a much less coherent picture. During the later nineteenth century, the subject had become so popular that audiences for the major figures were sufficient to fill large lecture halls: through the efforts of such educationalists as Thomas Henry Huxley, evening courses in geology were being given widely in Mechanics' Institutes and People's Colleges in major towns throughout Britain; and the geological collections featured in most local museums, were arranged and labelled for serious students willing to spend days in their study. In the twentieth century, however, the position has altered markedly and the present position presents many unexpected paradoxes. Thus, for example, no geological lecturer would expect to be able to pack a hall; yet the attendances at classes run by the W.E.A. and University extramural departments has never been higher. Geological societies relying on amateur support had a hard time to survive in the '30's, '40's and '50's; yet now they are doing well again, as is witnessed by the success of the East Midlands Geological Society and the impressive exhibits at the Geologists' Association's annual reunions. Television programmes on geology obtain good viewing ratings; plastic dinosaurs pop out of corn-flake packets: and there are more (and better illustrated) books on geology for children than ever before.

Yet, paradoxically, popular knowledge of the subject is surprisingly poor. A national newspaper recently was astonished that the findings of ammonites in a Midlands motorway excavation "proved that this part of the country was once under the sea"; a Sunday "intellectual" paper published a map of fossil localities which was a horrifying hotchpotch of errors; and an illustrated paper produced a feature section likening young pelicans to the pterodactyl, "the first bird". Often, indeed, the subject is confused with archaeology. (The writer recollects being asked whether he spent his time "digging up pyramids"!).

Museum collections of rocks and fossils have all too often come to be sadly neglected: most provincial museums nowadays are staffed by biologists or archaeologists, unwilling or incompetent to revise geological displays in such fashion as to attract the museum visitors of these more hasty times. In some instances, indeed, geological collections have actually been thrown out: the collection of a London borough museum was only narrowly saved from the refuse heap by Reading University, and the collection of a museum in the northeast was actually used as road-building material!

More serious is the flagrant disregard of geology by architects and planners, with consequent wastage of public and private money and the erection of unsatisfactory, uncomfortable and, even dangerous structures. Politically, geology has made scant progress to date. Legislation enforcing adequate surveys before civil engineering works is still lacking; a recent bill enforcing the geological surveying of tips has been formulated only after the need had been so horrifyingly underlined by the Aberfan disaster. The laws governing prospecting are a creaking wilderness of antiquated regulations and injustice - a serious deterrent to investment in the exploitation of British raw materials. The geologist in Britain is not a recognised professional figure: there is no organisation to protect the interests of the consultant geologist. Science in schools has for long come to mean "physics + chemistry", with biology taught as a rather apologetic addition: geology only rarely figures in curricula as a special subject, despite an encouraging growth in recent years in the number of schools teaching it, and its inclusion in general science courses is generally only perfunctory.

In an attempt to remedy an unsatisfactory situation, Section C of the British Association for the Advancement of Science set up a sub-committee to enquire into the reaching of geology in schools. The almost total lack of liaison between schools and Universities was speedily recognised and Professor L.R. Moore (University of Sheffield) suggested that a national association of teachers of geology be formed to provide common meeting ground. This matter was further explored during the Nottingham British Association meeting in 1966; a questionnaire was prepared and circulated to ascertain the probable support for such an organisation. Sufficient favourable replies were received to encourage further action; and, at a meeting at Keele, Staffs. in 1967, the Association of Teachers of Geology came into being, with the avowed object of advancing teaching in Universities, schools and colleges throughout the United Kingdom. In the following year, a further Conference was organised: and now the Association has published its first journal, under the simple but comprehensive title "Geology".

The journal presents an agreeably mixed bag of contents. A brief account of the formation of the Association is given by D. Emlyn Evans; and articles by Rex. L. Birch and Victor R. Paling discuss the teaching of geology in primary and secondary schools respectively. A.C. Higgins and E.C. Spinner give a clear description of techniques for the extraction of microfossils, though the hazardous character of some of the chemicals employed necessitate laboratory facilities unlikely to be available to most of their readers. (The figures accompanying this article contain two errors: Micrhystridium is mis-spelled "Micrhrystidium" and the form figured as "Tasmanites" is in fact a Dictyotidium.) Finally, two topical articles are included: an account of the search for natural gas in the North Sea by Rex L. Birch and a fascinating anthology of writings about William Smith, the "Father of English Geology" born just two centuries ago, presented by Douglass A. Bassett.

It is hoped that the Association may succeed in a wider sense than its objects embrace; we, as a nation, are in urgent need of geological education, for it is vital that our restricted land area should be used intelligently and our resources exploited to the fullest extent.

WILLIAM A.S. SARJEANT

G.M. BENNISON & A.E. WRIGHT, 1969. The geological history of the British Isles. London; Edward Arnold. Boards £5.0.0.: paper £2.10.0. (£2.50).

Geologists this century have not been well served by texts on the stratigraphy of the British Isles. In the fifty years following the publication of Horace B. Woodward's classic "Geology of England and Wales" (1887), no authors had the courage to attempt works on a similar scale: the "Handbook of the geology of England and Wales" (1929) was a compilative work, with chapters of very variable quality, and its companion volume, "The handbook of the geology of Ireland" (1924) is a slight work of small value. In 1937 A.K. Wells' "Outline of historical geology" appeared; this work, misleadingly titled since its scope is wholly British, was revised by its author, in collaboration with J.F. Kirkaldy, in 1948 and again in 1959: it was to be a standard text for University geologists for some 35 years and has the assets of clarity and digestibility, but did not attempt to be as comprehensive as Woodward or the "Handbooks" and was of slight value at postgraduate level. By the 1950's, then, publication of a new comprehensive work on the stratigraphy of Britain was long overdue.

In the last and the present decade, the picture has been entirely transformed. Ireland has been especially well served, with three texts: H.E. Nevill's "Geology and Ireland" (1963), and two works by A.K. Charlesworth: "The geology of Ireland; an introduction" (1953) and "The historical geology of Ireland" (1963). G.Y. Craig has edited an excellent compilative work, "The geology of Scotland" (1965) and P.C. Sylvester-Bradley and T.D. Ford, a comprehensive "Geology of the East Midlands" of England (1968). A new, revised and greatly enlarged edition of Wells & Kirkaldy appeared in 1966, with additional chapters and earlier sections rewritten: and in 1967, Dorothy H. Rayner's "The stratigraphy of the British Isles" appeared (see review in Mercian Geologist" Vol. 3, no. 1, pp. 104-5). Hard on its heels comes the work here reviewed. The paper covered edition, received for review, has a pleasingly designed cover of a bronze hue: unfortunately, it shows signs of wear after only a single reading. It is not typographically attractive; the type-fount employed is too small and the lines too closely spaced for ready reading. Illustration is by text-figures, mostly culled from earlier books and papers by other authors, though a few are original: these show correlations of strata, reconstructions of past palaeogeographies, structural reconstructions and isopachyte maps. No illustrations of fossils are included.

The plan of the contents is straightforward. The book is divided into six sections: the first is on "General Principles" and the succeeding five sections each treat with a major division of geological time (Pre-Cambrian, Lower Palaeozoic, Upper Palaeozoic, Mesozoic, Cainozoic). After a single chapter on the Pre-Cambrian, the chapters are devoted to a particular system or major orogeny. The division of the Cainozoic into "The Tertiary" and "The Pleistocene", however, is surprising - the immense amount of data on the Pleistocene fully justifies a separate chapter but, since the Pliocene is also dealt with, it would have been better entitled "The Quaternary":

and surely the effects of the Alpine orogeny merited more extended treatment?

The text attempts to summarise the whole, complex stratigraphic story of the British Isles; it is thus, inevitably, packed with bed and locality names and with other detailed information. It is a hard task indeed to attempt to incorporate such a vast mass of data and yet to keep the text readable. The authors have, unfortunately, achieved only intermittent success; though particular sections are quite lucid (notably some of those on structural geology), the work as a whole does not make for ready digestion.

The authors append a section of fossils to each stratigraphical chapter. Their approach is strictly "classical": their attention is confined to invertebrates, vertebrates and macroscopic plants. Microfossils, in contrast, receive very scant treatment; foraminifera and ostracods are each mentioned only twice, conodonts once and spores not at all, though Quaternary pollen spectra gain brief mention. This blinkered view of palaeontology has produced at least one unfortunate mis-statement: that in Caithness and Orkney "the absence of fossils makes it impossible to determine when Old Red Sandstone sedimentation ceased" (p.180). In fact, the work of J.B. Richardson has demonstrated that it is possible to make both local and long-distance correlation of these strata by means of fossil spores (e.g. Palaeontology, vol. 7, pt. 4, 1965). The importance of Chitinozoa, acritarchs, dinoflagellates and diatoms in correlation at different stratigraphic levels is not mentioned; and foraminifera and ostracoda are only mentioned as being useful in the lower Tertiary and the Purbeck Beds respectively, whereas they have been a major tool, in subsurface correlation especially, throughout the geological column from mid-Palaeozoic onward. The mis-statement that radiolaria, an exclusively marine group, occur in lakes (p.29) should be noted: and the authors were unaware of work by Downie and Ford (Proc. Yorks. Geol. Soc. Vol. 75, pt.3, 1966), who have used acritarchs to demonstrate that the Manx Slates are, in part at least, of Ordovician age.

To the uninformed reader, the authors' use of stages and stage-names will be a source of recurrent confusion. The definition of a stage on p.24 ("divisions of strata corresponding to a longer division of time than a zone") is not very specific: and the follow-up note that "The stage has been evolved to augment or to define more precisely in terms of time the divisions of the stratigraphical column called series" is not helpful. Indeed, the authors' usage of stages in subsequent chapters is inconsistent, suggesting some confusion in their own minds. Thus, in the Ordovician chapter, only series names are listed and it is not made clear that the British series names are the basis for the international stage names: in contrast, Devonian stages are clearly tabulated (p.161). On p.99, the so-called "stage" names employed (Costonian, Marshbrookian, etc.) are purely local names formulated for Shropshire and without wider application: this also is not made clear. In successive tables on pp. 122, 124 and 125, "Wenlock Series", "Wenlock" and "Wenlockian" are used (the latter also appears as a subheading); since a table on p.117 introduces the local name: "Eltonian", Whiteliffian", etc., as zone names, the author might legitimately be confused as to the significance of "Wenlockian". On p.161 and elsewhere, the word "Gedinian" appears; this Devonian stage-name is more usually spelled "Gedinnian". The retention of the old stage-name "Purbeckian", which overlaps the Jurassic-Cretaceous boundary, is indefensible after its formal abandonment at international level: "Purbeck" should be used as a series or facies name only. The names "Argovian", "Rauracian" and "Sequanian", shown as used in Western Europe, never achieved currency outside France and have likewise been abandoned by formal international agreement: the two latter were viewed as substages of the Oxfordian, rather than as successor stages to a reduced Oxfordian. "Palaeocene" (p.352) is correctly spelled "Paleocene": most Tertiary workers would nowadays consider that the Montian and Danian are synonyms and many would place the Landenian, or at least the Thanetian, into the Paleocene, so that the lower part of the British Tertiary succession would include that "system". The table on p.335 is inadvertently misleading, in that it suggests that all Oligocene "stages" are present in Britain: in fact the highest, the Chattian, is absent. The status of the divisions of the

Neogene quoted on p.351 is not made clear and the implication that the Pliocene consists of one "stage" only must be presumed to be inadvertent.

A number of other specific points merit mention. The divisions of the Precambrian quoted on p.12 are not the product of international agreement and are oddly chosen; the Eocambrian is usually considered part of the Proterozoic, itself part of a threefold division including Azoic and Archaeozoic. (They form a sequence of diminishing duration, with Archaean immensely longer than Proterozoic and Eocambrian very brief.) On p.14, Corallian is cited as a synonym of Oxfordian, whereas it is merely Upper Oxfordian. On p.24 the duration of the Lower Jurassic is quoted as "less than 10 million years": Howarth (in the symposium volume "The Phanerozoic Time Scale", Geol.Soc.Lond.1964) quotes a duration for the Jurassic of 55-60 million years and for the Lower Jurassic of about 24 million years. On p.32 the origin of deep-sea red clays is discussed; it is highly probable that meteoritic dust is a major constituent, in view of the daily rain of debris from space onto the earth - a point not mentioned. The statement on p.67 that the Uriconian volcanic rocks are "mostly acid" is an oversimplification; certainly in the Stretton Hills, andesitic and basic materials figure largely. The Orusia Shales of the Shropshire Cambrian (p.82) escape mention. On p.302 the archaic name "Estuarine Series" is used without comment in the Yorkshire Middle Jurassic sequences: the name "Deltaic Series" is more general in modern literature. The diachronous nature of the London Clay, considered by the authors to be speculative, is strongly supported by recent, still unpublished studies of microplankton assemblages.

This work is a compact compendium of stratigraphical data. It is, in part, the geological history that the title leads one to expect, in that an account is given of the movement of shorelines of structural events and of sedimentological conditions. However, the living landscape of the past - its animals, its plants and their environment - is not dealt with. The beginner will find this book heavy going: its dense packing of detailed facts will be hard for him to digest and the frequent use of technical geological terms that have not been defined will bemuse him. A geologist with a good background in his subject, however, will find it a worthwhile purchase; he will recognise its faults but he will find them to be outweighed by its merits as a convenient sourcebook for stratigraphical information.

WILLIAM A.S. SARJEANT

Secretary's Report, February 1969 to August 1969

The commencement of the Society's sixth year saw no changes in the membership of the governing body, for at the A.G.M. in February there was little excitement to record as the previous Council was re-elected without opposition for a further year. During the 1968 session, Council met on seven occasions to conduct the Society's business and continued to do so during 1969 unchanged in composition. The President in his Presidential Address continued his account of the East Midlands Coal Measures, this time concerned with sedimentary processes. This address will undoubtedly be considered, along with his first, as a first class contribution to our knowledge of British Coal Measures.

At the beginning of March, 1969, Mr. R.J.B.Kenna gave a brilliant talk on the East Midlands Iron Ore deposits. Many members commented on the presentation of this lecture and voted it into a high place on the lecture list.

The indoor programme was completed by the Collector's Evening. Although the number of exhibits was a little lower than the previous year, the quality was high. Attendance was excellent and the meeting is obviously a popular activity of the Society. Can I ask all members who have not yet brought along specimens to this type of meeting to make a special effort to support the efforts of the regular exhibitors? How about an exhibit from one or more of our schools subscribers? The date of the next Collector's evening is 7th March, 1970.

So far in 1969 we have had four field excursions. The weekend meeting in Shropshire - too long delayed according to some members - was ably led by Dr. I.D. Sutton and Dr. W.A.S. Sarjeant during early May. The excursion was centred at Church Stretton and is fully described in this issue (Vol. 3, No. 3) of the journal. It was duly observed that these two leaders had led a full week's excursion in this area for another group previously so that they should have a further Shropshire excursion available for a future occasion.

Everybody cannot afford to be away for a weekend and as we had two such excursions scheduled for the 1969 programme another type of excursion was organised during May. This was a half-day excursion, the first to be run by this Society. It visited an open-cast coal site near Ripley and was arranged with the co-operation of the site contractor, by Mr. G. Jago (N.C.B. Open Cast Executive). Although this visit was a return visit to the site, at Street Lane, Ripley (Mercian Geolgist Vol. 2 No. 4 pp. 439-442) attendance was excellent and including many who were unable to attend the longer field excursions.

On a magnificient day in June, Mr. A.M. Honeyman took the Society around the Jurassic exposures of Ancaster and Lincoln. Many members will have photographs of their fellow members crawling around a surface of the Lincolnshire Limestone looking for pockets of fossils on the limestone surface. The Lias clay pits were for once not waterlogged. A remarkable day, organised and presented to the Society by an enthusiastic and able geologist.

In July, the Society travelled to N.Staffordshire, and were met by Mr. E.A.Francis. In contrast to the previous excursion the weather at the start was almost wintry but we understood that it was good, for that part of the country. The mixture of sedimentary and tectonic structures and palaeontology, ensured ample variety for all members. Our thanks are given to Mr. Francis for travelling fown from Newcastle-upon-Tyne to lead the Society over ground he knows extremely well

The policy of the Society has been to have a larger number of day excursions compared with those of longer or shorter duration. It has also been considered best to hire a coach rather than to use private cars. This year we have never had any doubt that a coach, other than a 41 seater, would be necessary. Your continued support of our excursion programme suggests that our general policy is acceptable. However, do please contact your Council - any member will do - if a modification of the programme is thought necessary.

Membership continues to rise, although during the middle part of the year the rate slowed down a little. At the end of July there were 407 members in the Society.

The Society has continued to receive help from many individuals and institutions. Although not listed on this occasion, may I offer a collective vote of thanks to them all. Please continue to offer assistance and help in the organisation of Society affairs.

F.M. Taylor

THE MERCIAN GEOLOGIST

Journal of the East Midlands Geological Society

The journal first appeared in December, 1964. The following numbers have since been published:-

Vol. 1 No. 1. December 1964	Vol. 2 No. 2. June 1967
Vol. 1 No. 2. June 1965	Vol. 2 No. 3. December 1967
Vol. 1 No. 3. January 1966	Vol. 2 No. 4. August 1968
Vol. 1 No. 4. September 1966	Vol. 3 No. 1. January 1969
Vol. 2 No. 1. January 1967	Vol. 3 No. 2. August 1969

The journal deals especially with the geology of the Midlands of England, but other articles have been accepted which are of current interest to geology generally. Manuscripts should follow the format of papers included in this number of the Journal and be sent to The Editor, "Mercian Geologist", at the address below.

In Vol. 1, there are 25 original articles, 5 general papers, 2 Presidential addresses, 10 excursion reports and a number of book reviews. It comprises 383 pages, 24 plates, numerous text figures, an index, title page and cumulative contents list.

Vol. 2 has a similar content, except that the second number of this volume was devoted to a bibliography of the geology of the Peak District of Derbyshire compiled by Dr. T.D. Ford and Dr. M.H. Mason. It contains 450 pages and 25 plates.

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