MERCIAN Geologist

The Journal of the East Midlands Geological Society

Volume 13 Part 2 July 1993

MERCIAN Geologist

VOLUME 13 PART 2 JULY 1993

Journal of the East Midlands Geological Society

Address for Correspondence
General information and membership details:
The Secretary, E.M.G.S.
Beech Cottage, Main Street
Cropwell Butler, Nottingham NG12 3AB
Tel: (0602) 335448

The Mercian Geologist is published by the East Midlands Geological Society and printed by Norman Printing Ltd, Nottingham and London.

ISSN 0025 990X

Contents

Report 66
Geological Collections of the Natural History Museum, Wollaton Hall — Neil Turner

Mercian News 68
New Geological Survey of Nottingham; Woolly Rhinoceras Skulls; GHASP from BGS; Ecton Educational Centre

M. K. G. Whateley and H. K. Eardley 69
The Use of Satellite Data for Improved Structural Interpretation in the Leicestershire Coalfield Area

A. Dawn 79
Brittlestars from the Bathonian of Lincolnshire and Northamptonshire

R. J. Aldridge 83
Conodont Colour and Thermal Maturation in the Lower Carboniferous of North Wales

M. G. Sumbler 87
The Lias Succession between Fulbeck and the Vale of Belvoir

Excursion Reports 95
A. Brandon, H. C. Ivimey-Cook, M. G. Sumbler — Traverse across the "Lower Lias" south-east of Newark, Nottinghamshire
N. Aitkenhead — Field excursion to Ramshaw Rocks and Chrome Hill

Secretary's Report 102
S. M. Miles — Report for 1991-92

Obituary 104
Philip Speed

Book Reviews 104

REPORT

The Geological Collections of the Natural History Museum, Wollaton Hall, Nottingham

History of the Museum

The first public natural history museum in Nottingham was established in 1867 in rooms at 25 Wheeler Gate. It consisted of "a collection of natural history, botanical, geological and other specimens, mineralogy, antiquities and general curiosities made by Nottingham Naturalists Society (now defunct), the Committee of the Mechanics Institution and the trustees of the late Mr George Walker" (Jones, 1934). The Museum first opened to the public on the 16th April, 1872. With the growth in size and importance of the collections came the need for bigger and better accommodation, so in 1881 the Museum was moved to a specially-built west wing of the University College building in Shakespeare Street/ Bilbie Street. It was placed under the charge of the Professor of Biology, J. W. Carr, who was also responsible for the Department of Geology.

In 1925, Wollaton Hall and the surrounding park were bought by Nottingham Corporation from Lord Middleton, and a year later the Museum's collections were transferred there. Sir Francis Willoughby (1547-1596) used some of his inherited wealth to build Wollaton Hall in 1588. It remains one of the finest Elizabethan mansions in the country. In 1927 the administration of the Natural History Museum passed from the University to Nottingham Corporation, and Professor Carr was appointed curator.

The Geological Collections

Since the establishment of the Museum in 1867, the geological collections have been added to continuously, with some large and many small donations and purchases. The collections currently number around 45,000 specimens, comprising approximately 40,000 fossils, 4,000 minerals and 1,000 rocks.

The Fossil Collections

Fossil collections have been built up over the years by Museum staff and through important donations. One of the first to be acquired was the Samuel Carrington collection, in 1870. Samuel Carrington (1798-1870) lived at Wetton, near Leek, Staffordshire, and made an important collection of Lower Carboniferous fossils from the North Derbyshire and East Staffordshire areas (Zoeteweij, 1986).

Fig. 1. Wollaton Hall

The next major acquisition, in 1876, was a collection of Pleistocene mammal remains from the Cresswell Crags caves made by the Reverend John Magens Mello (1836-1914), who was Rector at Brampton, Chesterfield. He was intrigued by the archaeological potential of the caves, and in 1875-76 was involved in the exploration and excavations there, along with Thomas Heath, Curator of the Derby Museum, and William Boyd Dawkins, Curator of the Museum at the Victoria University of Manchester (Jenkinson and Gilbertson, 1984). Recent research on the collection by Dr Roger Jacobi of the Archaeology Department, University of Nottingham, has revealed that some of the mammal specimens in the collection were photographed and illustrated by Mello (1891) in a book on the geology of Derbyshire.

In the 1870s, the Museum also received an important collection of Wenlock Limestone fossils made by Mr E. J. Hollier, who lived at Dudley in the West Midlands and was a chemist and a former Mayor of the town. He was also a Joint Hon. Secretary of the Dudley and Midland Geological and Scientific Society and Field Club in 1862-63 (Cutler, 1981). His collection includes many fine invertebrate fossils including several specimens of the trilobite *Calymene blumenbachii* (Brongniart), which has become widely known as "The Dudley Locust".

Collections acquired this century include British fossils collected by the Reverend T. C. B. Chamberlin of East Retford, Nottinghamshire, and donated in 1911, and, in the 1930s, Upper Carboniferous plant fossils from the Derbyshire coalfield collected by A. R. Horwood (1879-1937), several of which are figured specimens. In 1972, a collection of Permo-Triassic footprints made by Prof. H. H. Swinnerton from the Mapperley area of Nottingham and described by Prof. W. A. S. Sarjeant was transferred from Nottingham University to the Museum (Sarjeant, 1983). In 1989, the Museum added to its footprint collection the footprint of a mammal-like reptile from the Upper Permian Cadeby Formation of Gregory Quarry, Mansfield. This specimen now forms part of the new fossil display at the Museum.

The Mineral and Rock Collections

Since the 1880s, the Museum has purchased minerals and rocks from dealers, including Friedrick Krantz, Gregory, Bottley and Co. and Robert Damon. This century, the Museum has acquired three major collections. In 1911, a mineral collection made by Mr G. T. Davy in the latter half of the 19th century was donated, consisting mainly of specimens from Chile and Peru, where he had once lived. The next major donation, in 1926, was the collection of Frederick Gillman (1845-1925), a mining engineer of Anglo-Swiss parentage. He was born in London and studied mining engineering at Freiburg, Saxony, after which he was involved in the management of silver mining operations near Granada, Spain, which were controlled by his father, Robert. Rocks and minerals from the silver and lead mines of southern Spain form the majority of the collection.

In 1954, the Henry Crowther (1848-1937) collection was donated to the Museum. Henry Crowther's interests covered a wide range of subjects, including molluscs and geology, particularly related to mining. He was Curator of Leeds City Museum on two separate occasions, with a period in between as lecturer in geology and mineralogy at the School of Mines in Camborne, Cornwall. His collection consists mainly of Cornish minerals.

Displays and Services

On 15th June, 1991, a new fossil gallery called "The Fossil Story" opened at the Museum. The gallery explains what fossils are, followed by seven reconstructed landscapes showing scenes from life on Earth during the last 430 million years. Part of the mineral collection is on display in the Minerals Gallery. This first opened in 1982 and houses a wide range of specimens. In one half there is a systematic arrangement of minerals based on their chemical composition and in the other is an aesthetic display of larger specimens.

In addition to the display material, the geological reference collections are available for inspection by the public by appointment. The Museum is also the record centre for Nottinghamshire in the National Scheme for Geological Site Documentation. The role of the Museum is to inspire, please and educate people about geology and natural history. We hope to continue to do so for many years to come.

References

Cutler, A., 1981. A short history of the Dudley and Midland Geological Societies. *The Black Country Geologist*, **1**, 1-21.

Jenkinson, R. D. S., and Gilbertson, D. D., 1984. *In the shadow of extinction: a Quaternary archaeology and palaeoecology of the lake, fissures and smaller caves at Cresswell Crags SSSI.* Nottinghamshire and Derbyshire County Councils.

Jones, H. P., 1934. *Guide to the Public Natural History Museum, Wollaton Hall.* Cooke and Vowles, Nottingham.

Mello, J. M., 1891. *Handbook of the geology of Derbyshire.* Bemrose and Sons, London, 2nd ed.

Sarjeant, W. A. S., 1983. British fossil footprints in the collections of some principal British museums. *The Geological Curator*, **3**, 541-560.

Zoeteweij, F., 1986. Samuel Carrington (1798-1870). *The Geological Curator*, **4**, 281-286.

Neil S. Turner
Keeper of Geology
Natural History Museum
Wollaton Hall
Nottingham
NG8 2AE

MERCIAN NEWS

New geological survey of Nottingham completed

Andy Howard writes: March 1993 saw the completion by the British Geological Survey of a major resurvey of the geology of the Nottingham region. The project, supported by the Department of the Environment, commenced in April 1987 with a survey of Nottingham City and adjacent districts. The aim was to produce a synthesis of geological information relevant to planning and development. In addition to geological maps at 1:10 000 and 1:50 000 scales, thematic maps were prepared, each concentrating on specific aspects of geology relevant to land use. These were published in 1990, together with a descriptive report (BGS Technical Report WA/90/1).

In September 1991 further surveys began to cover rural areas east of Nottingham, as far as a line joining Newark and Bottesford. Most of the 1:10 000 maps and open-file reports covering this area are now available; the remainder will be published this summer. The new Nottingham Sheet 126 will be scaled down and generalised from the 1:10 000 component maps, with publication of the map and accompanying memoir expected in about two years.

The existing Nottingham Sheet 126, based on surveys carried out in 1903-5, depicts only broad lithological divisions of the Permo-Trias and Lower Jurassic strata, and shows very little faulting. Since that time, additional borehole data, mine plans and seismic reflection data have become available to BGS and have supplemented the results of field surveys. It has now proved possible to subdivide and map the Permo-Trias and Lower Jurassic in considerably greater detail. Faulting in these rocks is now known to be extensive, with patterns mimicking those of the Carboniferous at depth.

The new Nottingham maps represent a major advance in knowledge of the stratigraphy and structure of the region. Together with other recently completed surveys in the Coventry and Grantham regions, they now provide a firm base on which to build up a detailed understanding of the geological evolution of the East Midlands. This will be strengthened over the next few years as planned new surveys extend into the Loughborough, Leicester and Melton Mowbray areas.

Further details about publications and other information held by BGS on the geology of the East Midlands can be obtained from Dr. A Howard, British Geological Survey, Keyworth, Nottingham NG12 5GG. Tel: 0602 363100.

Find of two woolly rhinoceras skulls

Alan Dawn writes: In spring 1991 excavations in a gravel pit east of Peterborough exposed a series of Pleistocene silt and clay channels incised into the underlying Oxford Clay. These middle to late Devensian cold stage deposits yielded tusks and bones of *Mammuthus primigenius, Equus ferus, Rangifer tarandus, Bos, Bison* and, most notably, two skulls and a mandible of the woolly rhinoceras *Coelodonta antiquitatis*. One skull is quite well preserved with two upper molars in place. A nearby mandible, also with teeth in place, may belong to the same animal. The second skull is rather abraded and has lost part of the right side; it has no teeth. Several limb bones attributable to *Coelodonta* were also found close by. All the bones are now housed in Peterborough City Museum, Priestgate, Peterborough; the skulls and mandible bear the accession numbers M487, M488 and M496.

A ghasp from the BGS

The British Geological Survey has developed a **Geo-HAzard Susceptibility Programme (GHASP)** to provide geological information upon which to assess the risks of subsidence in different parts of the country. This is intended as an aid to insurers and their customers, allowing premiums to be directly related to risks based on the geological facts. Information from the Survey's mapping programme is fed into GHASP, which gives a display on PC of all the 9233 post code sectors. For each one it shows a map of the main types of subsidence or a table quantifying the insurance risk that they represent. It is intended that GHASP should be extended in the medium term to cover other hazards such as fluvial and coastal flooding, contaminated land, landfill and environmental problems, and the Survey is also working to make the GHASP databases available down to a site-specific level.

The Ecton Educational Centre was the venue on 27th September 1992 for a most interesting and comprehensive field excursion. It involved an introduction to the history of copper mining at Ecton, a trip underground along Salt's level, activities demonstrating mineral separation and a walk over Ecton hill to look at the surface geology. When combined with a splendid alfresco lunch, it made a most enjoyable experience.

The Centre is primarily concerned with providing one-day courses at weekends for 'A' level students studying Chemistry, Geology or Physics. All courses have a framework of standard activities, similar to the ones we experienced, with appropriate variations for the particular needs of each group. They also welcome College and University students and geological societies.

Further information can be obtained from Zoe D Haydon, 1 Vicar's Close, Oulton, Stone, Staffs ST15 8UQ. Tel/Fax: 0785 816862.

Sandstone Caves of Nottingham

Judith Rigby writes: Tony Waltham's article featured in the Mercian Geologist Volume 13 Part 1 September 1992 continues to be available in attractive booklet format as a result of a second printing. The Society is pleased to report that the first impression of 1000 copies was sold out in less than six months. It is on sale at many local outlets as well as from me at my home address priced £3.50 including post and packing; 223 Mansfield Road, Redhill, Nottingham NG5 8LS. Telephone: 0602 267699.

The Use of Satellite Data for Improved Structural Interpretation in the Leicestershire Coalfield Area

M. K. G. Whateley and H. K. Eardley

Abstract: Comparison of the results of interactive digital processing of Landsat multispectral scanner (MSS) and Thematic Mapper (TM) images with regional geophysical data and known geological faults has led to an improved understanding of the geological structure in and around the Leicestershire Coalfield in the East Midlands. Spatial filtering of the digital Landsat data enhanced the images for structural interpretation despite superimposed landuse patterns. A high correlation between Landsat lineaments and known geological fault patterns suggests that Landsat images will enable high confidence structural analyses to be made of areas that have significant cultural effects.

The distribution of sediments in various depositional environments is believed to be influenced by structures in the underlying basement, which also affect outcrop patterns. The purpose of this study is to establish the relationships between known structures, such as faults and fold axes, and structures inferred from geophysical anomalies and Landsat lineaments in the Leicestershire coalfield region (Fig. 1). The aim is a greater understanding of the relationship between the regional structural setting and structure found within the coalfield. Also, the structural setting of the Carboniferous rocks of the Leicestershire coalfield needs to be examined in some detail before conclusions can be drawn about the effects of structure on sediment distribution.

Only limited structural data are available from the basement and cover rocks in the area. This information has been supplemented with data inferred from Landsat images and geophysical maps. Known geological faults were digitized from published 1:250 000 (Institute of Geological Sciences, 1983), 1:50 000 (Institute of Geological Sciences, 1974, 1982) and 1:10 000 geological maps of the area. Other lineaments were interpreted and digitized from the regional gravity and aeromagnetic maps, available at scales of 1:625 000 and 1:250 000 (Geological Survey of Great Britain, 1956, 1964). Lineaments were also digitized off annotated overlays of Landsat multispectral scanner (MSS) and thematic mapper (TM) satellite images.

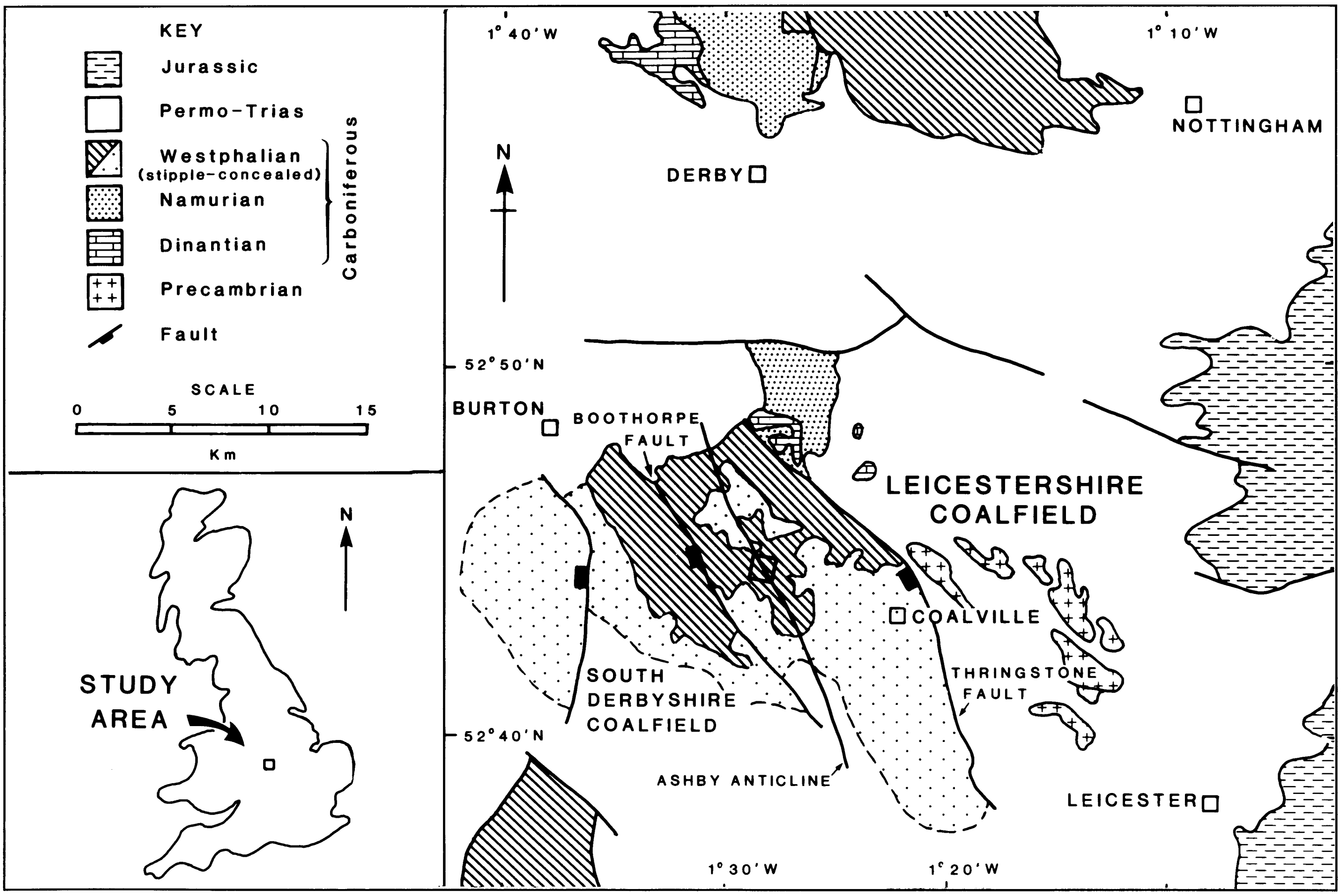


Fig. 1. Location of the study area, with simplified geology and structure.

Geological Setting

The basement rocks in the study area consist of Precambrian (Charnian) and Lower Palaeozoic rocks (Soper *et al.*, 1987; Pharaoh *et al.*, 1987). Charnian rocks crop out to the east of the Leicestershire coalfield (Fig. 1) and are thought to extend, in the subsurface, as far west as the Boothorpe fault (Whitcombe and Maguire, 1981b; Fulton and Williams, 1988). In outcrop the Charnian rocks are folded into an anticline (Watts, 1947) with a NW-SE trend. The rocks display both fracture and slaty cleavage with a strike of 280° (Evans, 1968, 1979). The NW or WNW trend is commonly referred to as the Charnoid trend.

Cambrian rocks have been identified adjacent to the Thringstone Fault to the east of the coalfield where they are folded, fractured, and cleaved with an E-W strike (Butterley and Mitchell, 1946; Evans, 1979). To the east of the Precambrian outcrops the Upper Palaeozoic and Mesozoic sediments are underlain by volcanic rocks associated with cleaved greenschist facies Lower Palaeozoic sediments (Pharaoh *et al.*, 1987). The boundary between the Precambrian and Lower Palaeozoic rocks trends NW-SE (Fig. 2).

To the west of the Boothorpe fault, subsurface data indicate that Lower Palaeozoic rocks form the basement of the South Derbyshire coalfield (Fulton and Williams, 1988). The Leicestershire coalfield itself has a complex pattern of faults and folds, dominated by NNW-SSE trending structures, e.g. the Thringstone and Boothorpe faults (Fig. 1).

The Dinantian limestone, which unconformably overlies the Cambrian and Precambrian basement rocks, was strongly affected during deposition by active block faulting in the basement (Falcon and Kent, 1960; Collinson, 1988). A number of narrow basins, separated by more stable blocks, have been identified from geophysical exploration and borehole data (Fig. 2) (Anderton *et al.*, 1983). One such basin is the Widmerpool Gulf, which has an E-W alignment and lies immediately north of the Leicestershire coalfield (Fig. 2).

The Dinantian rocks in Derbyshire have been formed into a dome with an axis which strikes approximately SSE. Results of a 40km seismic survey (Whitcombe and Maguire, 1981b) between Ballidon Quarry in the north and Cloud Hill Quarry near Charnwood in the south (Fig. 2), indicate a positive structural feature which crosses the Widmerpool Gulf. This effectively creates an extension of the dome axis southwards, to link with the SSE trending Ashby anticline which lies between the Leicestershire and South Derbyshire coalfields.

The limestone is succeeded by relatively undeformed Namurian and Westphalian strata. These in turn are overlain unconformably by Triassic sediments and further east these are covered by Jurassic rocks.

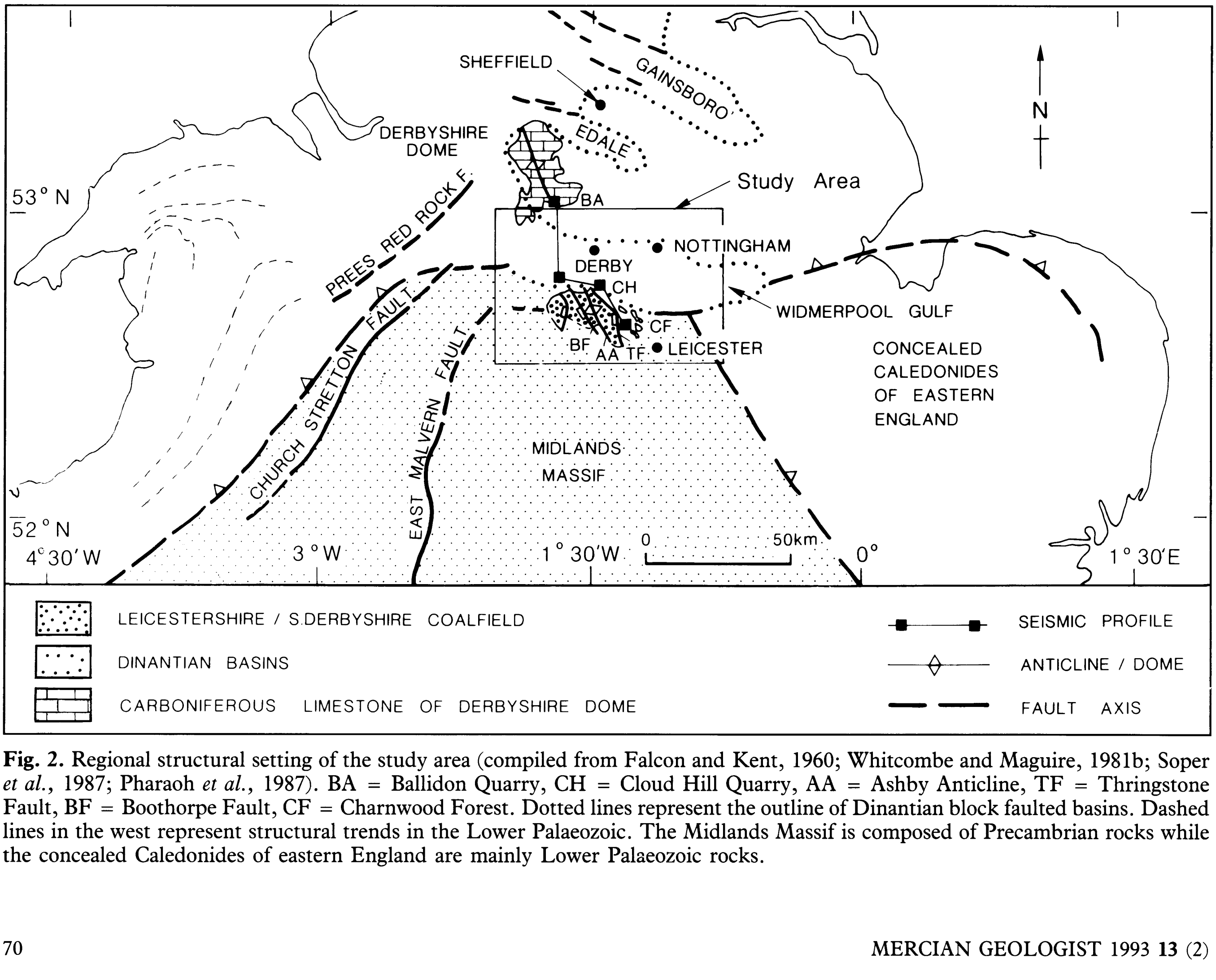


Fig. 2. Regional structural setting of the study area (compiled from Falcon and Kent, 1960; Whitcombe and Maguire, 1981b; Soper *et al.*, 1987; Pharaoh *et al.*, 1987). BA = Ballidon Quarry, CH = Cloud Hill Quarry, AA = Ashby Anticline, TF = Thringstone Fault, BF = Boothorpe Fault, CF = Charnwood Forest. Dotted lines represent the outline of Dinantian block faulted basins. Dashed lines in the west represent structural trends in the Lower Palaeozoic. The Midlands Massif is composed of Precambrian rocks while the concealed Caledonides of eastern England are mainly Lower Palaeozoic rocks.

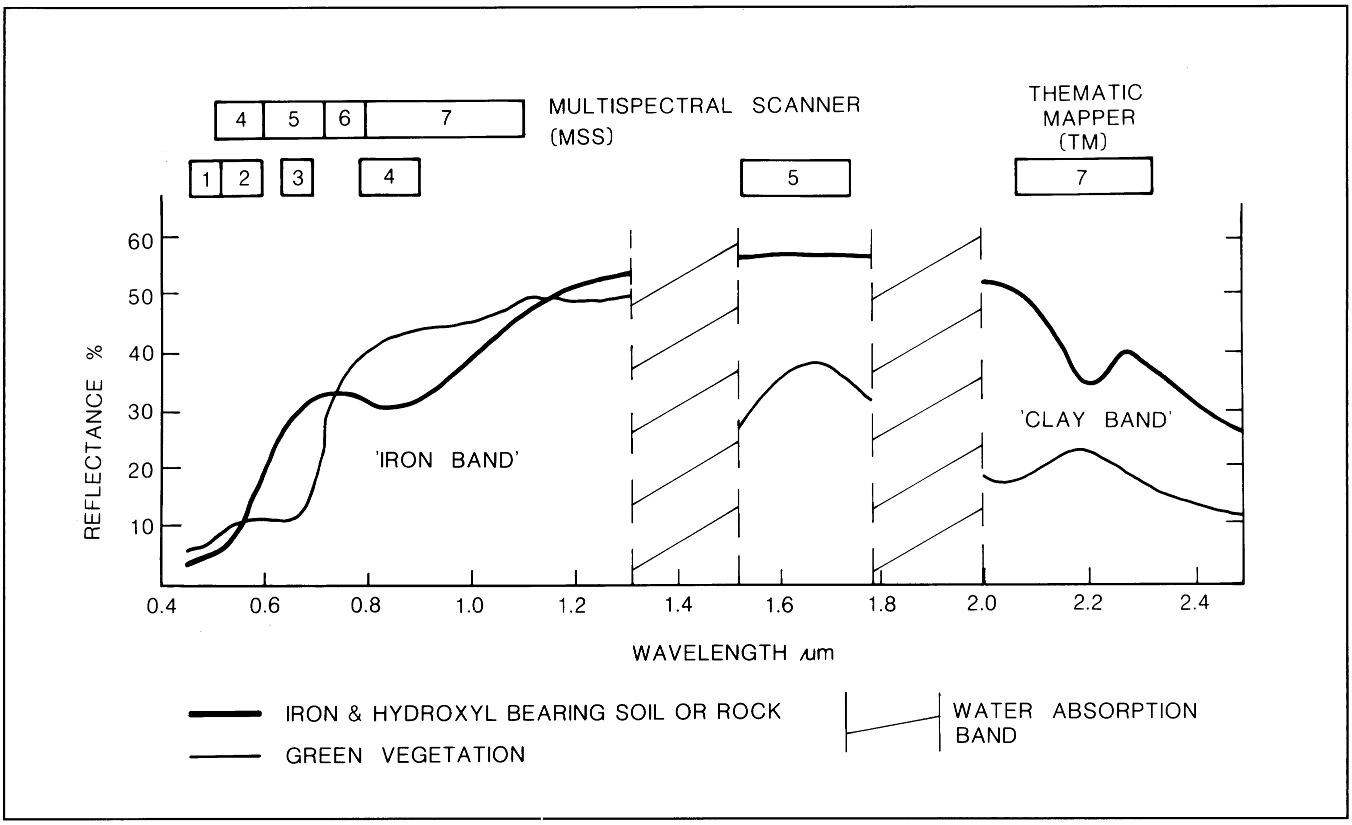


Fig. 3. Reflectance spectra of green vegetation and iron- and hydroxyl-bearing soil or rock in the visible to short wavelength infrared regions, illustrating the wavelengths for which data are recorded by the Landsat multispectral scanner and thematic mapper (modified after Abrams, 1984).

Remote Sensing

Remote sensing of geological structures has been used successfully in mineral exploration (Smith, 1977; Nash *et al.*, 1980; Peters, 1983; Guinness *et al.*, 1983), oil exploration (Bailey and Anderson, 1982; Peters, 1983, Lake *et al.*, 1984), exploration for water (Walters, pers. comm.) and geothermal energy. Satellite images provide a synoptic view of an area and allow the interpreter to see the regional structural/morphological patterns. Comparisons can then be made between the lineaments (inferred structures) observed from the synoptic view and those observed on the ground, and the relationship of the two sets of data rationalized (Drury, 1986).

Drury (1986) pointed out that there has been little success in structural analysis by remote sensing in areas with considerable cultural cover (housing, farms, roads, etc.) such as the East Midlands because of thick soils, modern sedimentological or geomorphological processes and the camouflaging effects of agricultural patterns and urbanization. Structural analysis has been most successful in semi-arid or arid terrains with a high percentage of rock exposure (Berhe and Rothery, 1986). Areas of natural vegetation are now also available for interpretation (Chang and Collins, 1983; Sabins, 1983), because residual soil reflects the underlying bedrock composition, and different rock types have differing mineral contents which may affect the vegetation cover. Extreme concentrations of minerals may induce stress in the natural vegetation, affecting reflectance properties.

It has been demonstrated that interactive processing of satellite images preserves fine detail and clarifies the position of lineaments. Various image processing techniques were adequately described by Lillesand and Kiefer (1979), Siegal and Gillespie (1980), Rothery (1985), Drury (1987) and Sabins (1987).

The Landsat multispectral scanner (MSS) bands 4, 5, 6 and 7 (Fig. 3) were designed for use by earth resources scientists studying vegetation and land-use. Hence they discriminate between soil and plants and between different plant species. Thematic mapper (TM) bands 1, 2, 3 and 4 are used in a similar way. The electromagnetic spectrum cannot be monitored in its continuous range because certain wavelengths are absorbed by water giving rise to areas through which energy is not transmitted. TM bands 5 and 7 record data in atmospheric windows between water absorption bands (Fig. 3). Band 5 was designed to monitor plant moisture content variations as well as maximum rock reflectance. As plant moisture content changes, so the depth and width of this window changes (Goetz *et al.*, 1983). Drury (1986) suggested that the variations between soil and plants are at a minimum between late January and late March in the northern hemisphere and that the cultural clutter is muted, so structural interpretation becomes possible. Here we examine the possibility of using data acquired during summer for structural interpretation. Empirical observations of TM bands 5 and 7 of a cloud-free June image showed that band 7 gave better enhancement of linear features. Therefore a portion of Landsat TM band 7 covering part of the East Midlands was used in this study as well as a portion of a cloud-free June Landsat MSS band 7 image of the same area (Fig. 4). The MSS image was used for comparative purposes. MSS band 7 has been shown by previous workers (Larson, 1982; Lake *et al.*, 1984) to respond well to enhancement techniques for structural interpretation.

Image Processing

Two data sets were available for this study, Landsat TM data with 7 bands and MSS data with 4 bands. The TM data from path 202, row 23, was flown in June 1984 and the MSS data from path 213, row 28, was acquired in June 1976. Only TM band 7 and MSS band 7 were used in this study. The MSS image was pre-corrected to fit the National Grid, while the TM image was geometrically corrected using control points recognized on Ordnance Survey topographic maps.

Image Enhancement

The area chosen was broken down into a series of adjacent 512 x 512 subsections (Fig. 5), and the same enhancement techniques were applied to both the MSS and TM subscenes. Each 512 x 512 subscene was subjected to a linear intensity (contrast) stretch.

Digital images consist of discrete picture elements called pixels. Associated with each pixel is a number that is the average radiance, or brightness, of that very small area within the scene. An image is built up of a series of rows and columns of pixels. The image intensity level histogram is a useful indicator of image quality (Fig. 6). The histogram describes the statistical distribution of intensity levels, or grey levels, in an image in terms of the number of pixels (or percentage of the total number of pixels) having each grey level. Figure 6 shows the general characteristics of histograms for a variety of images. A histogram of a typical untransformed image has low contast (Fig. 6a, b) and in this case the input grey level is equivalent to the transformed grey level (Schowengerdt, 1983). A simple linear transformation, commonly called a contrast stretch, is routinely used to increase the contrast of a displayed image by expanding the original grey level range to fill the dynamic range of the display device (Fig. 6c).

In this study the histogram 'tails' were clipped manually for each scene because the subscenes around the edges of the study area incorporated large areas of constant illumination where no data were recorded, and other subscenes included large conurbations. A general contrast stretch did not necessarily give the best results in any given subscene.

Spatial Frequency Filtering

Spatial frequency filtering is used to enhance (or suppress) edges. An edge is determined by the gradient of brightness with distance. For example, a white line on a black background can be resolved digitally at a closer spacing than a light grey line on a dark grey background (Drury, 1987). High frequency, high amplitude features have steep brightness gradients and are known as edges. Descriptions of filtering techniques used to enhance edges, or linear features, were given by Sabins (1987) and Drury (1987) amongst others. By selection of an appropriate rectangular or square

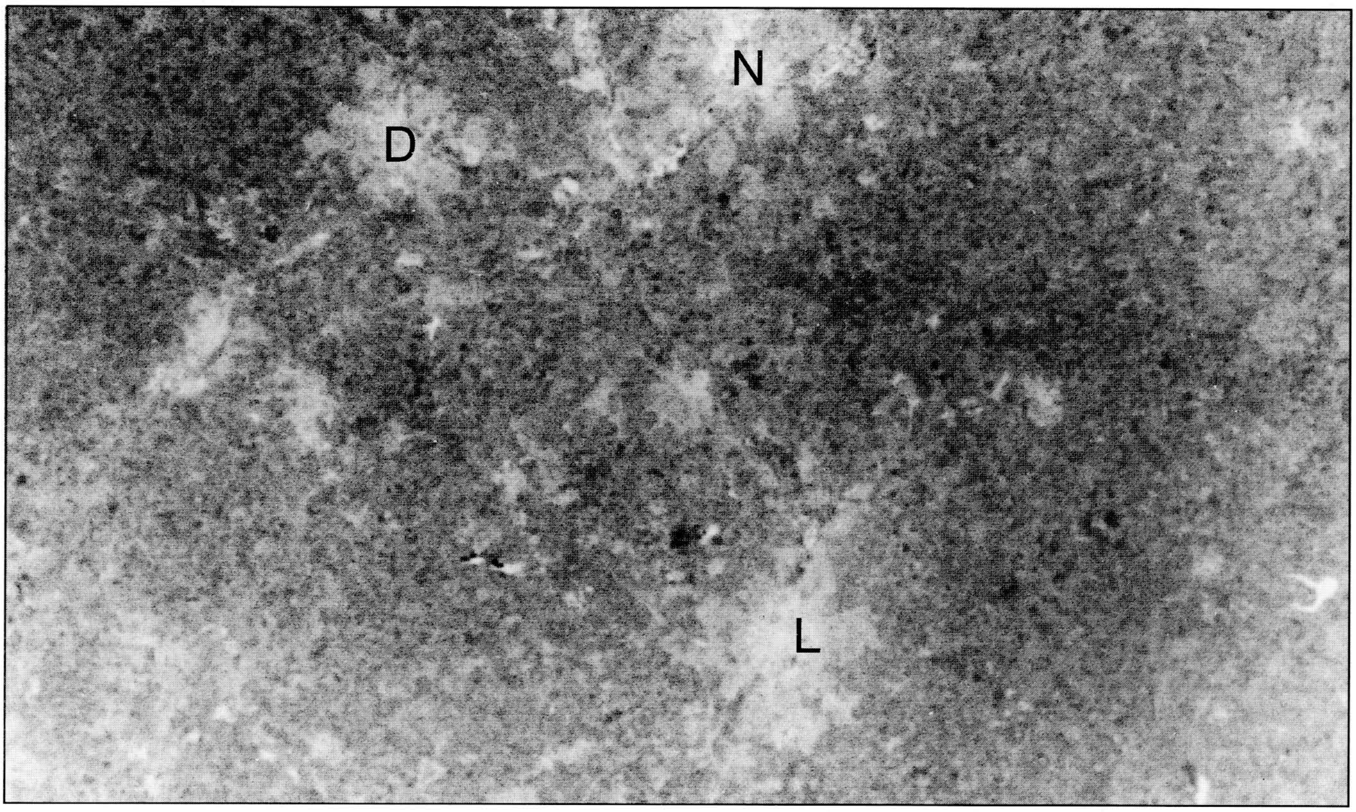


Fig. 4. A resampled Landsat MSS band 7 image of the study area. L = Leicester, N = Nottingham, D = Derby.

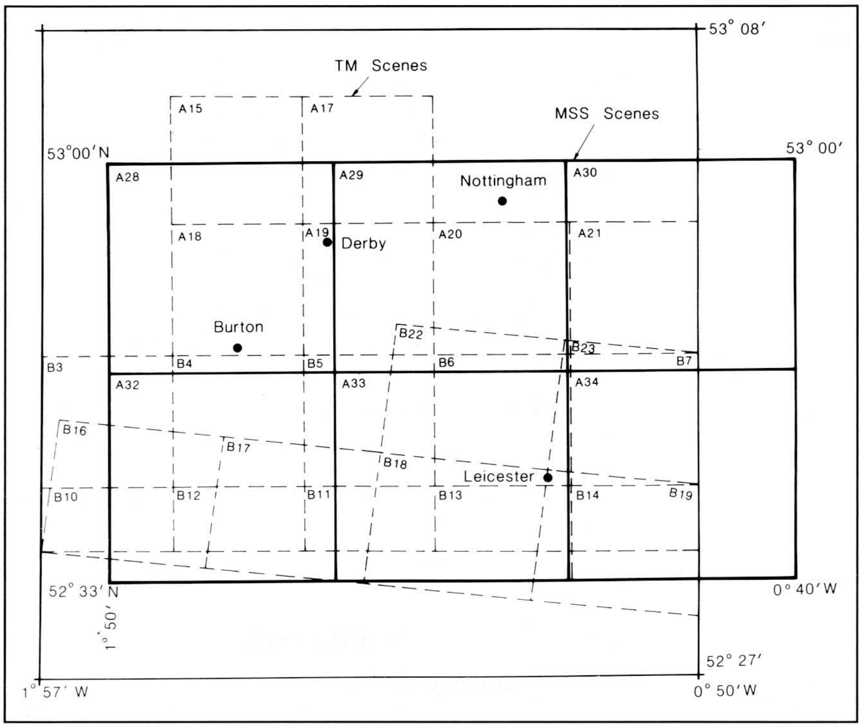
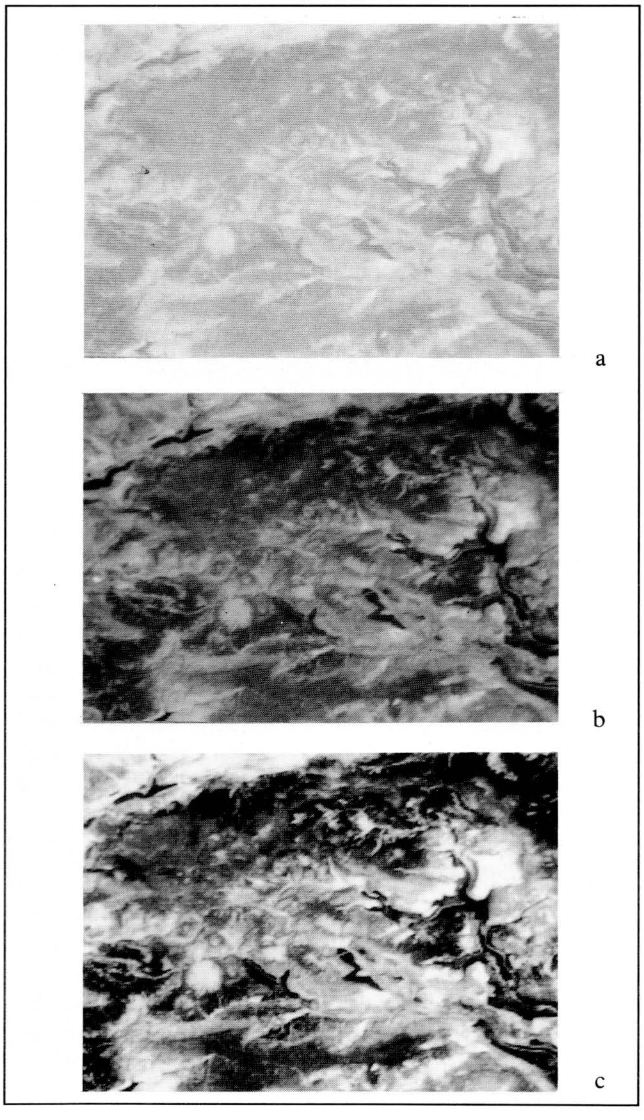


Fig. 5. Location of Landsat MSS and TM subscenes in the study area.



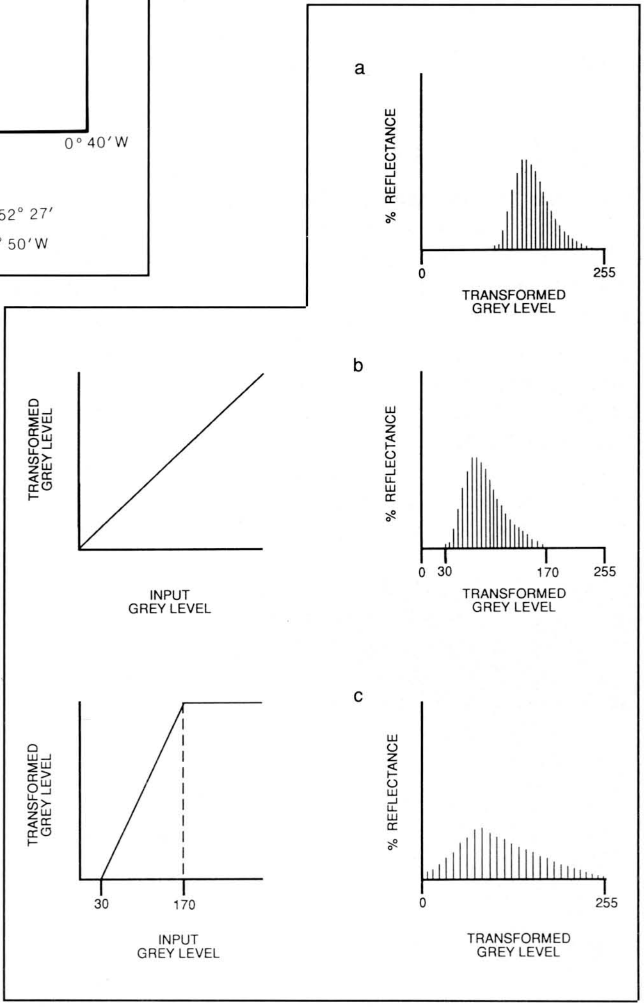


Fig. 6. Histograms of the grey levels (intensity levels) of different images. The image is part of Landsat 5, TM band 3 taken on 26 April 1984 of the High Peak District of northern England. The area is approximately 15 x 15 km. The dark areas are water bodies; those in the upper left corner are the Longdale reservoirs whilst those in the lower right are the Derwent Valley reservoirs. The two E-W trending bright areas in the lower right of the images are the lowland valleys of Edale and Castleton (Mather, 1987). (a) A bright (high radiance), low intensity image with low spectral resolution and its associated histogram. (b) A dark, low intensity, low contrast, low spectral resolution image with its associated histogram. (c) An image with high spectral resolution but low reflectance values. Increased spectral resolution has been achieved with a simple histogram transformation, also known as a histogram stretch. Modified after Schowengerdt (1983).

convolution matrix, different high spatial frequency features can be enhanced and/or other features suppressed.

Directional enhancement is achieved by using square convolution matrices with cell weightings arranged asymmetrically about an axis. For example:

$$\begin{matrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{matrix}$$

If an edge is orientated N-S, with the bright side of the edge on the east (right), as one would expect in summer imagery collected at 9.30 a.m. local time, then this filter produces maximum enhancement of N-S features.

Many different combinations of matrix type and size were applied to both data sets. For this particular area it was found empirically that the following matrices provided the greatest discrimination:

$$\text{TM images} \quad \begin{matrix} -2 & 0 & 0 & 2 \\ -2 & 0 & 0 & 2 \\ -2 & 0 & 0 & 2 \\ -2 & 0 & 0 & 2 \end{matrix} \qquad \text{MSS images} \quad \begin{matrix} -2 & 2 \\ -2 & 2 \end{matrix}$$

Ideally, two perpendicular directional filters are needed, but because of the time required to process each 512 x 512 subscene, and the limited time available on the image processing system, only one filter was used.

The major structures in the area trend NE-SW and SE-NW, and high pass directional filtering in either of these directions would enhance features perpendicular to it and subdue features parallel to it. The filters shown above fall midway and should highlight both structural trends. Lineaments trending SE-NW are generally suppressed on Landsat images because of the southeasterly illumination. It was felt that the chosen filter would maximise the potential for enhancing the expected structural features.

Image Interpretation

Black and white photographs of each enhanced subscene were made and used for structural interpretation (e.g. Fig. 7). Transparent overlays of each subscene were annotated, several times by different people, with lines indicating possible structural trends (Larson, 1982). The obviously spurious lineaments identified by, say, only one interpreter, were ignored as unreliable (cf. Wise, 1982). A compilation of reliable lineaments (compared with the local knowledge of the authors) was made and a field checking exercise undertaken. Prominent topographic and cultural features enabled lineaments to be located on the ground fairly accurately. Lineaments resulting from straight roads or field boundaries were identified and removed from the compilation.

It became evident that the majority of non-cultural lineaments resulted from the alignment of river or stream valleys and topographic ridges (see Saunders and Hicks, 1976). Some lineaments were caused by variation in surface texture, particularly on the TM images. These probably result from a variation in landuse or repetition of tonal change over a short distance giving the effect of texture. Upon compilation it became apparent that some of the lineaments extended over several images, although they were not necessarily continuous. For consistency, only the annotated lineaments were recorded while interpolations were omitted.

Fig. 7. Landsat MSS subscene A29, an example of the hardcopy black and white photograph used for annotation (see Fig. 5 for location).

Known, geologically controlled, lineaments were identified in a few instances, e.g. the Jurassic scarp and the Carboniferous Limestone inliers at Breedon on the Hill. Some previously mapped faults were also detected on the satellite images, such as the eastern boundary fault of the Leicestershire coalfield, the Thringstone Fault.

Topographic ridges of differing widths were detected by TM and MSS because of their ground resolution (30m and 80m respectively). Generally, ridges between 30-70m wide were detected on TM images, and 50-200m wide ridges on MSS images, although ridges at different scales were seen on both. Vegetation cover did not significantly affect a ridge's detection potential, and prominent ridges could be detected in urban areas by shadowing. Where there was a sharp change in slope, such as along stream and river banks, lineaments had good definition.

Correlation of Data Sets

In order to correlate data sets, the Landsat lineament data and known geophysical and geological data were digitized in stream mode, i.e. the digitizer collected data at a rate of 10 points per mm, so continuous, detailed definition of the lineaments was recorded. Each set of data points could then be plotted as a curvilinear feature (Figs 8-10).

For each data set, rose diagrams were plotted of lineament frequency and length (Figs 11-13). In length plotting mode, the program determines the midpoint of each lineament, and plots the direction on the rose, the radius of which corresponds to the lineament length. In frequency mode the program determines the maximum number of data points on a lineament which occur within a sector with a predetermined search angle. The smaller the search angle the greater the detail recorded. Rose diagrams for each data set were plotted for length (search angle 15°) and frequency with search angles set at 3°, 7° and 10°. The 3° search angle is used to illustrate the latter rose diagrams. Artifacts can be produced at angles away from the main directional filter, which may affect rose diagrams and hence interpretation.

The MSS lineaments (Fig. 8), although sparse, display two distinct trends, ENE-WSW and WNW-ESE. The lineament lengths are similar in both directions although there is a higher frequency of

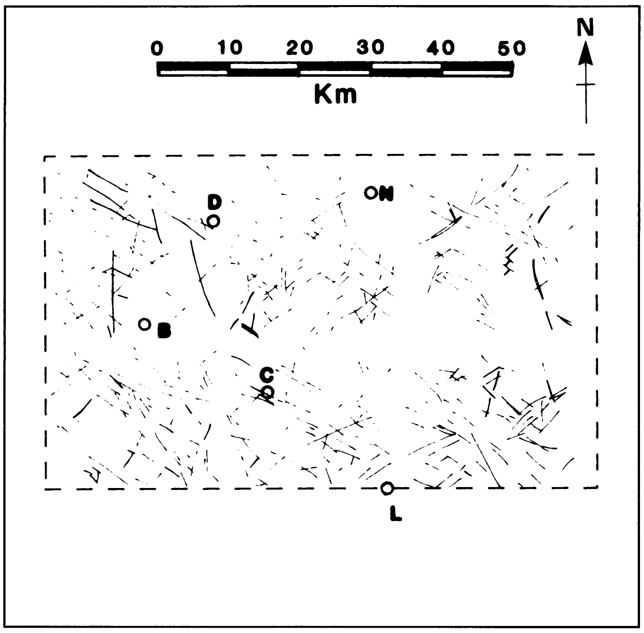


Fig. 8. A plot of the digitized lineaments annoted off Landsat MSS subscenes. D = Derby, N = Nottingham, B = Burton, C = Coalville, L = Leicester.

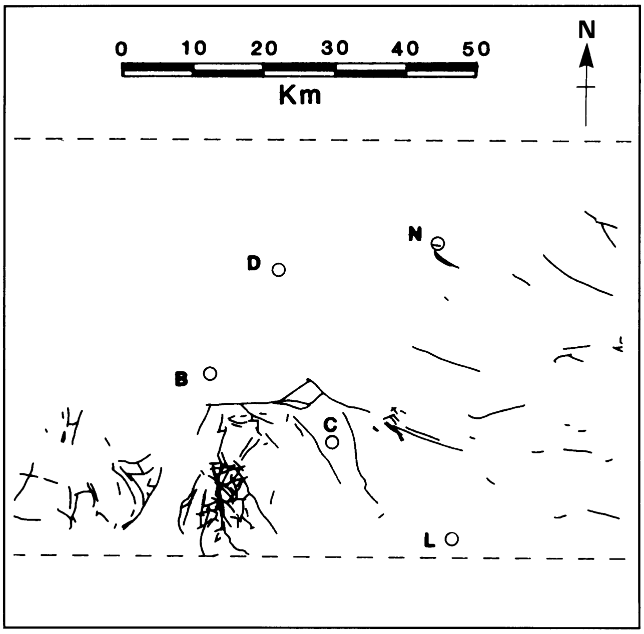


Fig. 10. A plot of the known faults in the study area, digitized off published geological maps (Geological Survey, 1964, 1982, 1983).

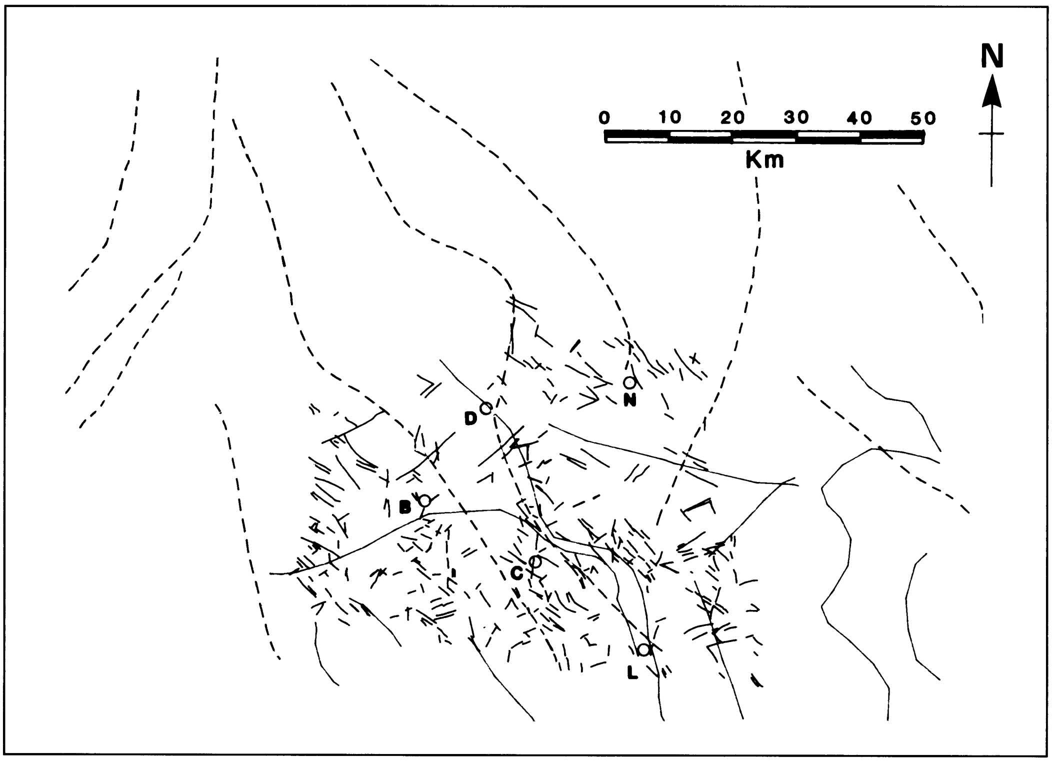


Fig. 9. A plot of the digitized lineaments annotated from Landsat TM subscenes. Dashed lines represent digitized linear gravity anomalies and long solid lines represent linear magnetic anomalies.

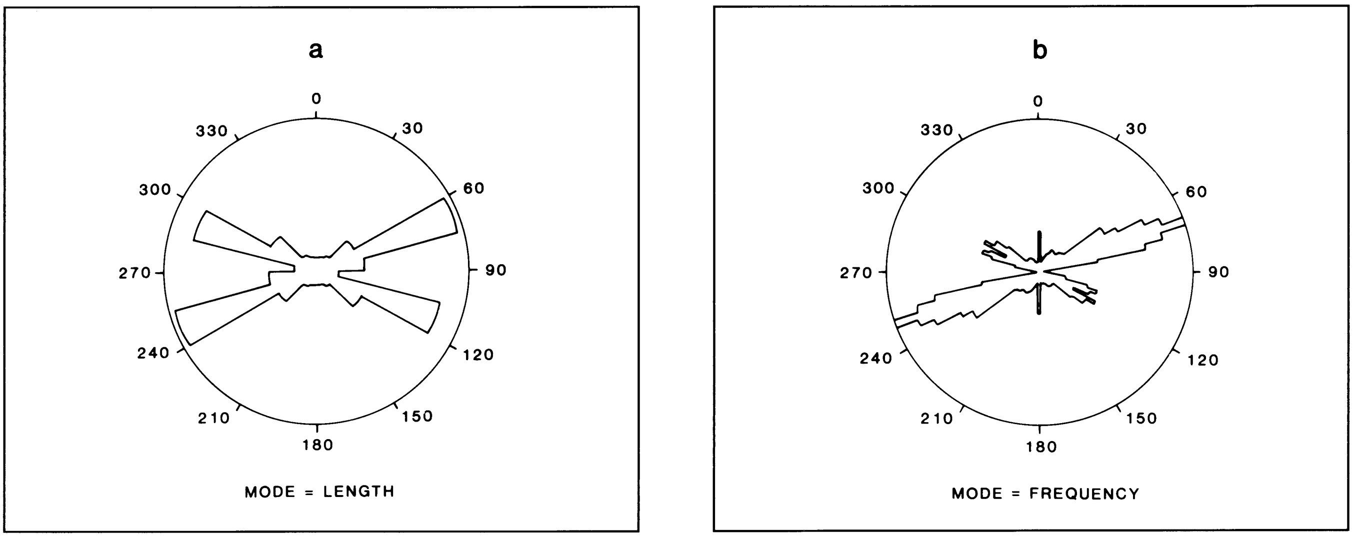


Fig. 11. Rose diagram of inferred structures derived from Landsat MSS imagery of the East Midlands. (a) Length mode with a 15° search angle. (b) Frequency mode with a 3° search angle.

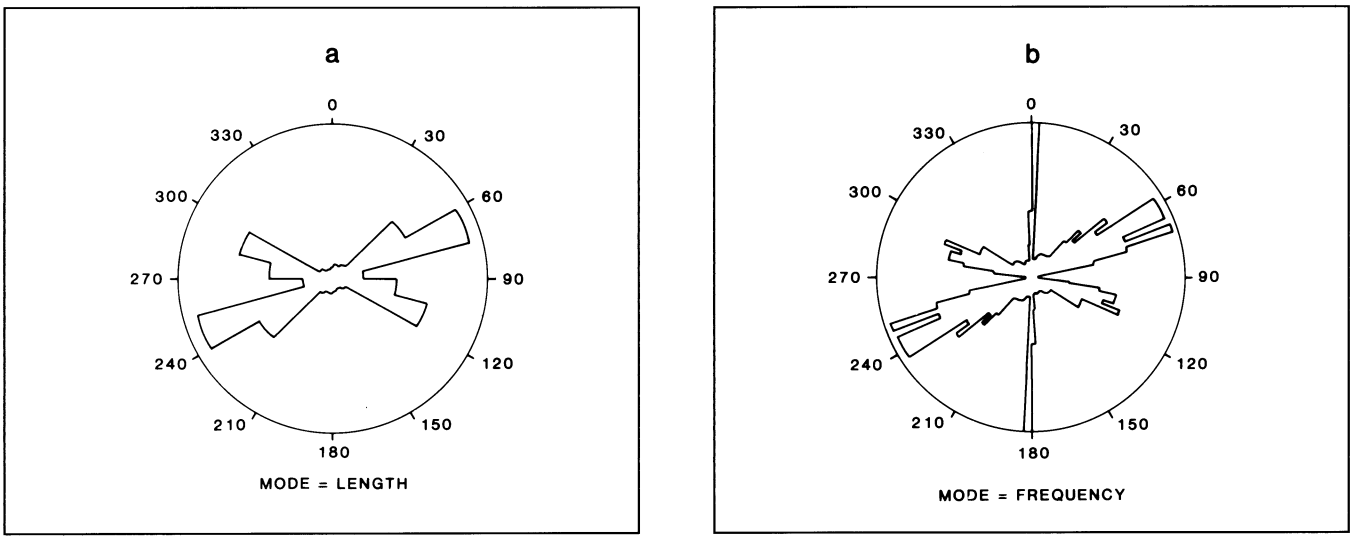


Fig. 12. Rose diagram of inferred structures derived from Landsat TM imagery of the East Midlands. (a) Length mode with a 15° search angle. (b) Frequency mode with a 3° search angle.

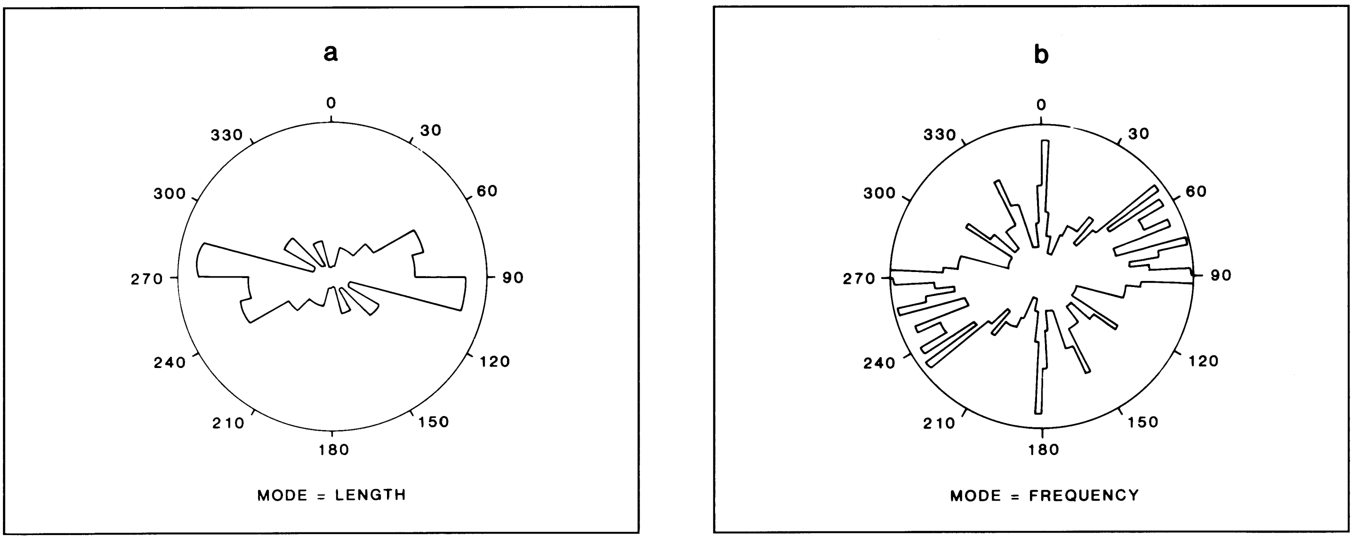


Fig. 13. Rose diagram of known structures derived from faults digitized off geological maps of the East Midlands. (a) Length mode with a 15° search angle. (b) Frequency mode with a 3° search angle.

lineaments in the ENE direction. A small number of lineaments with a N-S component occur in frequency mode (Fig. 11b). A similar pattern appears in the rose diagrams of TM data (Fig. 9). The ENE trend is composed of slightly longer lineaments (Fig. 12a). The N-S component is much more strongly developed (Fig. 12b).

The digitized faults show a greater variability (Fig. 10). In length mode the dominant trend is E-W (Fig. 13a), while in frequency mode there is a distinct pattern in the ENE direction (Fig. 13b). There is a well defined N-S trend as well.

These results suggest that there is a strong correlation between known (faults) and inferred (lineaments) structures. This positive correlation indicates that no artifacts were introduced into the rose diagrams. The dominant E-W trends are subparallel to the Widmerpool trend and the well defined N-S trend is parallel to the strike of Dinantian limestone bedding and faults (Ford, 1978) SE of Cloud Hill (Fig. 2). The length mode should provide a more representative result and implies that the lineaments show a stronger correlation to basement features such as the control on the Widmerpool Gulf (Saunders and Hicks, 1976).

A relationship between basement structures and inferred (geophysical) lineaments is also recognized. Interpretation of the Bouguer anomaly gravity map based on gravity survey overlay, sheet 11 (Geological Survey of Great Britain, 1956) and the aeromagnetic map (Geological Survey of Great Britain, 1964) provided the basis for the geophysical lineaments (Eardley, 1985). Whitcombe and Maguire (1981a, b) and Maguire (1987) have demonstrated with seismics the presence of a structural feature which runs ESE from Mountsorrel (near CF on Fig. 2) to Ticknall (near CH on Fig. 2). This coincides with both gravity and aeromagnetic lineaments (Fig. 9) and is closely aligned with the eastern margin of the Midlands Massif as depicted by Soper *et al.* (1987) (Fig. 2). These authors inferred that hidden Acadian (late Caledonian) basement structures beneath the East Midlands controlled the Dinantian block and basin topography. The controlling faults on these structures trend ESE. Folds in this area show interference between ESE and N-S sets, both trends which feature strongly in the pattern of inferred structures.

Discussion

The study area lies astride the northern margin of the Midlands Massif (Fig. 2). This massif has been described as a rigid indenter (Soper *et al.*, 1987). It acted as a cohesive unit which moved northwards, resulting in reactivation of existing faults, and deformation of the Lower Palaeozoic rocks. Soper *et al.* (1987) also speculated that the curvilinear patterns of faults and folds of the Upper Palaeozoic rocks in N England provide evidence of movement of the rigid indenter. As a result the indenter is flanked at depth by arcuate structures of Lower Palaeozoic age (Soper *et al.*, 1987). To the west of the massif in central Wales, the traditional NE-SW Caledonian (Acadian) trend has been used to describe the tectonic grain. However, in N England, including the NE Midlands there are significant departures from this trend (Fig. 2). In the NE Midlands, the block and basin topography of the pre-Dinantian (Collinson, 1988; Lee, 1988) can be used to infer hidden Acadian structures (Soper *et al.*, 1987). For example, the Gainsborough Trough and Edale Gulf appear to be controlled by ESE trending faults, which are presumed to reflect the Caledonian basement trend. Lee (1988) suggested that a number of faults which control this block and basin topography are orientated N-S, parallel to the N-S Malvernian trend, as extrapolated to other areas in Britain by Haszeldine (1988). The Widmerpool Gulf has a more E-W alignment (Falcon and Kent, 1960; Kent, 1966; Collinson, 1988). The Precambrian basement rocks exposed in Charnwood exhibit a NW-SE Charnian trend, as does the eastern margin of the massif.

Elements of all four structural trends are present in the study area, the NW-SE Charnian trend, the NE-SW Acadian (Caledonian) trend, the N-S Malvernian trend and the E-W Widmerpool trend. The structural patterns that appear on the rose diagrams are ESE, ENE and E-W. It is suggested here that these patterns result from modification at the apex of the rigid indenter of the NE and NW trends on the west and east sides of the Midlands Massif respectively. The northern end of the indenter would not have been a sharp point, but an area of gradual transition and interaction between the NE and NW trends. This would result in a 'rounding off' with the main trends merging to produce hybrid trends to the ESE and ENE.

This combined pattern is further modified in this area by the occurrence of the E-W Widmerpool trend. Soper *et al.* (1987) suggested that this appeared to be controlled by the northern margin of the Midlands Massif. As the Midlands Massif moved northwards, the Lower Palaeozoic rocks were deformed. The northern contact may have been a thrust fault, with the Lower Palaeozoic rocks thrust southwards up on to the Midlands Massif along a roughly E-W line. Reactivation of the 'thrust' fault in pre-Dinantian times, in an opposite sense as a listric normal fault (Quirk, 1988), would have resulted in the formation of a deeping basin, the Widmerpool Gulf, in which thick Dinantian sediments accumulated.

The analysis of known structures correlates with the structural pattern identified in the basement i.e. ESE, ENE and E-W. Further, there is a strong correlation between known structures and inferred lineaments. Despite the speculative origin of the Landsat lineaments in the East Midlands, this correlation lends weight to the theory that basement control is a major factor in their formation.

We suggest that, with care, lineament analysis can be used to infer the presence of structurally controlled geological features, despite cultural camouflage. This work was carried out some time ago, and although some of the software and hardware for image processing has improved, the basic principles applied are still sound. For example, image processing hardware is now capable of undertaking an edge enhancement over an entire MSS or TM scene, without the necessity of creating 512 x 512 pixel subscenes.

Acknowledgements

Financial assistance for this study was given to M. K. G. Whateley by the University of Leicester Research Board and to H. K. Eardley by a NERC postgraduate grant. The help given by A. McDonald at NERC Swindon (now at BGS Keyworth) is gratefully acknowledged. P. K. H. Maguire, T. D. Ford and J. McM. Moore read earlier versions of the manuscript and we are grateful for their constructive criticisms. Our thanks also to those members of the 1985 Mineral Exploration M.Sc. course at Leicester University who assisted with lineament interpretation.

References

Abrams, M. J., 1984. *Joint NASA GEOSAT Test Case Report.* American Association of Petroleum Geologists, 3 Vols.

Anderton, R., Bridges, P. H., Leeder, M. R., and Sellwood, B. W., 1983. *A dynamic stratigraphy of the British Isles.* George Allen and Unwin, 301 pp.

Bailey, G. B., and Anderson, P. D., 1982. Applications of Landsat imagery to problems of petroleum exploration in Quaidam Basin, China. *American Association of Petroleum Geologists, Bulletin,* **66,** 1348-1354.

Berhe, S. M., and Rothery, D. A., 1986. Interactive processing of satellite images for structural and lithological mapping in northeast Africa. *Geological Magazine,* **123,** 393-403.

Butterley, A. D., and Mitchell, G. H., 1946. Driving of two drifts by the Desford Coal Company Limited at Merry Lees, Leicestershire. *Transactions of the Institution of Mining Engineers,* **104,** 703-713.

Chang, S. H., and Collins, W., 1983. Confirmation of the airborne biogeophysical mineral exploration technique using laboratory methods. *Economic Geology,* **78,** 723-736.

Collinson, J. D., 1988. Controls on Namurian sedimentation in the Central Province basins of northern England. *In* Besley, B. M., and Kelling, G. (Eds) *Sedimentation in a synorogenic basin complex,* Blackie, 85-101.

Drury, S. A., 1986. Remote sensing of geological structure in European agricultural terrains. *Geological Magazine,* **123,** 113-121.

Drury, S. A., 1987. *Image Interpretation in Geology.* Allen and Unwin, 243 pp.

Eardley, H. E., 1985. The assessment of the use of Landsat MSS and TM lineament mapping in the East Midlands. Unpubl. MSc. dissertation. Leicester University, 80pp.

Evans, A. M., 1968. Precambrian Rocks, Section A, Charnwood Forest. *In* Sylvester-Bradley, P. C., and Ford, T. D. (Eds) *The Geology of the East Midlands.* Leicester University Press, 1-12.

Evans, A. M. 1979. The East Midlands aulocogen of Caledonian age. *Mercian Geologist,* **7,** 31-42.

Falcon, N. L., and Kent, P. E., 1960. *Geological results of petroleum exploration in Britain 1945-1957.* Memoir of the Geological Society of London, **2.**

Ford, T. D., 1978. The Carboniferous Limestone. *In* Sylvester-Bradley, P.C., and Ford, T. D. (Eds) *The Geology of the East Midlands.* Leicester University Press, 59-79.

Fulton, I., and Williams, H., 1988. Palaeogeographical change and controls on Namurian and Westphalian A/B sedimentation at the southern margin of the Pennine Basin, Central England. *In* Besley, B. M., and Kelling, G. (Eds) *Sedimentation in a synorogenic basin complex,* Blackie, 178-199.

Geological Survey of Great Britain, 1956. Gravity Survey Overlay Map Sheet 11, 1:253,440, Ordnance Survey, Chessington, Surrey.

Geological Survey of Great Britain, 1964. Aeromagnetic map of Great Britain. 1:250,000, sheet 5. Ordnance Survey, Southampton.

Goetz, A. F. H., Rock, B. N., and Rowan, L. C., 1983. Remote sensing for exploration: An overview. *Economic Geology,* **78,** 573-590.

Guinness, E. A., Arvidson, R. E., Leff, C. E., Edwards, M. H., and Bindschadler, D. L., 1983. Digital image processing applied to analysis of geophysical and geochemical data for southern Missouri. *Economic Geology,* **78,** 654-663.

Haszeldine, R. S., 1988. Crustal lineaments in the British Isles: their relationship to Carboniferous basins. *In* Besley, B. M., and Kelling, G. (Eds) *Sedimentation in a synorogenic basin complex,* Blackie, 53-68.

Institute of Geological Sciences, 1974. Sheet 141, Loughborough, 1:50,000. Director General of Ordnance Survey, Southampton.

Institute of Geological Sciences, 1982. Sheet 155, Coalville, 1:50,000. Director General of Ordnance Survey, Southampton.

Institute of Geological Sciences, 1983. East Midlands, Sheet 52°N-02°W, 1:250,000. Director General of Ordnance Survey, Southampton.

Kent, P. E., 1966. The structure of the concealed carboniferous rocks of north-eastern England. *Proceedings of the Yorkshire Geological Society,* **35,** 323-353.

Lake, S. D., Munday, T. J., and Dewey, J. F., 1984. Lineament mapping in the Wessex Basin of southern England: a comparison between MSS and TM data. *Satellite Remote Sensing — review and preview: Proceedings of 10th Annual International Conference, Reading University, Sept. 1984.* Remote Sensing Society, 361-374.

Larson, B. S., 1982. Examination of some factors used in selecting Landsat imagery for lineament interpretation. *Proceedings of the International Symposium on Remote Sensing for Exploration Geology, Fort Worth, Texas,* 293-302.

Lee, A. G., 1988. Carboniferous basin configuration of central and northern England modelled using gravity data. *In* Besley, B. M., and Kelling, G. (Eds) *Sedimentation in a synorogenic basin complex,* Blackie, 69-84.

Lillesand, T. M., and Kiefer, R. W., 1979. *Remote sensing and image interpretation, 1st edition.* Wiley and Sons.

Maguire, P. K. H., 1987. CHARM II — A deep reflection profile within the central England microcraton. *Journal of the Geological Society of London,* **144,** 661-670.

Mather, P. M. ,1987. *Computer processing of remotely-sensed images.* John Wiley and Sons, 352pp.

Nash, C. R., Boshier, P. R., Coupard, M. M., Theron, A. C., and Wilson, T. G., 1980. Photogeology and satellite image interpretation in mineral exploration. *Mineral Science and Engineering,* **12,** 216-244.

Peters, E. R., 1983. The use of multispectral satellite imagery in the exploration for petroleum and minerals. *Philosophical Transactions of the Royal Society of London,* **A309,** 243-255.

Pharaoh, T. C., Merriman, R. J., Webb, P. C., and Beckinsale, R. D., 1987. The concealed Caledonides of eastern England: preliminary results of a multidisciplinary study. *Proceedings of the Yorkshire Geological Society,* **46,** 355-369.

Quirk, D. G., 1988. Structure and genesis of the South Pennine orefield. Unpublished Ph.D. Thesis, University of Leicester, 252pp.

Rothery, D. A., 1985. Interactive processing of satellite images for geological interpretation — a case study. *Geological Magazine,* **122,** 57-63.

Sabins, F. F., 1983. Geological interpretation of Space Shuttle radar images of Indonesia. *American Association of Petroleum Geologists, Bulletin,* **67,** 2076-2099.

Sabins, F. F., 1987. *Remote Sensing. Principles and Interpretation. 2nd edition.* Freeman, 449pp.

Saunders, D. F., and Hicks, D. E., 1976. Regional geomorphic lineaments on satellite imagery — their origin and applications. *Proceedings 2nd International Conference of Basement Tectonics, Newark, Delaware,* 326-352.

Schowengerdt, R. A., 1983, *Techniques for Image Processing and Classification in Remote Sensing.* Academic Press, 249pp.

Siegel, B. S., and Gillespie, A. R., 1980. *Remote sensing in geology.* Wiley and Sons.

Smith, W. L., 1977. *Remote sensing applications for mineral exploration.* Dowden, Hutchinson and Ross Inc.

Soper, N. J., Webb, B. C. and Woodcock, N. H., 1987. Late Caledonian (Acadian) transpression in north-west England: timing, geometry and geotectonic significance. *Proceedings of the Yorkshire Geological Society,* **46,** 175-192.

Watts, W. W., 1947. *Geology of the ancient rocks of Charnwood Forest, Leicester,* 160pp.

Whitcombe, D. N., and Maguire, P. K. H., 1981a. A seismic refraction investigation of the Charnian basement and granitic intrusions flanking Charnwood Forest. *Journal of the Geological Society of London,* **138,** 643-652.

Whitcombe, D. N., and Maguire, P. K. H., 1981b. Seismic refraction evidence for a basement ridge between the Derbyshire Dome and the W of Charnwood Forest. *Journal of the Geological Society of London,* **138,** 653-659.

Wise, D. U., 1982. Linesmanship and the practice of linear geo-art. *Bulletin of the Geological Society of America,* **93,** 886-888.

Michael K. G. Whateley and Helen K. Eardley
Department of Geology
University of Leicester
Leicester
LE1 7RH.

Brittlestars from the Bathonian of Lincolnshire and Northamptonshire

A. Dawn

Abstract: Rock samples bearing numerous *Ophiohybris griesbachii* (Wright, 1854) from two separate localities in the Great Oolite Group (Bathonian: Middle Jurassic) are reported. Both samples derive from the base of the Blisworth Limestone, close to its junction with the Rutland Formation. The occurrence of *O. griesbachii* in clusters compares closely with the behaviour of living *Ophiothrix fragilis*.

The Middle Jurassic formations of the East Midlands consist of a repeated sequence of limestones and clays (Arkell, 1933; Sylvester-Bradley and Ford, 1968). The Lincolnshire Limestone ('Inferior Oolite') is overlain by the clays of the Rutland Formation ('Upper Estuarine Clay'). These in turn are covered by the Blisworth Limestone ('Great Oolite Limestone'). Many quarries exploit both the limestones and clays for industrial purposes, and there are numerous exposures of these three formations. The samples described here bearing *Ophiohybris* are of a fairly hard limestone from the base of the Blisworth Limestone. They are lodged in Peterborough City Museum, Priestgate, Peterborough.

Localities and accession numbers

Specimen no. 3448/G was found at Gregory's Quarry, Ancaster (SK 985 414), by Mr Robin Hix. Gregory's Quarry (Fig. 1) is a working quarry and permission to enter must be sought by applying to the manager on site during working hours. The specimen comprises

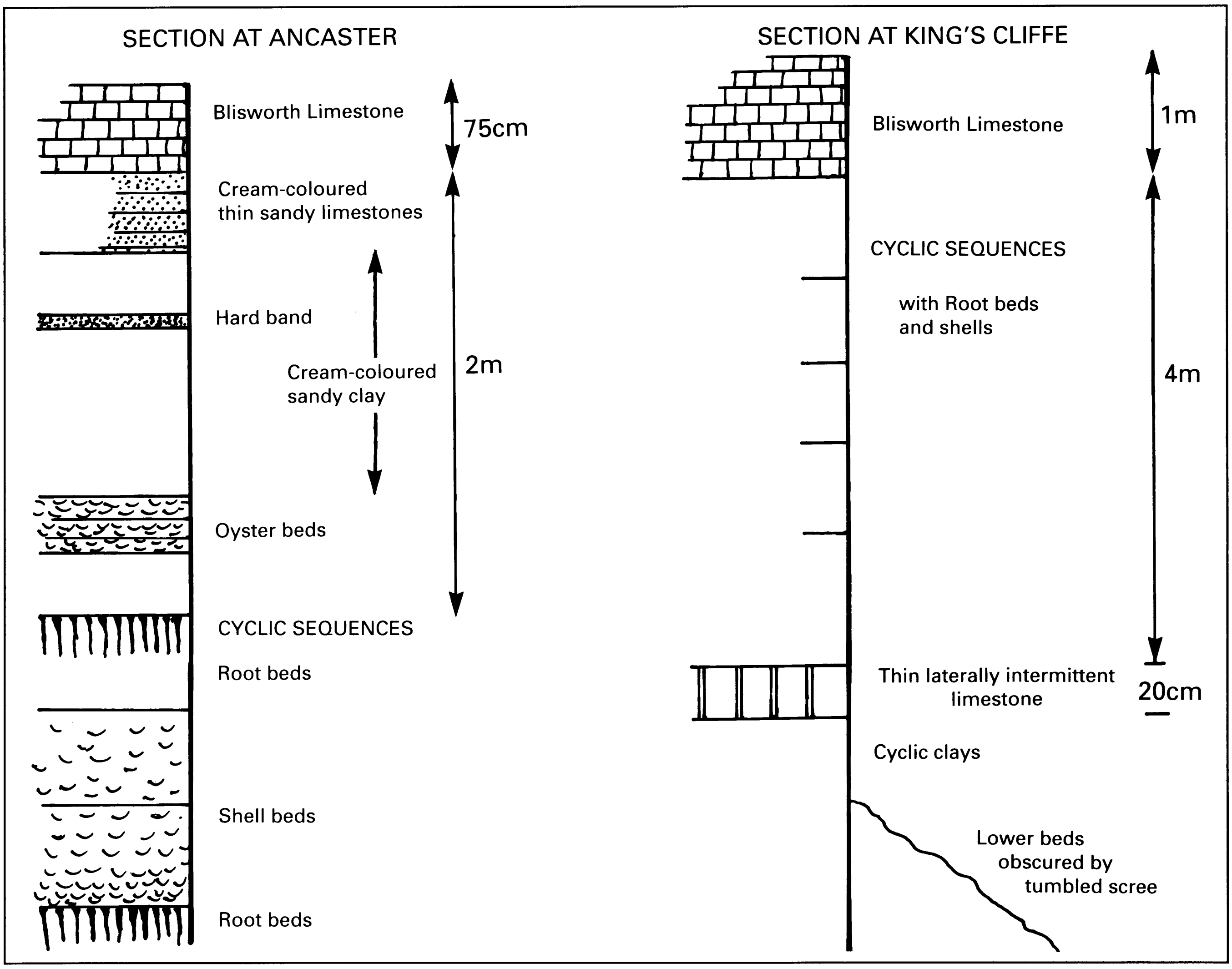


Fig. 1. Diagrammatic sections at Gregory's Quarry, Ancaster and at King's Cliffe Quarry.

about eight animals and disassociated fragments (Fig. 2). It was found in loose scree composed of thin sandy limestones. Many of these limestone slabs contain burrows of worms and other organisms. Further searching has failed to reveal the exact source horizon or further specimens. These light-coloured thin sandy layers occur high in the clay sequence and seem to be transitional from the clay to the limestone proper. There is no sharp and distinct contact in this quarry at the top of the Rutland formation.

Specimen nos. 5062/G (Fig. 3), *5063/G, 5064/G* (Fig. 4) and associated fragments were found in a quarry about 1km south-east of King's Cliffe, Northants (TL 012 966), by Dr J. A. D. Dickson. The King's Cliffe Quarry (Figs 1, 5) is no longer worked. Permission to enter the site should be sought at the farm near the quarry entrance, between Kingscliffe and Apethorpe villages.

These three blocks bear tangled masses of animals, and there are also numerous disassociated fragments. The appearance of the limestone is similar to that of the base of the Blisworth Limestone which caps the clays in this quarry. The junction between the Rutland Formation and the Blisworth Limestone is here quite sharply defined, unlike at Ancaster.

Classification, Morphology and Life Habits of Brittlestars

Brittlestars fall into the phylum Echinodermata, subphylum Asterozoa, class Stelleroidea and sub-class Ophiuroidea. The geological range of brittlestars is Ordovician to Recent. The ophiuroids possess five arms radiating in a horizontal plane from a central pentagonal disc which forms the main body, which contains the viscera and the mouth (Fig. 6). The mouth is surrounded by five centrally facing tooth-like projections (Fig. 7). The arms are moved by a complex water-vascular system and some forms can move their arms in all planes, enabling the creatures to walk and climb over the sea-floor.

Brittlestars are abundant in the seas today. Some forms live at abyssal depths, and others on hard-grounds on rocky shores where there are moderate currents. They disintegrate rapidly after death and become scattered, so they are rarely preserved in the fossil record. When a group of specimens is found articulated it would seem to indicate the burial of a life assemblage beneath a cloud of sediment. Clarkson (1979) stated that modern ophiuroids are unable to escape from sediment more than 5 cm thick.

Observations on living ophiuroids have been published by Broom (1975) and Warner (1971), based on a series of S.C.U.B.A. dives in Torbay, Devon, between Berry Head and Hope's Nose. Ophiuroid beds of *Ophiothrix fragilis* (Abildgaard) at a depth of 15 m extended for some 1000 m by 200 m. The animals occurred in patches or clusters, rarely less than 100, and often in concentrations of 1000-2000 per m^2. Individuals separated from a cluster walked until they found another cluster to join. They are suspension feeders and collect food by raising some of their arms vertically so that the adoral surface, which is underneath, is exposed to the suspended matter in the current.

Warner (1971) suggested several advantages in the aggregation behaviour of *Ophiothrix:*

1. There is stability when large numbers hold the sea floor together against currents.
2. The interlocking mass of animals allows them to extend more arms into the current and so increase the suspension feeding potential of each individual.

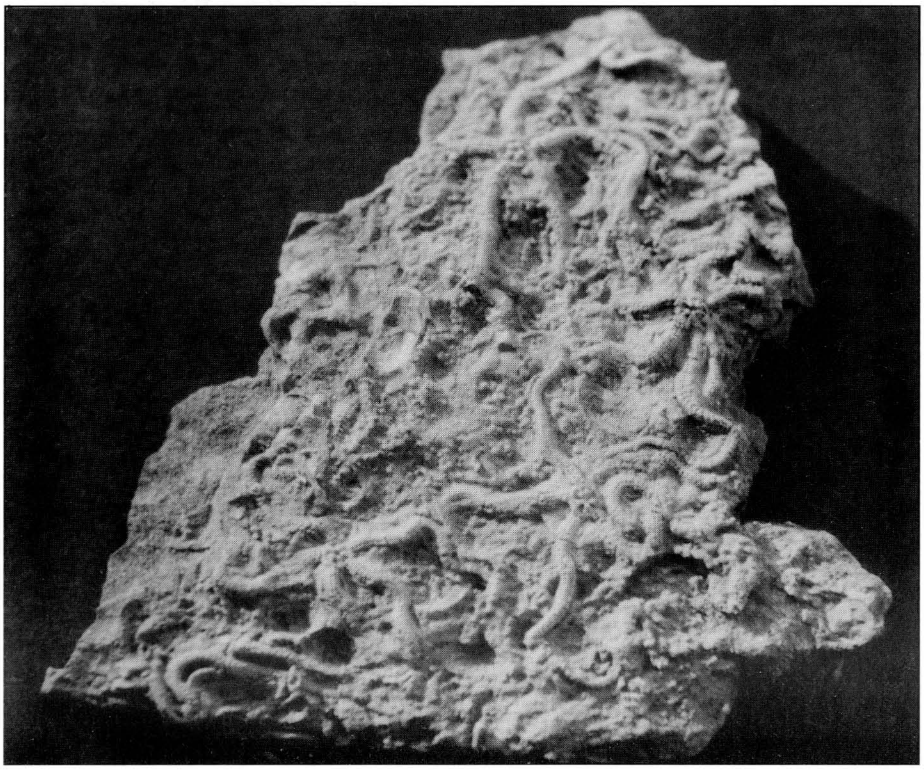


Fig. 2. *Ophiohybris griesbachii* (Wright), Blisworth Limestone, Gregory's Quarry, Ancaster. Peterborough Museum no. 3448/G. Scale ×1.

Fig. 3. *Ophiohybris griesbachii* (Wright), Blisworth Limestone, King's Cliffe. Peterborough Museum no. 5062/G. Scale ×3.

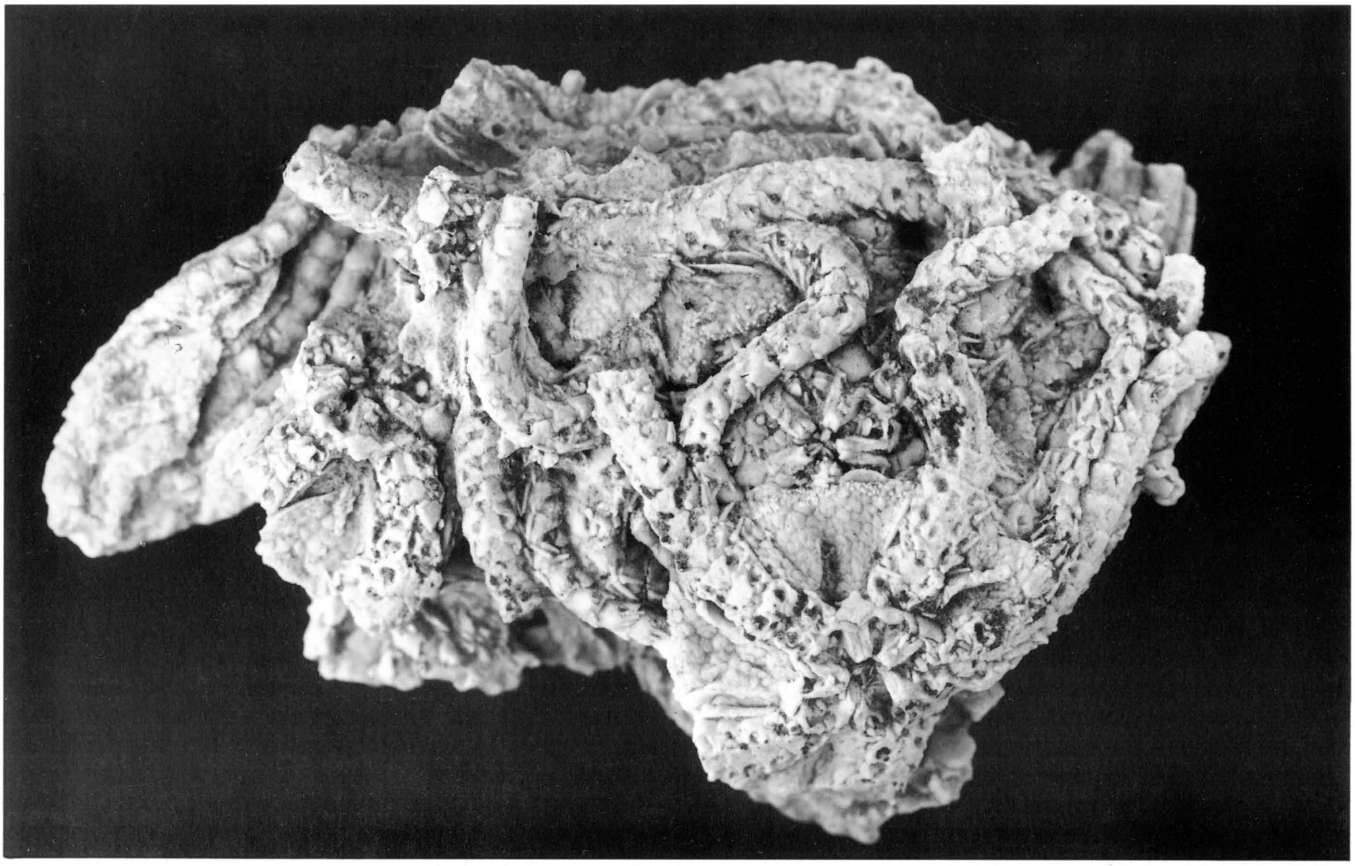


Fig. 4. *Ophiohybris griesbachii* (Wright), Blisworth Limestone, King's Cliffe. Peterborough Museum no. 5064/G. Scale ×3.

3. The current will slow somewhat within the mass of extended arms, thus allowing suspended material to be deposited.
4. The presence of many adults creates a greater certainty of fertilisation during the breeding season.

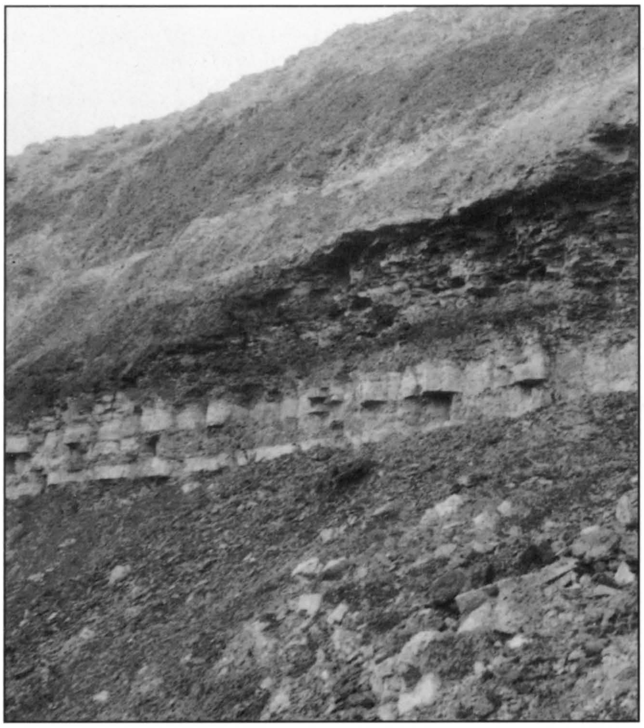


Fig. 5. The exposed face at King's Cliffe Quarry.

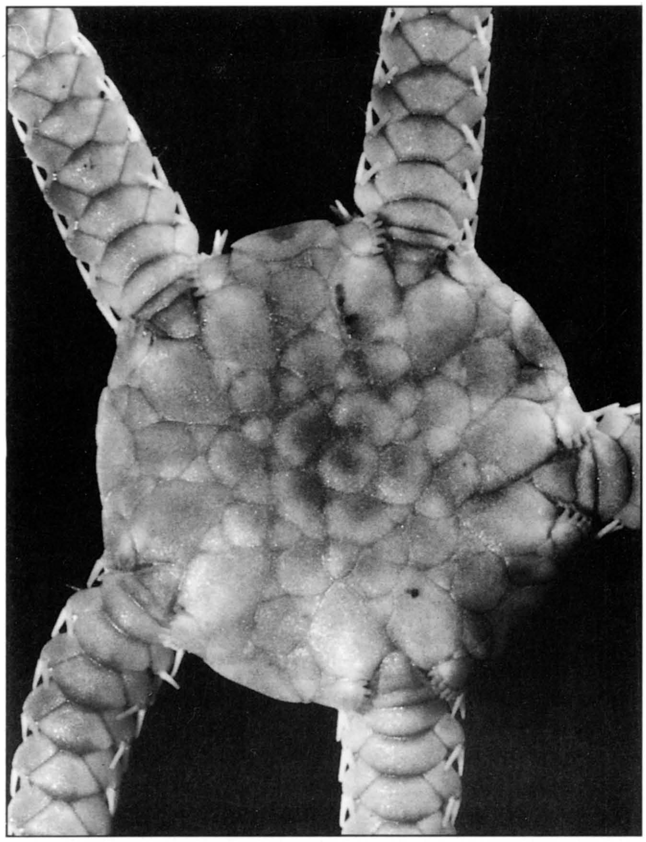


Fig. 6. *Ophiothrix fragilis* (Abildgaard), a modern brittlestar. Upper (aboral) surface of disc with radiating arms. Scale ×6.

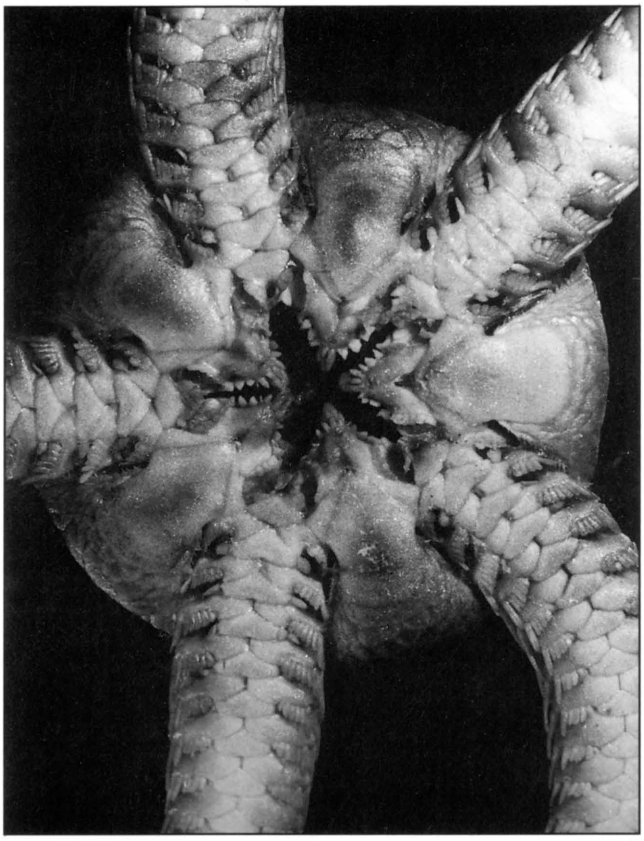


Fig. 7. *Ophiothrix fragilis* (Abildgaard). Lower (adoral) surface showing tooth-like projections around the mouth. Scale ×6.

It seems probable that the life-style of the ophiuroids has changed little through geological time, and that the specimens of *Ophiohybris* reported here lived much in the same way as the modern *Ophiothrix*.

Acknowledgements

The author is indebted to the following for their help: Dr J. A. D. Dickson of Cambridge University for providing the King's Cliffe specimens, the photographs in figs 3, 4, 6, 7, the modern material of *Ophiothrix fragilis*, and some of the literature; Dr A. Smith of the Natural History Museum for identifying the Ancaster specimen; Mr Robin Hix for donating the Ancaster specimen; Dr R. G. Clements of Leicester University for suggesting references, and Dr G. R. Chancellor of Peterborough Museum for checking the draft.

References

Arkell, W. J., 1933. *The Jurassic System in Great Britain.* Oxford, 681pp.

Broom, D. M., 1975. Aggregation behaviour of the brittlestar *Ophiothrix fragilis. Journal of the Marine Biological Association UK,* **55,** 191-197.

Clarkson, E. N. K., 1979. *Invertebrate palaeontology and evolution* (first edition). London, Boston and Sydney, 323pp.

Hess, Von Hans, 1964. Die Ophiuren des Englischen Jura. *Eclogea Geologicae Helvetiae,* **57,** 787-789.

Sylvester-Bradley, P. C., and Ford, T. D., (Eds) 1968. *The geology of the East Midlands.* Leicester University Press, 400pp.

Warner, G. F., 1971. On the ecology of a dense bed of the brittlestar *Ophiothrix fragilis. Journal of the Marine Biological Association UK,* **51,** 267-282.

Alan Dawn
26 Sutherland Way
Stamford
Lincs
PE9 2TB.

Conodont Colour and Thermal Maturation in the Lower Carboniferous of North Wales

R. J. Aldridge

Abstract: Conodont colour alteration index (CAI) values have been obtained for 20 localities in the Carboniferous of North Wales. In the area between the Dinorwic and Bala faults values range from 1 to 2 and can be accounted for by burial under an overburden of later Carboniferous and younger strata. Anomalously high values of 2.5 to 3 are recorded in eastern Anglesey, which is to the north of the Dinorwic Fault, and possibly to the south of the Bala Fault, near Llangollen. These enhanced values cannot be the result of burial, but the possible presence of a concealed granite beneath northwest Anglesey provides a partial explanation.

Very little has been published on the Carboniferous conodonts of North Wales. The first report was a listing of species from the Carboniferous Limestone succession of the outcrop between Prestatyn (NGR SJ 074 821) and Dyserth (SJ 063 790) in Clwyd by Aldridge *et al.* (1968). Subsequently, Reynolds (1970) described and illustrated specimens recovered from a borehole core drilled by the Institute of Geological Sciences (now the British Geological Survey) in the nearby Pentre Quarry, Gronant, Clwyd (SJ 0950 8279), and Austin and Aldridge (1973) listed and figured elements from a knoll limestone at Graig Fawr, Meliden, Clwyd (SJ 062 806). A single specimen of *Cavusgnathus* sp. was reported by Somerville *et al.* (1989) from the Foel Formation of Pentre-bach Quarry, Dyserth, Clwyd (SJ 061 782). All of these records come from a very restricted geographical area, and conodont elements have not been reported from any of the other extensive exposures of Carboniferous Limestone in North Wales.

Conodont elements are the microscopic remains of the feeding apparatuses of extinct eel-like chordates (Aldridge *et al.*, 1986). They are formed of layers of crystalline calcium phosphate, with interlamellar traces of organic material. If unweathered and thermally unaltered, conodont elements are pale yellow to light amber in colour, but heating causes them to darken through carbonisation of the organic matter. Epstein *et al.* (1977) demonstrated by field investigations and laboratory experiments that conodont element colour is largely dependent on the degree and duration of the heating to which the specimens have been subjected, and that it is possible to use colour variation as a semi-quantitative index of the thermal history of the host strata. From the results of their experiments, they introduced a Colour Alteration Index (CAI), with values related to particular temperature ranges. The unaltered, pale amber conodont elements are designated CAI 1, and with increasing temperature they turn dark amber (CAI 2), brown (CAI 3-4), then black (CAI 4-5). Where heating has persisted for a considerable time, as would be expected geologically, these changes correspond to a temperature range from less than 50°C to more than 300°C. CAI mapping is now widely employed as a tool in the elucidation of the thermal history of sedimentary basins, in the estimation of eroded overburdens and in the regional location of hydrocarbon reservoirs.

As part of a co-ordinated study of conodont colour in British Carboniferous strata, reconnaissance sampling has been undertaken in all the major outcrop belts in North Wales. This material has been supplemented by small undescribed collections housed at the Universities of Leicester and Southampton. Although the data base is now vastly improved, the investigation is still at a preliminary stage in this area, and many gaps remain to be filled. Values of the Conodont Alteration Index (CAI) of Epstein *et al.* (1977) assessed for the productive localities in the Carboniferous of North Wales are shown on figure 1. Samples collected to date from the Little Orme, Llandudno, Gwynedd (SH 814 823), from near Llysfaen, Clwyd (SH 893 766), and from the cliffs at Creigiau Eglwyseg, Llangollen, Clwyd (SJ 220 445), have failed to yield conodont specimens.

In recent years the stratigraphy of the Dinantian of North Wales has undergone considerable revision (Somerville and Strank, 1984a, b; Warren *et al.*, 1984; Somerville *et al.*, 1986; Davies *et al.*, 1989; Somerville *et al.*, 1989). Strata previously regarded as restricted to the Asbian and Brigantian stages (George *et al.*, 1976) are now recognised to span at least to the Chadian in some areas, and it has been suggested that the Basement Beds of the succession in the Prestatyn district may possibly be as old as latest Courceyan (Somerville *et al.*, 1986). The marine inundantion of North Wales apparently commenced in the Chadian, with peritidal and shallow marine limestones deposited from Prestatyn to south of Mold (Somerville *et al.*, 1989; Davies *et al.*, 1989). This initial transgressive pulse was followed by a larger Arundian transgression, which drowned a wide area of North Wales delimited by the Dinorwic fault in the north-east and the Bala fault in the south-east. Between these faults limestones accumulated in an area of subsidence termed the "Mold Gulf" by Somerville and Strank (1984a), with the surrounding platforms of Anglesey and the Llangollen area not being inundated until the Absian.

Material

Locality details are given in the appendix. The Prestatyn-Dyserth area remains the only intensively sampled Dinantian outcrop in North Wales, although reasonable numbers of conodont elements have been recovered from samples from Anglesey, from the Great Orme, Llandudno, and from Halkyn Mountain, north of Mold. In general, yields from North Wales samples have been low, and the other CAI values plotted in figure 1 are based on relatively small collections. These would clearly benefit from corroboration by additional samples.

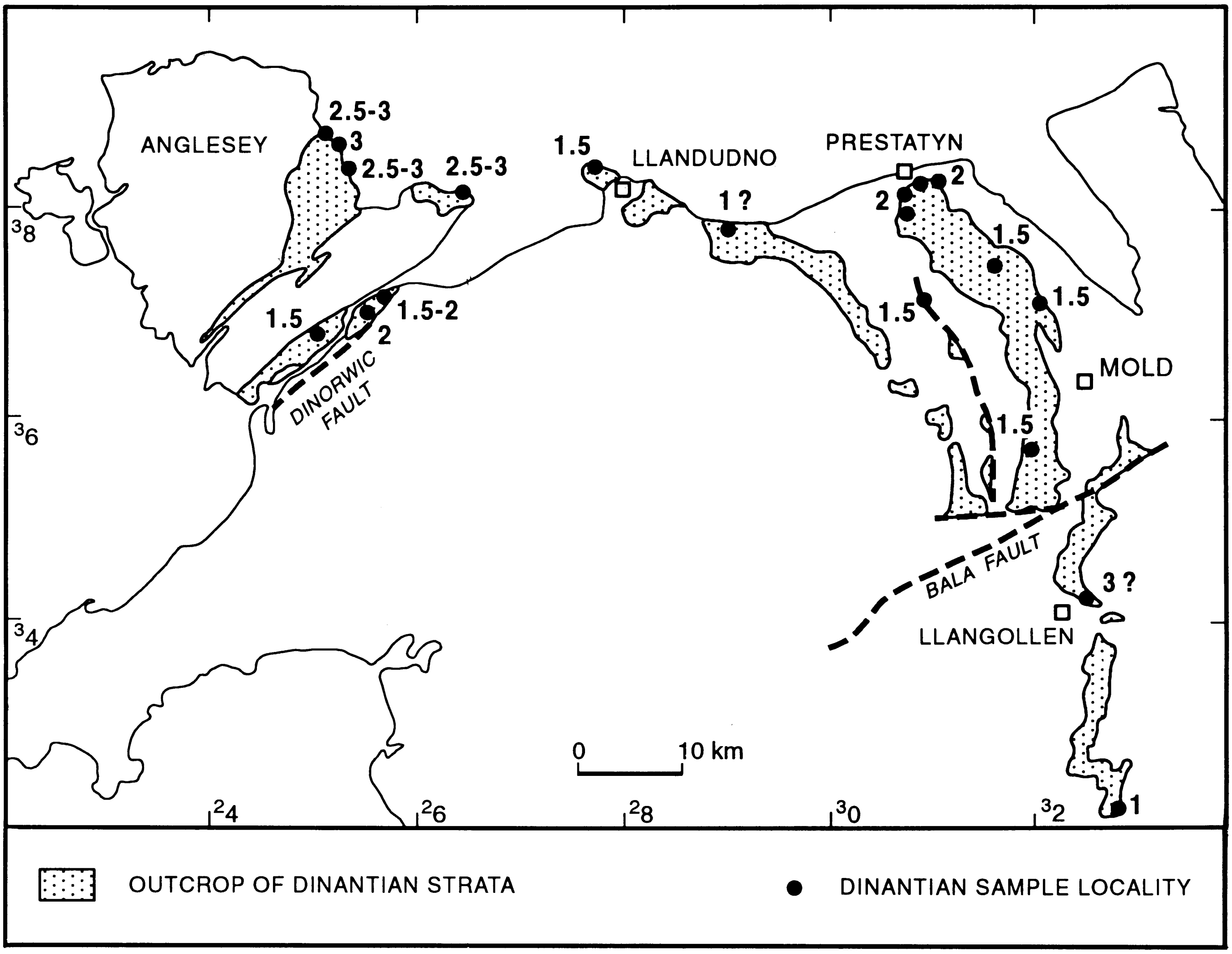


Fig. 1. Dinantian outcrops and conodont CAI values in North Wales. CAI values were, wherever possible, determined on elements of the genus *Gnathodus*, and measured between the basal cavity and the margin of the unit. In most cases, the value recorded is based on several specimens from each sample.

CAI Values

The conodont colour values in the Mold Gulf are universally low, ranging from 1 to 2. The lowest figure, from a single sample near the north coast at Old Colwyn (SH 890 783), is based on one fragmentary element only and must be regarded as equivocal. Otherwise, all samples gave a value of 1.5 or 2; this is equivalent to a temperature range of 50-140°C (Epstein *et al.*, 1977). To the north of the Dinorwic Fault, values range from 1.5 to 3 (50-200°C), with samples from the east coast of Anglesey providing a consistent indication of relatively high thermal maturation with figures in the range of 2.5 to 3. A sample from near Llangollen, south of the Bala Fault, provided a tentative value of 3 (110-200°C)., but this is based on fragmentary, delicate elements only and further collecting in this region is necessary to confirm this apparently high thermal maturation. Further south, at Llanymynech Hill, Powys (SJ 265 217), fragments recovered from thick-bedded dolomites showed a CAI of 1.

Discussion

The CAI values obtained from strata in the Mold Gulf are low enough to be attributable simply to burial under the known overburden. The higher values to the north of the Dinorwic Fault and at Llangollen are, however, anomalous and require an explanation other than burial heating. One possibility is that they relate to local heating during an episode of mineralization, but there is no independent evidence of this. Indeed, mineralization, of the Carboniferous Limestone in North Wales appears to have been concentrated in the Mold Gulf. Hydrocarbon minerals are recorded in association with the metallic ores in this area and their known distribution was reviewed by Parnell (1983). He noted that lead-zinc mineralization is particularly extensively developed around Halkyn Mountain, near Mold, where the CAI is only 1.5. Lead-zinc mining near Prestatyn has also produced associated hydrocarbon minerals, probably derived from the bituminous Carboniferous Limestone, but again CAI values in the area are not markedly elevated. The Great Orme, where samples collected to date give a CAI value of 1.5, is also the site of copper mineralization.

A similar, apparently anomalous, distribution of CAI values in late Viséan rocks of northern England was reported by Burnett (1987), who found palaeothermal highs over the Askrigg and Alton blocks and lower values in the surrounding trough sediments. He attributed the high values on the blocks to the channelling of mantle-derived heat through the Wensleydale and Weardale granite plutons that underlie them. A similar explanation for high CAI values in the Carboniferous strata of the Isle of Man has been forwarded by Swift (1993). On Anglesey, the late Precambrian Coedana granite crops out within ten kilometres of the exposures of Carboniferous Limestone on the east coast. Although originally thought to be intrusive (Callaway, 1902; Greenly, 1919), the granite is now regarded as a fault-bounded slice within the tectonic collage of the Mona Complex (Gibbons, 1984), and does not represent a more extensive submerged pluton. This interpretation is supported by the pattern of gravity anomalies, which show only a minor gravity low associated with the granite. A concealed granite body would be indicated by an area of low gravity on a Bouguer anomaly map, but the area of high CAI values in SE Anglesey is characterized by anomalously high gravity readings (Powell, 1956; Griffiths and Gibb, 1965; Reedman *et al.*, 1984). In contrast, a low gravity anomaly does occur to the south of the Dinorwic Fault, along the Padarn ridge, and this has been ascribed to an underground extension of the Twt Hill Granite of Caernarvon (Powell, 1956; Cornwell and Dabek, 1982), although Reedman *et al.* (1984) favoured an explanation involving a thick development of tuffs of the lower Cambrian Arfon Group. Low gravity is also recorded in the northwest of Anglesey, and this anomaly has, indeed, been recently interpreted as an indication of a buried granitic pluton beneath Holyhead Bay (Cornwell and Smith, 1993). Although this postulated pluton does not directly underlie the Carboniferous strata with raised CAI values, it may be close enough to account for the enhanced heatflow they record. The age of any granite is uncertain, but Cornwell and Smith (1993) favoured either a Precambrian/Cambrian or Caledonian age. If this is the case, then the colour of the Carboniferous conodonts cannot have been produced by direct heating from the intrusive pluton, but would be the result of mantle-derived heat channelled to the surface through the granite body.

The possible high CAI value at Llangollen does not coincide with a gravity low. An elongated anomaly is recognized just to the east of the Carboniferous Limestone outcrop, but this has been accounted for by a local thickening of the Namurian Cefn-y-Fedw Sandstone Group (Cornwell, 1987). The anomaly has a steep western margin, and it is apparent that the sandstones thinned rapidly towards the west and an enhanced thickness cannot be used in overburden calculations for the Llangollen limestones. Somerville (pers. comm. 1989) suggests that the thermal effects at Llangollen may relate to movement along a splay of the Llangollen Fault System which runs along the foot of the Eglwyseg Rocks. This explanation may be tested by a much more detailed examination of thermal maturation patterns in the area than has been attempted to date. At present, though, the high CAI values in Llangollen remain unexplained.

Acknowledgements

I thank Dr R. L. Austin, University of Southampton, for providing data for three localities, Moelfre, Benllech and Bangor. Data from the Gronant Borehole is included with the permission of the Director, British Geological Survey. Mr A. Swift provided valuable field and laboratory assistance, and also reviewed a first draft of this paper. I also acknowledge the benefit gained from discussions with Dr R. B. Evans and Dr J. D. Cornwell, British Geological Survey, and with Dr R. D. Burnett, Trinity College Dublin. Dr I. D. Somerville, University College Dublin, and Dr J. R. Davies, British Geological Survey, generously provided unpublished information and made very useful comments on the manuscript. Dr A. G. Harris, US Geological Survey, kindly supplied a set of conodont colour standards.

References

Aldridge, R. J., Austin, R. L. and Husri, S., 1968. Viséan conodonts from North Wales and Ireland. *Nature*, **219**, 255-258.

Aldridge, R. J., Briggs, D. E. G., Clarkson, E. N. K. and Smith, M. P., 1986. The affinities of conodonts — new evidence from the Carboniferous of Edinburgh, Scotland. *Lethaia*, **19**, 279-291.

Austin, R. L. and Aldridge, R. J., 1973. Conodonts from horizons with *Goniatites crenistria* Phillips in North Wales and the Isle of Man. *Geological Magazine*, **110**, 37-42.

Burnett, R. D., 1987. Regional maturation patterns for late Viséan (Carboniferous, Dinantian) rocks of Northern England based on mapping of conodont colour. *Irish Journal of Earth Sciences*, **8**, 165-185.

Callaway, C., 1902. A descriptive outline of the plutonic complex of central Anglesey. *Quarterly Journal of the Geological Society of London*, **58**, 662-679.

Cornwell, J. D., 1987. Gravity anomalies associated with the Cefn-y-Fedw Sandstone Group, northeast Wales, and their geological significance. *Geological Journal*, **22**, 261-272.

Cornwell, J. D. and Dabek, Z. K., 1982. Gravity evidence for concealed granite intrusions in north-west Wales (abstract). *Geophysical Journal of the Royal Astronomical Society*, **69**, 277.

Cornwell, J. D. and Smith, I. F., 1993. A possible concealed granite beneath part of Anglesey, North Wales. *Journal of the Geological Society, London*, **150**, 83-87.

Davies, J. R., Riley, N. J. and Wilson, D., 1989. The distribution of Chadian and earliest Arundian strata in North Wales: implications for Dinantian (Carboniferous) lithostratigraphy and palaeogeography. *Geological Journal*, **24**, 31-47.

Epstein, A. G., Epstein, J. B. and Harris, L. D., 1977. Conodont color alteration — an index to organic metamorphism. *US Geological Survey Professional Paper*, **995**, 27pp.

George, T. N., Johnson, G. A. L., Mitchell, M., Prentice, J. E., Ramsbottom, W. H. C., Sevastopulo, G. D. and Wilson, R. B., 1976. A correlation of Dinantian rocks in the British Isles. *Geological Society of London Special Report*, **7**, 87pp.

Gibbons, W., 1984. Stratigraphy, subduction and strike-slip faulting in the Mona Complex of North Wales — a review. *Proceedings of the Geologists' Association*, **94**, 147-163.

Greenly, E., 1919. The geology of Anglesey. *Memoir of the Geological Survey of Great Britain*, (2 vols.), London.

Griffiths, D. H. and Gibb, R. A., 1965. Bouguer gravity anomalies in Wales. *Geological Journal*, **4**, 335-341.

Parnell, J., 1983. The distribution of hydrocarbon minerals in the Welsh Borderlands and adjacent areas. *Geological Journal*, **18**, 129-139.

Powell, D. W., 1956. Gravity and magnetic anomalies in North Wales. *Quarterly Journal of the Geological Society of London*, **111**, 375-397.

Reedman, A. J., Leveridge, B. E. and Evans, R. B., 1984. The Arfon Group ('Arvonian') of North Wales. *Proceedings of the Geologists' Association*, **95**, 313-321.

Reynolds, M. J., 1970. A Lower Carboniferous conodont fauna from Flintshire, North Wales. *Bulletin of the Geological Survey of Great Britain*, **32**, 1-19.

Somerville, I. D., Mitchell, M. and Strank, A. R. E., 1986. An Arundian fauna from the Dyserth area, North Wales and its correlation within the British Isles. *Proceedings of the Yorkshire Geological Society*, **46**, 57-75.

Somerville, I. D. and Strank, A. R. E., 1984a. Discovery of Arundian and Holkerian faunas from a Dinantian platform succession in North Wales. *Geological Journal*, **19**, 85-104.

Somerville, I. D. and Strank, A. R. E., 1984b. Faunal discoveries from Viséan limestones of North Wales (abstract). *Proceedings of the Geologists' Association*, **95**, 394-395.

Somerville, I. D., Strank, A. R. E. and Welsh, A., 1989. Chadian faunas and flora from Dyserth: depositional environments and palaeogeographic setting of Viséan strata in northeast Wales. *Geological Journal*, **24**, 49-66.

Swift, A., 1993. Mantle-derived heat recorded by conodont colour alteration in the Carboniferous of the Isle of Man. *Geological Journal*, **28**, 171-177.

Warren, P. T., Price, D., Nutt, M. J. C. and Smith, E. G., 1984. Geology of the country around Rhyl and Denbigh. *British Geological Survey Memoir.*

Appendix: Sample localities, horizons and CAI values for North Wales

Localities are listed geographically from north-west to south-east.

1. South side of Lligwy Bay, Anglesey, SH 500 871. Carboniferous Limestone, Asbian. CAI 2.5-3.
2. Moelfre, Anglesey, SH 513 864. Carboniferous Limestone, Asbian/ Brigantian. CAI 3 (sample collected and evaluated by Dr R. L. Austin).
3. Benllech, Anglesey, SH 525 824. Carboniferous Limestone, Brigantian. CAI 2.5-3 (sample collected and evaluated by Dr R. L. Austin).
4. Near Penmon, north coast of promontory at east tip of Anglesey, SH 637 815. Carboniferous Limestone, Brigantian. CAI 2.5-3.
5. Old quarry, near Bryn-Siencyn, Anglesey, SH 492 678. Carboniferous Limestone, ?Brigantian. CAI 1.5, but specimens somewhat leached and red-stained.
6. Roadside south of Britannia Bridge, Gwynedd, SH 544 707. Carboniferous Limestone, Brigantian. CAI 2.
7. West of Bangor, Gwynedd, SH 565 718. Carboniferous Limestone, ?Brigantian. CAI 1.5-2 (sample collected and evaluated by Dr R. L. Austin).
8. Great Ormes Head, Llandudno, Gwynedd, SH 767 833. Carboniferous Limestone, Brigantian. CAI 1.5.
9. Roadside near Old Colwyn, Clwyd, SH 890 783. Carboniferous Limestone, Arundian. CAI 1? (one fragment only).
10. Old quarry above Prestatyn, Clwyd, SJ 072 822. Carboniferous Limestone (Prestatyn Limestone Formation), Asbian. CAI 2.
11. Old quarry near Meliden, Clwyd, SJ 066 806. Carboniferous Limestone (Moel Hiraddug Limestone Formation), Arundian. CAI 2.
12. Graig Fawr, Meliden, Clwyd, SJ 062 806. Reef knoll in Carboniferous Limestone, Asbian. CAI 2.
13. Upper Dyserth Quarry, Dyserth, Clwyd, SJ 063 790. Carboniferous Limestone (Dyserth Quarry Limestone Formation), Arundian. CAI 2.
14. Gronant Borehole, Clwyd, SJ 0950 8274. Carboniferous Limestone, depth 345ft. to 467ft. Asbian and Brigantian. CAI 2.
15. Roadside quarry, near Pant-y Wacco, Clwyd, SJ 135 761. Carboniferous Limestone, Asbian. CAI 1.5.
16. Quarry east of Bodfari, Clwyd, SJ 095 704. Carboniferous Limestone, heavily sheared and veined, ?Asbian. CAI 1.5.
17. Old quarry on Halkyn Mountain, Clwyd, SJ 197 710. Carboniferous Limestone, Brigantian. CAI 1.5.
18. Old quarry north of Llanarmon-yn-Ial, Clwyd, SJ 190 573. Carboniferous Limestone (Llanarmon Limestone), Arundian. CAI 1.5 (one fragment only).
19. Old quarry at Trevor Uchaf, near Llangollen, Clwyd, SJ 243 425. Carboniferous Limestone, Asbian. CAI 3? (delicate fragments only).
20. Old quarry on Llanymynech Hill, Powys, SJ 265 217. Carboniferous Limestone, Asbian. CAI 1 (fragmentary specimens only).

Richard J. Aldridge
Department of Geology
The University
Leicester
LE1 7RH

The Lias Succession between Fulbeck and the Vale of Belvoir

M. G. Sumbler

Abstract: The Lower Jurassic beds of the area between Fulbeck and the Vale of Belvoir comprise the Lias Group, traditionally divided into Lower Lias, Middle Lias (including Marlstone Rock Bed), and Upper Lias. Until recently, knowledge of much of this sequence had advanced little since the early part of the century, and only small parts were known in any detail. Recent geological mapping and the drilling of cored boreholes at Fulbeck have enabled the detailed stratigraphy of the Lower and Middle Lias to be unravelled, and a new lithostratigraphic classification has been developed. The succession in the Vale of Belvoir is closely similar to that at Fulbeck, though there is a slight thickness increase. For the higher part of the Lias Group (Marlstone Rock Bed and Upper Lias), the present state of knowledge is briefly reviewed.

This paper arises from the author's lecture to the East Midlands Geological Society (1 July 1989) and a subsequent field excursion (28 October 1990; see Brandon, this issue).

Although the Lias is well exposed on the coast in Yorkshire, Dorset and South Wales, natural exposures are scarce inland. Quarry sections are restricted to specific parts of the sequence of economic interest, and cored boreholes are generally few and far between. For these reasons, in large parts of the country, the sequence is still very poorly known. Until recently, this was the case in the area discussed here (Fig. 1).

Prior to the work described below, virtually the only modern studies of the Lias of the region had been carried out by the late Sir Peter Kent. Between 1936 and 1941 he worked on oil exploration in central and southern England, including the Carboniferous petroleum prospects of Eakring and the Vale of Belvoir. During this period he examined many uncored exploration boreholes which penetrated the Lias. He also examined old quarries and temporary exposures and did some mapping near Foston and Long Bennington [SK 85 42]. Building on previous work by the Geological Survey (Jukes-Browne, 1885;

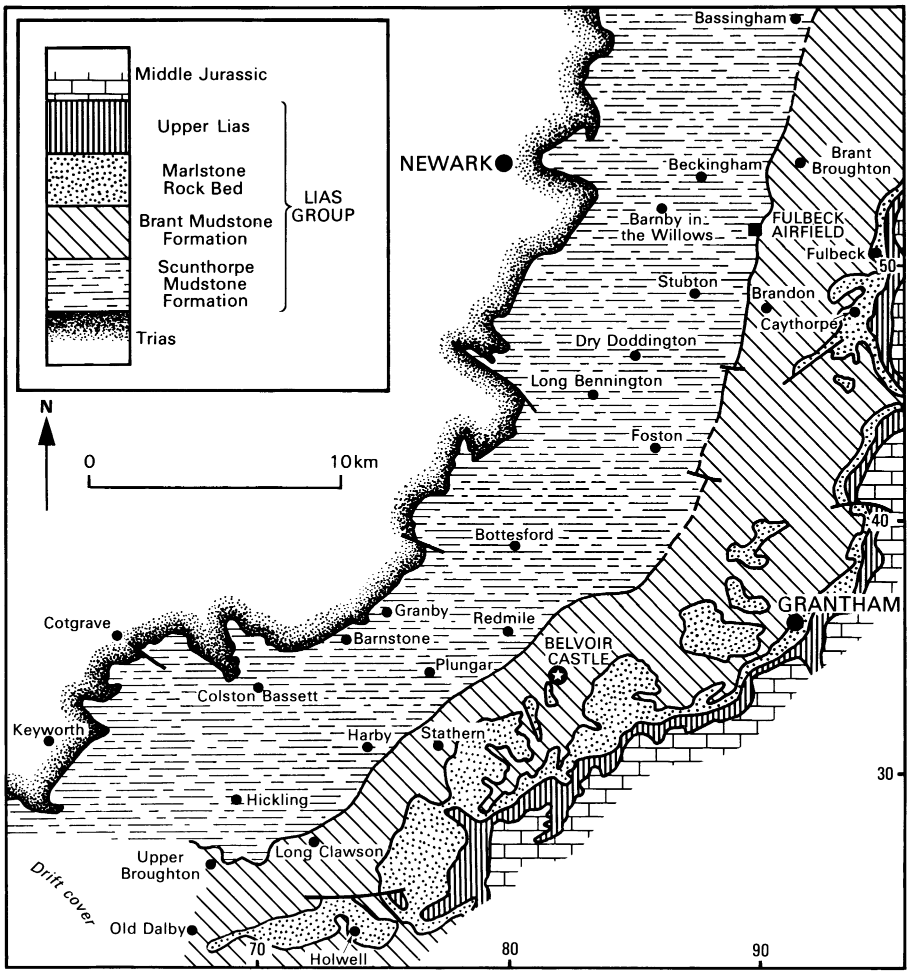


Fig. 1. Location of study area showing localities named in the text. The Vale of Belvoir comprises the area of Lias outcrop lying approximately between Old Dalby and Long Bennington.

Woodward, 1893; Lamplugh *et al.*, 1909) and Trueman (e.g. 1918), he established a lithostratigraphic scheme for the Vale of Belvoir and south Lincolnshire (Swinnerton and Kent 1949, 1976; see Fig. 2), which formed the essential framework for all subsequent work (Hallam, 1968; Cope *et al.*, 1980; Kent, 1980). In addition, he published many short papers on the local geology (1937, 1964, 1973, 1974) and left a considerable volume of manuscript notes, now held by the British Geological Survey (BGS).

Despite the undoubted value of Kent's work, the lack of modern geological maps and cored boreholes in the area meant that details of much of the sequence remained unknown. This situation was remedied in 1986, when UK Nirex Ltd selected the largely disused Fulbeck Airfield [SK 900 510], on the Lower Lias east of Newark, as a possible disposal site for radioactive waste. BGS was commissioned to carry out a geological survey of a large area around the site and a detailed site investigation of the airfield itself was undertaken by Sir Alexander Gibb and Partners. This involved trenching and the drilling of over 70 cored boreholes through the lower part of the Lias. Halved cores and specimens from two of these, F/B1 [SK 8889 5053] and F/B5 [SK 9062 5076], are now stored at BGS, Keyworth.

As a result of the work at Fulbeck, a new lithostratigraphic scheme for the beds between the base of the Lias Group and the base of the Marlstone Rock Bed was developed (Brandon *et al.*, 1990) and is summarised below. Subsequently, survey of the Lias outcrop of BGS 1:50 000 Sheets 126 (Nottingham) and 127 (Grantham) has continued south-westwards from the Fulbeck area into the Vale of Belvoir. Together with information from boreholes, this work has confirmed that the sequence in the Vale is essentially the same as that at Fulbeck, except for a slight overall thickness increase.

Nature and subdivision of the Lias

The Lias Group is a sequence of marine beds which, except for the very basal beds, is of Early Jurassic age. It is underlain by the Triassic Penarth Group (the former Rhaetic) and is overlain by the Middle Jurassic Inferior Oolite Group (Powell, 1984). In the area considered here, most of the Lias sequence comprises dark grey, shaly mudstone containing occasional beds of medium grey, harder, more calcareous mudstone. Limestones make up only a small proportion of the total thickness of the Lias and occur as sporadic nodules or as thin bands which, with the exception of the Marlstone Rock Bed, are seldom more than 0.2 or 0.3m thick. Despite their thinness, many are laterally very persistent, and can be traced for many kilometres. They include both primary limestones and secondary, diagenetic types (Hallam, 1964), the latter often passing laterally into bands of nodules.

Some beds in the Lias are highly fossiliferous. Generally, the fauna is dominated by bivalves, of which *Gryphaea* is conspicuous in the lower part of the sequence. Gastropods, belemnites, crinoids and brachiopods all occur commonly at certain levels, but for the stratigrapher, the most important fossils are ammonites which are the basis of the standard zonation (Fig. 2).

All of the deep boreholes at Fulbeck airfield were geophysically logged. For correlation purposes, the sonic and gamma ray logs proved most useful (Fig. 3). The sonic log measures the speed of travel of seismic waves, which is broadly a measure of rock hardness. In the Lias, this is governed principally by calcium carbonate content. The gamma ray log measures the minute amount of natural radioactivity which is present in all rocks. In sedimentary rocks, higher gamma ray counts tend to be associated with mudstones, and are reduced by an increase of calcium carbonate. Gamma ray logs from some of the British Coal boreholes in the Vale of Belvoir have been used as an aid to correlation; in most cases, individual beds can be recognised, and some can be traced into south Leicestershire, Warwickshire and Northamptonshire.

The Lias Group has traditionally been divided into Lower, Middle and Upper Lias. As originally conceived, these were lithostratigraphic units, but they have tended to become inextricably linked to the chronostratigraphic stages and substages; the Lower Lias with the Hettangian, Sinemurian and Lower Pliensbachian, the Middle Lias with the Upper Pliensbachian, and the Upper Lias with the Toarcian (Fig. 2). To avoid these chronostratigraphic connotations, the old stratal divisions of Lower and Middle Lias have been abandoned. Instead, the sequence below the Marlstone Rock Bed is divided into two new lithostratigraphic formations, the Scunthorpe Mudstone and the Brant Mudstone (Brandon *et al.*, 1990). Together they total about 220m in thickness. A comparable revision for the Marlstone Rock Bed and Upper Lias would be appropriate, but the traditional names are retained pending completion of the necessary detailed study.

Scunthorpe Mudstone Formation

The Scunthorpe Mudstone Formation (Gaunt *et al.*, 1992), forms the lower part of the Lias Group. It is 113m thick at Fulbeck and about 128m in the western part of the Vale of Belvoir, and comprises alternate units of mudstone with thin limestones, and mudstones in which limestones are rare or absent. These units constitute the five component members of the formation.

Barnstone Member (8 to 10m)

The Barnstone Member forms the basal unit of the Lias Group and consists of mudstones alternating with clayey limestones; the latter make up about 30% of the sequence. It forms a prominent feature which can be traced easily through the drift-free ground between Cotgrave [SK 66 35] and Newark [SK 82 54]. Individual limestone beds are typically 0.1 to 0.2m thick. Those in the lowest 2 to 3m are rich in shell debris, suggesting a moderately high energy environment, but most of the others are markedly laminated and form a characteristic flaggy brash in the fields. The intervening mudstones also include a large proportion of finely laminated, bituminous shales ("paper shales"), which are generally quite rare in the Lias. These laminated beds suggest deposition in very quiet anaerobic conditions, perhaps

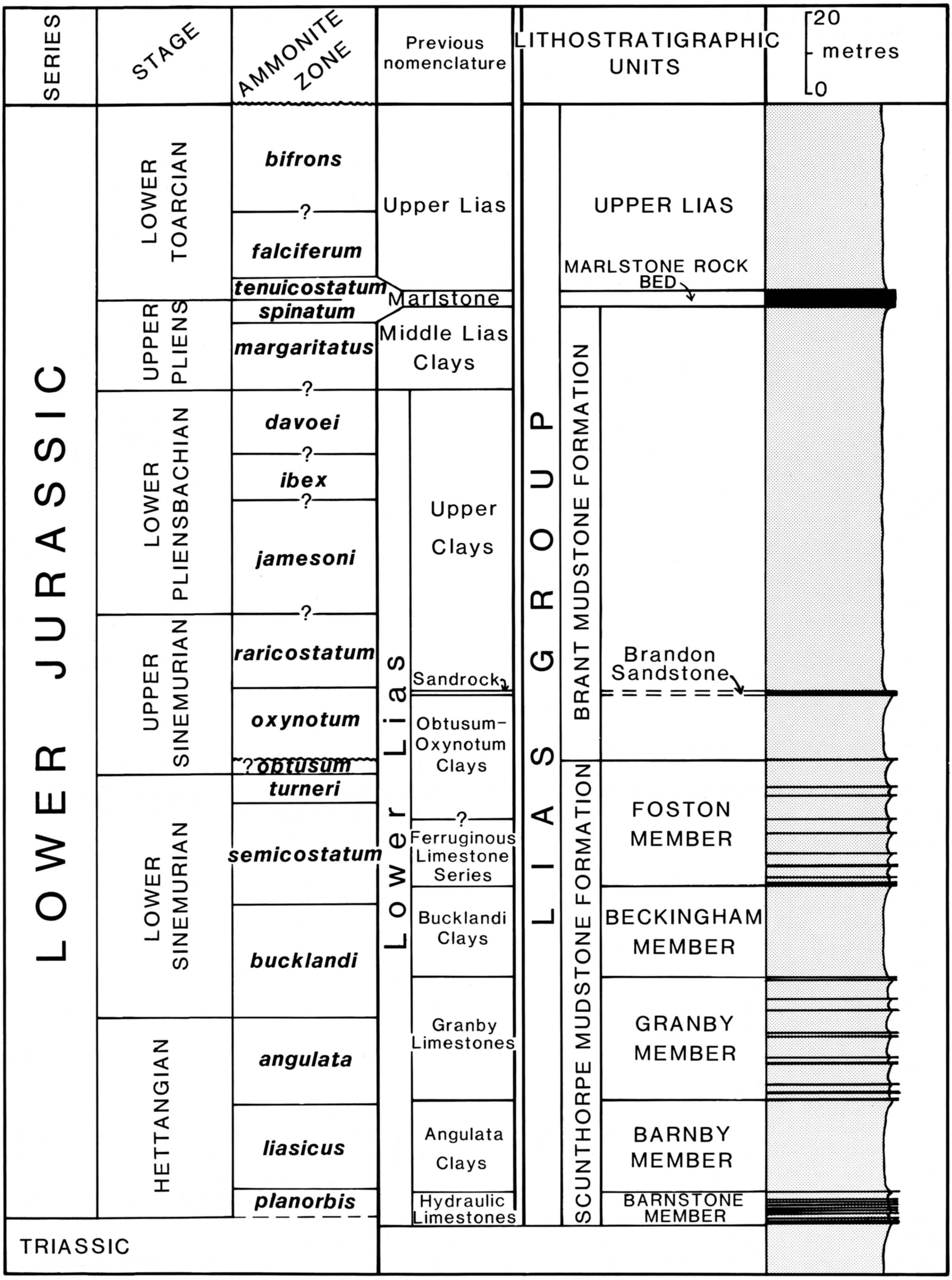


Fig. 2. Stratigraphical classification of the Lias Group in the study area.

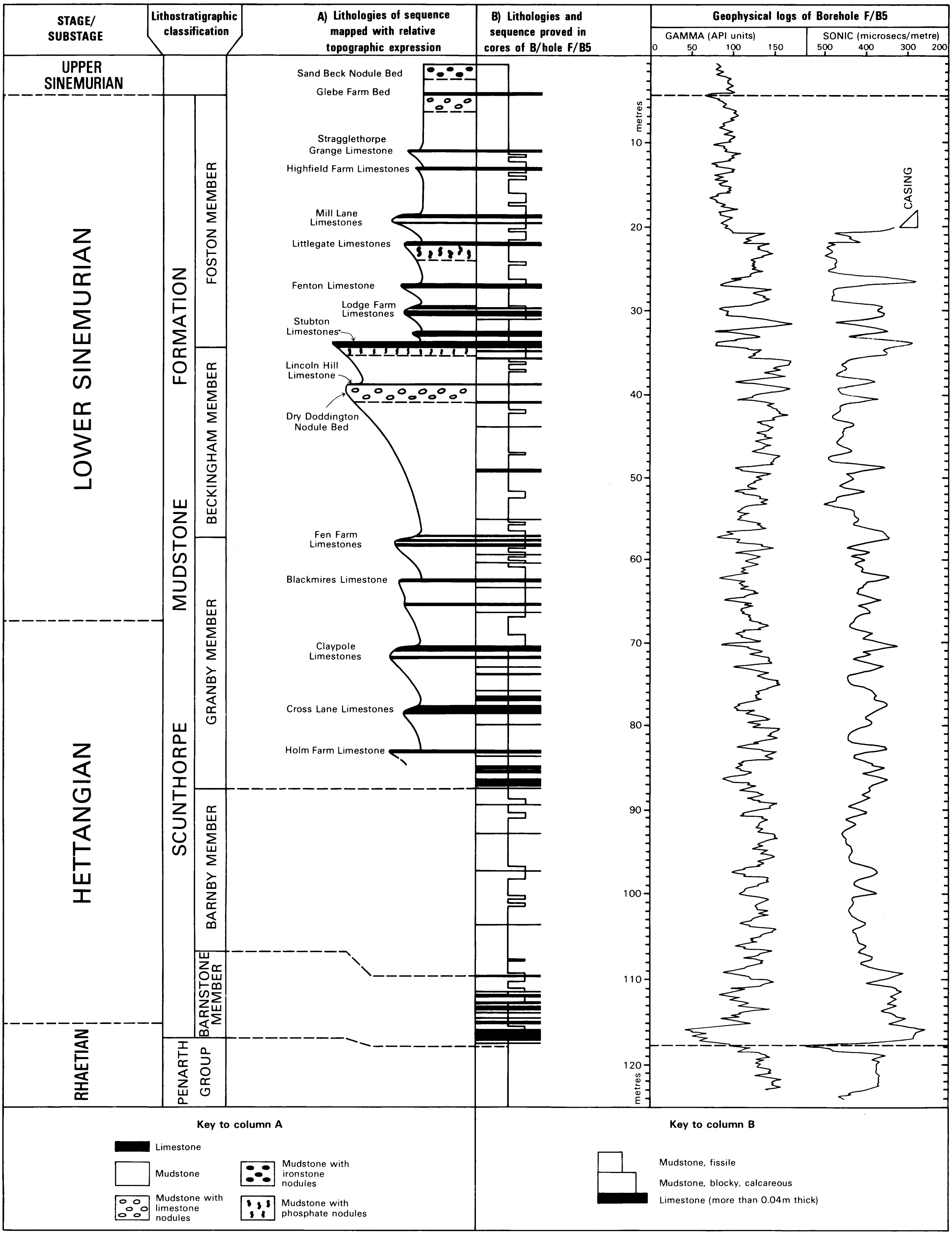


Fig. 3. Lithostratigraphy of the Scunthorpe Mudstone Formation. In columns A and B, the succession determined by mapping is compared with that proved in cores and by geophysical logs of Borehole F/B5. No grain-size variation implied. (Reproduced, with minor modification, from Brandon *et al.*, 1990, by permission of the Yorkshire Geological Society.)

on a wide, shallow shelf with negligible wave and current action. As might be expected, the fauna of the Barnstone Member is generally rather sparse, and the laminated bituminous shales lack bottom-living fauna, but occasionally contain abundant fish and insect debris and remains of marine reptiles such as plesiosaurs and ichthyosaurs.

The Barnstone Member was formerly known as the "Hydraulic Limestones", but because this name has been used elsewhere for beds of different age, the Member has been renamed after the village of Barnstone in the Vale of Belvoir [SK 734 354]. This is one of many sites along the outcrop where the beds were formerly quarried for building stone and cement making. The old name refers to the manufacture of hydraulic cement, i.e. Portland cement (which sets under water) for which the limestones (or "cementstones") had the ideal lime/silica composition. This industry eventually succumbed to competition from more efficient operations elsewhere, and all the quarries are long since disused and most are infilled. However, a few metres of strata are still exposed in a flooded quarry [SK 734 349] opposite the Blue Circle offices at Barnstone. A complete section of the member at this quarry was published by Kent (1937). Geophysical borehole logs indicate that individual beds in the Barnstone Member can be correlated throughout the region. However, correlation of published sections (e.g. Kent, 1937, 1964) is often more difficult; in part, this may be due to the passage of some limestone beds into nodule bands.

The Barnstone Member is largely of early Jurassic *Psiloceras planorbis* Zone age. However, the basal beds, at least 1.6m thick at Barnstone (Sykes *et al.*, 1970) and 2.7m at Fulbeck, have so far yielded no ammonites and are therefore currently classified with the Triassic (Rhaetian) (see Torrens, *in* Cope *et al.*, 1980).

Barnby Member (22 to 24m)

The Barnby Member consists of grey mudstones with a few thin, impersistent clayey limestones and nodule bands. Formerly known as the Angulata Clays, the member is actually almost entirely of *Alsatites liasicus* Zone, not *Schlotheima angulata* Zone, age. For this reason, it was renamed following Kent's (*in* Swinnerton and Kent, 1976) usage of the term "Barnby Clays", which derives from the village of Barnby in the Willows [SK 857 522], where, in 1940, Kent (in manuscript) recorded a section in the large Shire Dyke which extends southwestwards from the village. Fossils are mainly bivalves and, in the upper part of the member, include the earliest *Gryphaea* in the local sequence.

Granby Member (30 to 32m)

Kent (*in* Swinnerton and Kent, 1949) introduced the name Granby Limestones, having examined a section through the member in trenches south of Granby in 1940 (Kent, in manuscript). Although Kent's section, totalling some 20m of strata, cannot be reliably correlated, boreholes show that the sequences at Fulbeck and in the Vale of Belvoir are almost identical. The Granby Member consists of mudstones with many thin limestones, mostly 0.1 to 0.15m thick. The limestones make up less than 15% of the sequence (far less than in the Barnstone Member), and occur in five main groups of several closely-spaced limestones separated by intervals of a few metres of mudstone. Each group of limestone beds produces a minor dip and scarp feature with associated brash, by which it can be mapped. In contrast to the limestones of the Barnstone Member, those in the Granby Member are fairly well sorted, sparry, shell-fragmental limestones, representing periodic episodes of higher energy, possibly the result of storm-generated currents.

The top of the Granby Member is marked by a group of limestones (the Fen Farm Limestones) which forms a readily recognised marker because one, at least, of the beds contains abundant crinoid debris.

Beckingham Member (22 to 27m)

The Beckingham Member was formerly known as the Bucklandi Clays (Swinnerton and Kent, 1949) though it actually extends up from the *Arietites bucklandi* Zone into the *Arnioceras semicostatum* Zone. It is renamed after the village of Beckingham [SK 876 538]. It consists almost entirely of bluish grey shaly mudstones, with a very few thin limestones. Near the top, the Dry Doddington Nodule Bed consists of 2 to 3m of mudstone containing scattered limestone nodules, and is sandwiched between two thin shelly limestone beds. The nodules weather to a characteristic ochreous yellow colour, and are sometimes packed with small *Modiolus*.

The mudstones in the topmost 1m or so of the member contain abundant, small, fawn-weathering phosphatic nodules. These mudstones and a similar phosphatic nodule bed higher in the sequence have been worked in the past. The pits were probably dug to procure mudstone for brick-making, but the phosphatic nodules may possibly have been sought for fertilizer manufacture.

Foston Member (30 to 34m)

The Foston Member, named after the Foston Beck, east of Foston village, [SK 859 429], consists of grey mudstones with thin limestone beds which make up about 10% of the sequence. As in the Granby Member, the limestones are typically 0.1 to 0.2m thick, and occur in groups which form mappable dip and scarp features. The Foston Member is approximately equivalent to the "Ferruginous Limestone Series" of Swinnerton and Kent (1949), although this was never properly defined.

The base of the Foston Member is defined by the Stubton Limestones which include the only markedly ferruginous bed in the sequence; this corresponds with the Lower Ferruginous Limestone or Plungar Ironstone at the base of the "Ferruginous Limestone Series". The top of the "series" was said to be defined by the Upper Ferruginous Limestone, but this bed was never firmly identified. In the Vale of Belvoir, Lamplugh *et al.* (1909) may have considered it to be the Brandon Sandstone (Sandrock) though their quoted fossil evidence suggests a much lower level, within the *Arnioceras semicostatum* Zone (Fig. 2).

The Stubton Limestones form a prominent feature with a well-developed dip-slope. They comprise two to four beds of limestone of varying thickness interbedded with mudstone, together occupying a vertical interval of up to 2.5m. The lower limestones are impersistent, probably secondary, cementstones. However, the upper bed, about 0.6m thick, is persistent and very distinctive. Seen fresh in boreholes, it is a brown and grey mottled, bioclastic sparry limestone with many *Gryphaea*. Characteristically, it contains a scattering of brown, ferruginous (geothite and siderite) ooliths. The whole bed is ferruginous and weathers to an orange-brown colour with irregular, limonitic veins and patches.

Higher limestones in the Foston Member are all shelly and bioclastic limestones, each having individual characteristics by which it can be recognised in the field. One bed (the Highfield Farm Limestone) is distinguished by its high pyrite content.

From the Fenton Limestone upwards (Fig. 3), all the limestones contain a proportion of quartz silt or sand. This increases in abundance north-eastward through the Vale, and at Fulbeck some of the beds are best classified as calcareous sandstones. The sandiness becomes even more pronounced northwards into Lincolnshire, implying a northerly source. These sandy beds are the same age as the Frodingham Ironstone of the Scunthorpe area.

Between the Highfield Farm Limestone (*Caenisites turneri* Zone) and the base of the Brant Mudstone Formation (*Oxynoticeras oxynotum* Zone) no age-diagnostic faunas have been obtained. This gives a maximum of only 8m for the intervening *Asteroceras obtusum* Zone. Although Trueman (1918) recorded this zone from the Old Dalby railway tunnel [SK 684 234], it may actually be absent here (Kent, 1973). The thin development or local absence of the zone may be due to erosion preceding deposition of the Brant Mudstone Formation.

Brant Mudstone Formation

The Brant Mudstone Formation (Fig. 4) comprises the strata between the top of the Scunthorpe Mudstone Formation and the base of the Marlstone Rock Bed. It is named after the River Brant, which flows across its outcrop in the Fulbeck area. The sequence was established entirely from mapping and study of geophysical logs of coal exploration boreholes, as initially no borehole cores were available. Subsequently, the entire formation has been cored by the BGS Copper Hill Borehole at Ancaster [SK 9787 4265]. These cores are currently being examined and details will be published in due course.

From mapping, the formation is estimated to be 110m thick near Fulbeck and is about 150m in the south-western part of the Vale of Belvoir. It is made up of grey mudstones with many levels containing limestone, phosphatic or sideritic (ironstone) nodules, but the persistent limestone beds which characterise the Scunthorpe Mudstone are rare. The base is marked by the Glebe Farm Bed, about 0.4m thick. The lower part of the bed is a bioclastic limestone similar to those in the underlying Foston Member, but the upper (and greater) part is a distinctive brown, highly ferruginous limestone packed with geothite ooliths. The Glebe Farm Bed contains bored limestone and phosphatic pebbles which appear to be reworked nodules, suggesting an erosional relationship with the underlying strata. The bed has the same pebbly character throughout the Midlands and marks a regional non-sequence corresponding with that at the top of the Frodingham Ironstone. The rock contains a few shells, including the robust bivalve *Hippopodium*.

The Sand Beck Nodule Bed, 1 or 2m higher in the sequence has been identified in ditch dredgings across the Vale of Belvoir. It consists of 3 to 5m of grey mudstone with small red and brown-weathering sideritic ironstone nodules, many containing attractive specimens of the ammonite *Gagaticeras* indicating the *Oxynoticeras oxynotum* Zone.

The Brandon Sandstone, some 16m above the base of the formation, was formerly known as the Sandrock, but is renamed after a village [SK 903 483] near Fulbeck airfield. It forms virtually the only mappable feature in the Brant Mudstones, and can be traced from Fulbeck through the Vale of Belvoir as far as Upper Broughton [SK 684 262]. It is probably about 1m thick, perhaps rather less in south-western parts of the Vale, and is a slightly muddy fine-grained calcareous sandstone, which weathers down to a brown loam. Where seen as blocks dredged from the River Brant, it contains common bivalves, often concentrated in lenses, though near the top there are frequent large myids in life position.

The beds immediately below the Brandon Sandstone contain a proportion of fine-grained sand, and may locally include one or more thin impersistent sandstones. They were formerly worked for brick and tile-making at Hougham [SK 893 451] and Brant Broughton [SK 914 531]; this stratum was probably favoured because the sand content prevented undue shrinkage on firing.

The beds above are predominantly mudstones, which at several levels contain large limestone nodules. These occasionally contain ammonites indicating the *Echioceras raricostatum* Zone. About 20m above the Brandon Sandstone, the Loveden Gryphaea Bed comprises about 2m of *Gryphaea*-rich mudstone and associated shelly limestones of *Uptonia jamesoni* Zone age, which can be traced throughout the region. This stratum probably corresponds with the "70" geophysical marker of the south Midlands (Horton and Poole, 1977). The overlying 25m or so of mudstones contain abundant brown and red-weathering sideritic ironstone nodules, often with a concentric structure. The higher part of this interval includes thin shelly ironstones and platy limestones which may correlate with the Pecten Ironstone, a highly condensed bed near the base of the *Tragophylloceras ibex* Zone in north Lincolnshire (Gaunt *et al.*, 1992). Geophysical logs of boreholes suggest correlation of these beds with the "85" geophysical marker of the south Midlands, though the ammonite zonation seems to indicate the latter to be younger.

The highest beds of the formation form the steep scarp slope which forms the southern and eastern boundary of the Vale of Belvoir. These beds include strata of *Prodactylioceras davoei* Zone age, overlain by about 20m of so-called "Middle Lias" (i.e. strata of *Amaltheus margaritatus* Zone age). The latter are included in the Brant Mudstone Formation because, at Fulbeck, their lithology is not sufficiently different from that of underlying beds for a boundary to be mapped. Site investigation boreholes near Leadenham [SK 950 510] indicate that the beds are, however, slightly more silty and micaceous than the bulk of the Brant Mudstone. The sequence in the Copper Hill Borehole 10km to the south-east is significantly more silty, and in more southerly parts of the Midlands, silts and sands are developed at this level.

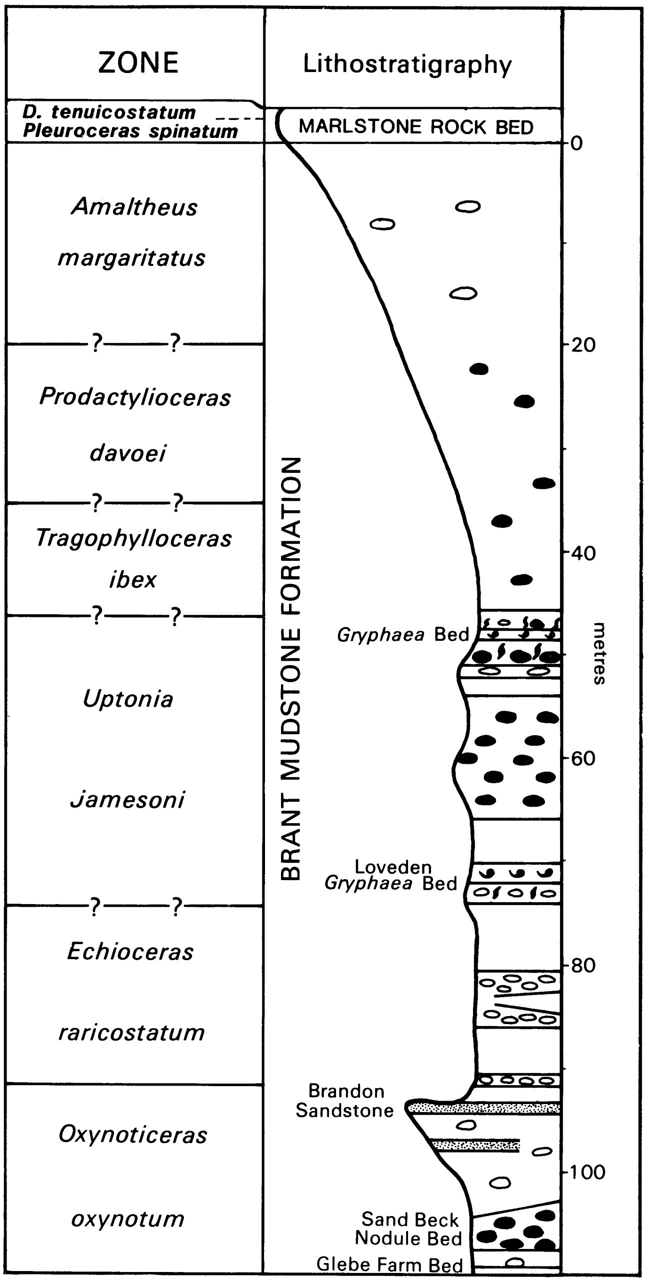


Fig. 4. Lithostratigraphy and biozonation of the Brant Mudstone Formation and Marlstone Rock Bed. Key as Fig. 3: stipple indicates sandy beds.

Marlstone Rock Bed

The Marlstone Rock Bed (actually a unit of formation status) forms a bench capping the major escarpment which rises to about 45m above the clay ground of the Vale of Belvoir, and for this reason is the most prominent unit of the Lias Group in the region. It is up to about 10m thick south of the Vale, 4.7m in the Copper Hill Borehole, and 3m thick at Fulbeck, but at Welbourne [SK 968 547] a few kilometres to the north it thins to zero and does not reappear until well north of Lincoln. Where absent, its horizon is marked by a thin bed with phosphatic pebbles. Ammonite evidence suggests that the thinning is due to condensation though there may be a slight erosive non-sequence at the base of the overlying Upper Lias.

The Marlstone Rock Bed is largely of *Pleuroceras spinatum* Zone age but at some localities the upper part includes strata of earliest Toarcian *Dactylioceras tenuicostatum* Zone age. These latter beds, 1.2m thick at Harston [SK 843 305] near Belvoir Castle, include the so-called "Transition Bed". This is the topmost part of the Marlstone modified by weathering which took place prior to deposition of the overlying beds (Howarth, 1980). The "Transition Bed" is included in the Upper Lias in some accounts (e.g. Hallam, 1968) because of its Toarcian age.

The Marlstone Rock Bed is a sandy, shell-fragmental oolitic limestone, often with a basal sandstone ("sandrock"). It contains a fauna mainly of bivalves and brachiopods, the latter sometimes occurring abundantly in "nests". Lenses of crinoid debris occur at some localities, and belemnites are also common, particularly near the top. When fresh, it is greyish green due to the presence of chamosite, which is the principal component of the ooliths.

Iron is also present throughout the rock as siderite. Weathering and oxidation of the iron produces a warm brown colour, making it an attractive building stone, widely used in the villages of the Vale.

The Marlstone Rock Bed was formerly the basis of a flourishing iron-ore industry. It has been extensively quarried throughout the area, and it is still exposed at many localities, of which the best is probably Brown's Hill Quarry, Holwell [SK 742 233] (Clements, 1989). When fresh, it has a very modest iron content, but in the weathered zone, oxidation and decalcification increases this to 30% or more. For this reason, quarrying normally ceased when the overburden reached 3m or so, and only at Holwell was it mined underground; here the old adits can still be seen in the quarry. Lamplugh *et al.* (1920) and Whitehead *et al.* (1952) described sections and the history of production.

Upper Lias

During mapping at Fulbeck, only a small area of Upper Lias was surveyed and very little new information was obtained. Since then, the Copper Hill Borehole has proved the entire sequence which will be described elsewhere; only brief details are given here.

The Upper Lias forms the slope, capped by the Middle Jurassic beds, which rises above the Marlstone

Rock Bed shelf. It is probably about 35m thick in the Holwell area, but is 45m at Copper Hill and Fulbeck. Northwards, it thins to only 15m at the Humber. This is the result of an unconformity at the base of the overlying Middle Jurassic, which cuts down onto progressively older beds of the Upper Lias: in our area only Lower Toarcian beds are present (Fig. 2).

The Upper Lias consists of blue-grey mudstones with little in the way of lithological variation to permit subdivision. Trueman (1918) gave a generalised section for the Grantham area based on various temporary sections together with that at Rudd's Brickyard [*c.* SK 910 352] west of the railway station, now lost beneath building development. His section amounts to 35m and consists dominantly of grey shales with scattered limestone nodules.

The basal few metres of the Upper Lias are seldom well exposed, but can still be seen in a few places in old Marlstone Rock Bed workings and in some of the associated railway cuttings (e.g. at Holwell [SK 742 233] and Caythorpe [SK 949 469]). These beds, of *Harpoceras falciferum* Zone age, are dominated by finely laminated, fissile bituminous shales. This facies is similar to the paper shales of the Barnstone Member and likewise contains occasional fish and insect remains, and also ammonites and belemnites, but a very restricted benthic fauna.

Conclusions

Geological mapping, first at Fulbeck and subsequently further into the Vale of Belvoir, has shown that the Lias is divisible into a number of units of distinctive lithological and faunal character. The information within this short paper should be sufficient for the reader to be able to identify the formations and members on the ground. Those wishing for more detailed bed descriptions and faunal lists are referred to the account by Brandon *et al.* (1990).

Acknowledgements

Thanks are due to Drs A. Brandon and H. C. Ivimey-Cook, my co-workers on the Fulbeck project, without whose contribution this account would not have been possible. I am also grateful to Drs R. A. Bazley and N. G. Berridge for their useful comments on the text. Fig. 3 is reproduced by permission of the Yorkshire Geological Society. This paper is published by permission of the Director, British Geological Survey (NERC).

References

Brandon, A., Sumbler, M. G. and Ivimey-Cook, H. C., 1990. A revised lithostratigraphy for the Lower and Middle Lias (Lower Jurassic) east of Nottingham, England. *Proceedings of the Yorkshire Geological Society*, **48**, 121-141.

Clements, R. G., 1989. Tailor-made geology 4: Brown's Hill Quarry, Holwell Leicestershire. *Geology Today*, **5**, 28-30.

Cope, J. C. W., Getty, T. A., Howarth, M. K., Morton, N., and Torrens, H. S., 1980. *A correlation of Jurassic rocks in the British Isles. Part 1: Introduction and Lower Jurassic*. Geological Society of London, Special Report No. 14.

Gaunt, G. D., Fletcher, T. P. and Wood, C. J., 1992. *Geology of the country around Kingston upon Hull and Brigg*. Memoir British Geological Survey, sheets 80 and 89.

Hallam, A., 1964. Origin of the limestone-shale rhythm in the Blue Lias of England: a composite theory. *Journal of Geology*, **72**, 157-169.

Hallam, A., 1968. The Lias. *In* Sylvester-Bradley, P. C. and Ford, T. D. (Eds) *The geology of the East Midlands*. Leicester University Press, 188-210.

Horton, A. and Poole, E. G., 1977. The lithostratigraphy of three geophysical marker horizons in the Lower Lias of Oxfordshire. *Bulletin of the Geological Survey of Great Britain*, **62**, 13-24.

Howarth, M. K., 1980. The Toarcian age of the upper part of the Marlstone Rock Bed of England. *Palaeontology*, **23**, 637-656.

Jukes-Browne, A. J., 1885. *The geology of the south-west part of Lincolnshire with parts of Leicestershire and Nottinghamshire*. Memoir Geological Survey, Old Series Sheet 70.

Kent, P. E., 1937. The Lower Lias of south Nottinghamshire. *Proceedings of the Geologists' Association*, **48**, 163-174.

Kent, P. E., 1964. The basal Lias near Long Bennington. *Transactions of the Lincolnshire Naturalists' Union*, **16**, 20-22.

Kent, P. E., 1973. The Lias at Old Dalby, Leicestershire. *Transactions of the Leicestershire Literary and Philosophical Society*, **67**, 39-44.

Kent, P. E., 1974. A Lower Lias section in the River Till, Lincolnshire. *Mercian Geologist*, **5**, 143-144.

Kent, P. E., 1980. *Eastern England from the Tees to The Wash. British Regional Geology* (2nd Edition). HMSO, London.

Lamplugh, G. W., Gibson, W., Wedd, C. B., Sherlock, R. L. and Smith, B., 1909. *The geology of the Melton Mowbray district and south-east Nottinghamshire*. Memoir Geological Survey, Sheet 142.

Lamplugh, G. W., Wedd, C. B., and Pringle, J., 1920. *Bedded ores of the Lias, Oolites and later formations in England. Special reports on the mineral resources of Great Britain, Vol. 12*. Memoir Geological Survey.

Powell, J. H., 1984. Lithostratigraphical nomenclature of the Lias Group in the Yorkshire Basin. *Proceedings of the Yorkshire Geological Society*, **45**, 51-57.

Swinnerton, H. H. and Kent, P. E., 1949. *The geology of Lincolnshire*. Lincolnshire Natural History Brochure no. 1 (1st edition). Lincolnshire Naturalists' Union, Lincoln.

Swinnerton, H. H. and Kent, P. E., 1976. *The geology of Lincolnshire from the Humber to The Wash*. Lincolnshire Natural History Brochure no. 7 (2nd edition). Lincolnshire Naturalists' Union, Lincoln.

Sykes, J. H., Cargill, J. S. and Fryer, H. G., 1970. The stratigraphy and palaeontology of the Rhaetic Beds (Rhaetian: Upper Triassic) of Barnstone, Nottinghamshire. *Mercian Geologist*, **3**, 233-264.

Trueman, A. E., 1918. The Lias of south Lincolnshire. *Geological Magazine*, Dec. 6, 5, 64-73; 100-111.

Whitehead, T. H., Anderson, W., Wilson, V. and Wray, D. A., 1952. *The Mesozoic Ironstones of England — The Liassic Ironstones*. Memoir Geological Survey.

Woodward, H. B., 1893. *The Jurassic Rocks of Britain. Vol. 3: The Lias of England and Wales (Yorkshire excepted)*. Memoir Geological Survey.

Michael G. Sumbler
British Geological Survey
Keyworth
Nottingham
NG12 5GG

EXCURSION

Traverse across the "Lower Lias" south-east of Newark, Nottinghamshire

Leaders: A. Brandon, H. C. Ivimey-Cook and M. G. Sumbler, British Geological Survey, Keyworth, Nottinghamshire.

28th October 1990

Most of the data required for the compilation of lithological sequences and BGS geological maps in lowland Britain comes not from the study of well exposed rock sections, or borehole and mining information, but from an appreciation of the disposition of surface landforms and associated soil types, i.e. from a study of the geomorphology. By walking a west to east traverse over ploughed land across much of the outcrop of "Lower and Middle Lias" rocks from near Claypole to Caythorpe, east of Newark, it was proposed to demonstrate, or at least get a flavour of the following:

i. the nature and detailed lithostratigraphy of the "Lower and Middle Lias" rocks as recently revised for the ground east of Nottingham (Brandon *et al.*, 1990; see also Sumbler, herein).

ii. that very detailed geological maps can be made in an area with little or no exposure by studying the disposition of low relief landforms (features or cuesta) here formed by gently inclined limestones and rare sandstones within the softer "Lower Lias" mudstones. By augmenting the data with evidence from ditch dredgings, the method allows a three-dimensional model of the surface rocks, including dip directions, dip values and the nature and position of faults, to be established with a high degree of confidence.

iii. that by collecting fossils from the brash of the harder rocks on dip-slopes and from ditch dredgings a reliable biostratigraphy can be added to the lithostratigraphical framework.

In addition, it was intended to demonstrate the existence of an abandoned river course at Fulbeck dating from the last interglacial period.

The party of about 30 people, mostly arriving by coach from Nottingham, assembled at Oyster Lane (SK 8568 4976), Claypole at around 11.00 hrs. The day was fine, but there was a biting cold wind blowing across the Lias plain. After an introductory briefing in the coach the party set off across the fields on an easterly traverse (see Fig. 1). We first walked across the low features formed by three limestones in the Granby Member, namely the Claypole, Blackmires and Fen Farm limestones. The beds are much affected by a series of reverse ENE-WSW faults hereabouts (SK 86 49) and the offset and repetition of the features was demonstrated. Many fossils were collected loose on the dip-slopes of the three Granby limestones, including the rare colonial coral *Septastraea* from the Claypole Limestones (SK 8576 4950). The party then climbed a fairly steep bench-like feature produced by the Dry Doddington Nodule Bed and adjacent limestones in the Beckingham Member. The nodules are composed of grey, ochreous-yellow weathering, clayey limestone and are commonly crowded with small *Modiolus*. Just below the crest of the feature produced by the Stubton Limestones at the base of the Foston Member, small phosphate nodules were found weathered out from the mudstone. This is apparently the lowest bed of such phosphate nodules in the local sequence, though they become characteristic of the mudstones of the overlying Foston Member. Numerous fossils, especially *Gryphaea* and other bivalves, were collected from the extensive dip-slope of the overlying ferruginous Stubton Limestones, from immediately north (SK 876 498) of the village of Stubton. Proceeding eastwards, the party briefly saw brash of the Lodge Farm Limestone, collected numerous ammonites from ditch-dredged blocks of the Fenton Limestone (SK 884 497) and crossed the features of the Littlegate and Mill Lane Limestones.

The morning traverse finished near Stubton Gorse Farm (SK 890 497). Here, next to a pond dug through old river gravels, was displayed a huge block of typical sandy Mill Lane Limestone, full of *Chondrites* burrows, *Pseudopecten* and *Gryphaea*. This had been dug from the bottom of the pond. There was also a large block of Littlegate Limestone containing abundant beautifully preserved arnioceratid ammonities. The party was treated to a display of mammalian bones and teeth, including those of hippopotomus, the extinct straight-tusked elephant, the extinct narrow-nosed rhinoceros and bison or aurochs. This assemblage of bones was recovered from the gravels at the pond by the local farmer and is typical of the larger mammalian herbivore fauna that lived in Britain during the Ipswichian, or last interglacial period about 125,000 years ago, when the climate was not much different from that of today. The mammalian locality is one of several in the area where gravels of a now abandoned Ipswichian course of the River Witham have been dug. In a wider context, their discovery has enabled the chronology of the nearby River Trent terraces to be revised (Brandon and Sumbler, 1989). The party then adjourned for lunch to a pub at Caythorpe where the leaders readily accepted the offer of a round of drinks from committee members.

In view of the short daylight hours it was decided that the higher beds of the Foston Member at the top of the Scunthorpe Mudstone Formation should be omitted from the afternoon itinerary and the party commenced the afternoon by visiting the isolated 'type locality', near Hougham (SK 8872 4500) (Fig. 1, locality A), of the Glebe Farm Bed, which lies at the base of the Brant Mudstone Formation. The bed represents a renewal of deposition following a period of non-deposition and erosion. It contains numerous burrowed and reworked limestone and phosphate nodules derived from the underlying beds. Amongst the many fossils collected was the ammonite *Gagaticeras,* indicative of the *Oxynoticeras oxynotum* Zone. The eastwards traverse was then resumed along Sand Beck (from SK 8974 4851), west of the village of Brandon. Here numerous sideritic ironstone nodules from the Sand Beck Nodule Bed, the next higher unit in stratigraphical sequence, were examined from ditch dredgings and the ammonite *Gagaticeras* collected. Proceeding eastwards, the party crossed the broad feature formed by the Brandon

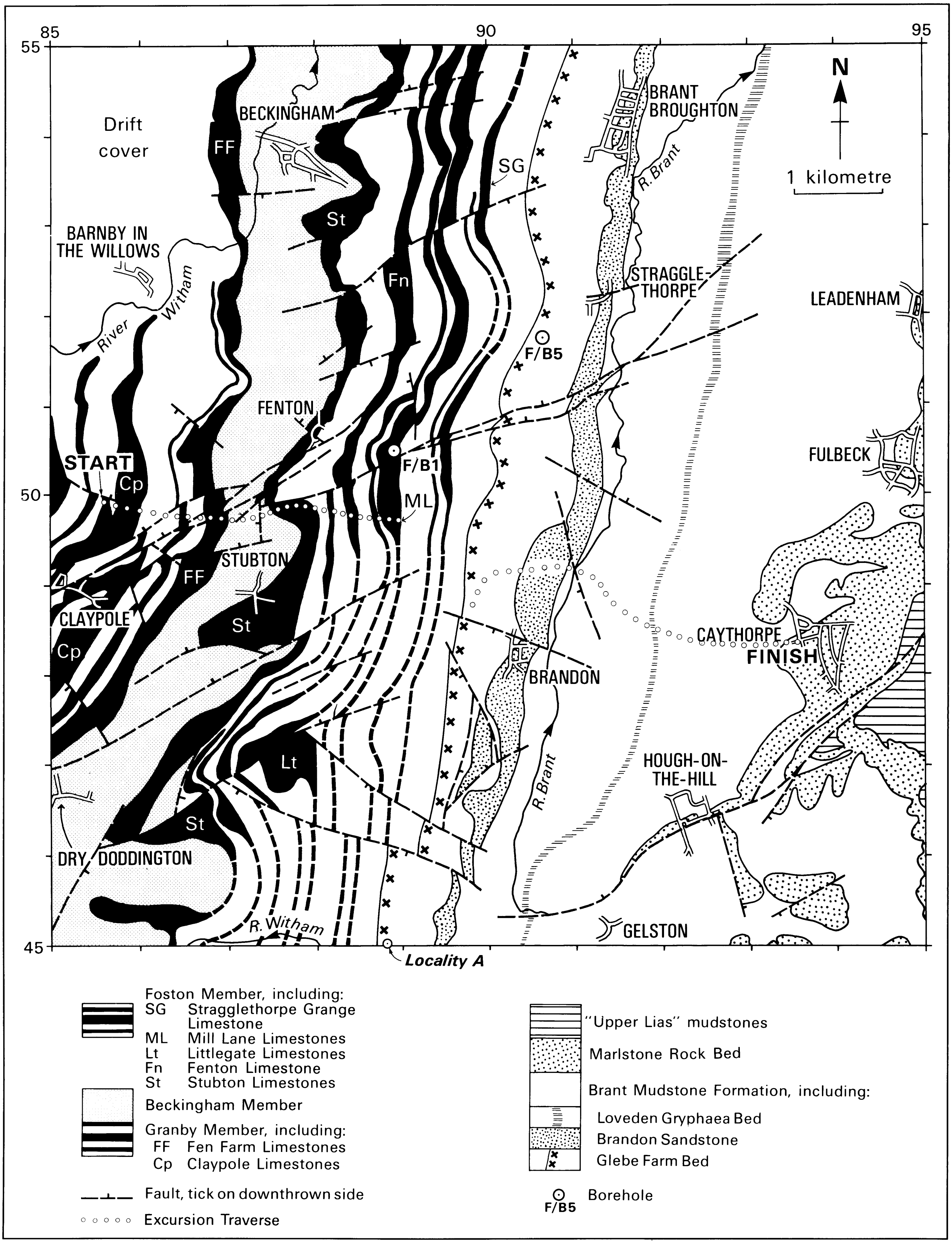


Fig. 1. Simplified geology of the Fulbeck area (from four BGS 1:10 000 geological maps by Brandon and Sumbler). Selected boreholes and faults are shown. The west to east traverse is indicated as well as locality A, the 'type locality' of the Glebe Farm Bed. Modified after Brandon *et al.* (1990) by permission of the Yorkshire Geological Society.

Sandstone or "Sandrock" and collected ammonites and other fossils from dredged blocks of typical calcareous sandstone along the River Brant (SK 9107 4920), north of Brandon. Of particular interest was a spiral burrow-fill, later to be identified by Dr Pemberton as *Gyrolites*, a trace fossil thought to have been formed by a crab-like creature.

Appreciation of the nodular beds higher in the Brant Mudstone sequence was spoiled by the rapidly failing daylight and, possibly, increasing tiredness. There followed a brisk climb along Wheatgrass Lane, up to the rising escarpment slope capped by the Marlstone Rock Bed, to a welcome rendezvous with the coach at Caythorpe (SK 9360 4835) at about 16.00 hrs.

Acknowledgements

The leaders would like to thank several farmers along the route, especially Mr D. Burtt of Stubton, for allowing free access to their ploughed land. They also express their gratitude to the officers of the Society for their kindness in subsequently laying on a superb Chinese meal.

This account is published by permission of the Director, British Geological Survey.

References

Brandon, A. and Sumbler, M. G., 1988. An Ipswichian fluvial deposit at Fulbeck, Lincolnshire and the chronology of the Trent terraces. *Journal of Quaternary Science,* 3, 127-133.

Brandon, A., Sumbler, M. G., and Ivimey-Cook, H. C., 1990. A revised lithostratigraphy for the Lower and Middle Lias (Lower Jurassic) east of Nottingham, England. *Proceedings of the Yorkshire Geological Society,* **48**, 121-141.

Allan Brandon,
British Geological Survey,
Keyworth,
Nottingham
NG12 5GG.

EXCURSION

Field excursion to Ramshaw Rocks and Chrome Hill

Leader: N. Aitkenhead, British Geological Survey, Keyworth, Nottinghamshire.

9th June 1991.

As it turned out, this excursion, advertised as "Chrome Hill and The Roaches", was not as ambitious as the title implies for it would have been impossible to do justice to both of these fine areas in one day. Fortunately, most of the 60 or so members and friends attending must also have read the itinerary in the circular before packing their sandwiches and waterproofs and realised it wasn't to be the gruelling marathon a clamber along the Roaches *and* an ascent of the Chrome Hill would have become.

En route to Ramshaw Rocks, the first objective, the coach took us for some eight miles along the summit of the long broad ridge of Morridge. This major feature, on the western limb of the north-south trending Mixon-Morridge Anticline, is formed by the combined resistant effects of a number of sequences of thinly bedded protoquartzitic turbidite siltstones and sandstones of Pendleian to Arnsbergian age (Namurian E_1-E_2), collectively known as the Minn Sandstones. At a suitable vantage point about halfway along the ridge (SK 0288 5961), the party briefly left the coach to view what must be one of the finest and most instructive landscapes in England for illustrating the inter-relationship of geology and scenery. In particular, to the north-west lies the southerly culmination of the Goyt Syncline (formerly known as the Goyt Trough), the longest and most clearly defined of all the major north-south trending folds that involve the Carboniferous rocks between the Derbyshire Dome and the Cheshire Plain. Before the view was obscured by the first heavy shower of the day, the feature that best reveals the synclinal culmination was pointed out. This comprises the craggy escarpments of the Roaches Grit forming the rim of the synclinal basin at the Roaches, Hen Cloud and Ramshaw Rocks. These face west, south and east respectively. At this viewpoint it was also suggested that members tried to imagine what this view would have been like some 20,000 years ago when the Devensian ice sheet would have extended from the slope just below, across the Cheshire Plain, to the western horizon.

The structure, stratigraphy and drift geology are also well illustrated by the geological maps of the area published by the British Geological Survey, namely the special 1:25 000 sheet SK06 (The Roaches and Upper Dove Valley) and the 1:50 000 sheet 111 (Buxton).

As our coach approached Ramshaw Rocks on the A53 Buxton-Leek road some of the party caught a glimpse of the famous Winking Man. This is not exactly what the name suggests but a trick of the light passing, apparently momentarily, through a hole in one of the outstanding buttresses, silhouetted against the sky when seen from a moving vehicle.

Leaving the coach on the A53 (0192 6193), a short walk took the party to the foot of the crags of Ramshaw Rocks where it was explained that from early Namurian (Pendleian, E_1) times river deltas had prograded from a general northerly direction into the Pennine region depositing thick sequences of coarse feldspathic sand to form successive formations of the Millstone Grit Group. However, it was not until late Kinderscoutian (R_{1C}) times that the first feldspathic sand reached this area of north-east Staffordshire. These earliest deposits took the form of turbidites at foot of the slope of the delta that deposited the Kinderscout Grit. Furthermore, it was not until the middle of the Succeeding Marsdenian Stage in R_{2b} times that the river channels of another great delta, prograding from the south-east but probably having its ultimate source far to the north, finally reached the region to deposit the Roaches Grit, a full fluvial-delta sequence.

The full sandstone-dominant sequence is estimated to be about 400m thick in the Roaches area (Aitkenhead *et al.*, 1985, fig. 33). It mostly comprises the Five Clouds Sandstones of mainly turbidite facies deposited in fans at the foot of the delta slope and the Roaches Grit itself, mainly of fluvial delta top facies.

The sedimentology of the crags before us had been studied by Dr Colin Jones (1980) who here recognised two major coarse sandstone lithofacies. These comprise 'giant cross-bedding in solitary sets' which can be up to 20m thick, and beds with faint lamination revealed by bands of small quartz pebbles which tend to occur at the bases of channels with well marked erosion surfaces. The main stop was at a point where such an erosion surface was well displayed at the base of a channel cut into giant cross-bedding from an earlier channel-fill (Fig. 1; see also Jones, 1980, pl. 2, fig. 1).

Before the party left this locality, Dr Aitkenhead invited Dr Bill Read to say how he saw the Roaches Grit in terms of the concept of sequence stratigraphy, the subject of his recent lecture to the Society and of an even more recent publication (Read, 1991). Dr Read pointed out that for several decades it has been accepted that the cyclical alternations of deltaic sand and marine mud that characterised Millstone Grit deposition were mainly due to eustatic sea level oscillations. The Roaches Grit was deposited in a major turbidite-fronted delta which prograded during a eustatic lowstand and which closely resembled the 'lowstand systems tracts' of the sequence stratigraphy concept (Posamentier and Vail, 1988).

After a lunch stop at Earl Sterndale, the coach took us to Dowel Farm (also known as Dowall Hall). From here, for the remainder of the afternoon and with the kind permission of the farmer, Mr Bill Etches, we were to look briefly at the Dowel Dale and then walk over Chrome Hill. Before setting off, a brief account of the general geological setting was given; this is also described in the BGS memoir covering the Buxton district (Aitkenhead *et al.*, 1985) and is covered by the published BGS geological maps, especially the 1:25 000 sheet SK06, which shows a cross section that includes Chrome Hill and Dowel Dale. The area lies at the western margin of a Dinantian carbonate shelf or platform that reached its acme of growth during Asbian times.

The platform is founded on a basement high and is thought to have been built up during an epoch of generally rising sea level, largely by the accumulation of calcareous sand. This was derived locally from the abundance of lime-secreting organisms that lived in the clear, warm and well oxygenated tropical waters. Being self-generating, the platform, especially in Asbian times, developed steep margins on which lime mud paradoxically accumulated and an assemblage of organisms existed that was even more abundant and varied than on the platform. These contrasting facies were described in a classical paper by Wolfenden (1958) and it was largely his interpretation that formed the basis

Fig. 1. Roaches Grit at Ramshaw Rocks showing a well-marked erosion surface at the base of a faintly laminated sandstone channel fill cut into large-scale cross bedding of an older channel fill. British Geological Survey photograph L1226 previously published by Jones (1980, pl. 2, fig. 1). Reproduced with permission of the Director, British Geological Survey, NERC; and of the Yorkshire Geological Society.

for the afternoon's excursion. The Geological Survey has used the term 'apron reef' for the fossiliferous fine-grained limestones of the marginal facies that are part of the formation now known as the Bee Low Limestones. The apron reef includes the reef and fore-reef limestones of Wolfenden (1958), who found that, as the reef is approached from the platform side, there is an increase in the proportion of well-rounded grains in the well-bedded shelf calcarenites. Nearer the reef, bedding becomes increasingly ill-defined, the grain size diminishes and the fossil content becomes more abundant and diverse. The reef itself forms only a small and discontinuous part of the apron reef. It consists of wall-like masses, up to 24m high and 9m wide, of micritic limestone comprising, according to Wolfenden (1958), a framework of stromatolitic algae supporting encrusting bryozoans and sponges. This facies passes laterally into the fore-reef limestones which have an even more abundant and varied fauna and a well marked but rather irregular bedding with a steep dip towards the basin. Geopetal infillings of shell cavities have been used to show that these dips are largely depositional. From this it follows that the present day fore-reef dip-slopes approximate to the original submarine slopes.

Many of these features are well displayed around Dowel Dale and Chrome Hill. However, the details of the limestone facies could only be elucidated by the sort of study that Wolfenden (1958) made, involving the examination of large numbers of samples in thin section or etched surface. Indeed, the limestone crags exposed on the west side of Dowel Dale are generally coated with lichen. Nevertheless, at one point (0759 6751) the wall-like form of the algal reef could be seen overlain by bedded limestones, indicating that vertical reef growth had ceased and the shelf limestones had prograded over the top. Further down the dale (0754 6751), the irregular steeply inclined bedding in the fore-reef limestones is visible and members soon discovered the abundantly fossiliferous nature of this facies by examining loose fragments. Many of these had been deeply etched by humic acids from the enclosing soil before being released by erosion to fall to their present resting place at the foot of the crag. Nearby, at the base of the slope, a large tree had been uprooted revealing an exposure of dark grey weathered shaly mudstone. This was taken as a strong indication that the broad amphitheatre before us is floored by these mudstones which are almost certainly of early Namurian age. The geological map (Figs 2, 3) showed this amphitheatre to be largely surrounded by fore-reef limestones, probably near original submarine slopes on the north and east sides but complicated by faulting and folding on the south and west sides. Later, from half way up the northern slope of Chrome Hill, the deeply embayed topography of the platform margin could be easily seen and it was recalled that Hudson (1931) had first recognised that the topography was pre-Namurian and had been exhumed by the erosion of the relatively soft, unconformably overlying mudstones. However, it was the work of Wolfenden (1958), followed by Broadhurst and Simpson (1967), on the margin at the opposite side of the platform at Castleton, that led to the conclusion that the fore-reef slopes are largely original. This was further refined at Chrome Hill by the discovery by Timms (1978) that brachiopod communities at various levels on the fore-reef slope are each associated with a particular relative water depth.

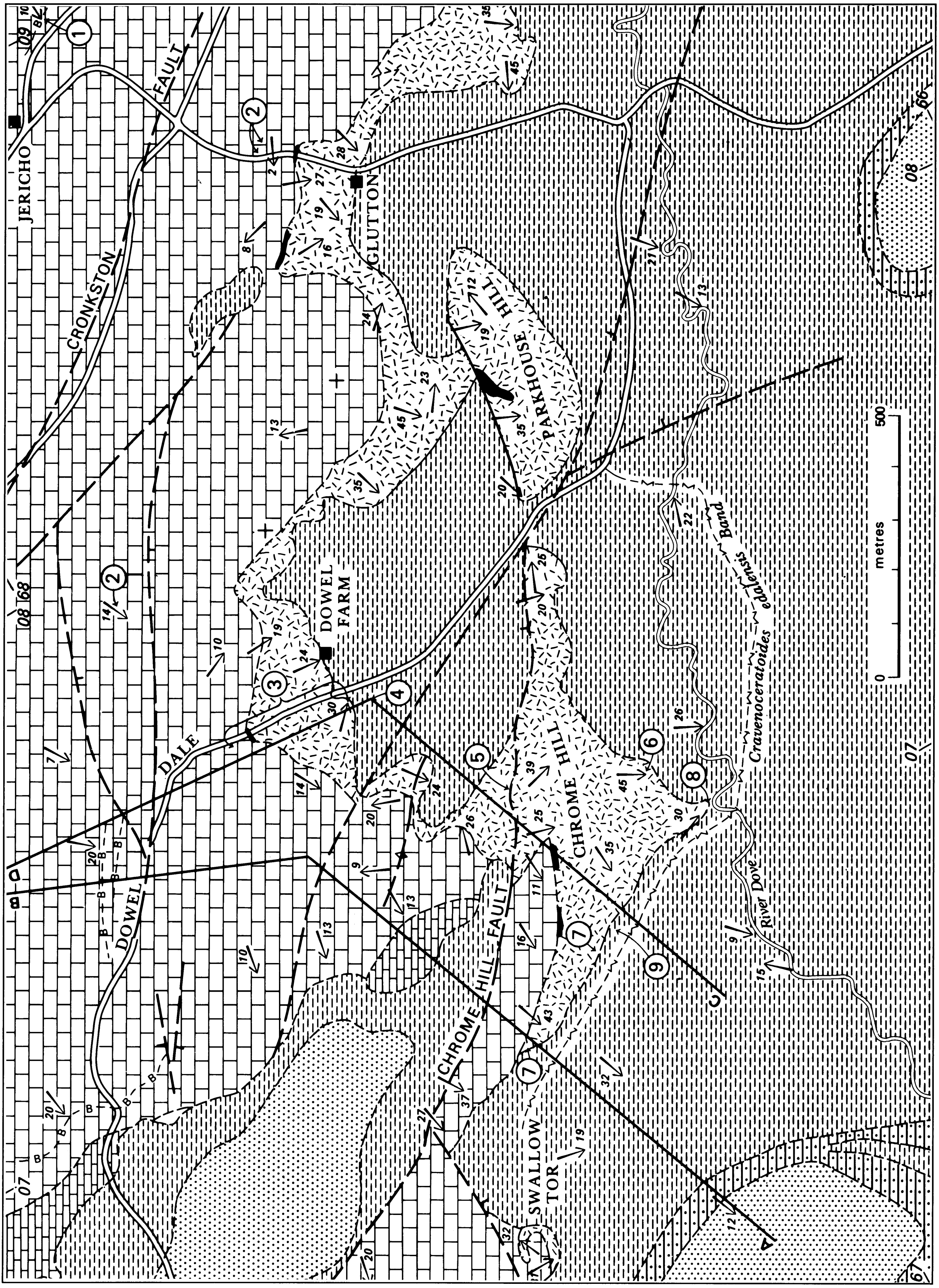
Half way up Chrome Hill at the foot of the steepest part of the north face, the party examined the mineralised fault plane of the Chrome Hill Fault, studded with small aggregates of galena crystals. Nearby, further along the line of the fault to the west (0712 6738), there is evidence of old diggings, presumably for lead, with bare patches of poisoned earth. One larger boulder of breccia contained small crystals of purple-pink fluorspar. Looking east, the line of the fault can easily be discerned along the foot of the north face of Parkhouse Hill. Beyond, a line of pits up the fore-reef slope flanking the east side of the Glutton embayment shows that the line continues as a mineral vein, apparently without fault displacement.

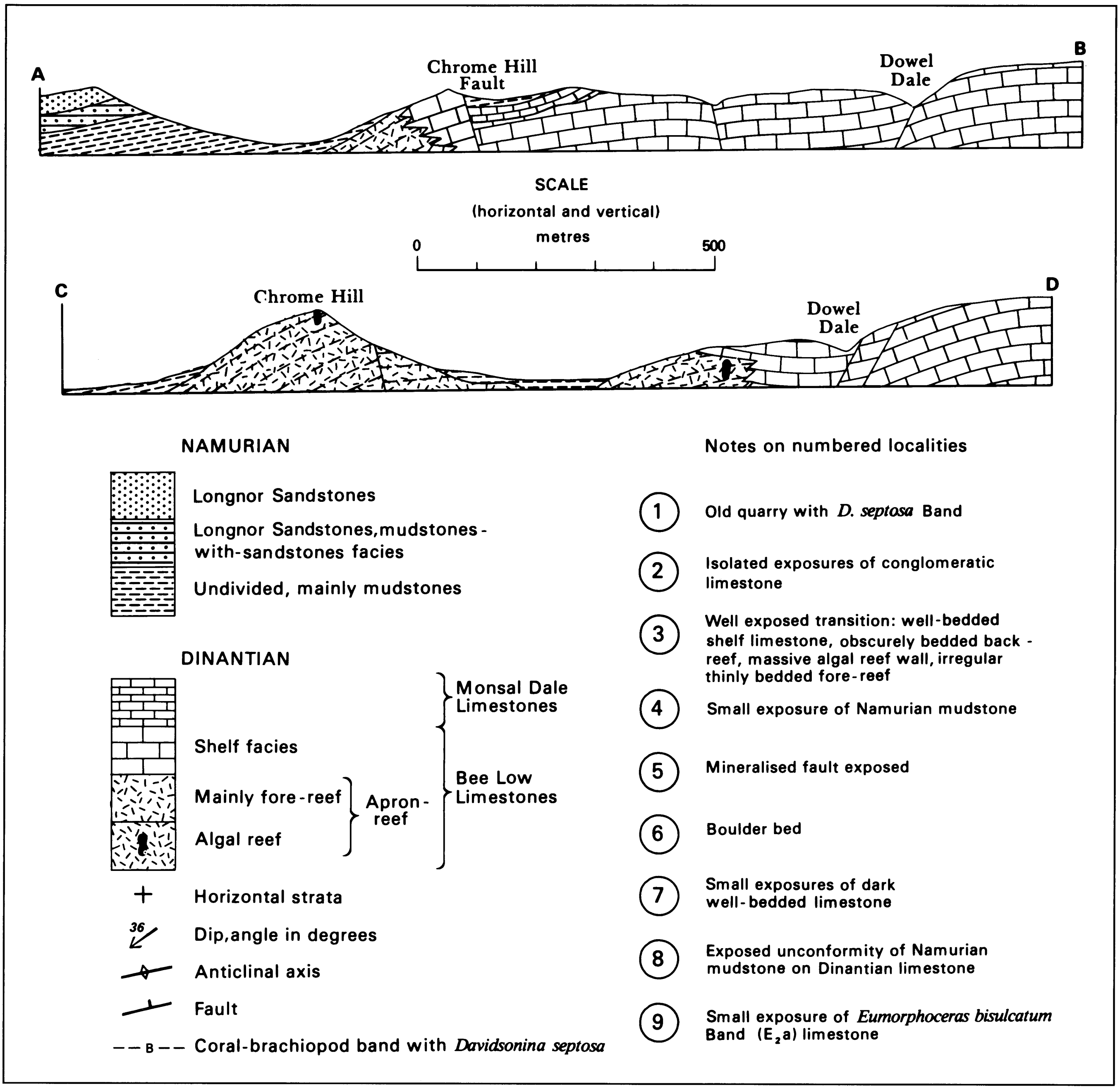
After walking a short distance to the west, the party could see further evidence of the succession of younger strata on the downthrow (or hangingwall) side of the Chrome Hill Fault. The low hill immediately to the north is largely composed of dark beds of the Monsal Dale Limestone of Brigantian age. Close by at its foot, a doline or sink hole has formed at the edge of the limestone outcrop where acidic waters have drained off the area underlain by the impervious Namurian shaly mudstones. Higher up the slope to the north-west, gorse bushes and dry stone walls built of dark grey brown sandstone show that the ground there is capped by the lowest sandstones in the Namurian sequence, the Longnor Sandstones.

At this point, there was some discussion of the possible pre-Namurian and late Brigantian age for the main movement of the Chrome Hill Fault. The geological map indicates that this is the case, since the fault line stops at the limestone-shale boundary on either side of Parkhouse Hill, but positive proof is lacking. Most of the party opted to climb the final slope to the summit where despite the gale force wind, members lingered long enough to enjoy the extensive views down the Dove and Manifold valleys to the south, and to the gritstone moors around Axe Edge and Kinderscout to the north.

Wolfenden (1958) found that the algal reef was developed at a second higher level near the summits of Parkhouse and Chrome hills, due to prograding of the shelf limestones and a consequential southward migration of the apron-reef facies towards the basin in later B_2 (Asbian) times. On Chrome Hill, the algal reef is weathered out as a tower of micritic limestone on the north side of the ridge 60m east of the summit, but again full identification of the facies is difficult because of the lack of naturally etched surfaces.

The final stop of the day was at a locality (0719 6706) at the foot of the fore-reef dip slope low on the southeast side of the hill. Here, members were able to examine a remarkable bed composed largely of gigantoproductids that rests unconformably on the fore-reef limestones. Nearby, highly discordant fabrics, some with a near-vertical alignment, suggest the presence of a boulder bed.


JERICHO
CRONKSTON
FAULT
GLUTTON
PARKHOUSE HILL
DOWEL FARM
DOWEL DALE
CHROME HILL
CHROME HILL FAULT
SWALLOW TOR
River Dove
Cravenoceratoides edalensis Band
0
500
metres
1
2
3
4
5
6
7
8
9
A
B
C
D
09
10
08
68
07
66
67



Figs. 2, 3. Geological sketch map of the Chrome Hill area, upper Dove valley (opposite page) with the key and cross sections along lines A-B and C-D shown above (this page). Localities 3, 4, 5 and 6 were among those visited on the excursion described in this article. (Modified from Aitkenhead *et al.*, 1985, fig. 9, and published by permission of the Director, British Geological Survey, NERC).

References

Aitkenhead, N., Chisholm, J. I., and Stevenson, I. P., 1985. Geology of the country around Buxton, Leek and Bakewell. *Memoir of the British Geological Survey*, Sheet 111.

Broadhurst, F. M., and Simpson, I. M., 1967. Sedimentary infillings of fossils and cavities in limestone at Treak Cliff, Derbyshire. *Geological Magazine* **104**, 443-448.

Hudson, R. G. S., 1931. The pre-Namurian Knoll topography of Derbyshire and Yorkshire. *Transactions of the Leeds Geological Association*, **5**, 49-64.

Jones, C. M., 1980. Deltaic sedimentation in the Roaches Grit and associated sediments (Namurian R_{2b}) in the south-west Pennines. *Proceedings of the Yorkshire Geological Society*, **43**, 39-67.

Posamentier, H. W., and Vail, P.R., 1988. Eustatic controls on clastic deposition II — sequence and tract models. *In* Wilgus C. K. *et al.* (Eds), *Sea level changes: an integrated approach. Special Publication of the Society of Economic Palaeontologists and Mineralogists*, **42**, 125-154.

Read, W. A., 1991. The Millstone Grit (Namurian) of the southern Pennines viewed in the light of eustatically controlled sequence stratigraphy. *Geological Journal*, **26**, 157-165.

Timms, A. E., 1978. Aspects of the paleoecology of productoid and associated brachiopods in the middle to upper Viséan 'reef' limestones of Derbyshire. Unpublished PhD thesis, University of Manchester.

Wolfenden, E.B., 1958. Paleoecology of the Carboniferous reef complex and shelf limestones in north-west Derbyshire, England. *Bulletin of the Geological Society of America.*, **69**, 871-898.

Neil Aitkenhead
British Geological Survey,
Keyworth,
Nottingham
NG12 5GG.

SECRETARY'S REPORT FOR 1991/1992

Recruitment to the Society has been maintained at a similar level to that of last year, and during the year 23 people have joined to give a total membership now of 394 individual members and 95 institutional. Against this, some longstanding members have had to resign due to inability to attend meetings, and it was with great sadness and shock that we learnt of the sudden death last June of one of our most active members, John Bush. John was until last March a member of Council but, having completed his three year period of office, he typically volunteered to take on another onerous task, that of producing the Society's Circular, and he remained on Council as a co-opted member. John's cheerful and willing contribution and his pleasant personality will be greatly missed. His death was a great loss to the Society, and our sincerest condolences are extended to his wife Joan who, following John's untimely death, immediately volunteered to carry on herself with the production of the Circular. Her help has been most warmly welcomed and her fortitude should be an example to all of us.

We have enjoyed the usual varied programme of events during the year, comprising eight indoor meetings commencing with last year's A.G.M., three whole day field excursions, two evening walks, a residential weekend excursion to the Sunderland area, and an underground experience to view the intricacies of Nottingham's cave system.

After we had disposed of the formal business at the A.G.M. last March, we were entertained to a liquid perambulation down the River Loire in the company of Dr. Frank Taylor, one of the founder members of the Society, and our only life member. Frank is, of course, an expert on wine and his vast experience was amply indicated, not only by the magnificent slides of the Loire Valley which he showed us, but more particularly by the superb choice of Loire Wines which were available afterwards for our delectation at a very modest fee!

For the April meeting, Dr. Mike Lovell, formerly of the Geology Department here at Nottingham but now of Leicester University, gave us a fascinating and entertaining insight into the work of the Deep Sea Drilling Project and the wealth of detail which their observations have been able to provide in interpreting the properties of the rocks of the ocean crust. The lecture was thoroughly enjoyed by all who attended.

The first field meeting of the season, led by the President, took place on a somewhat blustery day in early June, in weather more reminiscent of April. The coach was full, 52 members attending, and the day was greatly enjoyed. Before lunch we visited the Roaches to view the gritstone escarpments on that side of the Derbyshire Dome at close quarters and, after a lunchtime sojourn in the pub at Earl Sterndale which was packed to the doors due to the torrential downpour outside, we climbed Chrome Hill to be rewarded by magnificent views from the summit.

The excursion was followed by two thoroughly enjoyable evening walks, the first on Wednesday 9th June led by John Marriott to the Carboniferous rocks of the Holymoorside area. The walk had clearly been meticulously prepared and we were also treated to a wealth of information about the sites of local industrial archaeology. The evening was such a success that we continued into the twilight, our cars not being regained until 10.30 p.m. The second evening visit was held on a lovely evening in early July to the Williamson Cliff Quarry near Stamford where Alan Dawn introduced us to the Jurassic rocks to be found there. These evening trips have proved an extremely popular feature over the last few years, and are now a firmly established part of our field programme.

On the 21st July John Rees of B.G.S. took us to the Stoke on Trent area for an excellent day's excursion which integrated the industrial area with its geology quite beautifully, the day ending with the discovery of some exquisitely preserved plant fossils in the Newcastle Formation, part of the so-called 'Barren Measures' deposited during the later Westphalian.

Then, 22 members spent the weekend of 23rd/25th August at Sunderland enjoying the knowledge imparted by our leader Tim Pettigrew of Sunderland Museum of the classical Permian sequence of rocks in the Sunderland and Durham area. All came away with a considerably increased knowledge of the Permian Period.

The last day excursion of the season was to the Charnwood area. The leader, Bill Moffat of Loughborough University, took us on a lively walk through Swithland Woods and Bradgate Park to Newton Linford where we partook of lunch. In the afternoon we travelled to Whitwick and walked along the Charnwood Lodge Geological Trail, taking in an overview of the vast Whitwick Quarry before ending at Mount St. Bernards Abbey. The day was greatly enhanced by the wealth of non-geological titbits which Bill imparted from his fund of knowledge of local people, places and buildings.

Our first Autumn lecture took place on Friday 11th October with an experimental starting-time of 6.30 p.m. This was to enable the speaker to be entertained to a meal after his 'performance', the perceived benefits being that he would thus enjoy it somewhat more and that members at the meeting would not be kept waiting beyond the appointed time, as had not infrequently happened. The experiment received a mixed reaction from those who did comment, the majority view seeming to be that the early start would be far more acceptable if the meetings were on Saturdays. The speaker at this meeting was Professor Bob Stoneley of Imperial College who spoke on what must be one of the most topical and often posed questions of the last twelve months "Why is the Middle East so rich in oil and gas?" We learnt not only of the geological structures and formations which have made the accumulation of oil and gas possible, but also many fascinating statistics relating to the oil industry generally. Did you know that oil had been exploited in the Middle East since Noah's time? I certainly didn't, but then that is probably a reflection on my knowledge of the finer detail of the Book of Genesis. I should obviously have paid more attention in Sunday School.

The November lecture was given by Andy Chadwick of B.G.S. on the crustal dynamics of extensional sedimentary basins, and we learnt how important seismic evidence is in discovering the extent and depth of sedimentary basins. Some of the statistics were quite dramatic indicating huge throws of 2 to 3 kilometres on some of the large basin margin faults, and terrific depth of deposition such as in the Northumberland Trough where 45,000 feet of sediments have been estimated. I for one learnt a new word "rheology" which I now know means "the behaviour of rocks under stress".

On a Sunday morning in late November there was a large gathering of Society members and assorted family and friends for a visit to the underground spectacular of some of Nottingham's myriad cave systems led by the acknowledged expert in this field, Tony Waltham of Nottingham Polytechnic. All the scheduled caves were visited and, so far as we know, all those who went in also came out — at least we have received no complaints as yet. Tony Waltham was on duty again for our pre-Christmas party lecture on the mega-geological features seen by him on a recent trip to the Himalayas. Tony's talks are always entertaining and this one was an excellent preamble to the enjoyable social evening which followed.

1992 commenced with a totally up to the minute talk by Dick Aldridge (now of Leicester University, but formerly, like last April's lecturer Mike Lovell, of Nottingham) on his specialist topic, the microscopic conodont fossils. Amazingly, by the end of his lecture, he had convinced us that the evidence now available from detailed study of early Ordovician specimens all points to their having a structure identical to cellular vertebrate bone, and that they are indeed the "microscopic forerunners of the vertebrates" as the title to his lecture so incredibly suggested.

The last event of the Society year was, as ever, the Presidential Lecture, given by our President, Neil Aitkenhead. He chose Antarctica as his topic, a continent which he first visited in 1959, but it was clear from the title "Geologising by boat, ski and dog sledge in Antarctica" that we were going to hear of much more than pure geology. The talk was both entertaining and very informative as one might expect of Neil, and talking of statistics again, I think the most memorable statistic of this particular talk was the vast intake of calories considered to be essential on the wellbeing of the Survey's geologists in that forbidding terrain, namely four or five thousand a day! The lecture was, of course, followed by our Annual Dinner, which we held this year in Derby Hall at the University. Approximately 40 members attended, and greatly enjoyed the excellent buffet meal.

Seven council meetings have been held during the course of the year to discuss Society matters and to plan the programme of events. One of the items under discussion has been the timing of indoor meetings, and members comments have been heeded. For the future whenever possible we shall be holding the indoor meetings on Saturday evenings, as has historically been the case, with a starting time of 6.30 p.m. Friday meetings will be held if this is necessary because of a lecturer's availability, commencing at 7.45 p.m. It is impossible to accommodate all individual needs, but we hope that these times will meet with the approval of the majority.

A total of six circulars have been produced during the year, and I am deeply indebted to Joan Bush for all her help in producing these. There has not been an issue of the Journal since last March when Volume 12(2) was produced. There have been various reasons for this unfortunate gap in production, not least of which was our lack of an Editor until Dick Aldridge thankfully agreed to take on the leadership of an Editorial Board which presently comprises himself, Judy Small, Judy Rigby and Bob Brown (from whom you will be hearing in a few minutes). I do not wish to pre-empt the Editor's Report, but I can assure members that Volume 12 parts 3 and 4, comprising the Index to the whole of the first 12 volumes and compiled by Dorothy Morrow and Frank Taylor will be published in the very near future, to be followed closely by the new look *Mercian Geologist* Volume 13(1).

As ever, the Society could not possibly function as successfully as it does without the continued commitment of the members who regularly deliver copies of the Circular and Journal in their local areas; their help is very much appreciated and, needless to say, any new volunteers would be welcomed. Others who deserve particular thanks on my part are Jack Fryer and Ian Sutton who respectively take responsibility for organising the Indoor Lectures and Field Meetings. And, at this stage, I think it is also appropriate to mention the major input the Society enjoys from staff at the B.G.S. We are indeed fortunate to have them situated so close to Nottingham, and that they take such an interest in promoting and participating in the Society.

There are undoubtedly many other members whom I could and should mention as having voluntarily given of their time and efforts in making the Society the success it undoubtedly is, such as the members who have led excursions or given lectures for us and those who contributed to the Christmas Party. We are extremely grateful to them all. I must also, on behalf of the Society, acknowledge with gratitude the kindness of the University of Nottingham in permitting us to use this lecture hall for our indoor meetings; the use of these facilities is very much appreciated. I should finish this Report by a particular personal "thank you" to my own secretary, Celia Morris, who does all my typing and quite a lot of thinking for me, too; I could not possibly fulfil this job without her invaluable assistance.

Susan M. Miles

OBITUARY

PHILIP HENRY SPEED (1910-1993)

Founder member and former Treasurer of the East Midlands Geological Society

The death of Philip Speed in January of this year was a great loss to his family, many friends and members of the EMGS. He will be remembered for the way he was able to forge close links between professional geologists and amateurs.

Philip studied geology at University College, Nottingham, under the guidance of H. H. Swinnerton. His professional career was, for some time, with the British Geological Survey but by far the largest part of his working life was spent with British Rail, where he reached the status of Chief Geologist, responsible for all geological matters countrywide.

The inspirational teaching of Swinnerton undoubtedly rubbed off on Philip who developed a great love for geology. This enjoyment of the subject was shown most vividly in the great pleasure he had in passing on his own expertise in various part-time teaching capacities. Philip taught for a number of institutions in the East Midlands but largely for the Adult Education Department at the University of Nottingham, for whom he taught for 50 years. Many adult students were fortunate enough to attend his classes and it was largely from this group of extremely keen amateurs that the embers that fired the birth of the EMGS originated.

Philip's wide experience of geology throughout the British Isles enabled him to take his groups of students on what have been described as "memorable and wonderful field experiences" to all regions. He did, however, have a preference for the North, particularly the Lake District, the Pennines and perhaps his greatest love, Scotland. I had the privilege of being introduced to many parts of Scotland by Philip and I will particularly remember my first introduction to the Assynt area.

Philip was a tremendous colleague and friend. The great knowledge he had of the countryside, not only of geology but of flora and fauna and particularly ornithology was infectious. He had so many interests, being an extremely keen gardener and bee keeper as well as being noted for his knowledge of good eating and drinking establishments.

Despite this very full life, Philip made a most important contribution to the community, firstly through the energy he devoted to the Scout movement and later through the very influential role of his work for the deprived young of the East End of London, a far cry from his beloved Scotland. Philip had a rascally but marvellous humour; he was a great raconteur and will be remembered with much affection for a number of idiosyncrasies such as his complete failure ever to come to terms with bifocal lenses.

Philip will, however, be remembered most of all for his great love of life, the world and his great army of close friends. His passing is a tremendous loss to so many of us, particularly his wife Edith and his daughters and grandchildren. *Ian D. Sutton*

BOOK REVIEWS

They went that-a-way

LOCKLEY, M. *Tracking dinosaurs.* 1991. Cambridge University Press. £27.50 hardback, £9.95 paperback. ISBN 0 521 39463 5, 0 521 42598 0.

Martin Lockley heads a group in Colorado called the Denver Dinosaur Trackers Research Group. They have a logo and, naturally, it is based on a stylised dinosaur footprint, but it also includes the motto "230,000,000 BC to 2000 AD". This may strike you, as it did me, as a bit too American cute, but at least it shows that the Trackers are having fun with their footprints.

The way this book is written confirms this; easy to read and enthusiastic, it is also a good comprehensive review of dinosaur ichnology (trackway studies) from 1802 to 1990, with a special emphasis on recent discoveries.

I have to admit to a credulity problem with the "science" of palaeoichnology. David Attenborough worked with the Denver Trackers while filming the BBC series "Lost Worlds, Vanished Lives"; his contribution for this book's blurb is "Sherlock Holmes himself could not deduce as much from a footprint as Lockley does . . ." and I'm afraid the unintended implication, that dinosaur trackers sometimes get close to fiction — maybe they deduce too much from the easily misinterpreted evidence of fossil prints — is about right. My greatest difficulty is with the application of binomial nomenclature to fossil footprints. This implies either that "species" within a footprint "genus" are somehow related genetically (but how can "form taxa", created for particular shapes, sizes and stratigraphic ages of impressions in sediment, be related?) or that we know which animals made them (no-one has ever found a fossil footprint with its maker's skeleton standing in it). Even the footprint taxonomists recognise that one track "species" could be made by one of a number of different dinosaurs, or that a *Tyrannosaurus* might produce several trackway taxa according to whether it was walking, running, sitting down or paddling at the beach.

To be fair, Lockley points out all the problems of footprint names and interpretation — good for him. The most likely pitfall for amateur dinosaur trackers (the professionals have fallen for it often enough) is that a dinosaur stomping across soft sediment produces footprints not only in the surface layer, but as a superimposed pile, increasingly wide and indistinct, in all the unconsolidated beds beneath. Find an "underprint" of a small dinosaur and you may think you have found a sauropod, or, like Roland Bird in 1944, interpret indistinct underprints as evidence of a sauropod swimming just out of its depth.

The chapter headings indicate the book's broad and popular approach. Introductory sections provide basics for non-specialists, including a simple dinosaur family tree (monophyletic, and therefore perhaps not really "with it"), "how do we know a track was made by a dinosaur", general track geometry (left or right, front or back, two legs or four) and principles of estimating speed and size from an animal's tracks. The use of prints as evidence in the detective game of palaeoichnology is explained. Trackway fossilisation methods get a complete chapter; this is where we find out about underprints, why little dinosaur's prints seem rarer than brontosaurs', and also about natural casts and moulds (or "molds" — incidentally, the preparation of the British version from the original American text produces "ploughed" and "plowed" on the same page). "Discovery and documentation" begins to spread the subject rather more thinly and states the obvious, like the need to measure and map finds but perhaps to keep the locality secret, and fills half a page with a pie diagram showing that "dinosaur tracks are found in many natural and artificial terrains" (quarries and mines 26%, roadways 8%, fallen blocks 8%, etc., since you ask).

"A field guide" lists, with diagrams and photographs, the dozen or so best-known track genera in systematic order and gives the likely dinosaur makers whenever possible. Apparently there are a further 500 additional, but largely redundant, names in the literature for possible dinosaur tracks!

The real meat of the book is in its middle sections, where the interpretation and significance of prints and trackways is discussed in detail, and where the reader's credulity about the value of trace fossils for elucidating individual and group behaviour, ecology and evolution is tested. The descriptions of the deductive processes used are fascinating, but is it right, for example, to use a rule of thumb which says that a walking dinosaur's stride is less than four times its foot length while a running dinosaur's stride is greater than four times its foot length without considering the effect of relative leg length (which implies that you have guessed what kind of dinosaur made the trackway) to interpret dinosaur behaviour? Estimates for dinosaur speeds using "formulae" like these range from 3 to 40 kph. Some trackways seem to indicate that their makers made an abrupt 90° turn — should we speculate that the animal was surprised by another dinosaur, or might careful examination show that two poorly-preserved tracks crossing at right angles merely give the impression of one animal changing direction? One famous trackway appears to show a herd of brontosaurs, adults surrounding and protecting juveniles (less ideologically sound trackers have proposed "males" surrounding "females" and juveniles because, of course, the boys are always bigger and braver!), being followed by a carnivorous dinosaur. But, as Lockley points out, this is speculation; what if the "hunter" came along 3 days after the brontosaurs? The trackway might look the same. What if the apparent herd structure is actually the result of regular use of a dinosaur path over several days by a few separate animals?

In "Ancient ecology" one of the main claimed contributions of trackways to dinosaur palaeontology is explained. A general observation is that dinosaur bones and trackways are rarely preserved together in the same stratum. Thus, gaps in our bone-derived knowledge of dinosaur ecology and evolution can be filled by print-derived information. Lockley grades track-bearing deposits from 1 (footprints are the only evidence of dinosaurs) to 5 (footprints are unknown) to show their relative importance to palaeontological interpretation. This chapter is organised as a gazeteer of world footprint deposits: unfortunately it is America-biased, with claims like "the middle Jurassic is poorly known for dinosaur palaeontology" (what about England, Europe, North Africa and China?). Other palaeontological inferences are drawn from prints and trackways in further detailed chapters, before the Denver Trackers' own recent discovery and rediscovery of many "megatracksites" is described. It turns out that there are literally hundreds of square kilometres of bedding planes covered with dinosaur tracks in the western Rockies. Now that would be something worth seeing!

The book ends with "myths and misconceptions" (so Lockley is even-handed but seems to contradict some of what he has claimed earlier by so being), histories of the "dinosaur trackers" ancient and modern, and a "where next?" epilogue. There is a site by site guide, a good glossary and a well-organised "notes and bibliography" section which obviates the need for footnotes (good) but necessitates dodging to and fro to check what the superscript numbers mean. Design and typography are up to standard for an American publication at this price, but this is not a coffee-table production. Diagrams and decorative line illustrations are just adequate, and the 21 colour photographs are bound as a block at the midde; some of these are a bit like my old lecture slides, and some need to be turned upside down before they can be seen as footprint impressions because the light "falls the wrong way".

All in all this is a good introduction to dinosaur footprint studies aimed, I guess, at enthusiastic amateurs. It made me think about the potential of the Mercia Mudstone Group of the Midlands. There are dinosaur trackways in the upper Triassic of South Wales, and non-dinosaur tracks (*Chirotherium*) from Leicestershire and Nottinghamshire. So why not start looking locally, ready for the second edition?

John Martin

Breathing life into the earth sciences

WESTBROEK, P. *Life as a geological force.* 1991. W. W. Norton & Company, New York and London. £14.95 hardback, 240pp. ISBN 0 393 02932 8.

It's good to see life back in fashion. The plate tectonic revolution undoubtedly invigorated the earth sciences, but it also led many geologists to concentrate on physical and chemical processes and their role in shaping earth history, and consequently to neglect or negate the importance of palaeobiology. We are now, happily, emerging from that period, and the significance of life processes as part of the global system is now becoming generally recognised.

The wide realisation that the evolution of the earth and of life are inextricably linked is due in no small measure to James Lovelock's formulation of the Gaia hypothesis, in which the earth itself is regarded as behaving as a single living organism. To understand the earth we must study the development of the entire earth/life system. Peter Westbroek, who heads the Geobiochemistry Research Group at the University of Leiden, is a prophet of this approach, and in this somewhat idiosyncratic book he sets out to convince readers of its importance.

The book is essentially a set of separate, but interlinked, essays dealing with different aspects of the topic. They are arranged under three headings: the geology of the planet earth; life, the missing link; life at the planetary scale. The message is clear: if we view this planet as a chemical factory we will never understand how it works. Geochemical models of the earth, according to Westbroek, are like Frankenstein monsters, assembled from bits left over from dead bodies in the hope that they will come alive.

Westbroek is almost evangelical in promoting his view that the way forward in understanding the earth is through a melding of the sciences of geology and biology. Life is not a mere decoration on this planet, and it is not simply by chance that the oceans and atmosphere have remained in a sufficiently stable state to support life for most of earth history. Despite a constant increase in the energy output of the sun, a continual bombardment by meteorites and fluctuating internal dynamics, the Gaian system has maintained the narrow range of conditions necessary for life for 3.5 billion years. Westbroek even goes so far as to suggest that he would not be surprised if future research revealed that living things were essential for the maintenance of plate tectonics. Is he right? Read the book and judge for yourselves.

Richard J. Aldridge

Pros and cons of volcanoes

DECKER, R. W. and DECKER, B. B. *Mountains of fire (The nature of volcanoes).* 1991. Cambridge University Press. £30.00 hardback, £10.95 paperback, 198pp. ISBN 0 521 32176 X, 0 521 31290 6.

For anyone interested in volcanoes and volcanic activity the writings of Robert and Barbara Decker must be well known. Of all the subject areas of geology that least need bringing to life, volcanoes must be at the top of the list, but the Deckers always manage to make this exciting topic appear even more fascinating. In this present book they have certainly not let us down. The book consists of fourteen chapters divided into three sections; Volcanic mountains, Volcanic rocks and Volcanic Risk and Reward. Each chapter commences with a case study, well illustrated with thoughtfully chosen diagrams and text figures. In addition, in the middle of the book, there are 27 magnificent colour plates illustrating various aspects of volcanic activity.

Generally the book has been produced with a lay audience in mind and, although there is a wealth of information and also well chosen examples to illustrate various points, I do fear that the attempt to keep the book simple, interesting and readable to the person with a passing interest in the subject has resulted, in places, in a loss of accuracy in the sense that the reader may well end up with some misconceptions here and there. For example on pages 66-67 the description of the "Zone of partial melt" could well be misinterpreted as a localised zone just beneath volcanoes rather than the recognised more or less continuous zone in the earth's interior. Chapter 2 "Volcanic Belts" has a subsection of Volcanoes and Plate Tectonics and here the great importance of the relationship between Plate Tectonics and Volcanism is not stressed. It should have been. Moreover we have to wait until Chapter 6 before we have any diagrams to help non-geologists understand a little more about plate movements. In Chapter 4, on the Life Stages of Volcanoes, I fail to understand why the submarine phases of eruption of a Hawaiian volcano are separated from the sub-aerial phases by a section on the history of Surtsey Volcano. The description of the life stages of the Hawaiian volcano on page 44 does not relate to the section of Mauna Loa on page 70 (Fig. 6.5) and no reference is made on page 44 to this text figure. In a chapter on Life Stages of a volcano it might well have been most appropriate to discuss the known cyclicity of certain volcanoes, of which Vesuvius is perhaps the best known and documented.

I have chosen just a few examples of where I think improvements in the organisation of the book could have been made; I could cite more. It may be that I am being hypercritical about what may be considered small issues, but I do feel more thought should have been addressed to the overall organisation of the text. I must also make comment about the quality of some of the black and white photographs used in the text figures. I have no doubt that the original photographs may have been good but the reproduction is not. On page 69, Fig. 6.3. is supposed to illustrate the variation in colour, from the light silica rich lower portion of the deposit to the darker, less siliceous top part. Good photographs of this particular feature show this very well, this reproduced photograph does not!

I have given a few examples of the critical feelings I have about the general aspects of this book but I hope I am not misleading any readers into believing it is not a worthwhile publication. The book is, in fact, in most ways, an excellent text and for any person with an interest in volcanoes I thoroughly recommend it. Its virtues far outweigh the negative aspects I've commented on and the style is of the high quality we have come to expect from the Deckers. There are also many features which make the book much more worthwhile than the run of the mill texts on the subject. For example, I like the glossary where the Deckers have carefully reduced the technical jargon, which has had to be used, into very understandable language, and they are to be complimented on their selection of a sensibly long bibliography. What I find very pleasing and what makes most absorbing reading is the final section of the book on Volcanic Risk and Reward, which has brought together the extremely important aspects of volcanoes to man. This is an excellent concluding set of chapters to a book which will make good bedtime reading and, at the same time, provide a wealth of information on the subject. At the price of £10.95 (paperback) it is worth every penny!

Ian D. Sutton

Graptolite graphics

PALMER, D. and RICKARDS, R. B. (eds). *Graptolites: writing in the rocks.* 1991. Boydell and Brewer, Woodbridge, Suffolk. £39.50 hardback, xvi + 182pp., 138 plates. ISBN 0 85115 262 7.

At a time when there are so many academic and 'popular' books published on fossils it is hard to imagine that yet another publication series on palaeontology could find a niche in the market. Nevertheless with its novel and imaginative format, "Graptolites", the first in a new "Fossils Illustrated" Series from Boydell Press, can justifiably claim to have successfully done just that. It is a book I can recommend to all those interested in both the scientific aspects and the sheer beauty of fossils. This broad-ranging yet relatively concise review contains something for everyone — from the generalist eager to have a good introduction to this group of fossils, to the geologist/palaeontologist anxious to top up with more specialist knowledge or the latest ideas about graptolites.

The contents of the book covers the life, habits and geological uses of a very important group of large, Palaeozoic zooplankton, the graptolites. A quick dip into its pages soon dispels in a wonderfully immediate way the sometimes-expressed notion that this group of colonial hemichordates are ill-preserved and not especially interesting. "What can you see?", is an often-heard comment when those unfamiliar with the group first observe these "grey streaks" on rock slabs. Just what one can potentially "see" is spectacularly displayed in this book by no less than 138 magnificent plates which depict the morphology of graptolites and their closest living relatives, the petrobranchs. Superb single graptolite specimens and bedding plane assemblages, ultrastructural details and growth stages, structurally distorted specimens and exceptionally well preserved isolated material recovered by acid preparation — it is a palaeontological feast of beautiful, quality photographs and SEM micrographs, most of which are published for the first time. The accompanying explanations thoughtfully guide the reader to the features of particular interest on each plate.

The text is authorative: its 14 relatively short chapters are each written by relevant experts of 'Big G', members of the British and Irish Graptolite Group. Up-to-date, informative, and appealingly 'chatty' in style, there is plenty there for professional and layman alike. However, I do feel that, where appropriate, the occasional inclusion of a line diagram figure (there are virtually none) to accompany the text would have been helpful to the reader. "How did they live?"; "What was their sex life like?"; and "What use are they, anyway?" are just three of the entertaining questions (Chapter titles) that the authors address with obvious enthusiasm. By virtue of their biostratigraphical usage and potential, the value of graptolites has been appreciated by geologists throughout more than 150 years of study of the group. Surprisingly, there are still large question marks over the nature of the soft-parts and life habits of the animals themselves (the group became extinct in the Carboniferous); perhaps this is where we can expect to see major research efforts and advances in the immediate future. Having hooked the reader on graptolites, the eight so-called appendices include pieces on the meaning of the technical terms applied to graptolites, the best places (both in Britain and world-wide) to collect specimens and which organisations, graptolitologists and sources of literature could be consulted in order to answer relevant problems and to find out more about the group. Particularly appropriate and much appreciated by this reader was the concluding section of the book, which gives pen-pictures of eight graptolite workers, from Joachim Barrande to Professors Bulman and Mu, whose contributions to the field are internationally recognised. Appropriately the volume is dedicated to the senior member of 'Big G', Nancy Kirk, whose work on graptolites, particularly her ideas on their mode of life and supposed 'automobile' capabilities, have often been so rewardingly controversial.

The second volume of "Fossils Illustrated", on trilobites, is shortly to be published. The efforts of the editors of "Graptolites", Douglas Palmer and Barrie Rickards, and the other 'friends of graptolites' have ensured that subsequent titles in the series have a hard act to follow. These long extinct animals really come alive in the book — oh those marvellous plates!

David J. Siveter

A contentious collection

MÜLLER, D. W., McKENZIE, J. A. and WEISSERT, H. (Eds) *Controversies in Modern Geology, Evolution of Geological Theories in Sedimentology, Earth History and Tectonics.* 1991. Academic Press Ltd., London. £44.00, hardback, 490pp. ISBN 0 12 510340 9.

The title of this book is rather misleading, as becomes immediately apparent when you read the foreword. Thus it does not attempt to be a general review of, or to provide an even coverage of, the whole field of recent controversies in sedimentology, earth history and tectonics. Instead it has been compiled from papers submitted at a symposium which was held in Zürich in 1989 in honour of Professor Ken Hsü's 60th birthday and in appreciation of his work. Thus the book is biassed towards the work of Ken Hsü, his co-workers, colleagues and students.

Fortunately, he is a remarkable man who has built up a considerable reputation as an original and controversial thinker. He is particularly noted for stressing the importance of the rare event, as exemplified by his views on the Messinian salinity crisis and the catastrophic events at the Cretaceous — Tertiary Boundary. His background has embraced China, a period with the Shell Group in the USA and an academic period in Switzerland. His research interests cover an unusually wide spectrum, including geochemistry, tectonics, sedimentary sequences, facies models, dolomites, deep-sea and lacustrine environments, palaeoceanography, plankton, global biotic events, mass extinctions and evolution. Accordingly, the book covers a similarly wide spectrum of topics dealing with some ancient controversies as well as many that are still being vigorously argued.

The Introduction, Part I, Controversy and Geologic Theory, reviews some past and present controversies and summarises the topics covered. It includes the following two relevant and eminently quotable sentences. 'Ingenious ideas to solve old puzzles are seldom received with gratitude by those who have much invested in their own solution and useless arguments are propagated to defend false pride' and 'Given enough time, the improbable becomes inevitable'. These ideas set the scene for the following 18 papers, which are grouped under four headings.

Part II, Geologic Events and Non-uniform Sedimentation, deals with the problem that specific sedimentary events vary in magnitude during different eras of earth history. Topics include the Messinian salinity crisis, stromatolites, dolomites, phosphates, and deep-sea depositional systems.

Part III, Paleoenvironment and Evolutionary Change, deals with rapid and multiple terrestrial and extra-terrestrially induced changes. Individual papers deal with the extinction of the Mammoth, the Paleogene glacial history of Antarctica, possible Cretaceous glacial interludes, and the periodicity of extinction.

Part IV, Sea-level History and Sedimentation, deals with the long-standing arguments regarding the relative importance of eustasy and tectonism. Topics include pelagic sedimentation, isolated carbonate platforms, intraplate stress-induced subsidence, and modelling sedimentary sequences.

Part V, Tectonics and Mountain Building, covers extension of the continental crust, the classification of fault rocks, Indosinides and eastern Paleotethys, the old controversy on the Glaurus Nappes, and the timing of orogenic events.

Part VI, the final section, lists the abstracts of eight talks that were delivered at the 1989 symposium. These cover back-arc basins, giant lakes, mass extinctions, cleavage, environmental geochemistry, oceanic plankton, and whether geology is an environmental science.

Readers who, like the reviewer, lack the breadth of knowledge and interests of Ken Hsü are nevertheless likely to find some papers of immediate interest to themselves. Furthermore, other papers on less familiar topics provide instant updates on fields which, with the current trend towards integration of different disciplines, may subsequently become highly relevant. A high proportion of the papers have been written by acknowledged international experts and provide concise, authoritative accounts of controversies in specific fields. The individual lists of references are also very useful and an Index is provided.

The text and most of the diagrams are clear and well set out. However, not all of the diagrams are equally legible and some have been reduced beyond the point of clarity. The price is comparable with that of other hardback geological books and potential readers may reasonably consider buying it for themselves. This book is not just of interest to the specialist and deserves a wide audience. It should certainly be recommended to your library!

William A. Read

NOTES FOR CONTRIBUTORS

Scientific papers are accepted on the understanding that they have not been published or submitted for publication elsewhere; all contributions become copyright of the East Midlands Geological Society on publication. Two copies of papers should be submitted in a format as close as possible to that of the *Mercian Geologist* since Volume 13, Part 1 (1992); single copies of news, reports and review items are acceptable.

Abstract. Scientific papers should be accompanied by a brief abstract stating the essential information and conclusions presented in the text.

Text. Please present contributions on A4 (297 × 210mm portrait) paper, typed or word-processed on one side only, double-spaced if possible, with ample margins.

References. All references cited in the text should be listed; the author is responsible for the accuracy of references. In the text, references should be given as: (Smith, 1992); use (Smith *et al.*, 1992) for more than two authors. In the References, list all authors and do not abbreviate journal titles.

Illustrations. Line drawings and photographs will all be included as text-figures, and should be presented wherever possible to cover or be in proportion to one column (width 84mm) or two columns (width 178mm) and up to 245mm depth. When full page line drawings and photographs are used an appropriate allowance should be made for the required caption. The smallest lettering on line diagrams should not be less than 1mm high. A full list of figures, with captions, should be submitted on a separate sheet. Approximate locations for text-figures should be indicated in pencil in the margin of the text. Tables will be typeset and should be designed to fit single or double column widths and up to the maximum depth.

Photographs. Whilst colour prints are acceptable good clear monochrone prints are preferable.

Offprints. 25 free copies of scientific papers are provided.

Copyright. If any text, diagrams or photographs have been published elsewhere, it is the responsibility of the author to clear any copyright matters.

Typescripts and correspondence should be addressed to: Dr. R. J. Aldridge, Department of Geology, University of Leicester, Leicester LE1 7RH.

Contents

Report 66

Geological Collections of the Natural History Museum, Wollaton Hall — Neil Turner

Mercian News 68

New Geological Survey of Nottingham; Woolly Rhinoceras Skulls; GHASP from BGS; Ecton Educational Centre

M. K. G. Whateley and H. K. Eardley 69

The Use of Satellite Data for Improved Structural Interpretation in the Leicestershire Coalfield Area

A. Dawn 79

Brittlestars from the Bathonian of Lincolnshire and Northamptonshire

R. J. Aldridge 83

Conodont Colour and Thermal Maturation in the Lower Carboniferous of North Wales

M. G. Sumbler 87

The Lias Succession between Fulbeck and the Vale of Belvoir

Excursion Reports 95

A. Brandon, H. C. Ivimey-Cook, M. G. Sumbler — Traverse across the ''Lower Lias'' south-east of Newark, Nottinghamshire

N. Aitkenhead — Field excursion to Ramshaw Rocks and Chrome Hill

Secretary's Report 102

S. M. Miles — Report for 1991-92

Obituary 104

Philip Speed

Book Reviews 104