MERCIAN Geologist

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Contents

PROFILE

MRS SUSAN MILES

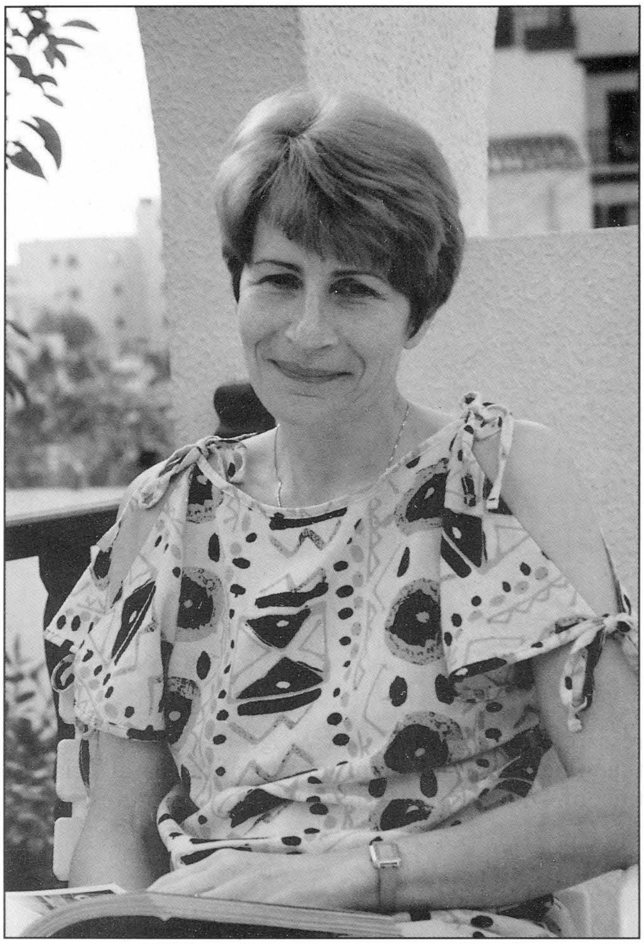
There has been a tradition in the East Midlands Geological Society that from time to time it elects as President a member who is not a professional geologist. This is very appropriate in a Society which, since its formation in the 1960s, has been successful in providing activities of common interest to both professional and lay geologists. We therefore welcome Sue Miles, an amateur geologist, as our President with effect from March 1994.

Sue is a very much an East Midlands person, being born at Market Harborough in post-war Britain (Second War!). Her childhood and schooldays were spent in Leicestershire, firstly at the local school in Kibworth and then from 1957 at Kibworth Beauchamp Grammar School. When her father was appointed Head Master of Humphrey Perkins School at Barrow-on-Soar in 1960, Sue and her family moved to that village, a place with many geological connections. After a school career that included an O Level in Geology, she went to Leeds University where she graduated in Law in 1968. Having completed her Solicitor's Finals exams in 1969, she returned to the East Midlands where she was articled to the Solicitors firm of Rich and Carr in Leicester and became a fully qualified Solicitor in 1971.

In 1971 Sue was married and moved to Nottingham to start work as a Solicitor with L. Bramley Lipman and Co., whose offices were then in Wheeler Gate. She became a partner in the firm in 1973, but left in 1975 when the first of her two sons, Richard, was born. Her younger son, James, was born in 1979.

During the period from 1975 to 1981 Sue's life had many facets. She joined forces with a friend to set up a successful business, making and selling hand-made patchwork clothes and dolls for young children, trading under the banner of "Mousetrap". While Sue looked after her two young boys and ran this business she was frequently called upon by her old firm of solicitors to cover for absences and vacations. In 1981 she returned to work part-time for Bramleys, which had moved to its current location in Oxford Street. As her boys became more independent she returned to work full-time, in 1987 becoming a partner once more and in 1990 being appointed as managing partner. Sue has worked in many areas of legal practice but now specialises in Court of Protection work, an area which suits her personality.

Sue's interest in geology began at school. Her first field trip with the school geography department to the Lake District in Easter 1963 really established this interest, which has progressively developed since then. Many members of the Society will know that she has no head for heights, and as that particular field trip involved climbing Helvellyn via Striding Edge the impression left behind by the Borrowdale Volcanics must have been especially memorable. Studying for geography A Level allowed Sue to enjoy the geologically related aspects of that subject, and following her Law training she once more turned to geology with enthusiasm, particularly encouraged by two people. Firstly, Sue's elder sister Lesley, a geography graduate and an active member of our Society, passed on her own enthusiasm for the subject. A little later, in the early 1980s, Sue was inspired like many others by the teaching of Philip Speed, whose University Extra-Mural class she attended. Since then Sue has become a serious student of geology, and with her considerable powers of observation her greatest enjoyment of the subject is in the field.



By 1983 Sue had become a very active member of the Society, was elected to the Council in 1987 and became Secretary in 1988 following Madge Wright's election as President. Sue served the Society as Secretary for six years in a typically meticulous way and Council has also greatly benefited from her professional advice on legal matters.

With such an active life it is surprising that Sue has much time for leisure pursuits. She combines her geology with a great love of walking and natural history in all aspects. Her more basic instincts can be recognized when she wields a tennis racquet or, in earlier days, a hockey stick. Today Sue lives in Cropwell Butler where she finds time to extend her interests to gardening, particularly favouring alpine plants.

Ian D. Sutton

MERCIAN NEWS

News from Leicestershire Museums Service

Arthur Cruickshank and John Martin write: In spite of Mike Taylor's move to the National Museum of Scotland and the freezing of his post as Assistant Keeper in palaeontology, activity in the Earth Sciences at Leicester has not markedly diminished, although the remaining staff are noticeably older and greyer!

After Easter, all the main galleries at the New Walk Museum were closed for a major refurbishment. In geology, the 1982 vintage "Lost Worlds" and the 1985 Palaeontology displays were dismantled (including the mounted skeleton of *Cetiosaurus*) in preparation for a complete change, with an emphasis on showing visitors real specimens. We re-opened, in record time, by the end of June.

We have aimed to share the rich scientific heritage of the Leicestershire collections with as many people as possible. Highlights, in a double gallery of star items, include stunning minerals, the Barwell meteorite and the holotypes of *Charnia* and *Charniodiscus* (displayed in a cast of the quarry face from which they came). *Cetiosaurus* is back, of course, in a new mount, and is joined by casts of *Plateosaurus* in a radical quadrupedal pose, of an Isle of Wight "Allosaurus" (perhaps *Thecodontosaurus*), and of *Coelophysis*, originally from New Mexico. Bang up to date are the clutches of dinosaur eggs, some of possible sauropods from southern France, and two from the incredible set of South China specimens that contain segnosaur embryos. Also on show are the Barrow-upon-Soar pliosaur (the "Kipper") and the best of our icthyosaurs with preserved soft tissues.

Naturally, the galleries also reflect our current research. For example, Gill Weightman is working out the mineralogy and environments of the basal Triassic unconformity in Leicestershire, and examples of the vanadium, copper and other metallic minerals she is finding are on display. A full description of *Cetiosaurus* is being undertaken by John Martin with Paul Upchurch (Cambridge), and work is under way on the biomechanics of this group of dinosaurs in an attempt to explain their strange anatomy. Meanwhile, Arthur Cruickshank's plesiosauran studies are gradually unwinding after producing more than a dozen papers since 1991.

These are not easy times for local authority museums. Funding is being cut, posts lost, and visitor numbers are down nationwide. Leicestershire Museum Service is not immune (and has also faced the threat of dismemberment by Local Government review), but we're delighted that with our new displays we're still here, and doing what museums should do.

A New Pliosaur for Peterborough

Alan Dawn writes: Bones of Mesozoic reptiles are regularly found in the Peterborough Member of the Oxford Clay, exposed in brick pits in the Peterborough area. Peterborough City Museum has an increasing collection of these ancient crocodiles, plesiosaurs, pliosaurs and icthyosaurs.

The most recent find was made in April 1994, during a visit by the North Norfolk Geologists' Association. A piece of rib was spotted projecting from the clay in the side of a drainage channel, and a little excavation indicated that further material was to be found, but was unfortunately buried beneath several hundred tons of spoil. Over the next few days volunteers were summoned, and an appeal to the work's manager resulted in the loan of a bulldozer for a few hours. The spoil heap soon vanished. Hand digging over the next two weeks revealed about half of the skeleton, including the articulated neck and part of the skull, complete with upper and lower jaws with teeth.

The animal is now being cleaned and re-assembled in Peterborough Museum. Most of the axial skeleton is present, with thoracic and gastral ribs. Some of the limb girdle bones have been recovered, but no paddle bones. The skull is being examined at Leicester Museum. A specific indentification is yet to be made, but the animal belongs to the genus *Peloneustes*.

A RIGS at Ketton, near Stamford

Alan Dawn also writes: The working face at Castle Cement's quarry, near Ketton, is more than a mile long and is well known to geologists. It exposes strata spanning the Bajocian, Bathonian and lower Callovian stages of the middle Jurassic. To the south, nearer to Ketton village, are a number of old and overgrown quarries. One of these, last worked in the 1930s, exposes the oolitic Ketton Freestone and the overlying clays of the Stamford Member of the Rutland Formation. Above this is a complete exposure of the Blidworth Limestone.

Two years ago the Stamford Geological Society embarked on negotiations to clear and develop part of this site as a Regionally Important Geological Site. English Nature approved and the management at Ketton Quarry permitted the development, so in early 1994 work finally commenced. A considerable amount of clearing has now been done. Trees and scrub have been cut and burned, and steps are being cut to allow nose-end access to the higher rock beds. The quarry management are providing a car park and access road, and an explanatory notice board and leaflets are being prepared. Support and funding have been made available by English Nature, the Geologists' Association and the EMGS. Members of the Stamford Geological Society turn out regularly to acquire aching arms and a few blisters!

If all goes well the site will be at least partially operational by the summer of 1995. An invitation will be extended to EMGS members to visit the site, to see not only the geology but also the abundant and varied flora growing on the limestone screes.

Sandstone Caves of Nottingham

Andrew Rigby writes: At the present time Tony Waltham is revising and updating the Sandstone Caves of Nottingham.

Letter to the Editor

Dear Dick

Paul Coones' bibliography of Forest of Dean geology was very useful. However, as I know to my cost, no bibiolgraphy *ever* succeeds in being comprehensive! I attach a paragraph from J. B. Delair & W. A. S. Sarjeant 1985 ("History and Bibliography of the study of fossil vertebrate footprints in the British Isles: supplement 1973-1983". *Palaeogeogr., Palaeoclimat., Palaeoecol.*, vol. 49, pp. 123-160):

> *Gloucestershire*
> In his review of "Tracks, Trails and Surface-Markings" T. Rupert Jones (1862, p. 134) mentioned "footprints in the Coal-measures of . . . the Forest of Deane [*sic*]" but furnished no details of their morphology or exact provenance. They were noticed equally vaguely in a footnote by the editor of *The Geologist* to the letter by "T" on Magnesian Limestone footprints (1862, p. 432) where it was noted also that Murchison had referred to them in his classic work *Siluria* (second edition, p. 323). Frustratingly, we have located no published description of these footprints, whose present whereabouts also eludes us.

The relevant references are:

JONES, T. Rupert, 1862. Tracks, trails and surface-markings. *The Geologist*, vol. 5, pp. 128-139.

["T"] 1862. Footprints in Carboniferous rocks. *The Geologist*, vol. 5, p. 432, figs. 1-3.

Justin Delair and I would welcome further information on these tracks, should any *Mercian Geologist* reader know more about them!

Dr. W. A. S. Sarjeant
University of Saskatchewan

Rock legends . . .

A new display board at Brewhouse Yard, below Nottingham Castle, tells the fascinating story of the formation of Castle Rock, the East Midlands' most famous geological landmark. The display is designed to appeal to schoolchildren and stimulate their interest in Earth Science. It explains how the Rock was carved by meltwater at the end of the Anglian ice age, and then takes the reader on a journey back through millions of years of geological time to the Triassic Period, describing what the world was like when the sandstone of the Rock was deposited.

The display, produced by the British Geological Survey and supported by Nottingham City Council, is also available as a poster, illustrated below (Fig. 1), from the BGS at Keyworth, Nottingham. It is the first of a series of posters that will be produced for famous geological landmarks in British cities.

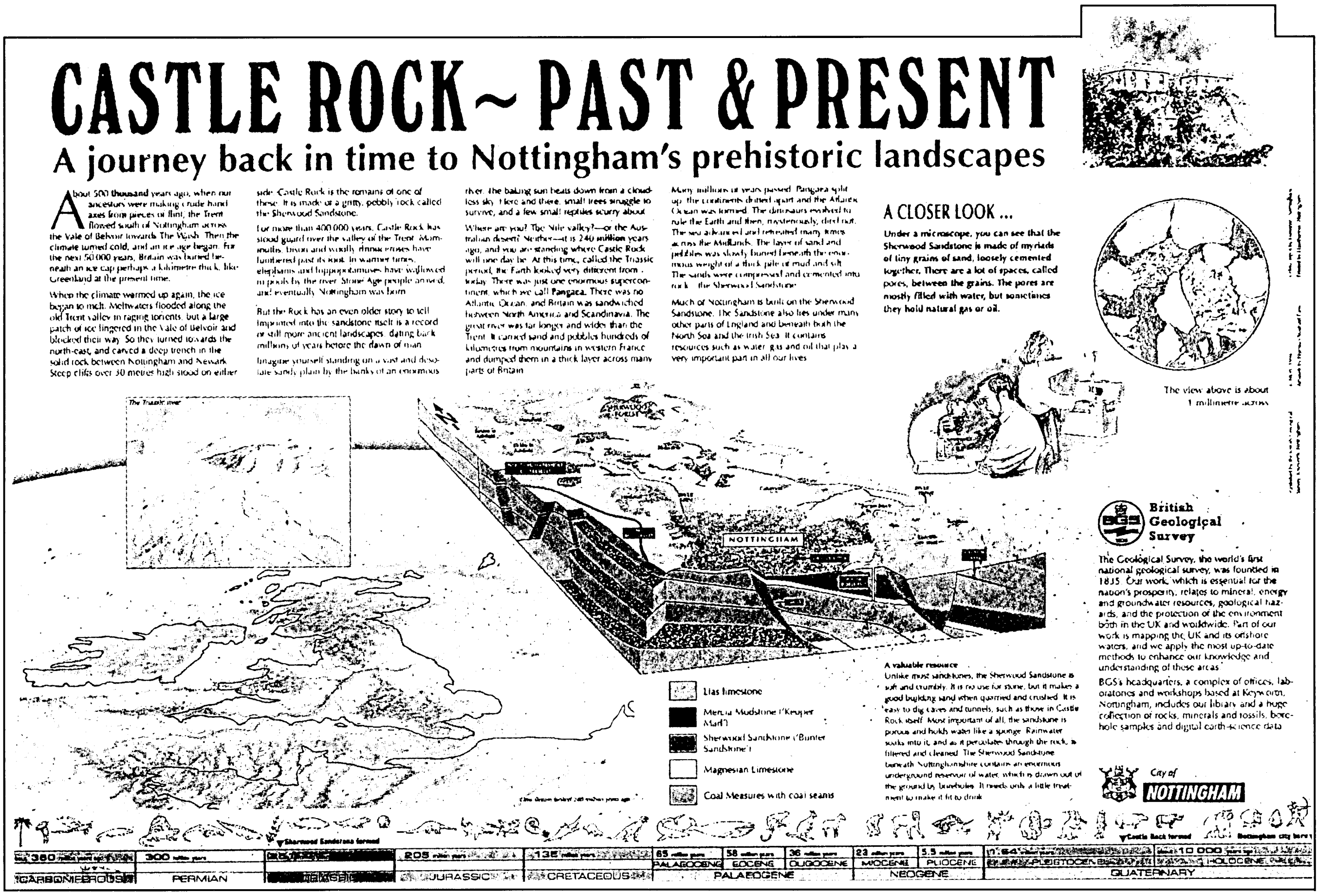


Fig. 1. Castle Rock display, available as a poster from the B.G.S.

White Watson (1760-1835) and his Geological Tablets

T. D. Ford

Abstract: Available information on White Watson's unusual geological sections, formed by inlaying samples of the strata in marble slabs, is updated. The history and whereabouts of 25 out of nearly 100 Tablets known to have been made are summarized.

White Watson was a pioneer Derbyshire geologist and craftsman, mainly in marble, whose work culminated in the publication of *A Delineation of the Strata of Derbyshire* in 1811 and in his preparation of "Tablets" illustrating the disposition of the strata of Derbyshire and occasionally of adjacent counties. I compiled a biography of Watson with a description of his contribution to geology in 1960 and a condensed version appeared in 1962. The 1960 version was re-issued with slight revisions as an introduction to the Moorland Publishing Co.'s reprint edition of Watson's *Delineation* in 1973. Further details have been added by Stanley (1973, 1976), Torrens (1975, 1977, 1978), Riley and Torrens (1980) and Cooper (1984).

The purpose of the present note is to record some further examples of White Watson's tablets. These show the disposition of the Carboniferous Limestone, toadstones, mineral veins, Millstone Grit sandstones and shales, and the Coal Measures along a series of lines across the Peak District and adjacent areas. The tablets were made by inlaying samples of the strata concerned in the appropriate arrangements of anticlines and synclines into slabs of Ashford Black Marble. Carrara marble was used for the sky and the title and place names were engraved in the black marble. Nearly a hundred are recorded in Watson's Cash Book (partly published by Robinson, 1990) and some of the purchasers can also be identified amongst the subscribers to the *Delineation* book of 1811. Prepared over a period from 1785 to 1831, the early tablets are diagrammatic only (e.g. Fig. 1), but from 1807 examples representing sections across Derbyshire and parts of adjacent counties were made with lengths to a scale of either 1 inch to 1 mile or ½ inch to 1 mile, but with

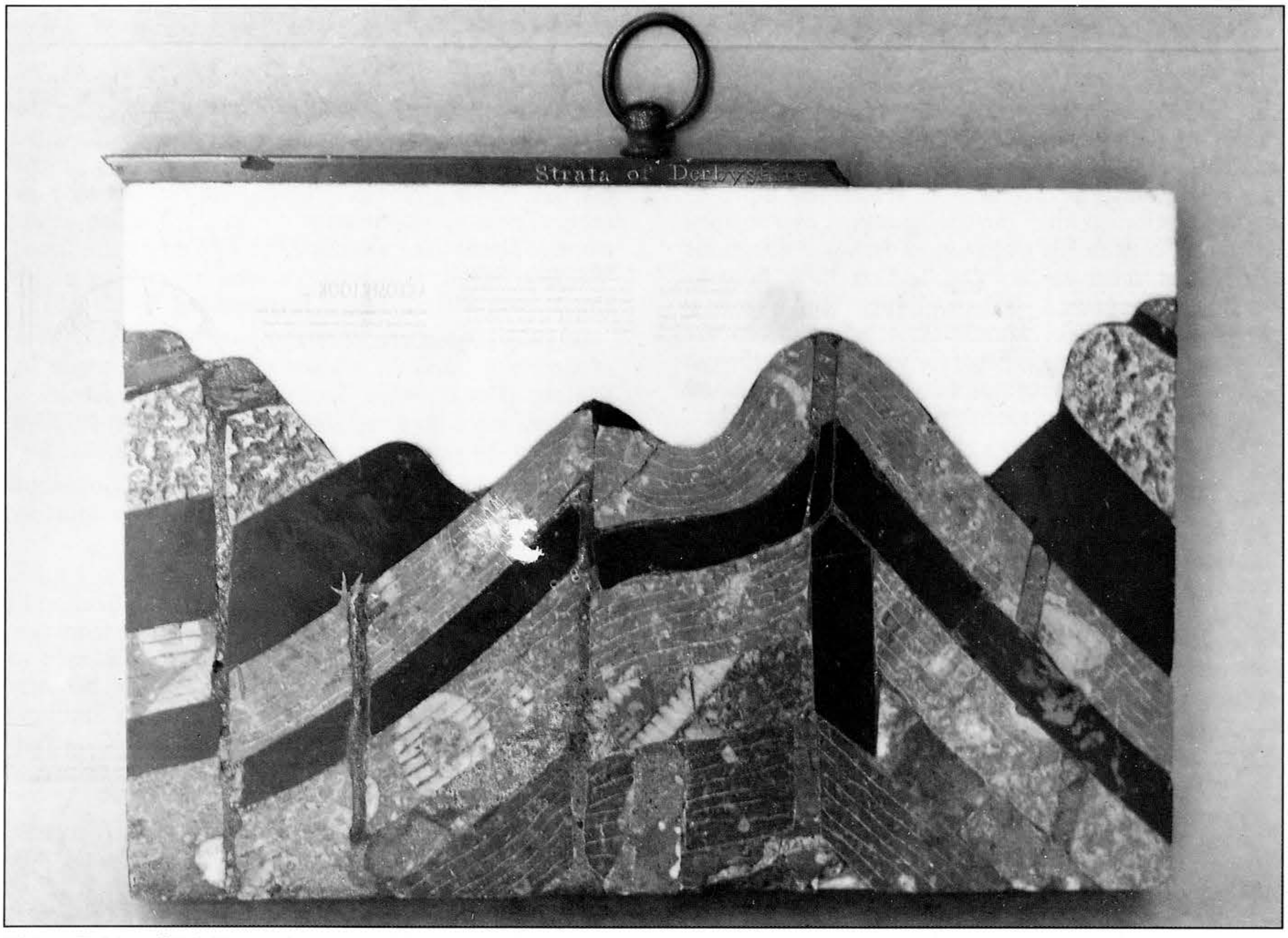


Fig. 1. Tablet of "A Mountain in Derbyshire", no date but probably made between 1794 and 1802, inscribed on the edge "Brown, Son & Maw, London". (Photo by Saffron Walden Museum).

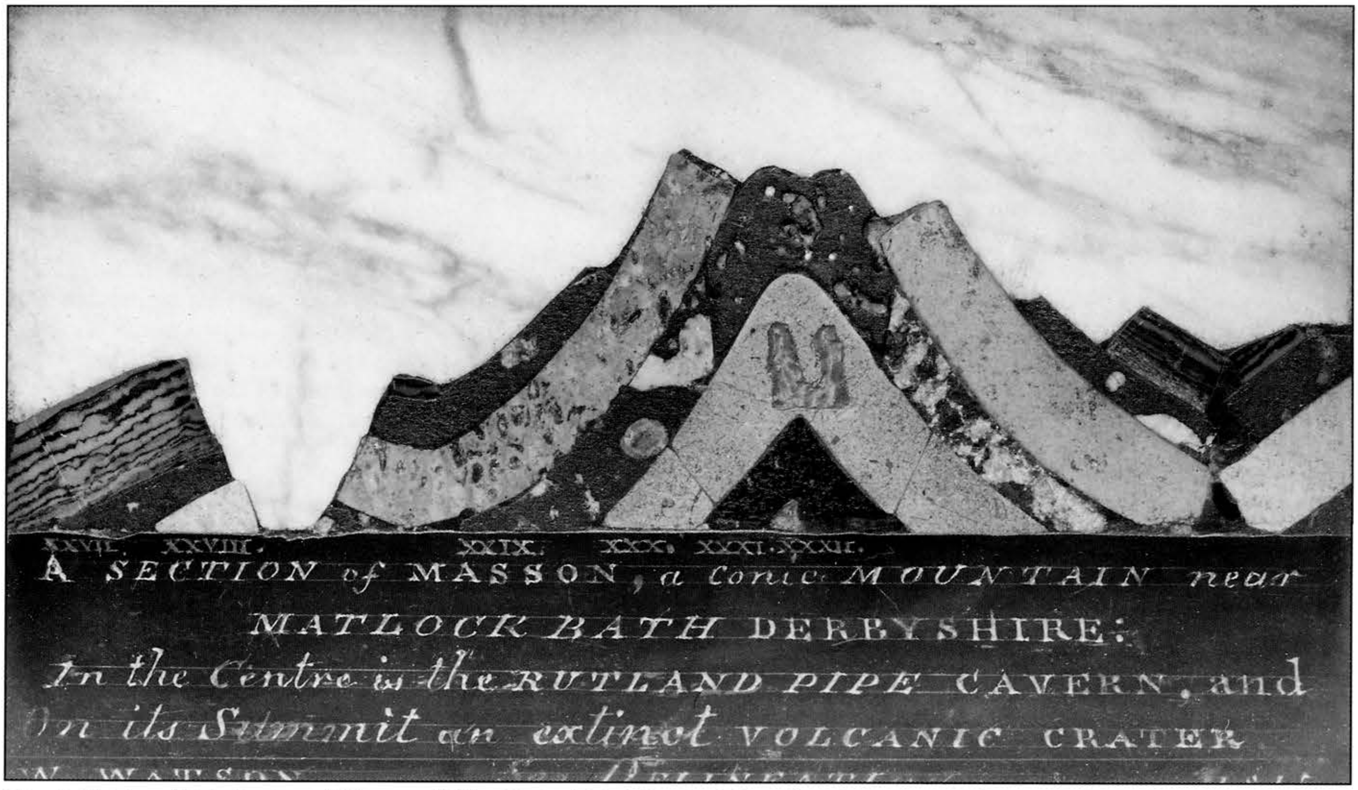


Fig. 2. Tablet of "A Section of Masson (Hill), Matlock Bath", 1815. In spite of the anticlinal form, Watson seems to regard the crest as a volcanic crater. (Photo by Sotheby's, Sussex).

thicknesses and heights exaggerated (Figs 2-4). Some of the early tablets have the thicknesses of stratal units engraved in the margins. Most tablets also have engraved Roman numerals to tie the strata shown to the descriptions, either in accompanying explanatory leaflets or later in his *Delineation*. In some museums or libraries these tablets and leaflets have become separated. The later *Delineation* tablets tend to follow main roads instead of straight lines. Some tablets are provided with brass rings fitted for wall hanging, though in one letter Watson recommended Professor Buckland to provide "a stay underneath" for extra support. Tablets varied in price up to 16 guineas.

Watson's classic section across the whole Peak District was prepared as a folding printed plate in his *Delineation*, and was based on a manuscript section drawn "by Mr Farey for White Watson" in November 1807 (note in Derby C.B.C. Local Studies Library MS 9626). It was given to the Duke of Devonshire on 20th February 1808, who rewarded Watson with a gift of 10 guineas, but it can no longer be found at Chatsworth. Farey and Watson apparently cooperated on this section as there is a note in Watson's notebooks "Nov 25th 1807 Mr. Farey and Watson chaise Bolsover-Langwith-Buxton tracing measures for a section hire chaise a good deal of time in Chesterfield stayed overnight at the Falcon £5-18-6". Farey first met Watson when he paid 2s 6d to see the "fossils" on August 22nd 1797. In the first decade of the 19th century Farey drew sections of the strata of various parts of England, but they remained unpublished (see Ford, 1967; Ford and Torrens, 1989). In 1806 Farey began surveying the minerals and agriculture of Derbyshire and visited Watson several times. They doubtless had many fruitful discussions on geological matters, each stimulating the other. In turn, information on the disposition of the strata of Derbyshire was passed on by Farey to his friend William Smith, who incorporated an outline in his classic map of the Strata of England and Wales (1815).

In 1973 I recorded the whereabouts of 17 tablets out of nearly a hundred known to have been made by Watson (Ford, 1973). Some have changed hands or locations since then and some additions to the 1973 list may now be made.

Two tablets were sold by Sotheby's for A. Longsdon in October 1992, and are illustrated here by courtesy of Sotheby's (Figs 2, 5):

1. A *Delineation* tablet, on a scale of 1 inch to 1 mile, 38½ × 5½ inches (96 × 14cm) entitled "A Section in the Strata of Derbyshire, forming the surface from east to west" (actually Coombs Moss, north of Buxton to Bolsover, near Chesterfield). Sold for £3800 (= hammer price, £4180 with commission etc.) to John Starmer, antique dealer of Liphook, Hampshire and later to David Pickup, who in turn sold it to John Bedford of Dowdeswell, near Cheltenham (Fig. 5).

2. A small tablet entitled "A Section of Masson, a conic mountain near Matlock Bath, Derbyshire", signed "W. Watson 1815". It measures 5¾ × 3⅜ inches (14.5 × 8.5cm) (Fig. 2), and was sold for £2400 to John Starmer, and later to David Pickup, who in turn sold it to John Bedford. It is only about the size of a postcard but with

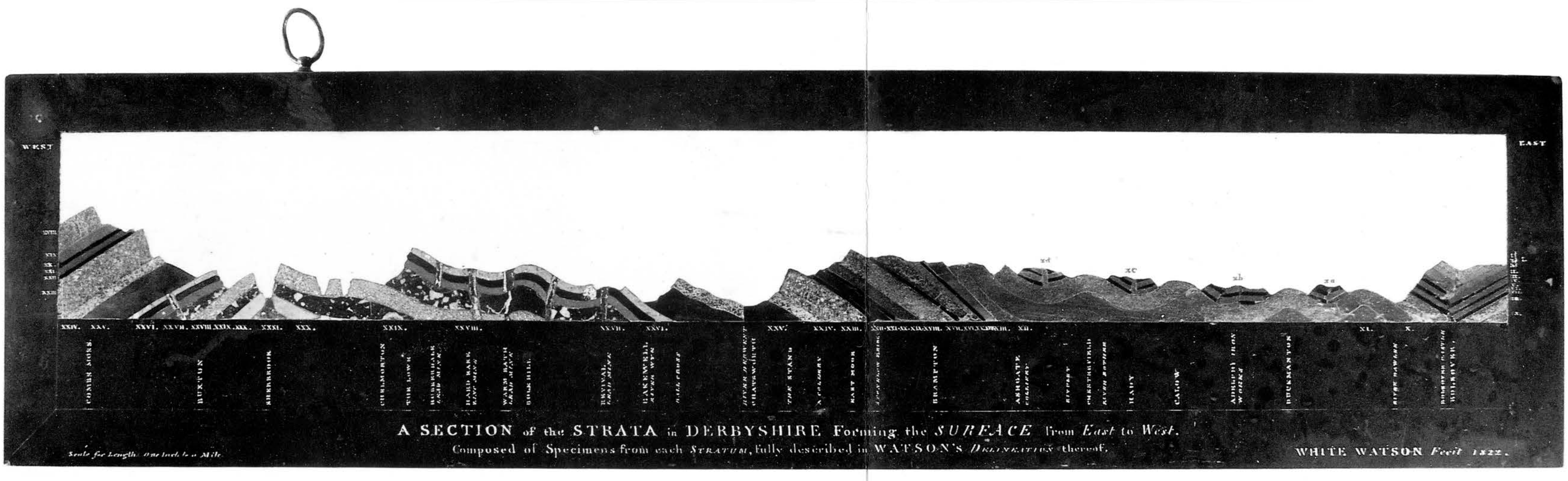


Fig. 3. Tablet of "A Section of the Strata of Derbyshire . . . from Coombs Moss to Bolsover", 1822. (Photo by Oxford University Museum).

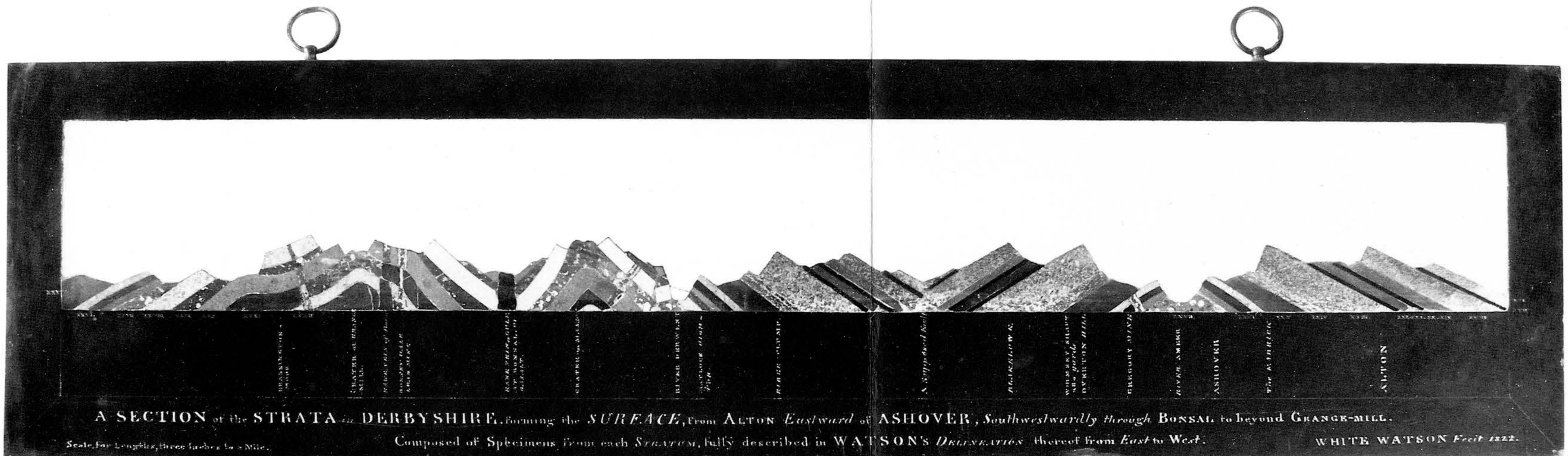


Fig. 4. Tablet of "A Section of the Strata of Derbyshire . . . from Alton to Grangemill", 1822. (Photo by Oxford University Museum).

a very wide gilded wooden frame and gives a vertically exaggerated section of the Masson Hill anticline and the adjacent Derwent Gorge; the toadstone outcrop on the summit is referred to as a crater!

James Longsdon of Longstone was among the original subscribers to the *Delineation*. He died in 1827 and his collections passed down through the family. Notice of an auction sale of the Longsdon collections by L. F. Bingham in Bakewell on December 17th 1896, includes two lots, which are tablets matching the Longsdon/ Sotheby's ones noted above, i.e. Lot 94 — a "Delineation Section" and Lot 95 — "an Inlaid Tablet illustrating High Tor, Heights of Abraham and Masson Hill". As no other High Tor-Masson Hill tablet is known it is almost certain that the latter is the same as that sold recently at Sotheby's. A cutting stuck in the flyleaf of the sale catalogue says that Lot 94 was thought to be worth £12 but was sold for £4, and other prices were ridiculously low. The Bingham sale raises the problem of how the tablets were still at Little Longstone Hall until the 1990s and one can only assume that they were bought back by some member of the family and returned home. Sotheby's 1992 prices are somewhat higher! Previously, in 1879, Bingham lent a substantial collection of White Watson's material for an exhibition at Derby Museum but whether this included tablets is not known, nor is it known how Bingham came to have the material.

Subsequent to Sotheby's sale, John Starmer put the two tablets in to Christie's Scientific instruments sale on May 6th 1993 and the Masson Hill section was sold for £3300 to David Pickup, antique dealer of Burford, Oxfordshire. The *Delineation* section did not reach its reserve price and was later sold privately to David Pickup for £5000. The two tablets have since been sold to John Bedford. By the time this note is published they may well have been sold again!

3. A double-sided tablet illustrating a "Section of the Strata of Derbyshire" on one side and on the other a section of the folded and faulted strata and the copper ore veins in Ecton Hill, Staffordshire, made by White Watson about 1800 is at the Hancock Museum, Newcastle-upon-Tyne (Stanley, 1976). It is signed by White Watson, F.L.S., measures 6¾ × 4½ inches (17.5 × 11.5cm) and has a brass ring for hanging.

4. A double-sided tablet is in Saffron Walden Museum, Essex, and shows the same diagrammatic section through a double anticline of Carboniferous Limestone on one side (Fig. 1) and a section through Ecton Hill on the other. It is almost identical to the Hancock Museum tablet (No. 3) and is also very similar to tablets in Derby Museum and in the Natural History Museum. However, the Saffron Walden Tablet has "(Bro)wn Son & Maw, London" engraved on the damaged edge (Bro is missing). It is slightly smaller than the Hancock Museum tablet and measures 6½ × 4½ inches (16.7 × 11.5cm). It also has a brass ring inset for hanging it on a wall. It is not dated but such tablets are known to have been made between 1794 and 1802, possibly later. Torrens (1992) has taken the marginal engraving to indicate that others made tablets besides White Watson, i.e. Brown's marble works in Derby, in which the pioneer Derbyshire mineralogist John Mawe

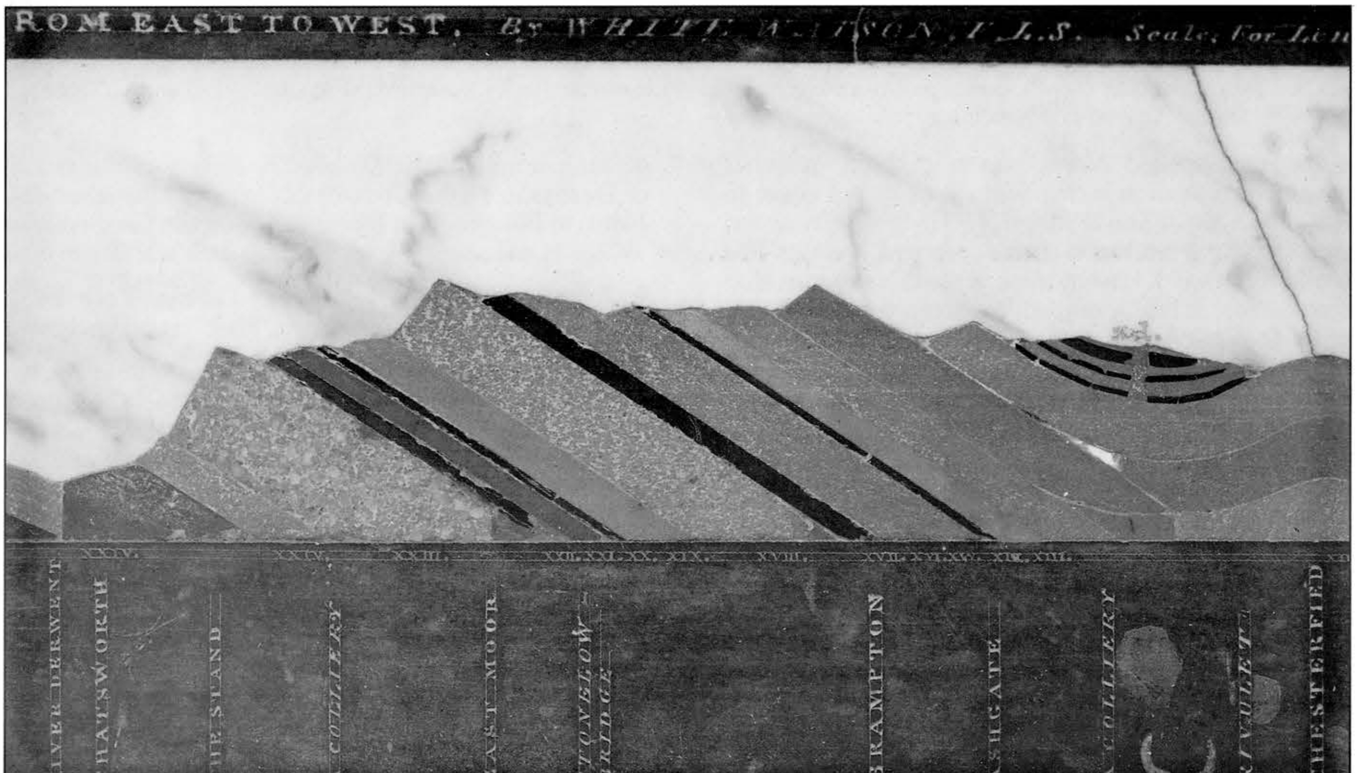


Fig. 5. Enlargement of part of a Tablet closely similar to Figure 3 above showing detail of the Millstone Grit from Chatsworth to Chesterfield; no date but probably about 1815. (Photo by Sotheby's, Sussex).

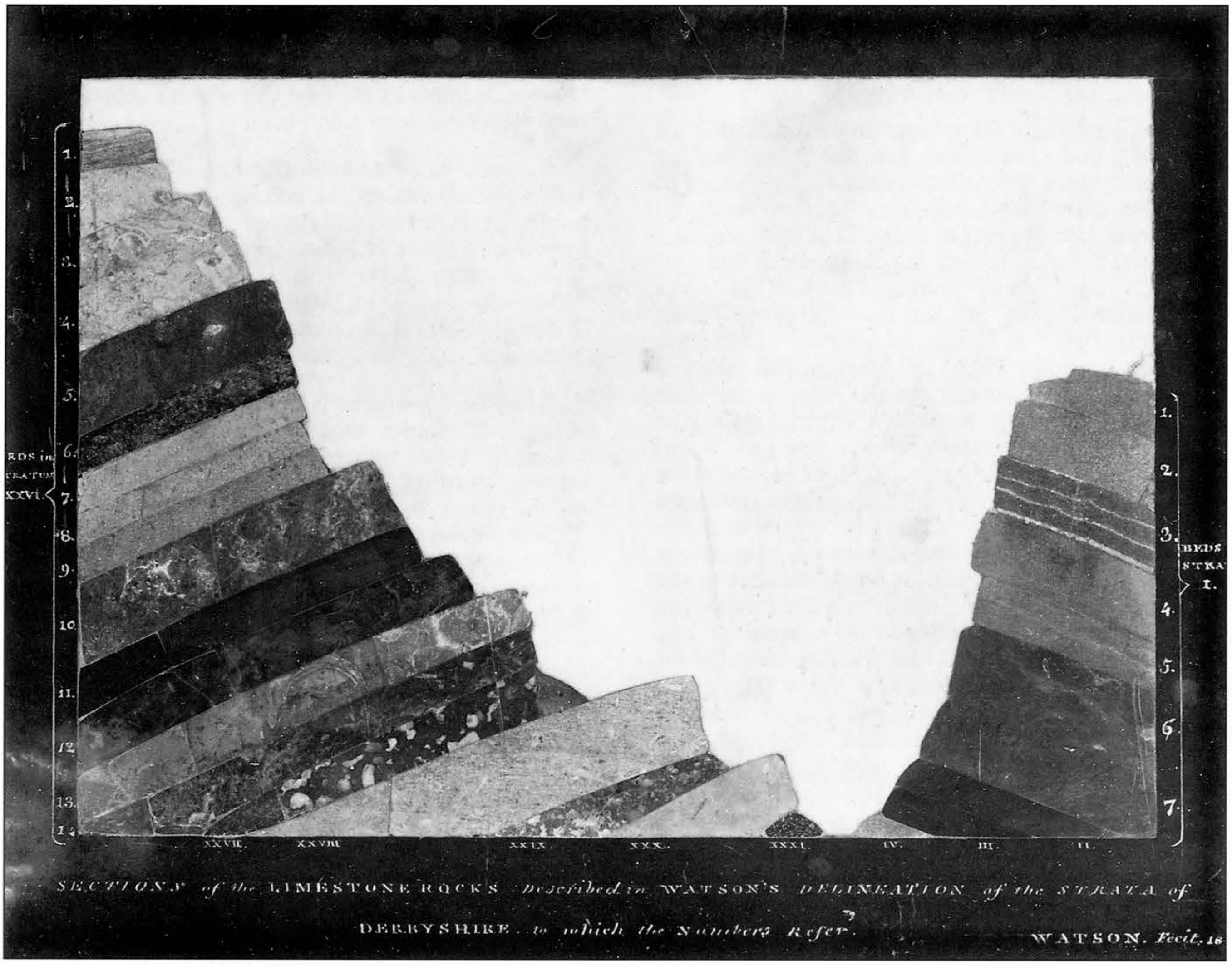


Fig. 6. Tablet showing a pseudo-escarpment arrangement of "Limestone Rocks described in Watson's Delineation", 1821. (Photo by Oxford University Museum).

(sometimes spelled Maw) was a partner. Another possible explanation is that Watson made the tablet to order for Brown, Son & Mawe, and they simply added their mark, a common trade practice today. The similarity to work known to be Watson's suggests that Brown, Son & Mawe copied Watson's work or that it really is Watson's.

5 and 6. In 1973 I noted that two tablets were in the possession of Dr. Arthur Raistrick. He died in 1991 and his geological collection including the two tablets is now in the Department of Civil Engineering, University of Bradford. His tablets include a "Section of the Strata in Derbyshire" made in 1797 and accompanied by a 26 page explanatory pamphlet, and a "Section of the Strata in Bewerley Liberty, Yorkshire" (the Greenhow Hill to Pateley Bridge area) by White Watson, F.L.S. 1800; made and sold by the author only, and accompanied by a 12 page explanatory leaflet, printed by H. Baldwin & Son, New Bridge St. London. The Raistrick tablets are duplicates of those in Derby Museum illustrated by Moyes (1990).

7. A small-scale version of the *Delineation* tablet, 52cm long, was lent for display at Loosehill Hall, Castleton in the 1980s, and is now in private hands in Bakewell.

8. An example of the *Delineation* section of the strata of Derbyshire from Coombs Moss (near Chapel-en-le-Frith) to Bolsover is in Blackburn Museum (see Stanley, 1976). It measures 21 × 6½ inches (53 × 16cm).

9. A tablet of a section of Bewerley Liberty, Yorkshire, is in private hands at Osberton Hall, near Worksop.

10. A small tablet of a "Section of Limestone Rocks Described in Watson's Delineation" dated 1821 is now at Oxford University Museum. Measuring 15 × 11½ inches (37.5 × 29.5cm), this has a sky of white marble over a valley flanked by two pseudo-escarpments composed of sequences of limestones and toadstones dipping outwards; numerals keying the sequences to the *Delineation* book are engraved in the margins (Fig. 6). This small tablet was despatched to Oxford together with the two *Delineation* style tablets previously recorded at Oxford. One is the Coombs Moss (Buxton) to Bolsover section (Fig. 3), and the other is from Grange Mill to Alton (northeast of Ashover) (Fig. 4); both measure approximately 41 × 10 inches (104 × 26cm).

11. A double-sided tablet almost identical to that at the Hancock Museum (No. 3), measuring 4½ × 6⅞ inches (11.5 × 17cm) was sold at Christie's on September 24th

1993, and bought by Derby Museum for £3500. Its history prior to the sale is not known.

12. A variant from the usual geological tablets has recently been uncovered in Chatsworth House. It is a spray of native copper mounted on white marble in a frame of black marble with a fillet of white marble. Although not signed it is described in Watson's own catalogue and is clearly his work.

Some background to the production, sale and distribution of tablets has emerged from Watson's correspondence. A draft of a letter to William Buckland in the Bateman MSS in Sheffield Museum refers to the two long tablets being sent in 1822 to Buckland at the Radcliffe Library in Oxford and, with the "Limestone Rocks" Tablet, they are now in the Oxford University Museum. They cost 16 guineas each. Watson's two letters to Buckland are also preserved in the University Museum. In his draft letter Watson noted that the crate was being sent by canal from Cromford and that the box contained a bonus of a Bewerley Liberty tablet, though this cannot be found at Oxford today. He also offered Buckland a tablet composed of Derbyshire toadstones designed like two pyramids, price £3. No pyramidal tablet is known today, unless this is a peculiar description of the "Limestone Rocks" tablet.

Amongst White Watson's many customers for tablets was William Bateman, antiquary, of Middleton-by-Youlgreave, Derbyshire. Much of William Bateman's material, and his son Thomas's, found its way to Sheffield Museum after his death but no Tablets can be found now. However, the Bateman MSS in Sheffield Museum include a collection of White Watson letters, 23 from Watson to Bateman, 69 from various correspondents to Watson and a scatter of rough drafts of letters from Watson to various people (Riley and Torrens, 1980). Some of these throw interesting light on the supply of tablets. In November 1831 Watson was trying to raise money by disposing of three tablets by lottery: one was a *Delineation* tablet, another a section from Grange Mill through Ashover to Alton, and a third was simply one composed of specimens of marbles, spars, ores, etc. Further light on the supply and demand for tablets is in White Watson's cash book (Robinson, 1990).

A letter from Watson to William Manning, M.P on 8th July 1830 recorded a recently completed tablet "representing the principal Strata of England from London, thro' Leicestershire and Derbyshire into Nottinghamshire, Price £6". No Tablet of such an extended section has been located today.

Fig. 7. Collection of sawn limestone slabs with cabinet and catalogue of "A Collection of Fossils, the Produce of Derbyshire, collected and arranged by White Watson, F.L.S., Bakewell, 1797". (Photo by the Booth Museum, Brighton).

Part of White Watson's business was the supply of collections of specimens of rocks, minerals and fossils to clients' orders. Some of these were simply small sawn and polished slabs of various rocks, including marble, and samples of mineral veins. Few of these Watson collections are recognizable entities today as the specimens have been merged with larger collections, but John Cooper of the Booth Museum in Brighton has sent me the accompanying photograph of a seven-drawer cabinet of small slabs compiled in 1796 (Fig. 7). It was bought by Sir Cecil Bishop, F.R.S. in Buxton in August 1796 (the MS catalogue is dated 1797) and was presented to Brighton Museum in 1935 by his descendant, the Baroness Zouche of Haryngsworth (now Harringworth, near Corby, Northamptonshire). Cooper gave a short description of it in 1984 and it is currently on loan to Buxton Museum, Derbyshire.

In 1960 and 1973 I recorded that I had found no trace of Watson having any children, but research by Edward R. Meeke has revealed firstly that Watson's wife was a widow, Mrs. Barker, with two children, who retained the name Barker, and secondly that Watson was assisted by a girl, Sarah, who was not a Barker. Sarah married James Bradbury and had two sons, James Watson Bradbury and White Watson Bradbury; these names suggest that Sarah had a close family connection with White Watson, though no baptismal or marriage certificate for Sarah has been found. Sarah may have been an unrecorded daughter or niece of White Watson. The great grandson Charles Bradbury was a Bakewell builder who later kept an antique shop in Baslow in the 1950s and 1960s.

If any reader knows of any more White Watson tablets, collections or manuscripts I would be pleased to know the details.

Acknowledgements

Thanks are due to Hugh Torrens (Keele University), Gaynor Boon (Sheffield Museum), Mick Stanley (Hull Museum), Nick Moyes (Derby Museum), E. R. Meeke of Millthorpe, Andrew Newman (Hancock Museum, Newcastle-upon-Tyne), John Cooper (Booth Museum, Brighton), John Martin (Leicestershire Museum), Michael Millward (Blackburn Museum), Philip Powell (Oxford University Museum), Ken Tidswell (Bradford University) and Roy Clements (Leicester University) for their help and interest.

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Appendix: a list of all 25 tablets now known to exist. Those marked with an asterisk are additions or amendments to the 1973 list.

Derby Museum:
- 1 tablet of the strata of Derbyshire from Buxton to Bolsover as in the *Delineation* (1811).
- 1 tablet of the strata at Ecton Hill, Staffs. (*c.*1797).
- 1 tablet of "A Mountain in Derbyshire" (*c.*1791).
- 1 tablet of the strata in Bewerley Liberty, Yorks. (*c.*1797).
- 2 double-sided tablets (one *) of a section of "A Mountain in Derbyshire" with "Strata of Ecton Hill" on the back (1794).

Manchester Museum:
- 1 tablet of the strata as in the *Delineation*, inscribed 1822.

Natural History Museum, London:
- 1 tablet of the strata in Bewerley Liberty (*c.*1797).

Oxford University Museum:
- *1 tablet of limestones (in pseudo-escarpments) dated 1821.
- 1 tablet of the strata as in the *Delineation*, inscribed 1822.
- 1 tablet of the strata of Derbyshire from Alton via Ashover and Matlock to Grange Mill inscribed 1822.

Leicester Museum:
- 1 tablet of toadstones, lavas and whinstones (1809).

University of Bradford:
- *2 ex-Raistrick collection tablets, one of "The Strata of Derbyshire" (1797) and the other of Bewerley Liberty (1800), as noted above.

*The Longsdon tablets,
with John Bedford at the time of writing (June, 1993).
- 1 *Delineation* section.
- 1 of High Tor, Heights of Abraham and Masson Hill, Matlock signed and dated 1815.

Hancock Museum, Newcastle-upon-Tyne:
- *1 double-sided tablet with a "section of the Strata of Derbyshire" on one side and "The Strata and Copper Veins of Ecton Hill" on the other.

Blackburn Museum:
- *1 *Delineation* tablet of the Strata from Coombs Moss to Bolsover, 53 × 16cm.

Saffron Walden Museum:
- *1 double-sided tablet almost identical to tablets in the Derby, Hancock and Natural History Museums engraved "Brown Son & Maw, London" (see discussion above).

Chatsworth House:
- 2 tablets of Derbyshire "Fossils" (comparative slabs of rocks and minerals), one dated 1788.
- 1 tablet of 18 varieties of toadstone.
- *1 mounted dendritic display of native copper in an oval slab of black marble with edging of white marble.

Osberton Hall:
- 1 tablet of Bewerley Liberty, Yorkshire.

In private hands:
- *1 *Delineation* tablet at ½ inch: 1 mile scale, exhibited at the Old House Museum in Bakewell in the summer of 1994.

Ediacaran Fossils from the Precambrian (Charnian Supergroup) of Charnwood Forest, Leicestershire, England

H. E. Boynton and T. D. Ford

Abstract: The Ediacaran fauna of Charnwood Forest is reviewed and several new forms are formally named and described, including a complex colonial form *Bradgatia linfordensis* and three new medusoid genera and species, *Ivesia lobata*, *Shepshedia palmata* and *Blackbrookia oaksi*. A new medusoid species *Cyclomedusa cliffi* is described. The frondose fossil *Charnia grandis* is recorded from Charnwood Forest for the first time. Three trails are also noted.

Introduction

Nearly 200 species comprise the Ediacaran/Vendian fauna, an assemblage of impressions of soft-bodied organisms now known from at least 25 localities on five continents (Runnegar, 1992). The phylogenetic position and evolutionary significance of this assemblage is still controversial, but understanding of the stratigraphical and geographical distribution is becoming better defined. The assemblage largely, if not entirely, pre-dates the first appearance of small shelly fossils of early Cambrian (Tommotian) age. Extinction of most Ediacaran forms appears to have taken place before the latter appeared (Fedonkin, 1978). The Ediacaran fauna has generally been assigned to the Vendian substage of the late Proterozoic (Sokolov, 1973), though other broadly equivalent and variously spelt substages have been proposed, e.g. Ediacaran (Termier and Termier, 1960; Jenkins, 1981), Ediacarian (Cloud and Glaessner, 1982; Glaessner, 1984), and Sinian (Grabau, 1922). Though all authors agree that the strata concerned are latest Precambrian, a formal stratigraphical nomenclature based on type localities is still being evaluated (Harland, 1989; Cowie and Brasier, 1989; Cowie, 1992).

Most Ediacaran fossils are preserved either as impressions on the upper surfaces of fine-grained sediments, as in Charnwood Forest, or as casts on the underside of overlying coarser-grained sediments, as at Ediacara.

Charnwood Forest, Leicestershire

Fossils were first discovered, though not recognized as such, in the Precambrian rocks of Charnwood Forest well over a century ago. Ramsay (1858) briefly noted ring-like markings on slates in the quarry north of Hanging Rocks near Woodhouse Eaves, and the quarry became known as the "Ring Pit". Harrison (1877), quoting Professor Ramsay, noted that the rings might or might not be of organic origin, possibly made by seaweeds swinging round in the tides. However, Hill and Bonney (1877-1880) dismissed these "curious concretionary markings" as inorganic. In a photograph by J. Burton taken on June 2nd 1881, entitled "Ring Pit Quarry looking north, Pocketgate, Woodhouse Eaves, Leicestershire" and now in Leicester Museum, the rocks were described as "Cambrian slates split along bedding planes on which are found numerous concentric rings ranging from 4 to 12 inches (10-30cm.) in diameter". These rings had apparently first been seen on one of the upper beds as early as 1840.

Other possible fossils were found in Charnwood Forest by Professor Lapworth, Mr J. Rhodes and Dr F. W. Bennett (Watts, 1947) who picked up pieces of banded slate traversed by what they thought were worm burrows in Deer Park Spinney in Bradgate Park, in beds now regarded as part of the Brand Group. The specimens (all but one are now in the British Geological Survey collections at Keyworth, specimen nos. 104548 and 01802/1-6; the other is in Leicestershire Museum, specimen no. 13/1904) were cylindrical tubular markings filled with coarser material, occasionally showing some parallelism of the infill to the wall of the tube. Another alleged worm tube was recorded by Friedman (1950) but it is a knobbly pyritic structure of probable inorganic origin (specimen no. 84592 in the British Geological Survey collection). Poorly preserved, they have all been hitherto regarded as pseudofossils, though the recent discovery of trace fossils in the Swithland Formation by Dr B. Bland (pers. comm.) may re-open the matter.

Records of the Charnian fauna known today date from 1957 when a schoolboy, Roger Mason, was climbing with friends in the Charnwood Golf Course North Quarry (the Ring Pit). He discovered a frond-like impression on one of the bedding planes; this was subsequently described and named *Charnia masoni* by Ford (1958). Together with *Charniodiscus concentricus* and several discoid fossils, this has been further discussed by Ford (1963, 1968, 1980), Boynton (1978), Boynton and Ford (1979) and by Sutherland *et al.* (1987). Re-interpretations of the detailed structure and biological nature of the Charnian fossils and their equivalents in other parts of the world have also been published by Glaessner (1959, 1966, 1971, 1979, 1984), by Glaessner and Wade (1966), by Jenkins and Gehling (1978) and by Runnegar and Fedonkin (1992).

As a result of intensive searches some 80 specimens have now been recorded by the authors in Charnwood Forest. Closer examination of the bedding surfaces has also revealed faint traces of structures not previously noted. Recent finds include some taxa and localities not previously recorded.

Charnian Supergroup: Stratigraphy and Age

Watts outlined a stratigraphical subdivision of the Charnian rocks in 1910 but a full description was not published until his posthumous book in 1947. Moseley (1979) remapped Charnwood Forest and has revised and formalized Watts' sequence (in Moseley & Ford, 1985) as in Table 1.

Previous records of Charnian fossils have mostly been from the Hallgate Member of the Bradgate Formation, formerly the Woodhouse Beds of Watts' 1947 classification. Ford (1968) recognized that the fossil occurrences at the Charnwood Golf Course Quarry, the Outwoods and the Memorial Crags were in the Woodhouse Beds (now Hallgate Member) at varying bed thicknesses above the Slate Agglomerate (now Sliding Stone Slump Breccia); this variation may be due to local changes in thickness of the basal part of the Hallgate Member. Moseley (1979), however, regarded the fossil occurrences as being at three separate horizons in the Hallgate Member. Other fossil occurrences are in the Old John Member of the Beacon Hill Formation in Bradgate Park, in the Lubcloud Greywacke Member of the Ives Head Formation, and in Cliffe Hill Quarry at Markfield, where owing to discontinuity of exposure and faulting the horizon is uncertain but is probably within the Hallgate Member. Thus, the majority of the known fossils occur in the Hallgate Member. Three occurrences of "worm" trails have also been found in this Member. As yet unpublished, burrows of *Teichichnus* type have recently been found in the Swithland Formation (B. Bland, pers. comm.). Despite several searches, no recognizable acritarchs have been found (C. Peat, pers. comm.).

The field relationships of the Charnian rocks strongly favour, but do not prove, a Precambrian age. In the Nuneaton inlier in Warwickshire, Cambrian beds unconformably overlie rocks closely similar to the Charnian, and both the Nuneaton and Charnwood Precambrian sequences appear to terminate in a phase of dioritic (markfieldite) intrusion. Radiometric dating indicates a late Precambrian age for some of the Charnian igneous rocks but still leaves considerable uncertainty about the date of sedimentation. Meneisy and Miller (1963) obtained a range of K-Ar dates for the Charnian volcanic (porphyroid) rocks of Bardon Hill, yielding a preferred age of 684±29 Ma; these extrusive igneous rocks were thought to be broadly contemporaneous with the Maplewell Group. The younger dates they obtained may be due to overprinting by later events, but the determination of 684±29 Ma seems to be too high, perhaps due to inherited argon. Cribb (1975, revised with a new constant by Pankhurst, 1982) obtained a "young" Rb-Sr date of 547±57 Ma for the southern group of diorites, including the intrusion at Markfield. Thorpe (1979, 1982) argued a case for the Charnian being part of a southern British calc-alkaline igneous province about 600±50 Ma. Recently Tucker and Pharaoh (1991) have obtained a U-Pb date from zircons in the Nuneaton diorite (markfieldite) at 603±2 Ma and Brasier (1992) has taken this to indicate the age of the whole Charnian Supergroup. However, no radiometric date has yet been obtained for any of the Charnian sediments and the dates obtained from associated igneous rocks still leave open doubts as to their relationship to the sediments. Overseas occurrences of Charnian fossils lie in rocks generally dated at around 550-570 Ma: such a date is reasonable for the Charnian fossils but, again, most overseas records are also in rocks where direct dating is not possible. In the present state of knowledge it is perhaps best to regard the Charnian fossils as in the 550-600 Ma age range.

As discussed by Ford (1980) these dates place the Charnian and its fossils in the Vendian division of the Late Precambrian as understood in Russia (Sokolov,

CHARNIAN SUPERGROUP		
Group	**Formation**	**Member**
BRAND (198-356m)	Swithland*	
	Brand Hills	Stable Pit Quartz Arenite Hanging Rocks Conglomerate
MAPLEWELL (1702-1608)	Bradgate*	Hallgate* Sliding Stone Slump Breccia
	Beacon Hill	Old John* Sandhills Lodge Beacon fine-grained tuffs(*?) Benscliffe
BLACKBROOK (1435-718m)	Blackbrook Reservoir	
	Ives Head*	South Quarry Slump Breccia Lubcloud Greywackes* Morley Lane Tuffs
The first thickness figure is from the southwest limb of the Charnwood anticline and the second from the northeast limb. Fossiliferous formations or members are shown by asterisks. After Moseley and Ford (1985).		

Table 1.

1972, 1973), which has been correlated with the Ediacaran of South Australia (Termier and Termier, 1960; Cowie and Brasier, 1989; Cowie, 1992). Similarly, correlation with some part of the Sinian System of China (Grabau, 1922) is very probable.

Sedimentary Environment

The Charnian sediments comprise a succession of coarse vitric tuffs, lithic tuffaceous pelites and slump breccias in the Blackbrook and Maplewell groups. These are followed by more mature sediments in the Brand Group, including quartz arenites, with localized conglomerates and thick pelites (Swithland Formation) in the upper part. Extrusive volcanic activity was largely confined to the Maplewell Group, though thick lavas and tuffs also occur beneath the lowest exposed beds of the Blackbrook Group in the Morley Quarry borehole (Pharaoh and Evans, 1987).

Sedimentation commenced in the Blackbrook Group with periodic volcanicity yielding silt-sized pyroclastic debris within a thick pelitic succession. Whereas most of the Blackbrook Group indicates quiet sedimentation, there are scattered slumped and contorted beds in a few localities. Deposition of pyroclastic silts and pelites continued into the Maplewell Group with episodes of short-lived explosive volcanic activity. Instability is represented by slump and pull-apart breccias of the Benscliffe, Sand Hills Lodge, and Sliding Stone members. The slump breccias indicate gravity slides of a mixture of coarse agglomerate with uprooted slabs of pelite, whilst the pull-apart breccias consist of clasts of pelite and tuffaceous pelite in matrices of arenite, greywacke or tuff.

The Brand Group shows a marked change to more mature sediments with sheets of quartz arenite containing conglomerate lenses passing up into thick pelites with scattered thin greywackes. The incoming of the Brand Group arenites suggests a hiatus with a considerable period of erosion but no clear contacts are exposed. Rounded pebbles of porphyroid in some of the conglomerate lenses demonstrate that some erosion of the Maplewell Group may have occurred, but no angular unconformity has been detected and so far no exotic pebbles have been found within the Brand Group.

The Charnian sediments appear to have been deposited in a subsiding basin with a volcanic arc lying somewhere to the west as shown by the rather coarser pyroclastic material of Bardon Hill and Whitwick in the northwest part of the Charnwood anticline (Moseley, 1979; Moseley and Ford, 1989). The orientation of current bedding and slump structures indicates that most of the basin infill was derived from the west but there was also some epiclastic detritus derived from a landmass to the southwest. The environment of the main (Hallgate Member) fossil horizon was one of pyroclastic detritus of variable but chiefly fine grained character. Both fine lamination and graded bedding have been noted. Shallow water-depth indicators such as mud-cracks and ripple-marks are lacking but at least some of the detritus probably fell from the atmosphere directly into the sea where it settled either as laminae of varying grain size or in agglomeratic beds which slumped due to seismic shocks.

No clear sedimentary water-depth indicators have been found. The community of benthic organisms with hold-fasts, planktonic medusoids and occasional trails could occur at any depth, though it seems likely that depths were not great adjacent to active volcanoes, perhaps little more than wave-base. Indeed, it seems unlikely that planktonic organisms could sink to great depths and still be preserved on bedding surfaces.

Palaeontology

The Charnian fossils fall into the following groups: (1) simple frondose colonies; (2) complex frondose colonies; (3) discs, with or without concentric rings; (4) circular to ovoid forms with various patterns of lobes; (5) possible worm burrows.

Some of the faintest impressions are difficult to see except in optimum lighting conditions; these are strongly oblique sunlight, normally only available at certain times of day, at certain seasons of the year, and varying between localities. Owing to the resistant nature of the outcrops and the slaty cleavage, collection of fossil-bearing slabs is rarely possible, and therefore most specimens remain in their field localities, where, regrettably, some vandalism has already taken place.

Preservation. Erosional removal of the overlying beds is an essential feature to reveal the fossils, and it has therefore been difficult to study the relationships between the fossiliferous beds and their cover. Only at one locality has it been possible to make thin sections through the fossiliferous bed and its cover. This showed little difference in lithology, no more than a slight increase in ash content of the overlying bed. Macroscopically at the Old John locality the immediate cover showed a hint of increased water movement and sorting. No equivalent of the distinct ash fall tuff beds in Newfoundland has been seen. The fossiliferous horizons thus represent brief preservational events in a continuum of volcaniclastic sedimentation.

The fossils are preserved as casts or external moulds on the upper surfaces of beds of indurated and cleaved fine-grained tuffaceous sediment. Weathering has enhanced the relief on some bedding planes, particularly if they are not too strongly cleaved. The relative resistance of the organisms' bodies to decay after burial was proposed as a reason for different preservation by Anderson (1978). External moulds could be formed where the bodies were compacted into the mud on which they came to rest. The strength of the relief in some specimens suggests that the bodies had sufficient strength in the body tissues to project upwards into overlying sediments during lithification, but no preserved upper surface of an organism within an overlying bed has yet been found, precluding a full comparison with the fossils at Ediacara, which are preserved in the undersides of overlying beds (Wade, 1968, 1969).

The Charnian sediments are on the borderline between high grade diagenesis and low grade metamorphism, and cleavage is present in most of the fine-grained rocks. Evans (1963, 1968, 1979) and Moseley (1979) have shown that although cleavage and fold axes are roughly parallel they were separate events, with cleavage imposed after the main folding event. The fossils occur on bedding planes where weathering has etched out morphological detail. Most discs are ovoid, but occasionally others are circular on the same bedding plane. The elongation of the ovoid discs is not always in the same ratio and not obviously related to cleavage. Three discs on the same bedding plane in The Outwoods have parallel elongation, but the ratios are 1.03, 1.37 and 1.6. The orientation is near to but not quite parallel to the cleavage; thus it seems unlikely that the elongation could be a cleavage effect and the orientation is more likely to have been due to current direction at the time of settlement. Thus the elongation of the ovoid discs is here more likely to be an original feature in contrast to the probable elongation by cleavage noted in Norwegian medusoids by Farmer *et al.* (1992). No distortion of the frondose fossils by cleavage has been detected.

Fossil horizons. Fossils have been found at six localities. Whilst four, and possibly five, of these are in the same member, they cannot be proved to be at exactly the same horizon.

1. Old John, Bradgate Park — Hallgate and Old John members
2. Memorial Crags, Bradgate Park — Hallgate Member
3. The Outwoods, Nanpantan — Hallgate Member
4. Charnwood Golf Club (North) Quarry — Hallgate Member
5. Cliffe Hill Quarry, Markfield — Hallgate Member?
6. Ives Head — Lubcloud Greywacke Member, Blackbrook Group

The Fossils. *1. Simple frondose colonies*. The best known of these are *Charnia masoni* Ford and *Charniodiscus concentricus* Ford. *C. masoni* consists of a frond composed of a series of lobes obliquely divergent from a sinuous median line suggesting that a supporting structure lay out of the plane of the impression. Each lobe is constricted at close intervals to give a segmented appearance. The distal end has lobes of decreasing size. In the Charnwood specimens of *C. masoni* the proximal end appears to have broken off from some form of attachment, but in both *C. concentricus* and some specimens from Ediacara the proximal end of the rachis merges with the centre of a disc which may have acted as a holdfast. In *C. concentricus* the lobes are less well-defined, closer together and arise at right angles to the rachis, with distal upward curvature.

In the original description, Ford (1958) suggested that the frondose organisms could be algal, but subsequently Glaessner (1959, 1966, 1984), Glaessner and Wade (1966), Jenkins and Gehling (1978) and Jenkins (1985) have argued that the organisms have greater affinity with cnidarians such as pennatulids. Others, such as Pflug (1966, 1970, 1973) and Seilacher (1984, 1992), have proposed that the frondose organisms are a totally distinct, and extinct, type of organism which requires a separate classification in a Phylum Vendobionta. Pflug's descriptions include diagnoses where it is difficult to separate factual observation from imaginary features. Seilacher suggested that the Vendobionta had a quilted air mattress body structure a few millimetres thick and that they were sessile obtaining their nourishment by absorbtion through the integument. We regard this interpretation as inapplicable both to the simple and the complex frondose colonies described herein which show evidence of being erect on the sea-floor with a three-dimensional structure. As Seilacher (1984) has suggested, no direct evidence of cnidarian polyps has been found. However, we agree with Glaessner (1966) who postúlated that the segments and the outer ends of the lobes might have been occupied by polyps, as seen in modern pennatulids (sea-pens). In both *Charnia* and *Charniodiscus* fronds the outer terminations of the lobes are poorly defined, so that no seatings or attachments for polyps are visible. Some of the medusoids have very faint traces of what may have been tentacles outside the discs.

These two frondose organisms are thought to have been benthic, attached to the sea floor by discoid holdfasts. Modern pennatulids have a bulbous organ inflated with water at the base of the rachis providing attachment in soft sediments and this may well have been the case with *Charnia*. The preservation of the fossils is through the fronds falling sideways on to the sediment surface; obverse or reverse impressions of different characters would result, some showing the rachis, others not.

Most *Charnia* specimens in Charnwood Forest are about 200 mm long but a single incomplete impression high on the Memorial Crags is about 600 mm long (Fig. 1), and when complete was possibly as much as a metre long (Brasier, *in* Cowie and Brasier, 1989). Comparable large fronds have been found in Newfoundland, Russia and Australia. Originally named *Rangea grandis* by Glaessner and Wade (1966), this large species was assigned to *Glaessnerina* by Germs (1973) though he said that *Charnia* and *Glaessnerina* might well be the same genus. Glaessner (1979, 1984) retained the generic name *Glaessnerina*, but this large form was referred to *Charnia grandis* by Runnegar (1992). The Memorial Crags specimen is here assigned to *C. grandis*. A cast is in Leicestershire Museums Geology collection, accession no. G31/1994 (Fig. 1).

Other frondose organisms found elsewhere broadly comparable with *Charnia* and *Charniodiscus* include *Charniodiscus arboreus* and *Phyllozoon hanseni* from the Bunyeroo Gorge, South Australia (Jenkins and Gehling, 1978), *Charniodiscus oppositus* Jenkins & Gehling (1978) from Ediacara, South Australia, *Charnia grandis* (Glaessner and Wade, 1966), *Pteridinium simplex* Gürich (1930) and *Rangea schneiderhöhni* Gürich (1930) from Namibia, *Pteridinium* cf. *simplex* Gürich from North Carolina, U.S.A. (Gibson *et al.* 1984), and *Rangea longa* Glaessner and Wade (1966) from Ediacara. Several types of fronds, including spindle-shaped forms, lobate and bush-like forms, all unnamed so far, have been found in the Conception Group of southeast Newfoundland and only limited descriptions are available (Misra, 1969; Anderson, 1972, 1978; Anderson and Misra, 1968).

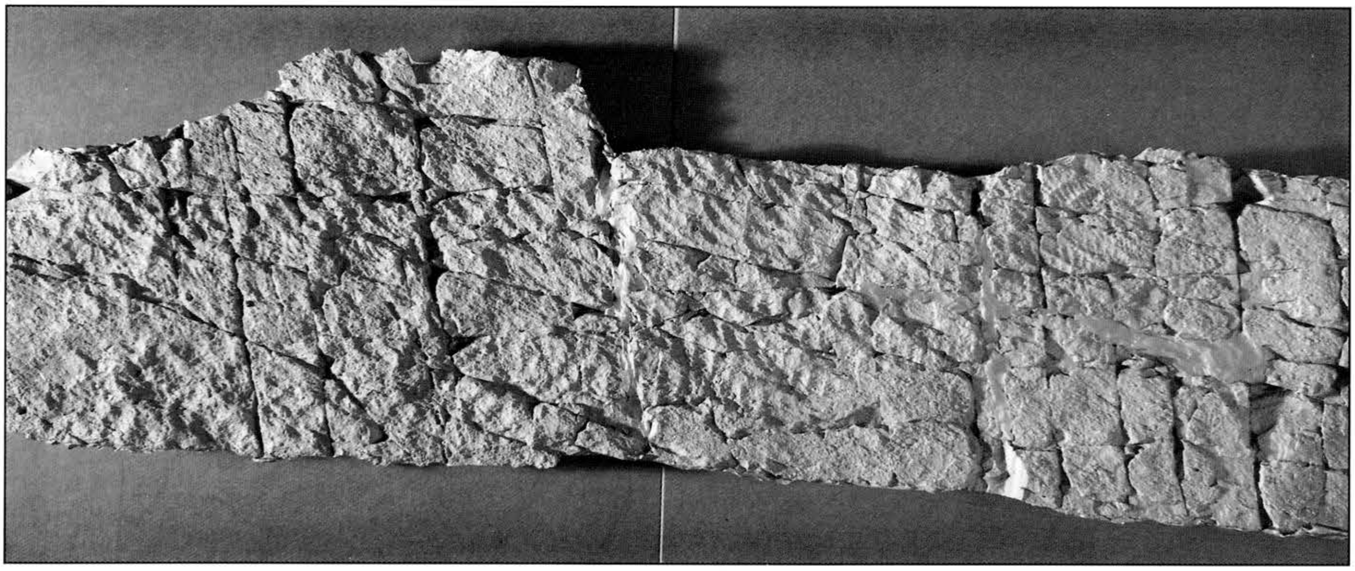

Fig. 1. *Charnia grandis* (Glaessner and Wade): cast of incomplete specimen about 600 mm long.

Charniodiscus cf. *arboreus* has been recorded with a variety of other metazoans in the Wernecke Mountains of the Yukon by Narbonne and Hofmann (1987). A wide variety of fronds, medusoids and trails has been found in the Mackenzie Mountains of northwest Canada (Narbonne and Aitken, 1990). *Charnia masoni* and *Pteridinium nenoxa* have been recorded with a variety of probable medusoids in north Yakutia, Russia, by Fedonkin (1990). Membranous, carbonized compressions in the Dengying Formation of the Sinian System of the Eastern Yangtze Gorge in China were originally described as a new species of *Charnia*, but were re-assigned to *Paracharnia dengyingensis* by Sun (1986a) on account of their much wider axial stems and shorter polyp leaves. The presence of a *Charnia* fauna in several parts of China, Siberia and northern Iran has been noted by Brasier (*in* Cowie and Brasier, 1989). Distinctions between these various frondose organisms have been made on the basis of details of the lobes, the presence and size of a stem and on the size of the colony. Several of the above species have been assigned and re-assigned to other genera at different times, and those given above are those currently in use.

The discovery in Charnwood Forest of a single miniature *Charnia*-type frond only 17 mm long with a very small disc holdfast (Fig. 2) suggests that at least some of the frondose organisms may have had a budding mode of reproduction; similar small feather-like fronds have been found on the margins of some of the complex frondose colonies of *Bradgatia* noted below, supporting the view that budding may have occurred from such colonies (Figs 4, 6, 8, 10).

The small impression *Pseudovendia charnwoodensis* Boynton and Ford (1979) was referred to as a primitive arthropod, but it may well be a fragment of a frond.

2. *Complex frondose colonies*. Ten highly complex but faint impressions have been found at the Memorial Crags locality and at first glance they resemble ball-like masses of sea-weed. They represent organisms which may have been up to 40cm in diameter and they can be broadly described as radiating bundles of *Charnia*-like fronds. The impressions suggest that the complex colonies may either have been sessile bush-like organisms, as shown diagrammatically by Jenkins (1984, 1985), or have represented floating colonies which later settled on the sea-floor in relatively quiet conditions. The radiating fronds appear to spring from one or more central protuberances which may represent either anchoring mechanisms or floats buoying up the cluster of fronds. The tissues may have been fairly rigid, strengthened by chitin or collagen, though no direct evidence of either of these has been found. Nor has evidence been found of crushing or wrinkling on

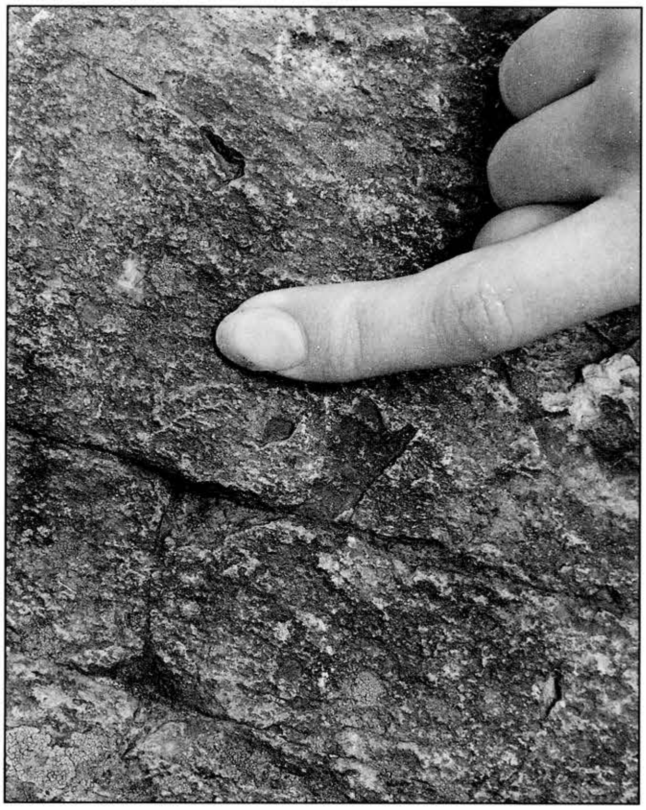

Fig. 2. Small *Charnia* frond, about 17 mm long.

settlement. These complex colonies are herein considered to be a single new monospecific genus with variations in the form of the impressions caused by the angle of rest on the sediments, the mode of preservation and perhaps by decay effects. They are herein named *Bradgatia linfordensis*. *Bradgatia* can be visualized as a colonial organism consisting of a large number of fronds emanating from an ill-defined central area (Figs 3-11).

Some of the trailing fronds resemble miniature *Charnia* (Figs 4, 6, 8, 10) thus suggesting that the organism could have been a colony of small *Charnia*-like fronds growing from a centre. This raises the question as to the relationship between the complex colonies and the solitary large frondose organisms. It is possible to speculate that they were alternating generations, but without further evidence the problem remains unsolved and the forms are treated as separate taxa.

3. Discs and disc-like impressions. By far the most common fossils in the Precambrian rocks of Charnwood Forest are discs. They are generally ovoid in shape, range up to 162 mm in length and have been found at five localities. Only a few circular discs have been found. Hitherto all have been referred to *Cyclomedusa davidi* Sprigg in its broader definition by Glaessner (1979) which incorporates forms with and without fine radial striations preserved.

Both ovoid and round forms may or may not have inner concentric rings of varying strength. Some are completely devoid of such features whilst others have numerous closely packed rings, which may be sharp ridges or more gentle convex ridges in cross-section. The centres of the discs may or may not have evidence of a distinct boss or the base of a stem-like projection which is now flattened. Whether these represent attachment points of fronds or the central organs of medusoids will be discussed below. Accordingly, the interpretation of the discs is either as benthic frond holdfasts attached to or embedded in the sea-floor or as the central organs of planktonic drifting jellyfish. Whether they are Hydrozoa or Scyphozoa cannot be determined at present, and nothing to support a morphological evolution from simple Hydrozoa such as *Cyclomedusa* to complex Scyphozoa such as *Mawsonites* proposed by Sun (1986b) has been found.

Discoid (medusoid?) impressions are common at most of the same localities as the frondose organisms and are known from other late Precambrian sequences which have not yielded fronds as yet, e.g. South Wales (Cope, 1977). A large medusoid fauna has recently been described from Finnmark by Farmer *et al.* (1992). The fossils show that there was a substantial variety of both frondose and discoid organisms round the world in late Precambrian times. At present no morphological types can clearly be shown to pre-date others so that no

Fig. 3. *Bradgatia linfordensis* holotype. About 410 mm wide.

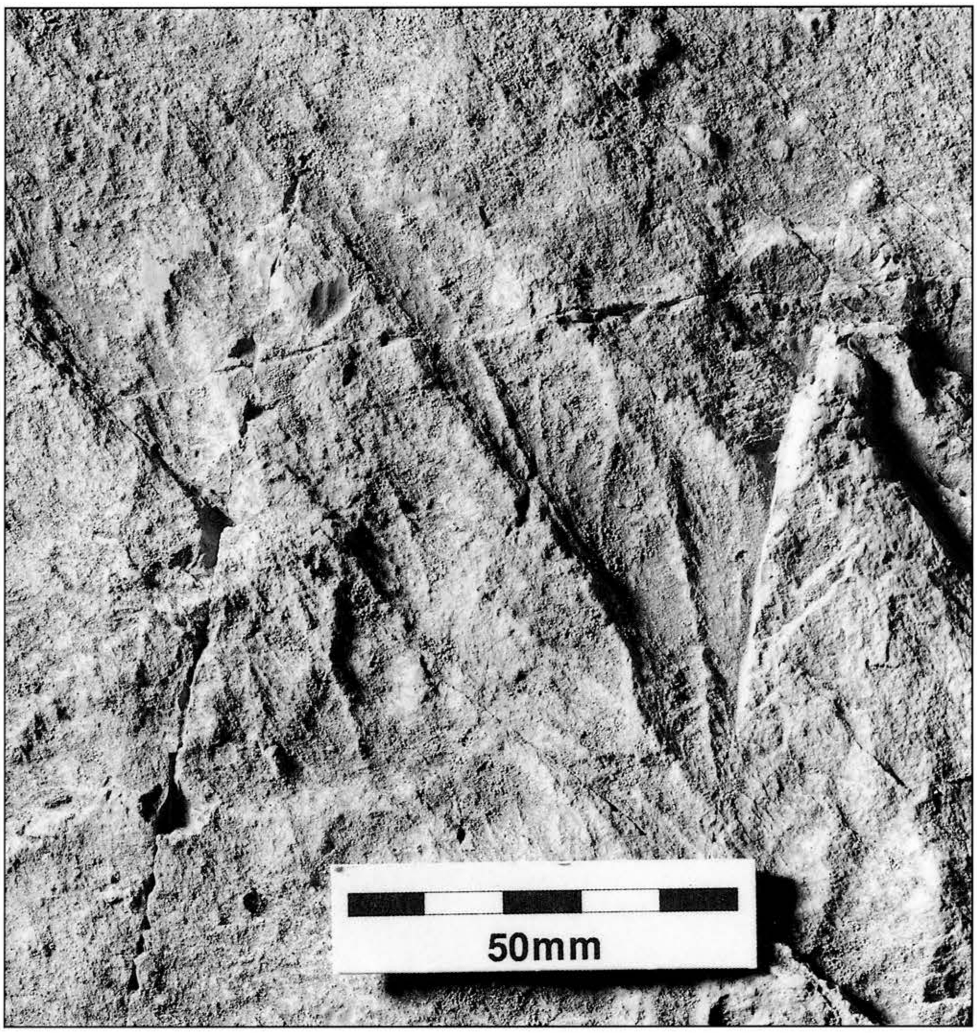

Fig. 4. Enlargement of upper right part of *Bradgatia linfordensis* showing the *Charnia*-like character of the small frondose branches.

phylogenies are known. The evolutionary lineage proposed by Jenkins (1984, 1985) is as yet unsupported by a sequential stratigraphical distribution of progressively more evolved forms.

The different types of disc-like fossil found in Charnwood Forest are:

a) An ovoid disc with a single raised rim but with no boss or concentric rings; only occasional small irregularities occur within the disc. Six specimens have been found, the largest in Cliffe Hill Quarry, Markfield. It is ovoid measuring 151 × 65 mm. Another specimen from the same locality shows two overlapping ovoid discs. These were noted but not named by Boynton (1978, pl. 22, fig. 4). They are not named here though they show some similarities to *Beltanella gilesi* Sprigg and to *Planomedusinites grandis* Sokolov.

b) Five large ovoid discs were found (three subsequently lost in quarrying) in Cliffe Hill Quarry. They consist of an outer, slightly wavy, convex, irregular rim separated by a smooth gentle depression from a raised central convex boss. These were listed as *Cyclomedusa* cf. *davidi* Sprigg by Boynton (1978, pl. 21, figs. 3, 4) and are broadly comparable with *Tirasiana disciformis* Palij (Fedonkin, 1978, pl. 3). They are assigned to a new species *Cyclomedusa cliffi*.

c) Circular to ovoid discs with slightly irregular rims and faint lobes in the central area. Figured but not named by Boynton (1978), these discs occur on Ives Head in beds of the Lubcloud Greywacke Member, some 2000 metres stratigraphically below the fossiliferous Hallgate Member of the Maplewell Group. They are poorly preserved in rather coarse volcaniclastic sediments. The locality has yielded two specimens with an ill-defined cluster of deformed, possibly coiled, lobes in the centre, *Ivesia lobata* gen. et sp. nov. (Figs 12, 13), another showing two (or possibly three) discs adjoining, herein named *Blackbrookia oaksi* (Fig. 17), and a third with a palmate disposition of markings and a faint suggestion of a stem, herein named *Shepshedia palmata* (Fig. 16).

d) Ovoid discs showing many concentric rings. Best known from the Hallgate Member of the Bradgate Formation, these occur in The Outwoods. The largest specimen is still *in situ* (cast in University of Leicester Geology Dept. accession nos. 115421/0 and 115422/0). It is 220 × 160 mm and has at least 12 concentric rings which are sharp ridges in cross-section. A small irregular oval boss (with an axis 2 mm long) occurs at the centre of one of these specimens and there are very faint traces of what may have been tentacles on the largest specimen, some apparently extending beyond the margin of the disc. Referred to *Cyclomedusa* cf. *davidi* by Boynton (1978) and herein, the many concentric rings indicate some similarity to *Kullingia concentrica* Føyn and Glaessner, though the rings are not as regularly spaced. *Kullingia* sp. of Narbonne and Aitken (1990) in northwest Canada and *Liaonanella multicyclia* Xing and Lui (in Hong *et al.* 1989) in China are other comparable forms. The multi-ringed form from The Outwoods also resembles *Madigania annulata* Sprigg which has been incorporated within *Cyclomedusa* by Glaessner (1979). These assignments have also been discussed by Narbonne and Hofmann (1987). Comparison may also be made to *Kullingia delicata* Narbonne *et al.* (1991), though its multitude of delicate rings distinguishes it from the Charnwood specimens. It has been suggested that these strongly ringed discs bear some resemblance to the umbrella structures of chondrophore floats (Føyn and Glaessner, 1979).

e) Other discs which do not fit into the above categories include some with variably developed central bosses and one specimen which has four concentric rings within a well-defined rim. These four rings are broad and gently arched in cross-section. Other discs have been figured by Ford (1963), Boynton (1978) and Jenkins and Gehling (1978), and comparable forms have been figured by numerous authors. A discussion of the comparisons between the various discs appears in Narbonne and Hofmann (1987). Some differ so little from the disc-like holdfasts of fronds such as *Charniodiscus concentricus* that it may be that most, if not all, are detached holdfast impressions. It seems unwise to assign these to new species and no formal names are proposed. A solitary circular mark on a very weathered dip slope of the Beacon fine-grained tuffs of Beacon Hill shows too little detail to be sure whether it is of organic origin or not.

4. *Trace fossils*. Three isolated occurrences of trails have been found, two in the Charnwood Golf Course Quarry and one on the Memorial Crags in Bradgate Park. One is a faint, shallow, curving groove 2 mm wide and 300 mm long and resembles *Planolites* or possibly *Gordia*. Another is in positive relief, about 6-7 mm wide and 100 mm long, looking rather like a faecal cast (Fig. 18). The third, on the Memorial Crags, is a straight wide flattened groove, possibly of *Planolites* type (Fig. 19), about 25 mm long and 3 mm wide. Some caution must be exercised in accepting these as evidence of former crawling organisms.

5. *Problematica*. Problematic fossils also occur at Ives Head, in Bradgate Park and in Charnwood Golf Club Quarry. They seem to be impressions of incomplete lengths of a stem or rachis with one or two branches each terminating in a rounded swelling which droops outwards. Examples up to 370 mm long have been found. With no other detail preserved it is impossible to assign these to any biological group at present.

Fig. 5. *Bradgatia linfordensis* Form A. 310 mm wide.

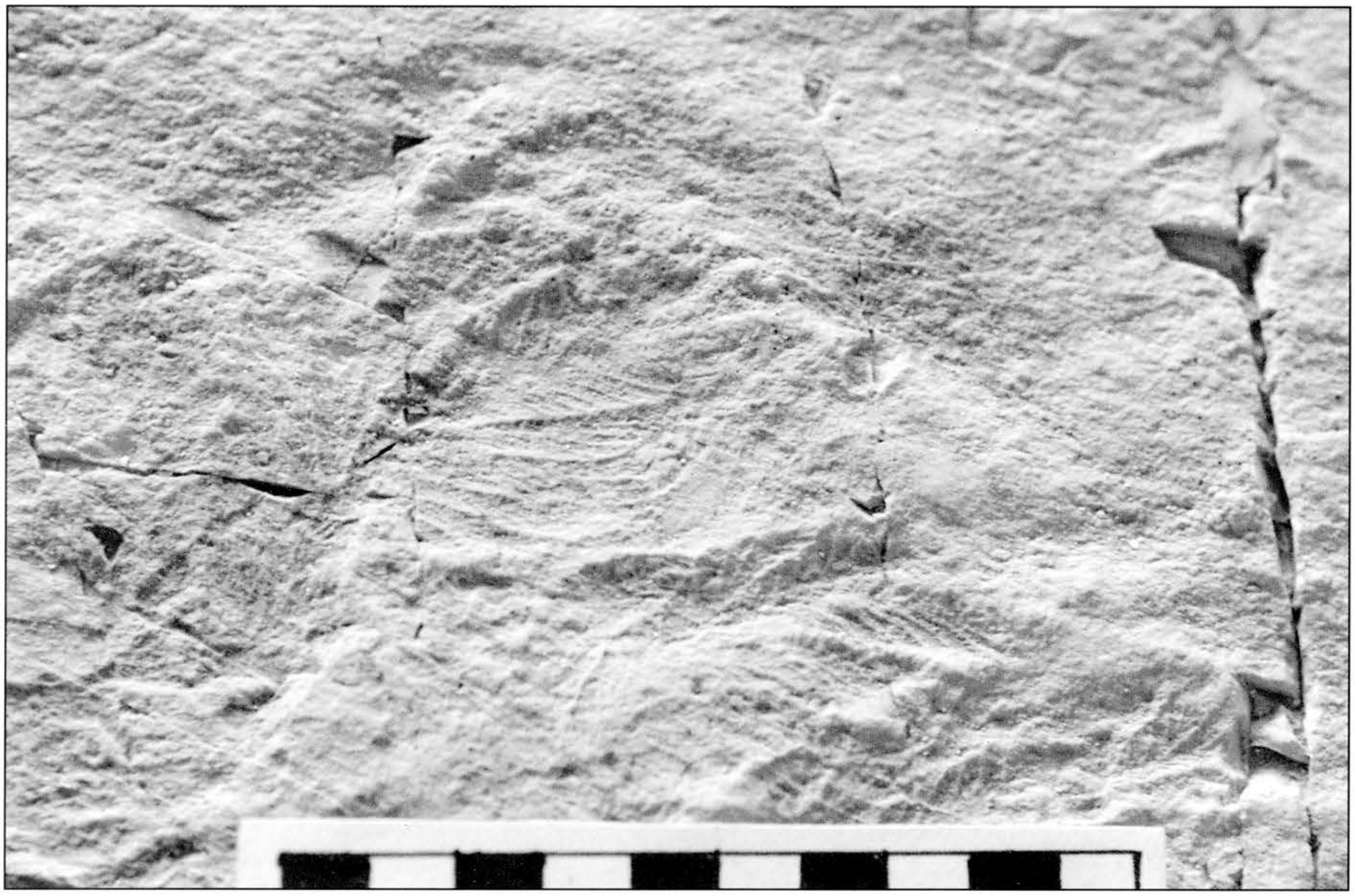

Fig. 6. Enlargement of part of Form A showing small *Charnia*-type branches about 50 mm long.

Fig. 7. *Bradgatia linfordensis* — cast of Form B. 416 mm long.

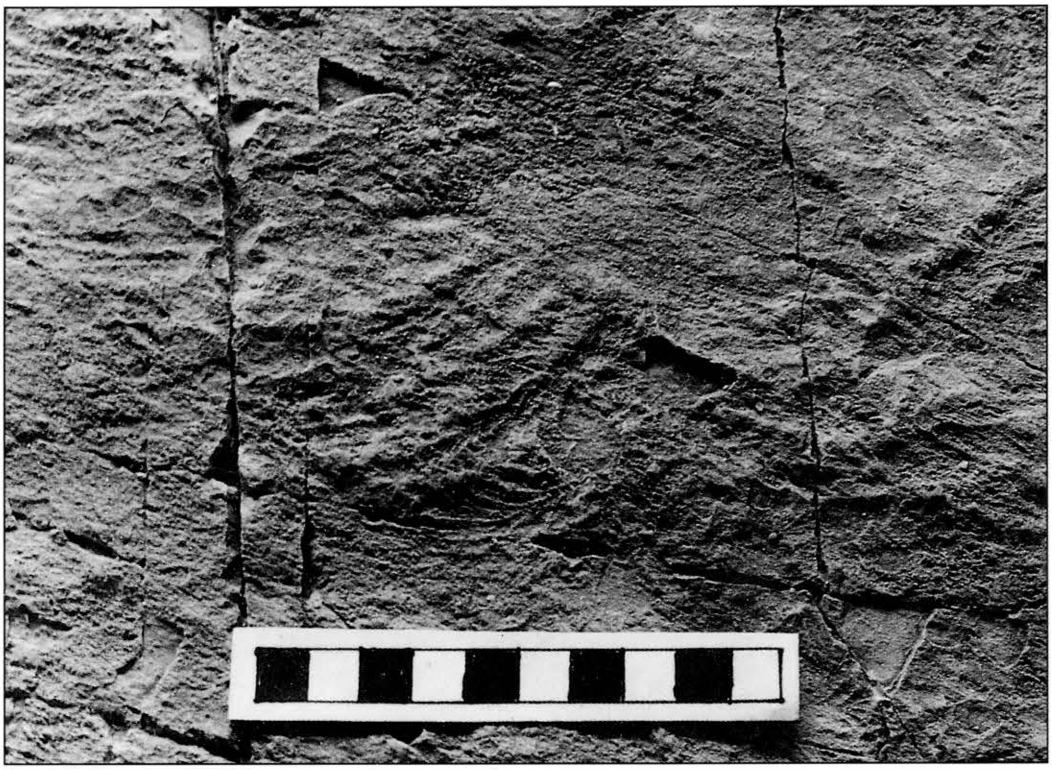

Fig. 8. Enlargement of part of Form B showing small *Charnia*-like branches about 50 mm long.

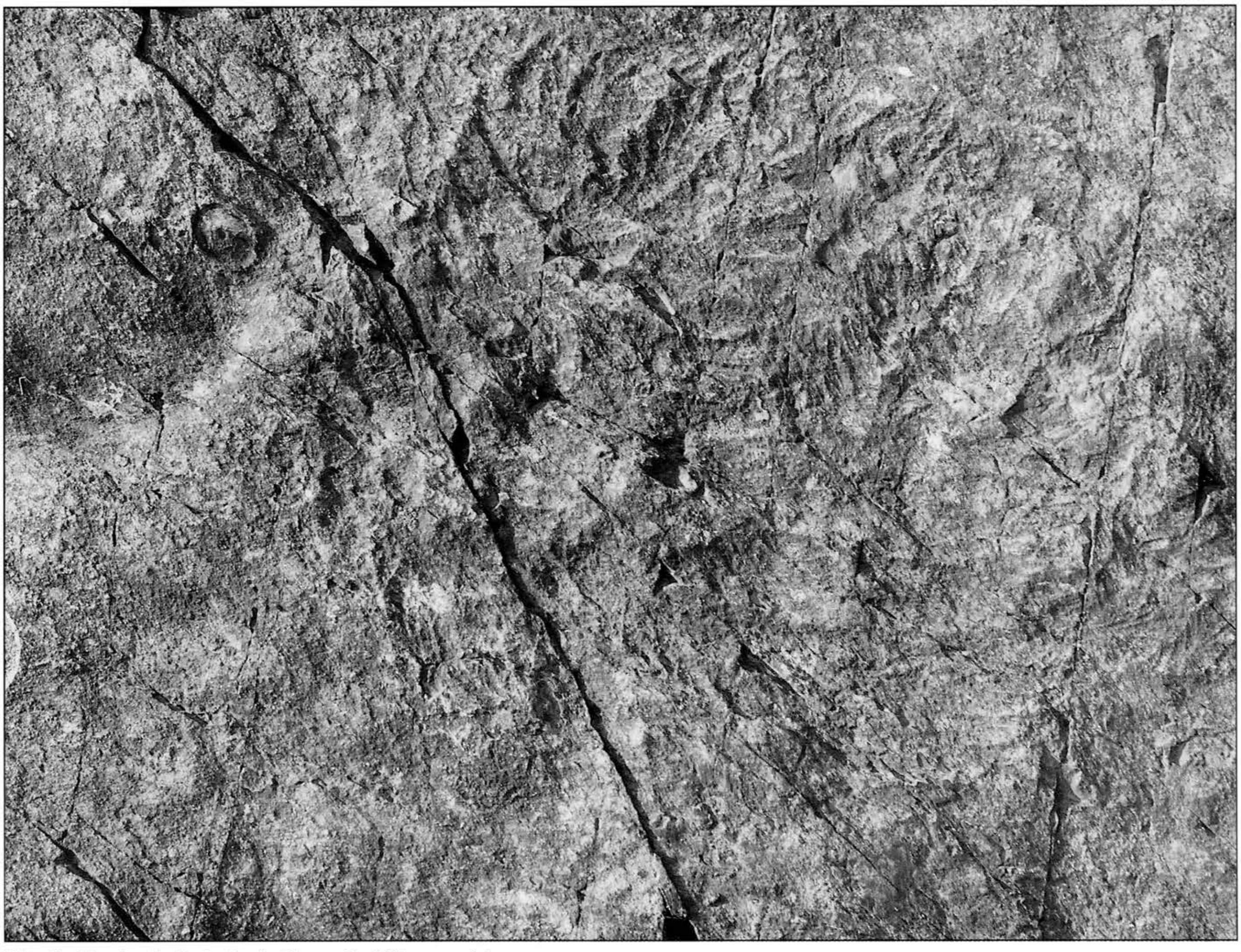

Fig. 9. *Bradgatia linfordensis* Form C. 200 mm wide.

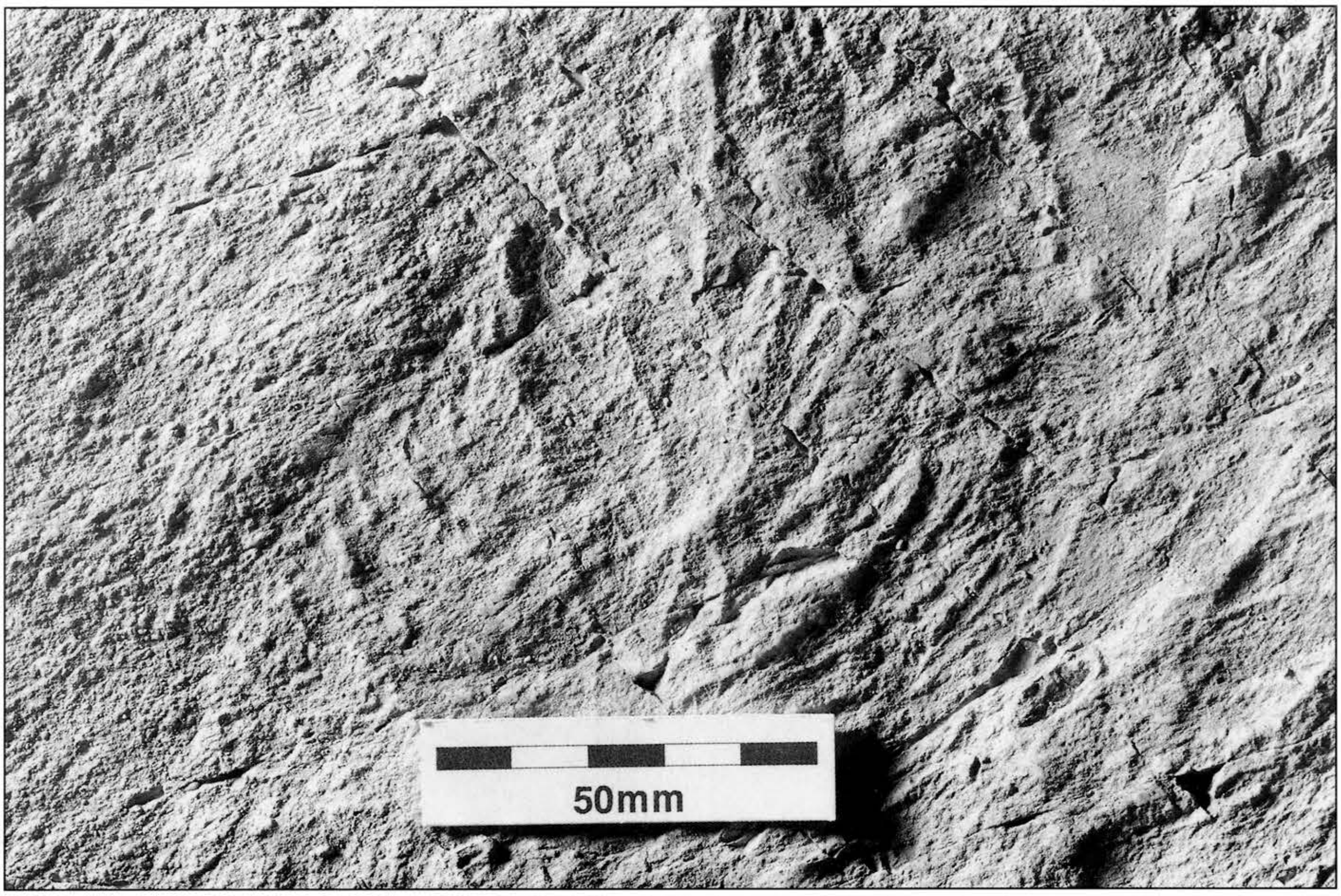

Fig. 10. Enlargement of part of Form C showing small *Charnia*-like branches about 50 mm long.

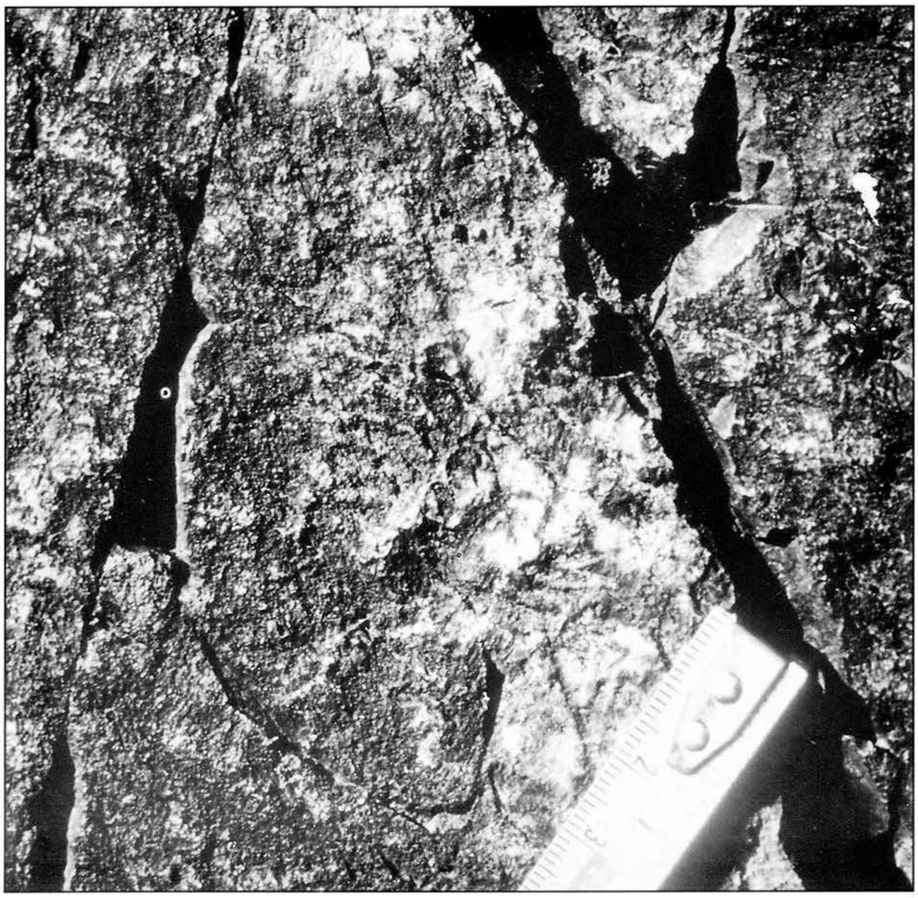

Fig. 11. *Bradgatia linfordensis* Form D. 50 mm wide.

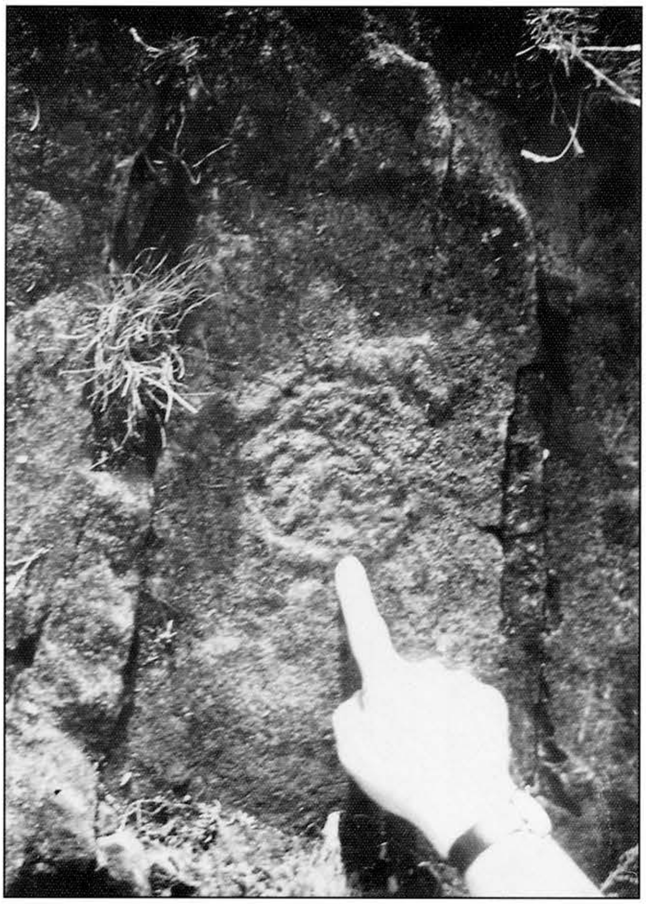

Fig. 12. *Ivesia lobata* — holotype. 150 mm wide.

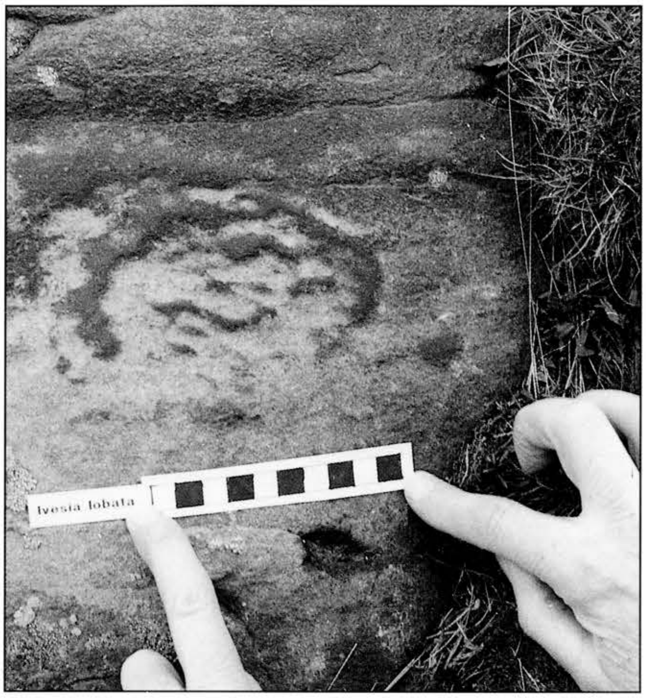

Fig. 13. *Ivesia lobata* — topotype. 150 mm wide.

Fig. 14. *Cyclomedusa cliffi* — holotype. 150 mm diameter.

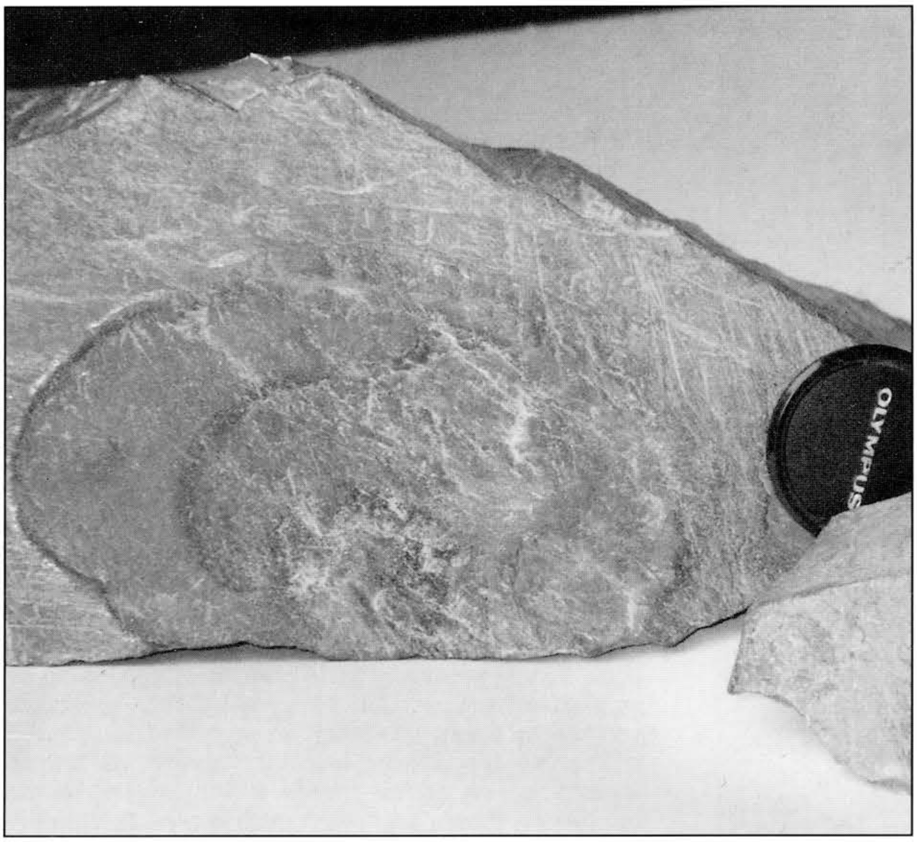

Fig. 15. *Cyclomedusa cliffi* — topotype. 160 mm diameter.

Fig. 16. *Shepshedia palmata* — holotype. 120 mm wide.

Fig. 17. *Blackbrookia oaksi* — holotype. Each subquadrangular impression is 160 mm in diameter.

Systematic Palaeontology

Four new monospecific genera are described below: *Bradgatia linfordensis*, *Ivesia lobata*, *Shepshedia palmata* and *Blackbrookia oaksi*; one new species *Cyclomedusa cliffi* is also proposed. Type specimens are mostly still *in situ* in the field. Plaster replicas have been deposited in either or both of the University of Leicester Geology Department collections or in Leicestershire Museums geology collections.

Phylum Petalonamae Pflug, 1972
(Problematical Coelenterata (Glaessner, 1979))
Class Rangeomorpha Pflug 1972
Family Charniidae Glaessner 1979

Genus *Bradgatia* nov.

Diagnosis: A colonial, soft-bodied but moderately rigid organism consisting of a complex cluster of *Charnia*-like fronds diverging from a central ring or boss-like structure. The stems have a plaited appearance and may bifurcate several times (Figs 3, 4).

Bradgatia linfordensis sp. nov.

Diagnosis: as for genus.

Etymology: after Bradgate Park and the nearby village of Newtown Linford, Leicestershire.

Horizon: Hallgate Member, Bradgate Formation, Maplewell Group, Charnian Supergroup.

Type locality: Memorial Crags, Bradgate Park, Leicestershire, England (SK 524 111); near the base of the bedding plane on the south face.

Holotype: still *in situ*. Plastotype replicas in the Geology Dept. University of Leicester, accession no. 115413/0, and in Leicestershire Museums Geology Collections Accession No. G26/1994.

Description: The holotype is an ovoid colony of fronds measuring 410 × 300 mm (Fig. 3). The fronds appear to arise from a centre composed of three small raised protuberances each 10 mm in diameter; two rings appear to mark further protuberances which have been damaged. The outer margin of the colony is a finely indented rim composed of the small distal ends of fronds. The number of these is indeterminate owing to poor preservation but there must be at least one hundred present. The rest of the colony is a complex cluster of fronds radiating from the central area by stems which may bifurcate; they decrease in thickness towards the margin of the colony. From these stems arise a series of fronds which occasionally show faint, segmented or lobate structures as in *Charnia*, each about 50 mm long. The fronds show little evidence of wrinkling or overlap so were probably stiffened by some substance such as collagen. The stems show a knotted, plaited or knobbly appearance particularly towards the central area. The tips of the fronds at the bottom of the impression show a slight curvature to the left, possibly due to current action. Several other specimens have been found on the same bedding plane, and faint traces also occur in Charnwood Golf Course Quarry and at other localities in Charnwood Forest. Each is treated as a separate form.

Fig. 18. Trail; Charnwood Golf Course Quarry. About 6-7 mm wide and 100 mm long.

Form A (Figs 5, 6) is still *in situ* (cast in University of Leicester Geology Dept. accession nos. 115414/0 & 115415/0; another cast in Leicestershire Museums Geology collection accession no. G27/1994); 310 × 260 mm with an elliptical raised boss 52 × 26 mm in the centre; the boss shows no detail but may represent a central float or anchoring mechanism which filled with sediment when the colony settled. Arising from the boss are stems up to 10 mm wide which bifurcate and thin to 1 mm nearer the margin. One stem has an irregularly knotted appearance. The margin of the colony is finely indented, consisting of the distal ends of fronds, best seen on the left-hand side. An ovoid disc is present within the left-hand side of the colony and faintly preserved within it are at least three *Charnia*-like fronds about 50 mm long (Fig. 6) radiating from a central point, again suggesting a possible budding mechanism of reproduction.

Form B (Figs 7, 8; cast in University of Leicester Geology Dept. accession nos. 115416/0 & 115417/0; and in Leicestershire Museums Geology collection accession no. G28/1994) lies towards the top of the Memorial Crags bedding plane. It is the largest of the known colonies at 416 × 234 mm. It is less ovoid owing to its mode of preservation. It has no clear central area, but the fronds do appear to radiate from the upper centre of the colony. To the left of the centre the fronds are less clearly defined making the stems relatively stronger and giving the pectinate appearance. Two fronds below the centre are about 50 mm long and show the *Charnia* type of segmentation. One of these is reminiscent of the lobate form described from Mistaken Point by Misra (1969, pl. 8b). The right-hand part of the colony is better preserved but split by an open joint. Some of the stems again show an irregularly knotted appearance. The indented margin of frond tips is well displayed.

Fig. 19. Possible trail about 25 mm long on the Memorial Crags.

Form C (Figs 9, 10) is still *in situ* in the lower centre of the Memorial Crags bedding plane (cast in Leicestershire Museums Geology collection accession no. G29/1994). An ovoid colony 200 × 180 mm without any distinct centre of radiation of fronds (Boynton, 1978; Brasier *in* Cowie and Brasier, 1989). Some of the fronds at the upper right give an impression of a water-lily. This part is again comparable with one of Misra's forms (Misra, 1969, pls 2a, 4d, 8b), noted by him as lobate-dendrite (see also Anderson, 1978, fig. 7; Anderson and Conway Morris, 1982, pl. 1, no. 3). Some fronds show faint segmentation, whilst distal portions of the fronds are small and feathery giving an indented margin to the colony. At the right-hand margin are two small *Charnia*-like fronds, each about 50 mm long (Fig. 10); they extend beyond the margin and may again represent budding juveniles.

Form D is much smaller than the other colonies (Fig. 11). It lies in the right centre of the Memorial Crags bedding plane (cast in Leicestershire Museums Geology collection accession no. G30/1994). Preservation is poor, and is made worse by slickensiding. It measures only 50 mm in diameter and appears to have two central disc-like depressions. Five curved lobes arise on the left, separated by prominent ridges, and are without segmentation. The lobes on the right are more pointed like the distal ends of *Charnia*. A small *Charnia* frond appears to be separating from the colony at the bottom left.

Two rather more faint impressions, not designated here as forms, lie to the left of Form C. One is an ovoid colony 170 × 130 mm. *Charnia*-like fronds are visible at the top left, some apparently showing bifurcation. There is no central area but an approximate focus of radiation near the top suggests that only half the colony may be present in the impression. A comparison may be made with one of the Newfoundland forms (Misra, 1969, pl. 4d). Another impression lies even further to the left of Form C, and appears at first to be a specimen of *Charniodiscus concentricus* but is much more complex; it consists of an ovoid disc with a central raised area bordered by two concentric ridges. Arising from these appear to be two faint branches. A less well-defined stem emanates from the bottom of the disc with very poorly defined lobes.

Discussion: As *Bradgatia linfordensis* is a previously undescribed type of fossil impression, and as its detail is faintly preserved, it is difficult to make comparisons with other organisms, living or fossil. The nearest possible comparatives are the impressions reported from the late Precambrian Conception Group of Mistaken Point, Newfoundland by Anderson and Misra (1968), Misra (1969) and Anderson (1978). These are unnamed and no detailed descriptions have yet been published so that meaningful comparisons cannot be made. However, Jenkins (1985, fig. 6) provided a sketch of *Bradgatia linfordensis* and noted similarities to *Rangea* *schneiderhohni*. He suggested that the latter had several fronds arising *Charnia*-fashion from a single holdfast (Jenkins, 1985, fig. 5). We visualize *Bradgatia* as probably nektonic rather than sessile, so the similarity may be more in the style of preservation than in the original biology. Form C may represent a colony preserved at maturity in the act of reproductive budding. Within the top left is a small ovoid disc which may or may not be related to the frondose colony. At the bottom right of the holotype is a small *Charnia* frond about 15 mm long, which may represent a juvenile either of an isolate frond or newly budded off the colony.

As described above, the fossil impressions give a hint of a budding mode of reproduction, which may of course alternate with a sexual mode. The frondose organisms *Charnia* and *Charniodiscus* may be mature buds from colonies, but without further evidence they are best left as distinct taxa.

Following Glaessner (1984) and Runnegar and Fedonkin (1992), *Bradgatia linfordensis* is regarded as a member of the Phylum Petalonamae (Pflug, 1972) at this stage, though future research may require re-assignment.

Phylum Cnidaria
?Class Cyclozoa Fedonkin 1983
Family Cyclomedusidae Gureev 1987

Genus *Ivesia* nov.

Diagnosis: a circular disc of medusoid type with the central area marked by prominent, irregular lobate structures, perhaps with radial arrangement (Figs 12, 13).

Ivesia lobata sp. nov.

Diagnosis: as for genus.

Etymology: after Ives Head and the lobate structures.

Horizon: Lub Cloud Greywacke Member, Ives Head Formation, Blackbrook Group, Charnian Supergroup.

Type locality: holotype *in situ* on Ivea Head, Shepshed, Charnwood Forest, Leicestershire (SK 477 170). Casts in Leicester University Geology Dept. Collections accession no. 115577, and in Leicestershire Museums Geology Collections accession no. G32/1994.

Description: the holotype is a circular disc 150 mm in diameter with a slightly wavy margin, which is preserved as a slightly irregular convex ridge (Fig. 12). The upper margin is less well-defined and appears to expand into a lobate protuberance. In the centre of the disc is a series of irregular lobes with a coiled, possibly weakly radiate, arrangement; one of the lobes extends to the left margin. Very faint markings around the disc may tentatively be interpreted as traces of fronds or tentacles arising from the central lobes.

Discussion: this fossil was described but not figured by Boynton (1978). After opinions from various expert visitors, it is herein considered to be a new form of medusoid. Preservation in rather coarse-grained sediment obscures all fine detail. A broad but tentative comparison may be made with the dubiofossil *Protoniobia* (Sprigg, 1949; see also Wade, 1972). A cast of another specimen at the same locality is in Leicestershire Museums Geology collection (accession no. G33/1994) (Fig. 13). These fossils are at a much lower stratigraphical horizon than most of the other Charnian fossils.

Although medusoids were referred to problematical Coelenterata by Glaessner (1979, 1984), *Ivesia lobata* and the other fossils described below are here placed within the Phylum Cnidaria.

Genus *Cyclomedusa* Sprigg 1947

Cyclomedusa cliffi sp. nov.

Diagnosis: ovoid medusoid impression characterized by a raised oval central boss and an irregularly crenulated margin (Fig. 14).

Etymology: after Cliffe Hill quarry, Markfield, Leicestershire.

Horizon: Hallgate Member, Bradgate Formation, Maplewell Group, Charnian.

Locality: Cliffe Hill Quarry, Markfield, Leicestershire.

Holotype: Leicestershire Museums accession no. G730.1993.

Description: a poorly preserved incomplete ovoid disc 150 × 120 mm (the latter estimated from the broken block) with a slightly undulating margin. Within this is a flat area 20 mm in diameter surrounding a slightly depressed area 20 mm wide. In the centre is a raised convex boss estimated at 30 × 22 mm.

Discussion: this species differs from other cyclomedusids in its greater ovality, strong ovoid boss and irregular margin. It resembles the form *Tirasiana disciformis* Palij, named in an abstract by Palij (1976) and more formally described by Bekker (1985).

Another specimen in a private collection measures 160 × 100 mm; it has a slightly raised and more crenulate margin, and two concentric flat areas separated by raised rings; each flat area is about 30 to 40 mm wide (Fig. 15). In the centre is a slightly raised boss 50 × 30 mm.

Class and Family Uncertain.

Genus *Shepshedia* nov.

Diagnosis: an ovoid impression with a palmate arrangement of three broad branches arising from a short stem (Fig. 16).

Shepshedia palmata sp. nov.

Diagnosis: as for genus.

Etymology: from the nearby town of Shepshed, Leicestershire, and the palmate style of the impression.

Horizon: Lub Cloud Greywacke Member, Ives Head Formation, Blackbrook Group, Charnian.

Type locality: holotype *in situ* on Ives Head, Shepshed, Charnwood Forest, Leicestershire (SK 477 170) (Fig. 16). Casts in Leicester University Geology Dept. Collections accession no. 115573, and in Leicestershire Museums Geology Collection accession no. G34/1994.

Description: the palmate impression measures 120 × 80 mm and consists of three main branches which dichotomise towards the margin yielding 11 terminations about 1 mm wide. There is a gap at the margin which suggests the former presence of a stem.

Discussion: the poor preservation in rather coarse-grained sediment precludes further description of this organism, which was originally described as a dubiofossil (Boynton, 1978). However, five other similar impressions have been found on the same bedding plane and no sedimentologist visiting the site has offered an inorganic explanation for them. *Shepshedia palmata* has some superficial similarity to the unnamed bush-like form noted in Newfoundland by Anderson and Conway Morris (1982, pl. 1, fig. 4). A cast of another specimen is in Leicestershire Museums Geology collections accession no. G35/1994.

Genus *Blackbrookia* nov.

Diagnosis: approximately square impressions of general medusoid character, possibly occurring as a pair, each with a raised rim (Fig. 17).

Blackbrookia oaksi sp. nov.

Diagnosis: as for genus.

Etymology: From the adjacent valley of the Blackbrook stream and reservoir, and the parish church of Oaks-in-Charnwood therein.

Horizon: Lub Cloud Greywacke Member, Ives Head Formation, Blackbrook Group, Charnian.

Type locality: holotype *in situ* on Ives Head, Shepshed, Charnwood Forest, Leicestershire (SK 477 170) (Fig. 17). Casts in Leicester University Geology Dept. Collections accession no. 115576, and in Leicestershire Museums Geology collection accessions no. G36/1994.

Description: the single impression consists of two subquadrangular impressions lying side by side with traces of a third alongside; each of the two measures 160 mm in diameter. The margin of the impression is an irregularly raised ridge up to 5 mm wide. Within this are very irregular lobate ridges comparable with those in *Ivesia lobata*.

Discussion: whether the two squares are part of the same organism is not clear in the coarse-grained sediment, but faint markings suggest that they may be linked, and there are traces of a stem and branches projecting to the left. The single impression was figured by Boynton (1978, pl. 22, fig. 2) as a dubiofossil but it is now regarded as a new genus probably of medusoid nature.

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Patterned Ground in the Lower Trent Valley near Brough, between Newark and Lincoln

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Abstract: Patterned ground is identified from aerial photographs of the terrace surface of the Balderton Sand and Gravel between Newark and Lincoln. It is interpreted to represent the surface expression of a network of ice wedge pseudomorphs, which are related to others exposed in quarry sections of the Balderton Sand and Gravel in the area. The ages of these pseudomorphs are reviewed and it is concluded that those giving rise to the patterned ground were developed and casted during the Devensian Stage, probably relating to the late Devensian Dimlington Stadial.

The area between Newark and Lincoln is notable for a sequence of sand and gravel deposits that indicate a complex history of drainage evolution during the Pleistocene (Fig. 1; Table 1). An assessment of archaeological cropmark features adjacent to the A46 Fosse Way and around the Scheduled Ancient Monument of Brough Roman 'small town' (SK 836 584), undertaken in response to Department of Transport plans to upgrade the route to dual-carriageway, involved inspection of 1:10 000 scale aerial photographs which revealed examples of patterned ground. Although periglacial features are frequently mentioned in published work on drift deposits of the Trent Valley, few examples of the surface expression of these features have been documented (e. g. Straw, 1979, fig. 3.8).

STAGE	DEPOSIT
Flandrian	Alluvium
Devensian	Floodplain Sand and Gravel
Ipswichian	Scarle Sand and Gravel Fulbeck Sand and Gravel
Wolstonian	Balderton Sand and Gravel
Wolstonian or Anglian	Eagle Moor Sand and Gravel

Table 1. Revised chronology of fluvial and fluvio-glacial sand and gravel deposits between Newark and Lincoln (after Brandon and Sumbler, 1988, 1991).

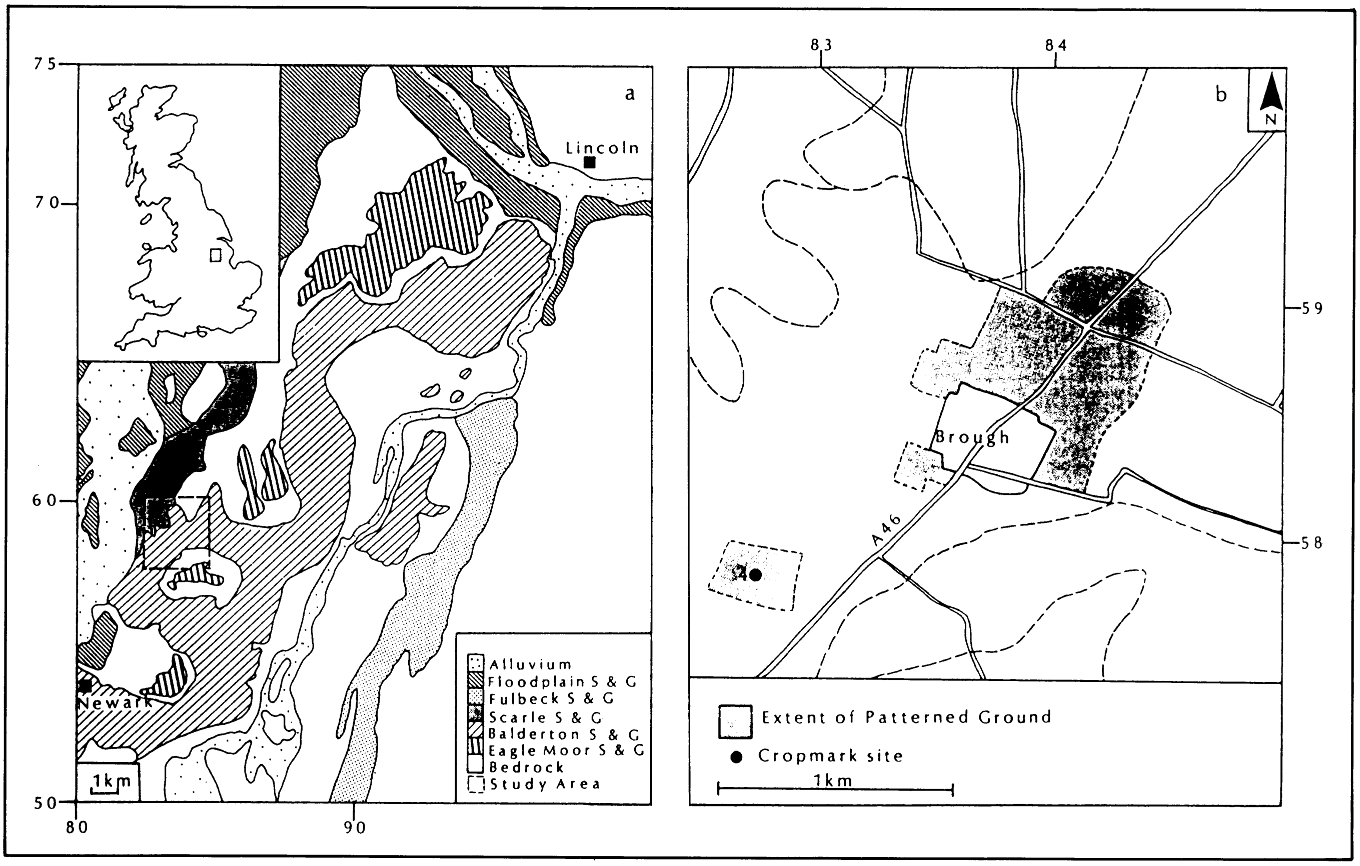

Fig. 1a. Distribution of fluvial deposits betwen Newark and Lincoln (based on BGS 1:50 000 sheets 113, 114, 126, 127, with amendments by Brandon and Sumbler, 1988, 1991). **1b.** Distribution of patterned ground and archaeological cropmark features. Site numbers are those of Knight and Kinsley (1991). Dashed lines indicate limits of superficial deposits.

Fig. 2. Aerial view of patterned ground looking south-west along the A46 Fosse Way. Reproduced by kind permission of Cambridge University Committee for Aerial Photography, CJO 26.

Description and interpretation

Patterned ground has been found at two localities on the terrace surface of the Balderton Sand and Gravel, which crops out in a sinuous tract between Newark and Lincoln (Fig. 1a). In total, the patterning covers an area of c.0.6km^2 and takes the form of semi-regular polygonal structures, on average 8-10m in diameter (Fig. 1b; Fig. 2). At one site, the patterning is truncated by archaeological cropmark features (Site 4, in Knight and Kinsley, 1991) dating from the Iron Age to Romano-British period (700BC-450AD). The patterned ground is similar to active (e. g. Harry and Godzik, 1988, fig. 7) and relict (e. g. Svensson, 1988, fig. 15) periglacial features recorded in high latitudes. They are, therefore, interpreted as the surface expression of a network of ice wedge pseudomorphs, formed by the development of perennially frozen ground during a former cold period (Washburn, 1979).

Quarry exposures of Balderton Sand and Gravel have, to date, revealed two generations of ice wedge pseudomorph development (Brandon and Sumbler, 1991; Howard, 1992). The first comprises syndepositional ice wedge pseudomorphs. These occur approximately in the middle part of the sand and gravel sequence and are erosionally truncated by an intraformational unconformity. Typically, these features penetrate vertically downward for c.2m, are c.1.5m wide and infilled by sand and gravel. They probably form polygons 5-10m in diameter. The second generation is represented by large, epigenetic ice wedge pseudomorphs, probably forming polygons of 70-100m diameter. These developed from the base of a former active layer (i. e. the layer of ground above the perma-frost which thaws in the summer and refreezes in the winter) c.0.5-1m thick and penetrated c.3-5m through the sequence of sand and gravel. The casts are 2-3m wide with infills of gelifluctéd clay (probably derived from the surrounding lower Jurassic rocks) and sands (Howard, 1992). Brandon and Sumbler (1991) stated that infills also include reddened Whisby Sand, interpreted as a fluvio-aeolian deposit comprising reworked material from the upper levels of the Balderton Sand and Gravel. The red colour or 'rubification' is thought to be primary (Brandon and Sumbler, 1991).

The patterned ground features described from the aerial photographs have never been recorded in the quarry sections despite regular inspections of working quarries in the Balderton Sand and Gravel over the last eight years (A. Brandon, personal communication, 1994). Their stratigraphic position is similar to the large epigenetic ice wedge pseudomorphs. It is likely that the features recorded on the aerial photographs are coeval with the large ice wedge structures, but represent locally smaller sized polygons. Alternatively, but less likely, they could have developed locally during a different cold phase and, by chance, not have been exposed to date by quarrying. It is possible that the features represent the surface expression of the syndepositional casts exhumed by erosion of the upper part of the deposit, although this seems unlikely since no evidence of erosion of the upper sequence has yet been recorded within the quarried exposures.

Age

The Balderton Sand and Gravel has recently been interpreted as a braided river deposit, aggraded during a post-Hoxnian to pre-Ipswichian cold stage ('Wolstonian'), most probably Oxygen Isotope Stage 6 (Brandon and Sumbler, 1991), although an earlier date within the 'Wolstonian' complex is possible (Howard, 1992). Hence the syndepositional ice wedge pseudomorphs must have formed during this complex stage. Analogous structures recorded at Stanton Harcourt, Oxfordshire (Seddon and Holyoak, 1985; but see Worsley, 1987, for discussion) and Marsworth, Buckinghamshire (Green *et al.*, 1984), within sediments assigned to a post-Hoxnian to pre-Ipswichian cold period, indicate the existence of intense permafrost conditions at this time (Worsley, 1987).

The upper levels of the Balderton Sand and Gravel include 'cover deposits' which, in particular the Whisby Sand, have probably been affected by pedogenesis (J. Rose, personal communication, quoted in Brandon and Sumbler, 1991). This alteration has been ascribed to the Ipswichian interglacial, primarily on the basis of red colouration (Brandon and Sumbler, 1991). The large epigenetic ice wedge pseudomorphs include infills of Whisby Sand (Brandon and Sumbler, 1991) which, together with their stratigraphic position, suggests that they were formed during a post-Ipswichian cold stage, i. e. the Devensian. Although the size of ice wedges cannot be directly related to the timescale of development (Mackay, 1988), the large scale of these features perhaps suggests a prolonged period of permafrost development, possibly indicating growth and casting during the late Devensian Dimlington Stadial, although an earlier Devensian date cannot be ruled out. No ice wedge pseudomorphs have been noted in the Floodplain Sand and Gravel north of Newark, but probable late Devensian examples have been noted in equivalent deposits at Hoveringham, east of Nottingham (A. Brandon, personal communication) and at Hemington, south-west of Long Eaton (C. Salisbury, personal communication).

Conclusion

This brief account has re-affirmed earlier accounts of Brandon and Sumbler (1991) and Howard (1992) that the periglacial features of the Newark to Lincoln area have a complex history of formation suggesting several phases of permafrost development. The patterned ground described from aerial photographs represents the surface expression of ice wedge pseudomorphs which were probably developed during the Devensian Stage, most likely the Dimlington Stadial. It is to be hoped that future topsoil stripping of the area where the patterned ground is developed (e. g. during road construction) will allow the infills of the pseudomorphs to be studied.

Acknowledgements

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REPORT

Industrial Minerals Unit, Department of Geology, Leicester University

The Industrial Minerals Unit forms a significant part of the Applied Geology Group within the Geology Department of Leicester University. It is devoted to the study of mainly non-metallic industrial rocks and minerals, from their geological occurrence through to their evaluation, processing and industrial performance. The aim is to utilise the best basic science to increase wealth generation. The group was first formed in Hull in 1977 to teach an MSc. course in Industrial Mineralogy, which moved to Leicester in 1989, along with the core staff. The MSc. is now renamed "Industrial Rocks and Minerals" and complements the more metalliferous bias of the long-standing Mineral Exploration MSc. also offered in the department.

The MSc. course covers the geology, mineralogy, industrial applications, assessment techniques and deposit evaluation of this vital class of commodities and attracts between seven and 15 UK and overseas graduates annually. As with many other such courses there are only limited funds for supporting UK graduates and selection is competitive. Overseas students come from as far afield as Pakistan, Malaysia, Saudi Arabia, Germany, Nigeria, Malawi and Malta, often bringing a wealth of experience from mature graduates who have been employed by companies or national geological surveys for some time. There is an ongoing link with Lahore University in Pakistan which will include aid in setting up their own industrial minerals laboratories. Parts of the course are also frequently used as research training for a wide range of petrologically based PhD. projects.

The unit maintains strong links with industry through its past graduates now in post, by obtaining contracts for analyses and through consultancy work. The MSc. student projects also play an important role, usually being undertaken in conjunction with a company investigating specific raw material related problems. Recent projects have been undertaken with Tarmac, Redlands, CAMAS, and Longcliffe, providing invaluable experience for the student and worthwhile data and solutions for the companies.

PhD. Research

The unit also supports a large group of PhD. students, with on-going research into a wide range of subjects including perlite, zeolite, aggregates, nepheline syenite, pillared clays, smectite-illite interlayered clays, bauxites and gemstones. The unit was particularly pleased this year to be approached by CAMAS aggregates with a NERC CASE studentship to study the controls exercised by the basal Triassic unconformity south of Leicester on aggregate availability and performance.

Other research by staff and associates includes fluorite mineralization, alkali silica reactivity in concrete, aggregates, building stones, archaeological mineralogy, clay mineralogy and sedimentary geochemistry.

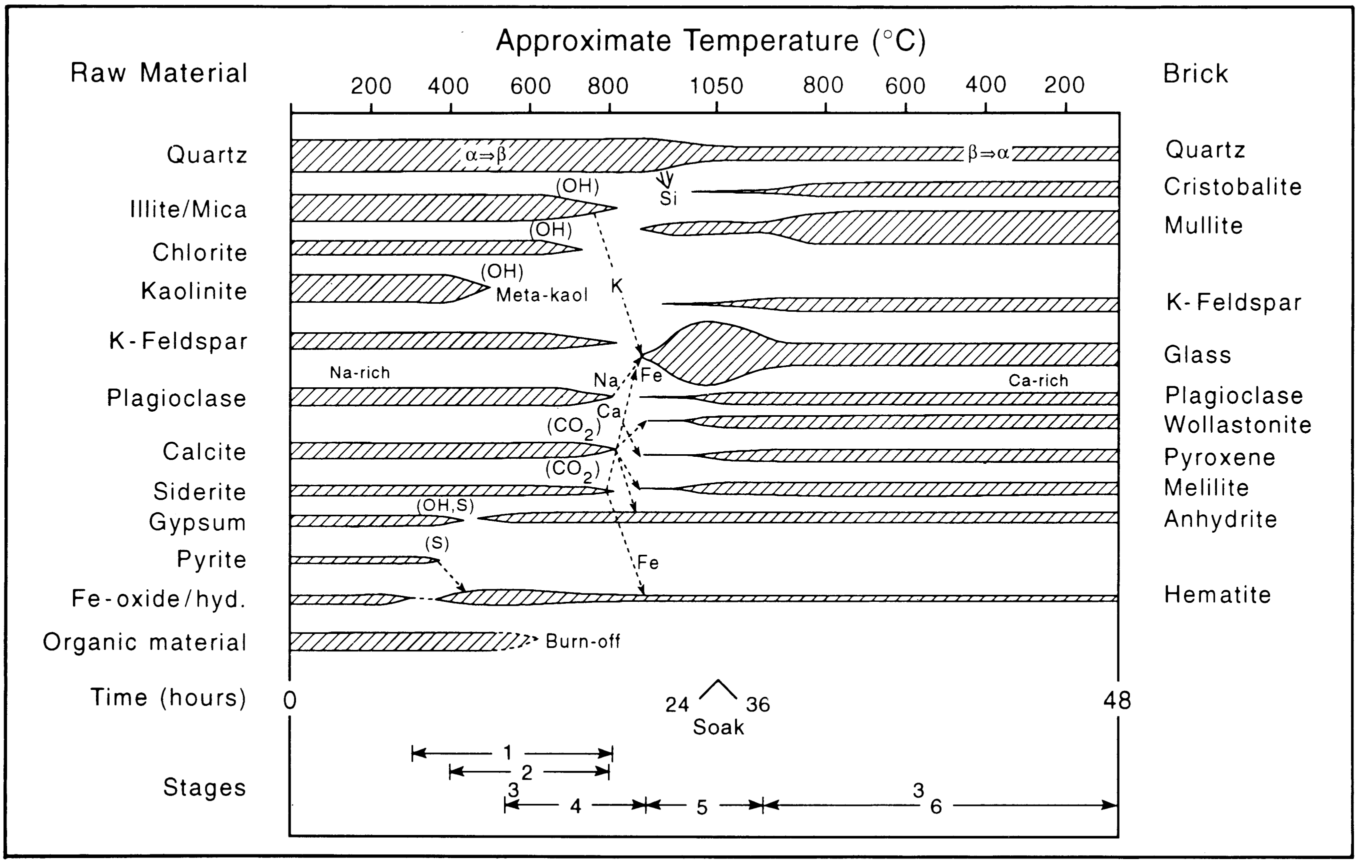

Fig 1. Phase transformation during brick manufacture (reproduced by permission of the Yorkshire Geological Society).

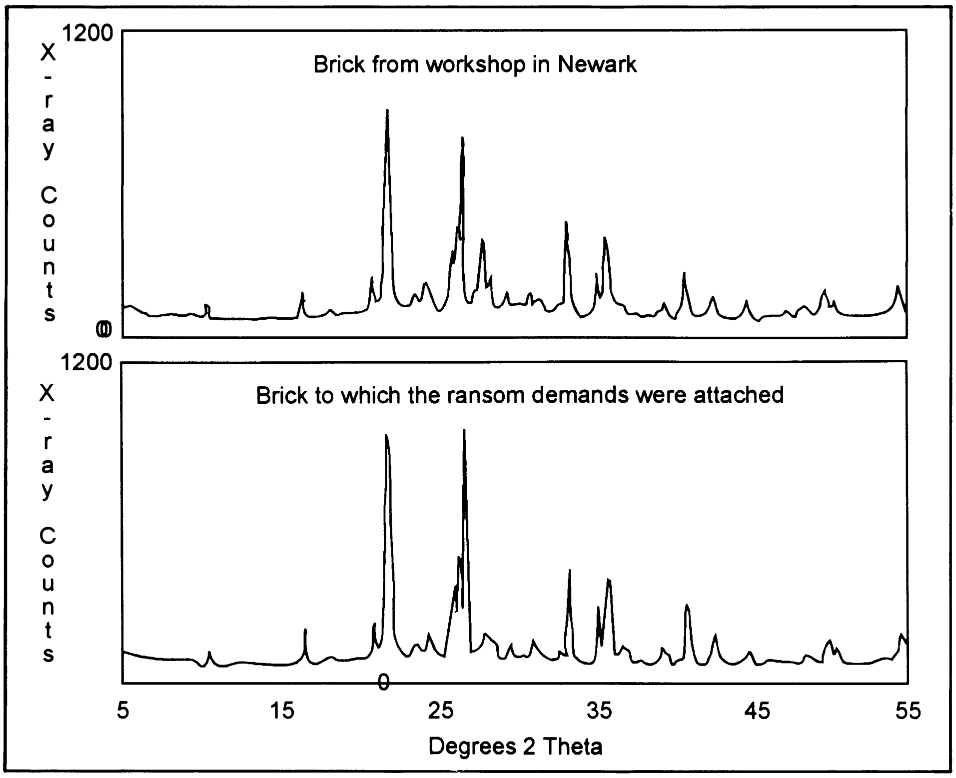

Fig 2. X-ray diffraction traces from the Sams murder investigation.

Gemstones

A new departure for the group is the development of teaching and research in coloured gemstones. Our analytical facilities and research methods complement those used by gemmologists and we are discussing with the Gemmological Association in London a route towards awarding specially prepared part time students an M.Sc in Industrial Mineralogy (Gemmology). Our current research in this area centres on the problems of defining the provenance of rough or cut corundum gemstones (sapphires and rubies). Rarity value, especially for top quality gems, is related to locality and stones are frequently fraudulently passed off as having specific origins. They may also have been treated to improve clarity and colour and we may be able to make the identification of such specimens easier.

Energy efficiency

The unit can also claim its green credentials through work sponsored by MIRO (the Mineral Industries Research Organisation), with the collaboration of the Government Energy Efficiency Office and the brick industry. Sampling and analysis of all the main raw materials used in brick manufacture has been undertaken to document their mineralogical and chemical compositions. All the materials were then fired over a series of different temperatures and for different durations to allow a Time-Temperature-Transformation (TTT) plot to be constructed. This identified the new mineral phases formed during the firing process (Fig. 1) and their stability fields, revealing that in many cases bricks could be fired to the same mineralogical compositions and physical properties at a slightly *higher* temperature but for a much *shorter* time than is currently used. The consequences for fuel economy are of considerable interest to both the brick manufacturers and the energy authorities.

Forensic mineralogy

The unit made local and national press headlines in 1993 with its work on the Julie Dart murder case. During the kidnap and subsequent murder of Julie Dart the murderer, Sams, left notes taunting the police, weighed down by bricks. As a result of the brick project described above, the unit at Leicester had a database of UK brick composition and mineralogy with which these bricks could be compared. It fortunately transpired that the bricks used by Sams were of a very rare kind and, through collaboration with the technical staff at Steetley, it was possible to identify the source of the raw materials (right down to the individual quarry!) and provide details of the geographical area into which they were sold. When Sams was eventually arrested for the abduction of Stephanie Slater a stock of the same bricks was found at his workshop and these linked him to the Julie Dart case (Fig. 2).

Since that time the unit has continued to ''help the police with their enquiries'' in connection with other murders and armed robberies. Mr. A. Smith, for example, has analysed several mud samples from boots worn by suspects using XRD methods and, with the aid of a palynological expert, helped to locate the remains of two murder victims near Rutland Water last year.

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EXCURSION

Precambrian and Lower Cambrian rocks of the Nuneaton Inlier: A Field Excursion to Boon's and Hartshill Quarries

Leader: J. N. Carney, British Geological Survey, Keyworth, Nottinghamshire.

Sunday, 25th October, 1992

The purpose of this field excursion was to examine the rock sequences exposed within the core of the Nuneaton Inlier, an elongate structural belt formed by tectonic uplift along the north-eastern margin of the Warwickshire Coalfield (Fig. 1). The field party first visited Boon's Quarry, to view Precambrian ('Neoproterozoic III') rocks of the Caldecote Volcanic Formation and the Lower Cambrian Hartshill Sandstone Formation, and to focus in particular on the erosional and angular unconformity that separates the two rock sequences. In the adjacent Hartshill Quarry, the traverse was continued through an extensive and unbroken section of strata which shows the evolution of sedimentation within the Hartshill Sandstone Formation. The locations of these quarries and their geological setting within the Nuneaton Inlier are shown in Figure 1.

Research into the geology of the Inlier was pioneered by Lapworth (1882, 1898) at a time when new quarry sections were being opened. Recent investigations, utilising geochemical comparisons, have confirmed that the Caldecote Formation is a component of the Charnian Supergroup (Carney and Pharaoh, 1993), whose type area is in the Charnwood Forest some 23km farther to the north-east (Moseley and Ford, 1985). The Charnian rocks in turn are part of a major crustal basement entity, termed the 'Charnwood Terrane' by Pharaoh *et al.* (1987), which is present at depth throughout much of the English Midlands. The sequence of events within the Charnwood Terrane, as demonstrated by the Nuneaton exposures, commenced with the phase of volcanic activity which formed the Caldecote Formation. This was then intruded by diorites, dated at 603 Ma (Tucker and Pharaoh, 1991), and subsequently folded and mildly metamorphosed. By latest Precambrian and earliest Cambrian times the Charnwood Terrane bordered the western margin of the Gondwana supercontinent, forming part of the province of Avalonia (McKerrow *et al.*, 1992). A period of erosion and weathering of this landmass occurred prior to inundation by the waters of the advancing Iapetus Ocean. This marine transgression resulted in deposition of the Lower Cambrian Hartshill Sandstone Formation (Brasier *et al.*, 1978), which is 260m thick. A continuation of marine conditions is represented by the overlying mudstones of the Stockingford Shale Group, of Lower Cambrian to Lower Ordovician (Tremadoc) age (Taylor and Rushton, 1971).

1. Boon's Quarry (SP3299 9467)

Formerly called Man-Abell's Quarry, Boon's is a disused roadstone quarry that is partly backfilled by the waste from nearby opencast coal workings. It is currently owned by ARC Central and managed from their office at Judkins' Quarry, Nuneaton. The localities visited, numbered in Figure 2, are part of a Site of Special Scientific Interest (SSSI) designated by English Nature.

Locality 1 exposes a well-bedded volcaniclastic succession, and is the type section for the Caldecote Volcanic Formation (Bridge *et al.*, in press). This formation probably accumulated in seas marginal to active volcanoes (Carney and Pharaoh, 1993), and is a markedly bimodal volcano-sedimentary association. The principal component is massive crystal-lapilli tuff, which represents the proximal deposits of powerful pyroclastic eruptions. Subordinate interbeds, collectively referred to as the 'tuffaceous siltstone facies grouping', represent a more distal facies accumulated at some distance from the vents, or at times of relatively subdued volcanism (Fig. 3).

At Locality 1, beds of the tuffaceous siltstone facies grouping form a series of upwards-coarsening cycles (A to E in Fig. 3) overlain by massive crystal-lapilli tuff (Bed 11 in Fig. 3). Tuffaceous mudstone forms the basal bed of most upwards-coarsening cycles. It is apparently structureless at outcrop, but polished slabs commonly show an intensely convoluted silty lamination. Tuffaceous siltstones typically show a well-developed planar lamination, and are cross-laminated near the middle of Bed 4 (Fig. 3). Convoluted lamination is displayed in the upper part of the same bed; the structure is attributed to processes of liquefaction or water-escape that operated within the unconsolidated sediment pile. The tuffaceous siltstones are at least in part of primary pyroclastic origin, since thin sections show that some of the silty laminae are composed of vitric tuff rich in fine ash-size shards of recrystallized volcanic glass. Tuffaceous sandstones are subordinate components of the succession. They commonly form discrete, pale grey, 5 to 20mm-thick parallel-sided and sharp-margined beds intercalated with tuffaceous siltstone near the tops of upwards-coarsening cycles. Some of these sandstones show evidence of load-casting and sediment mixing with adjacent mudstone and siltstone beds. In Bed 3, sandstone forms the basal parts of normally graded sedimentary layers, each measuring several centimetres thick. Such repetitive grading is typical of the 'Bouma' divisions B to E, described from turbidite beds deposited by sediment gravity flows (Walker, 1967). Most sandstone compositions are indicative of an epiclastic origin; they are rich in lithic grains, which include microcrystalline andesite or dacite, and crystals of feldspar and quartz. The grey to green colour variegation of these beds reflects the varying proportions of chlorite, epidote and white mica produced by metamorphic recrystallisation under lower greenschist facies conditions.

Crystal-lapilli tuff is exposed in the south-west of Locality 1 (Bed 11 of Fig. 3), and for much of the quarry face extending upwards to the Lower Cambrian unconformity. Identical rocks are thickly developed in the small pit to the east of the type section. The distinctive coarse-grained texture of crystal-lapilli tuff is best displayed on the weathered surfaces of debris

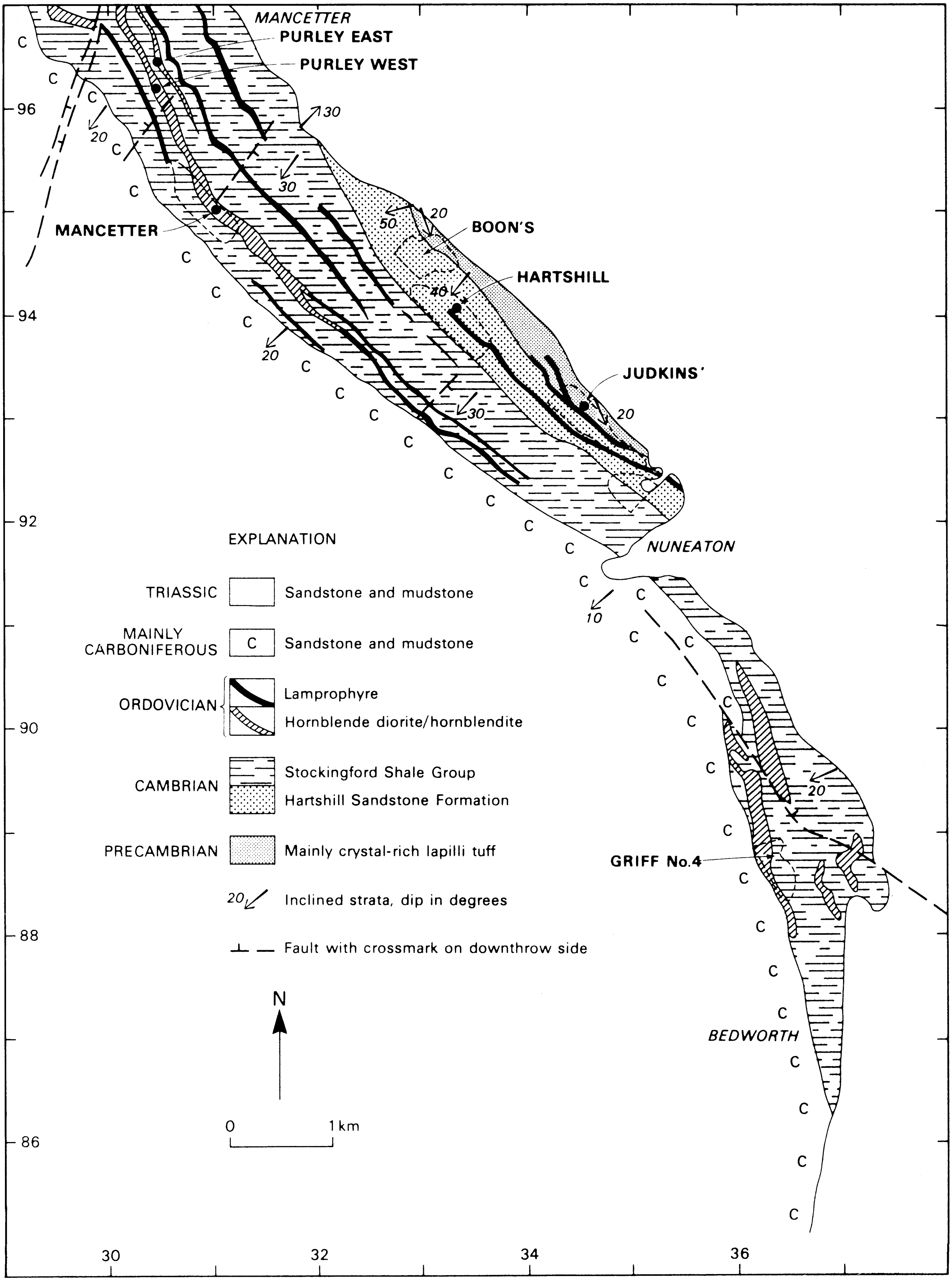

Fig. 1. Geological setting of the Nuneaton Inlier showing the locations of the principal quarries (in bold type).

at the base of the cut and along the roadway. Plagioclase feldspar forms the white to pale pink crystals, between 1 and 4mm in size, which constitute 50 to 60 per cent of the rock. Many are subhedral in form, with rounded-off crystal terminations; they additionally show extensive subgrain development, some having broken down to clusters of angular fragments. Quartz crystals (15-20% of the rock) appear grey and glassy. Their roundness, and the presence of groundmass embayments when viewed in thin section, are both interpreted as original magmatic features. Quartz crystals are of similar size to the feldspars and, like the latter, show modification due to internal micro-fracturing, many having disintegrated into smaller fragments. Individual matrix constituents are difficult to resolve microscopically in these rocks, owing to the pervasive lower greenschist facies alteration. Identical crystal-lapilli tuffs in Judkins' Quarry are fresher, however, and commonly show the outlines of devitrified and recrystallized glass shards in the matrix (Carney and Pharaoh, 1993). Blocky inclusions account for less than 10 per cent of the crystal-lapilli tuff, and are of two types. The first consists of dark porphyritic inclusions (also described by Allen, 1957). These have ovoid to equidimensional shapes and contain crystals in similar proportions to the enclosing tuffs. Thin sections suggest that the darker colour of these inclusions reflects, at least in part, the abundance of chlorite minerals in the matrix. The second inclusion type consists of angular lithic blocks, up to several centimetres across, variously composed of andesite or dacite, welded tuff with compressed vitric shards, and devitrified glass with relict perlitic texture. A primary pyroclastic origin for crystal-lapilli tuff, involving the explosive eruption of dacitic magmas, is inferred from the fragmental nature of the lithology, the abundance of juvenile volcanic constituents (crystals and vitric shards) in its matrix, and its chemical composition (Carney and Pharaoh, 1993). Allen (1957) suggested that these rocks are welded tuffs, but thin sections show that welding was not a significant process during compaction; for example, the devitrified glass shards in the matrix have suffered little flattening or plastic deformation. In gross lithology and petrography, however, crystal-lapilli tuffs bear a close resemblance to certain types of massive and crystal-enriched rocks found in volcaniclastic successions that have accumulated in seas marginal to active volcanic arcs. These are interpreted as the proximal deposits of subaqueous pyroclastic flows (e. g. Cas and Wright, 1987).

A subvertical sheet of basaltic andesite intrudes crystal-lapilli tuff at Locality 2. Its upper surface is truncated at the unconformity with the Hartshill Sandstone, proving its Precambrian age.

The unconformity is displayed intact at Locality 3. Coarse-grained breccias and granulestones of the Hartshill Sandstone Formation rest on an irregular surface of crystal-lapilli tuff. Convexities on this surface correspond to the tops of spheroid-shaped rock masses. These form an apparent weathering profile in the upper 2m of the Caldecote Volcanic Formation. Each spheroid or corestone is separated from its neighbour by red-coloured weathering rinds which have developed a tangential 'onion-skin'-like exfoliation fabric. Within these rinds, the only remaining components are granule-sized quartz crystals. These do not change in shape, distribution or abundance when traced into fresh tuff forming the interior of the spheroids, suggesting that they are relicts derived from *in situ* weathering of the tuff. Thin sections show the weathered rinds to be composed of white mica aggregates, probably representing diagenetically altered clay material, that are penetrated by anastomosing stringers and veinlets filled with opaque minerals. Certain aspects of this apparent weathering profile are worthy of discussion and further research. The first concerns the corestones (Brasier and Hewitt, 1979), which are similar in morphology to those developed below the saprolitic zones of modern tropical lateritic soil profiles, as described from Uganda by McFarlane (1983). By analogy, the weathering of these Precambrian rocks must have occurred when Avalonia lay at low latitudes. However, palaeogeographic reconstructions for the latest Vendian by McKerrow *et al.* (1992) place Central England at about 40°S, which would be outside of the modern tropical climatic belt. Possible explanations are that this type of weathering extended to higher latitudes in latest Precambrian-Early Cambrian times, or that the palaeogeographic reconstructions reflect a rapid southwards drift of Avalonia away from the tropics at a relatively late stage in the Vendian.

A few metres north-east of Locality 3 there is a minor inversion of the stratigraphy, with Precambrian rocks overlying a 0.5m thick, cleaved and fractured mudstone bed along a sharp contact. This mudstone contains a sparse acritarch fauna (genus *Leiosphaeridia*; Molyneux, 1992), suggesting that it is one of the marine beds in the Hartshill Sandstone. The overlying Precambrian rocks were thus moved into place along a reverse fault. Upwards, this fault appears to flatten out along the unconformity surface, which is therefore locally a shear plane.

The geological traverse through the Hartshill Sandstone Formation starts at Locality 3. The succession, summarised in Figure 4 and Table 1, consists of six members. For convenience, the Boon's, Park Hill and Tuttle Hill Members are subdivided further into packages of strata, lettered A to L, showing unifying characteristics of lithology and/or internal sedimentary structure (Carney, 1992).

The red-coloured strata resting on the unconformity surface at Localities 3 and 4 belong to Unit A of the Boon's Member. This member, recognised only in Boon's Quarry, was named by Carney (1992) as a revision of the previous scheme which placed the Park Hill Member at the base (e. g. Brasier *et al.*, 1978). Unit A is an association of two lithologies. Bouldery breccio-conglomerate beds, well-exposed at Locality 4, are poorly sorted and of immature composition. They contain sporadic very large (up to 2m dimension) cobbles and boulders of Caldecote Formation crystal-lapilli tuff whose rounded shapes indicate that they are corestones incorporated into the sediment from the weathered Precambrian land surface. Breccio-conglomerate beds are structureless and, apart from the

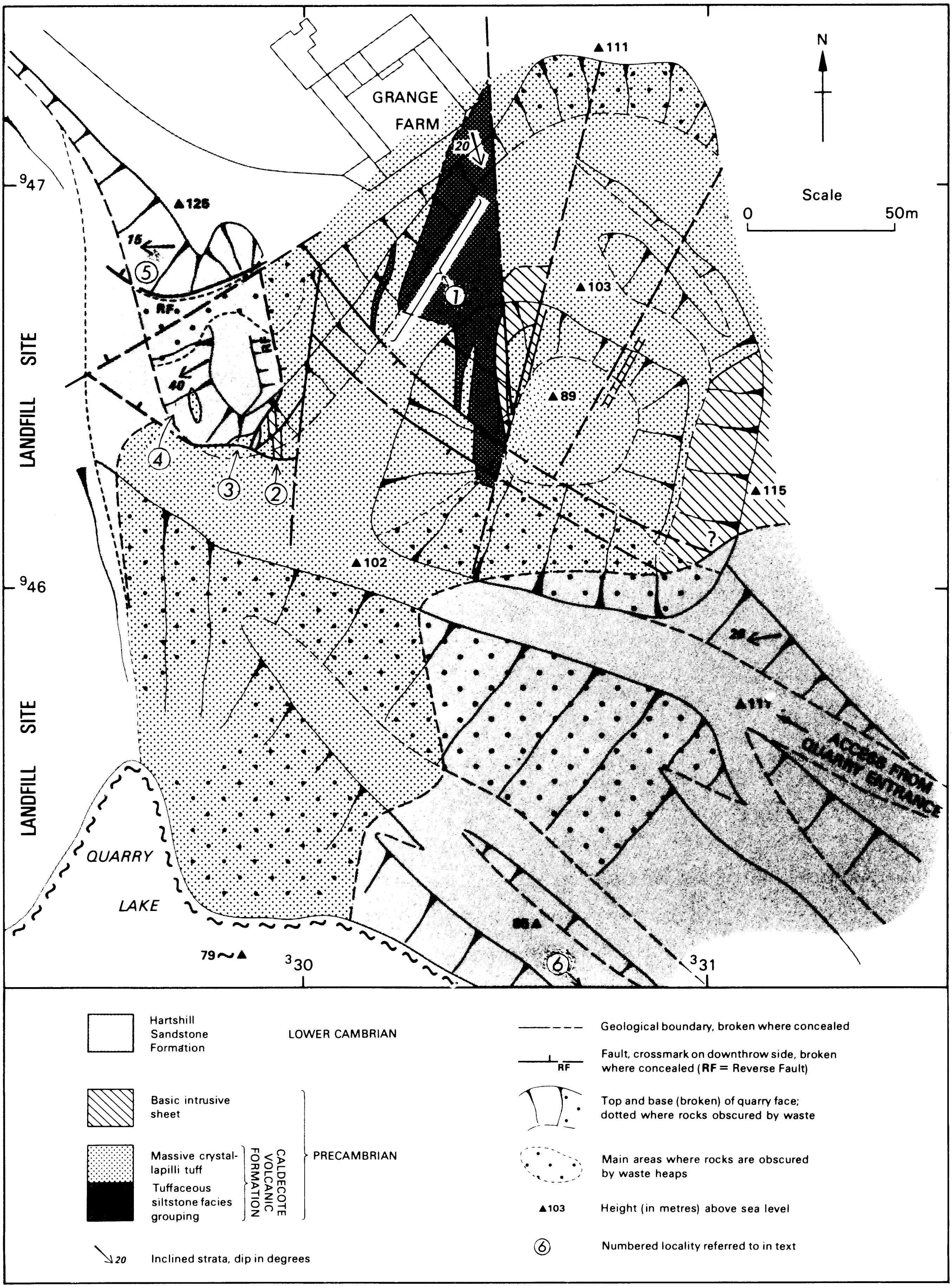

Fig. 2. Geological sketch map of the northern part of Boon's Quarry.

corestones, are principally composed of angular, fine-grained Caldecote Formation clasts averaging 0.5-2cm across. Granulestones are the second type of Unit A lithology; they also have abundant angular Precambrian clasts, but do not contain corestone fragments, are better sorted than the breccio-conglomerates, and show a crudely-developed internal planar bedding. This is defined by the parallel orientation of platy clasts and by layers relatively impoverished in the larger clasts and/or enriched in coarse-grained sand.

The Unit A association is envisaged to represent the deposits of debris flows (breccio-conglomerates) and sheet floods (granulestones) emplaced by gravity processes acting on weathered and consequently unconsolidated rock waste. A marine influence is also suggested, however, by the acritarchs found within sporadic thin mudstone beds in the Boon's Member (Molyneux, 1992). Unit A may then represent part of an alluvial fan/submarine fan delta complex developed at the margins of a steep, fault-controlled shoreline. Beds of Unit B, which may represent deposition on a more distal part of the fan delta, are described below at Locality 6.

The upper component of the Boon's Member, Unit C, is exposed at Locality 5, the lithic sandstones and breccias of Unit B having been faulted out. The succession comprises tabular beds of litharenite whose relatively mature composition is reflected by their grey colour and lower content of opaque and lithic grains. Most beds are structureless, but some have plane to low angle cross-bedding. The bed tops are in places slightly undulatory, providing the first indication of wave or current reworking in the Hartshill Sandstone.

Some of the lamprophyre sills that invade the Cambrian succession in the Nuneaton Inlier can be viewed at Locality 5. Related intrusions of hornblende diorite, up to 60m thick near Bedworth, have yielded a (Late Ordovician) radiometric age of 442Ma (Noble *et al.*, 1993).

North-westwards from Locality 5, up the incline past the landfill site, the exposed grey sandstones are much-fractured. At the top of this incline (not shown in Fig. 2), the north-western quarry face shows good sections through grey sublitharenites or lithic subarkoses forming the middle part (Unit E) of the Park Hill Member. These sandstones form sharp-based, tabular beds between 0.2 and 2m thick. Each bed is a coset of between 2 and 5 planar cross-bedded sets. The cross-bedding regularly changes its direction of inclination, from one set to the next, producing a 'herringbone' pattern which is characteristic of the Park Hill Member. Some of the lower bounding surfaces of the cosets have scoured bases. Their top surfaces may consist of rippled coarse-grained sandstone. Mudstone-draped partings are only sporadically seen. Cosets of this type are probably sections through sandwaves formed in a tidal regime in which the ebb and flood currents were apparently of equal strength, flowing to the south-west and north-east. Trough cross-bedding is sporadically seen, with foreset inclinations usually to the east or east-south-east.

Locality 6 is on the lower south-eastern quarry face, by the corner to the left of the roadway, about 100m

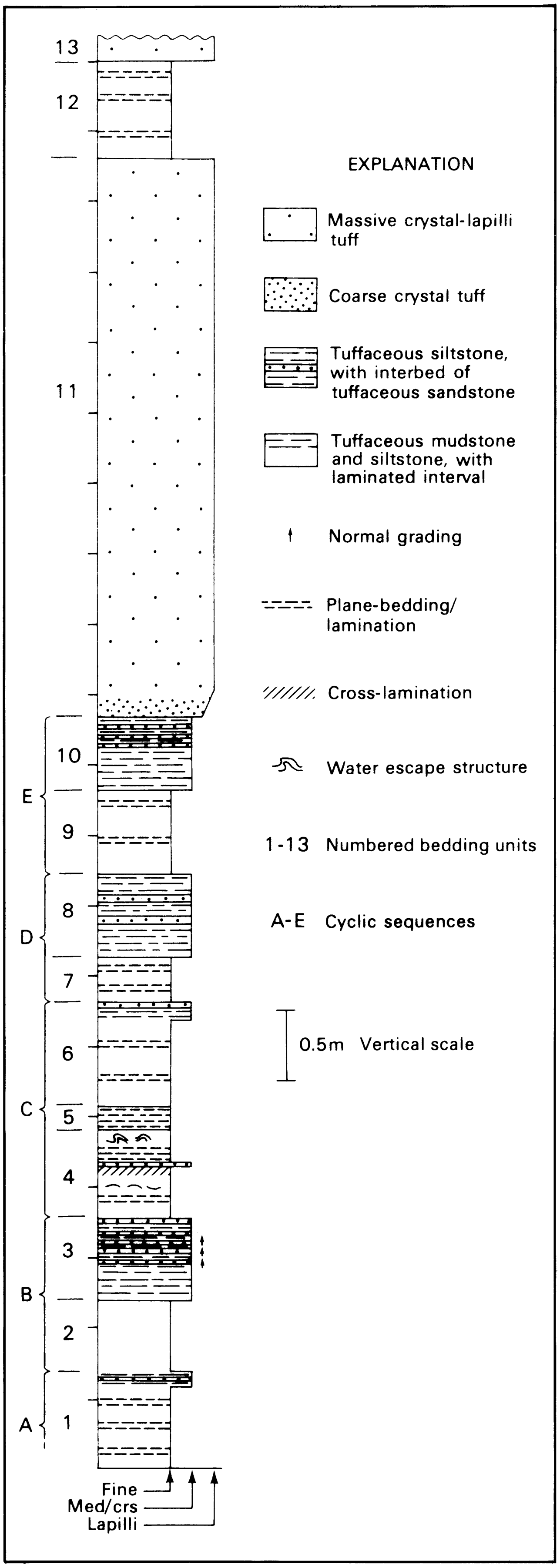

Fig. 3. Measured section in the Caldecote Volcanic Formation at Locality 1 (Fig. 2).

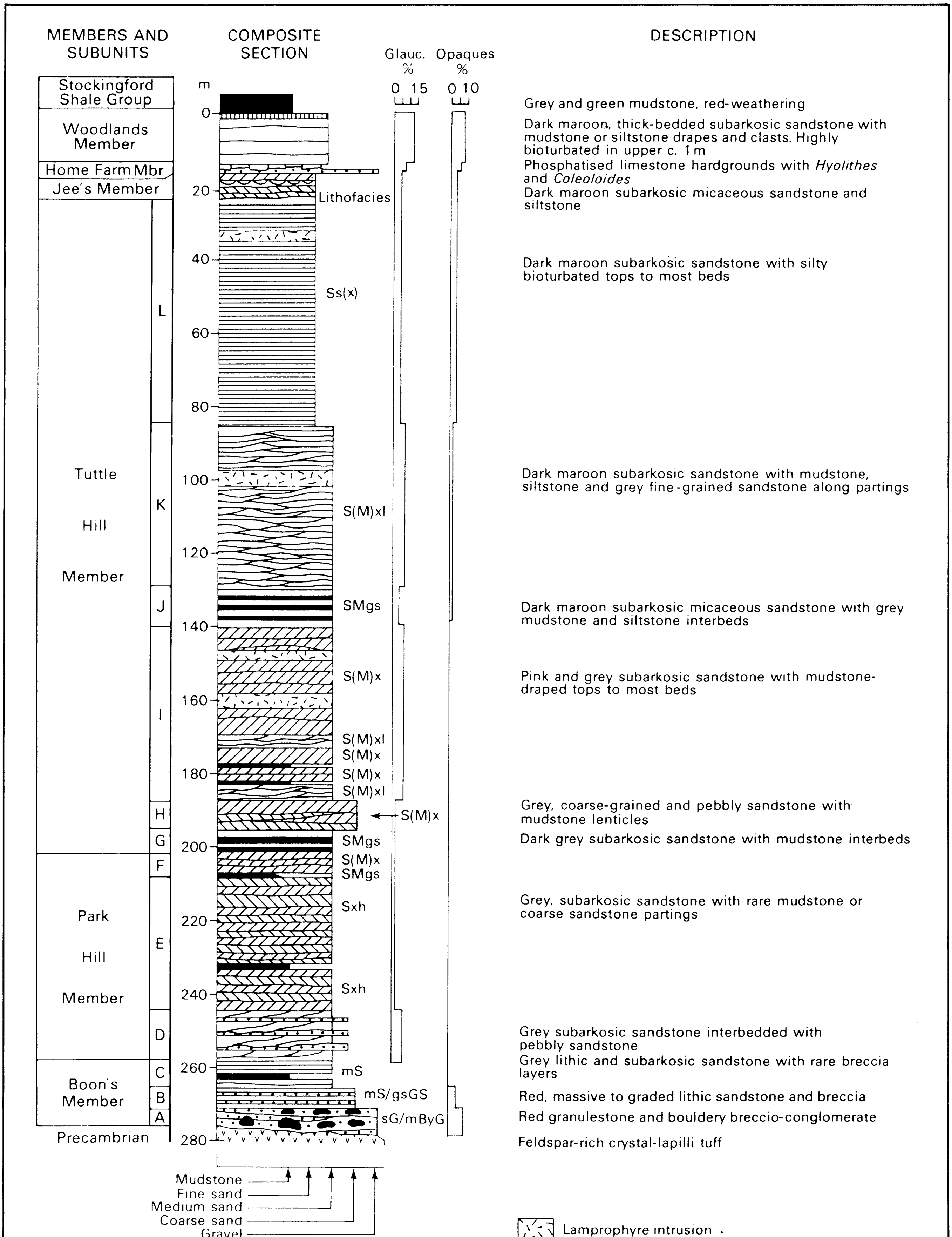

Fig. 4. Composite stratigraphical column in the Hartshill Sandstone Formation based on exposures in Boon's and Hartshill Quarries. An explanation of the lithofacies codes is given in Table 1.

CLASTIC SHELF FACIES ASSOCIATION

FACIES CODE	
Ss(x)	Sandstone with plane-bedding; rarely with low-angle cross-bedding
S(M)xl	Sandstone with mudstone drapes, in compound, lenticular cosets
S(M)x	Sandstone with mudstone drapes, in cosets of tabular-planar cross-bedding
Sxh	Sandstone with sporadic mudstone drapes, in cosets of herringbone cross-bedding
GyS(M)x	Coarse, gravelly sandstone with mudstone lenticles; massive to cross-bedded
SMgs	Sandstone and mudstone, plane-bedded and graded in part

FAN DELTA FACIES ASSOCIATION

FACIES CODE	
mS	Massive sandstone
gsGS	Sandstone with gravelly layers, graded and plane-bedded
sG	Granulestone, plane-bedded
mByG	Massive bouldery breccio-conglomerate

Other symbols

∼	Bioturbation
	Mudstone bed
	Clast

NB 'Plane bedding' or 'Plane lamination' refers to bedding or lamination that is planar and parallel to the bounding surfaces of the bed.

Table 1. Explanation of facies codes and other symbols used in Fig. 4.

farther down the incline from the arrow shown in Figure 2. It is the only exposure of the beds inferred to belong to Unit B in the Boon's Member. The unit, about 9m thick, consists of red, medium to coarse-grained lithic-rich sandstones with subordinate layers of matrix-supported breccia in the lower to middle part. The sandstones are plane-bedded or structureless, and the breccia layers, from a few to several centimetres thick, are parallel-sided and sharp-based. Such features are reminiscent of proximal turbidite sequences (Hiscott and Middleton, 1979; Ghibaudo, 1992), and compatible with deposition from sediment-laden currents. The lower proportions of angular pebble-size Precambrian clasts in these sandstones, compared to the Unit A beds, suggests a greater distance travelled by each flow prior to deposition.

2. Hartshill Quarry (SP336 937)

This was formerly known as Jee's Quarry. It is still being worked as a source of constructional aggregate by Tarmac Ltd. The best sections occur on the older faces, around the north-eastern and south-eastern parts of the quarry, which together expose about 80 per cent of the Hartshill succession (Fig. 4). The geology and locality information are given in Figure 5.

Spectacular bedding plane exposures in Unit E of the Park Hill Member occur along the north-eastern quarry levels. At Locality 1, the bedding plane is pock-marked by large (c.0.8m across), scoop-shaped scour pits whose asymmetry of profile indicates a current flow to the south-west (down-dip). The asymmetric ripple marks nearby also give this current direction. Analogous scour pits, described from Early Cambrian sandstones in the USA, are interpreted to have formed by the action of ebb tidal currents (Simpson and Eriksson, 1990). A similar interpretation here would indicate that the ebb current flowed south-westwards, away from a shoreline situated farther to the north-east, and that the north-easterly current direction measured in the complex 'herringbone'-patterned cosets of Unit E is that of the flood tide. Furthermore, the east to east-south-east current flow directions measured for many of the trough cross-bedded sandstones is possibly the longshore component of this tidal system.

One of the rare mudstone beds in the Park Hill Member occurs above this bedding plane; it is overlain by plane-bedded sandstone and cross-bedded coarse-grained sandstone which may represent storm deposits.

Locality 2 exposes a stratigraphically higher sandstone bedding plane which shows, in plan view, bedding and laminae disposed in strongly arcuate, overlapping patterns. This is interpreted as a planed-off section through a swarm of sinuous-crested megaripples formed by a south-easterly directed, possibly longshore, current.

Farther to the south-east, between Localities 2 and 3, many bedding planes show the marks of burrowing organisms. From this part of the succession, Brasier and Hewitt (1979) described the trace fossils *Psammichnites*, *Neonereites*, *Arenicolites* and *Planolites*, with *Diplocraterion* identified more recently (Brasier, written communication, 1990). Locality 3 shows a bedding plane with asymmetric ripples indicative of south-westerly current flow. Between Localities 3 and 4 are seen further extensive ripple-marked surfaces, and a series of northerly-trending raised sandstone ribs of problematic origin. Near Locality 4, large elliptical structures on a bedding plane were possibly produced by the escape of water during sediment compaction.

The contact between the Park Hill and Tuttle Hill members, at Locality 4, is placed at the lower surface of a 1.3m-thick bed consisting of mudstone with thin sandstone layers, forming the base of Unit G. In practice, there is a broad transition through the contrasting lithofacies of Units F, G and H. The sedimentological change is heralded in Unit F by a thinning of the sandstone beds near the base, where mudstone and siltstone intervals up to several centimetres thick are also intercalated. The succeeding, thickly developed, dark grey mudstones and siltstones at the base of Unit G of the Tuttle Hill Member suggest deposition following a flooding event on the Cambrian shelf. The overlying sandstones include beds with tabular geometry, showing plane-laminated internal structure, normal or reverse grading, or abrupt changes between texturally differing sandstone layers. They are interpreted as the deposits of sediment gravity flows induced by storm events acting on a shoreline that had receded as a result of the flooding event.

The shearing seen in the basal, mudstone-rich part of Unit G indicates a phase of north-eastwards directed compression during which most of the strain was taken up within easily deformable sedimentary layers; Caledonian or Variscan ages for this deformation are equally possible.

The next stage in the transition is represented at Locality 5 by Unit H. The grey pebbly sandstones seen here are amongst the coarsest-grained in the Tuttle Hill Member. The middle and lower parts of each sandstone bed are either massive or show poorly-developed cross-bedding with foresets, where seen, indicative of a north-easterly current flow (these directions are as observed, with no corrections made for subsequent tectonic tilting). The upper several centimetres of many of these beds are cross-laminated and show a reversed, south-westwards current flow. A distinctive feature of this unit is the occurrence of highly lenticular packages of laminated mudstone and siltstone between the sandstone beds; these are up to 0.7m thick. Mudstone also occurs as intraclasts within erosive-based sandstone beds. The overall character of Unit H could suggest deposition within a storm-influenced offshore ridge system similar to those described by Hein *et al.* (1991).

Unit I of the Tuttle Hill Member commences at Locality 6. The lower part of the unit comprises alternations of medium to thickly-bedded, planar (locally trough) cross-bedded sandstone and thinly bedded, compound-lenticular cross-bedded sandstone. Each of these sedimentary 'packages' measures several metres in thickness. The planar cross-bedded sandstones are interpreted as sections through migratory dune-like sandwaves formed in a north-east directed current regime; the compound-lenticular beds formed sandwaves in a more unsteady regime, with the mudstone drapes representing slack periods between each current event. The compound-lenticular cross-bedded sandstones show a heirarchy of internal discontinuities, commonly outlined by mudstone drapes or trails of mudstone clasts. In this respect, they resemble the Class V sandwaves of Allen (1980). Conditions of abundant arenaceous supply are suggested by the thickness (2m) of the planar cross-bedded sandstone beds in the vicinity of the two lamprophyre sheets intruded above the middle part of Unit I. Above this, the beds become thinner towards Unit J.

At Locality 7, beds in Unit J comprise a heterolithic (sandstone-mudstone) interval within the Tuttle Hill Member. The sandstones have parallel bases and tops and are either structureless, or show inverse or normal grading. In a well-developed example, ripple cross-laminated fine-grained sandstone and siltstone forms a several centimetre-thick capping. The sandstone beds may be of storm origin, similar to those in Unit G.

Commencing at Locality 8, Unit K is a thick and uniform sequence of compound-lenticular cross-bedded sandstones. Some of these beds show normal grading with ripple-marked sandstone or siltstone tops, while others are capped by poorly sorted sandy and silty layers containing mudstone rafts, possibly indicative of storm reworking of bed tops. Most beds are similar to the compound-lenticular sandstones near the base of Unit I, and are probably sections through sandwaves. The sandstones seen here are typical of the middle to upper parts of the Tuttle Hill Member; they are medium- to fine-grained, micaceous, dark maroon subarkoses or lithic subarkoses. Green glauconite grains are conspicuous on weathered surfaces, particularly when viewed by hand lens. Bioturbation is also commonly seen along the bedding planes.

A sharp sedimentological change is seen at Locality 9, where the lenticular-bedded sandstones of Unit K give way to a thick succession of perfectly planar-based and flat-topped beds in Unit L, the highest component of the Tuttle Hill Member. These beds of medium-grained sandstone, between 0.4 and 0.8m thick, commonly show faint plane-lamination, or very low-angle cross-lamination. Mudstone drapes are only sporadically present, but as the upper part of each sandstone bed is deeply bioturbated it is possible that the sand and mud components have been extensively mixed. The interpretation of these beds is problematic; each may represent a separate episode of storm-induced deposition on a part of the shelf situated close to an abundant supply of arenaceous material.

Locality 10 shows the Jee's Member to comprise cosets of planar and trough cross-bedded sandstone, with some plane-bedded intervals. Winnowed lags of coarse-grained sandstone occur along some of the bed tops. These features suggest greater exposure to wave and/or current action, perhaps indicative of a general shoaling of the shelf to shallower water depth. Brasier and Hewitt (1979) describe extensive bioturbation in this member, noting the presence of the trace fossils *Isopodichnus*, *Arenicolites*, *Planolites* and *Didymaulichnus* suggestive of the '*Cruziana* ichnofacies'; this is perhaps indicative of a shallow water, shoreface setting.

One of the most significant components of the Hartshill Sandstone is the Home Farm Member. It is only about 2m thick and is partly exposed at Locality 11. It principally comprises the red sandy limestones and phosphatised limestone conglomerates of the well-known *Hyolithes* Limestone. Quartz-pebble conglomerates, not exposed here, occur beneath the limestone, and rest erosively upon the Jee's Member.

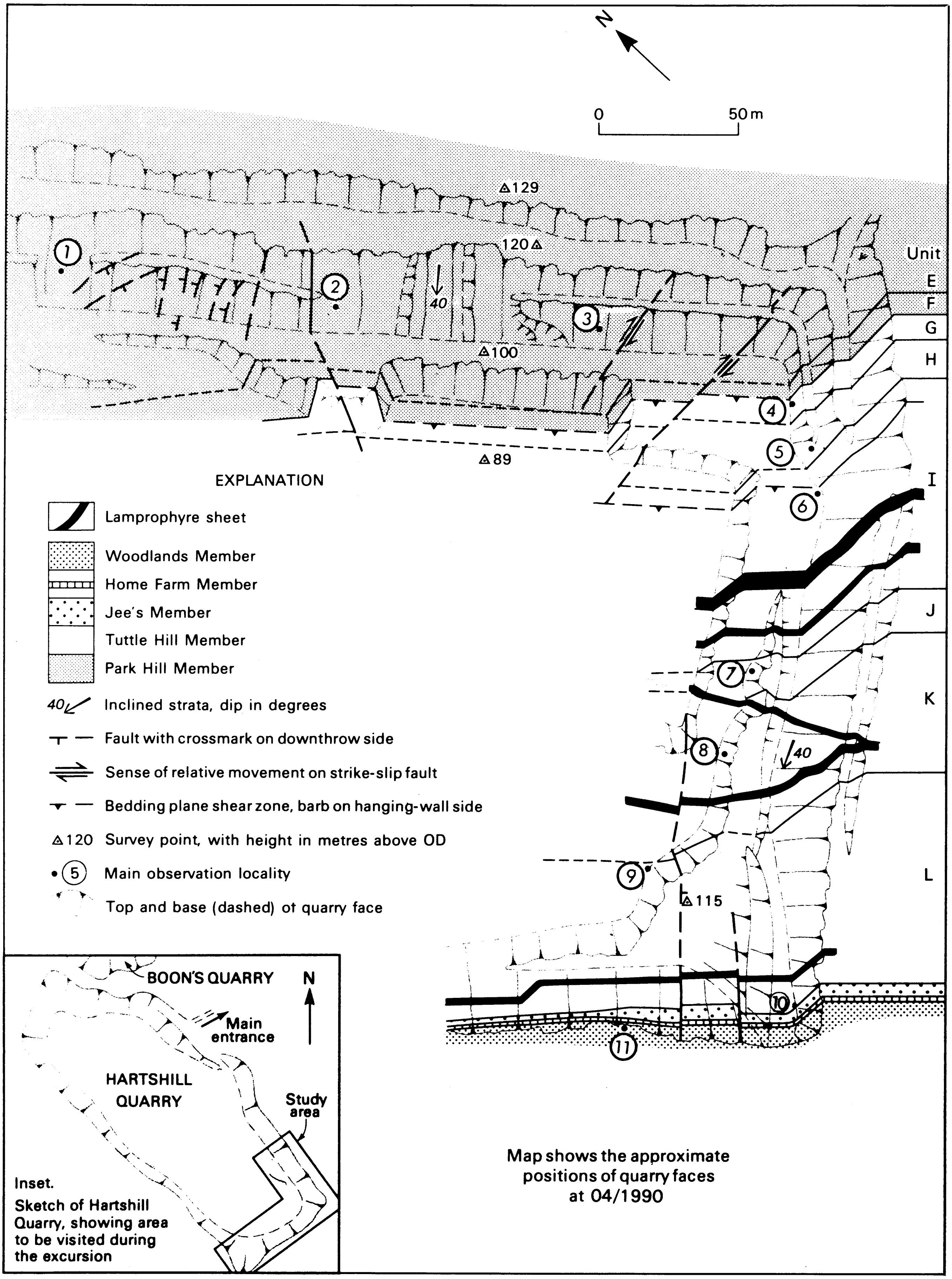

Fig. 5. Geological sketch map of the south-eastern part of Hartshill Quarry.

Tubular fossils, representing *Hyolithellus*, *Coleoloides* and *Torellela* are easily distinguishable on weathered surfaces at this exposure. They are part of the extensive and diverse fauna of this member, reviewed by Brasier (1989 and other publications), which spans the latest Tommotian and earliest Atdabanian stages of the Lower Cambrian (Brasier *et al.*, 1992). The sharply defined sedimentary discontinuities common throughout the *Hyolithes* Limestone are interpreted as hardground surfaces formed by successive episodes of marine erosion in an environment starved of arenaceous clastic material (Brasier and Hewitt, 1979). Such conditions typically arise during the accumulation of condensed sedimentary sections (e. g. Haq, 1991), suggesting that the base of the Home Farm Member is an important Lower Cambrian sequence stratigraphical marker horizon. In keeping with this are the regional correlations, summarised in Brasier *et al.* (1992), which show that the Home Farm Member corresponds to a hiatus in sedimentation that is recognised throughout the Early Cambrian province of England and Newfoundland.

Beds of the Woodlands Member are poorly exposed at Locality 11. They comprise dark grey, micaceous, glauconitic, subarkosic sandstones which commonly show a fine parallel lamination that is in part defined by entrained glauconite grains. Elsewhere in the quarry, these sandstones form thick beds with current-rippled tops. The Woodlands Member represents a renewed phase of arenaceous sediment supply to the basin, perhaps consequent upon a relative fall in sea level. A few hundred metres north-west of Locality 11, beds forming the upper 1.5m of the Woodlands Member are highly bioturbated and calcareous. This interval represents conditions of stillstand and sediment starvation, and was a prelude to the major shelf flooding event that initiated deposition of the Stockingford Shale Group.

Acknowledgements

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EXCURSION

Weekend Field Excursion to the Central Pennines

30th-31st July 1994

The valleys of the Central Pennines are incised into the Millstone Grit and Coal Measures, and the purpose of the excursion was to examine some of the sections through these ancient delta deposits. New interpretations based on the principles of sequence stratigraphy provided a recurrent theme throughout the weekend.

Saturday, 30th July

Leader: P. B. Wignall, Department of Earth Sciences, Leeds University.

The first day aimed to show the splendid late Namurian and early Westphalian sections to be seen in and around the well-developed U-shaped valley of Cliviger between Burnley and Todmorden.

1. Ratten Clough

The Yeadonian (latest Namurian) geology was examined in a steep ascent up Ratten Clough. The Gastrioceras cancellatum Marine Band is well displayed in the stream at the base of the Clough (SD 891 269) and both the Lower and Upper Haslingden Flags occur higher in the section. The Haslingden Flags prograded into the region from the west and this is one of the most distal/easterly developments of both these sand bodies. In fact siltstones dominate in Ratten Clough and the Flags are represented by only a few thin beds of sandstone. In contrast, the Rough Rock, the topmost sandstone of the Namurian, shows only minor lateral thickness variations and has a sharp (erosive) base. The sequence stratigraphical interpretation of the Rough Rock has been the subject of considerable recent debate, primarily because it refuses to be shoe-horned into any particular aspect of the sequence stratigraphy model.

There can be little doubt that the onset of Rough Rock deposition marks a significant shallowing, for the distal mouth bar facies of the Haslingden Flags is replaced by stacked low sinuosity, channel sands of the Rough Rock — a fluvial facies. Sea-level falls in the sequence stratigraphical model should be associated with incision and the development of palaeovalleys. No such erosive relief is seen beneath the Rough Rock (cf. Maynard 1992).

2. Coal Clough-Paul Clough

After lunch, further late Carboniferous sections were seen in several cloughs straddling the Yorkshire/ Lancashire border to the north of Cornholme. Coal Clough (SD 904 273) displays a well-exposed Westphalian shale section with the black paper shales of the Gastrioceras listeri Marine Band at the base. This rests on a thick coal, the Lower Mountain (Union) Mine, which in turn rests on the Ganister Rock, a thin sandstone. Like the Rough Rock, the base of the Ganister Rock is sharply erosive and abruptly overlies much finer (more distal?) sediments. In a sequence stratigraphical model this would be a candidate for a sequence boundary (unconformity) but further evidence of regional erosion at this level is required to validate this interpretation.

Paul Clough displays a long section in the Namurian including a repeat of the Yeadonian succession seen in Ratten Clough. However, the shales are better exposed here (SD 907 273) and the Gastrioceras cumbriense Marine Band can be found. Two metres below this level there is a hard, fissile black shale around 15cm thick. This is the Owd Bett's Horizon of Maynard *et al.* (1991) and is the first named example of a particular shale facies which recurs throughout the Namurian of the Pennines. It is characterised by its very high organic carbon content, high levels of radioactivity (due to its uranium content), abundant pyrite and fissile weathering. These are all features typical of true marine bands, but Owd Bett's Horizon contains no fossils. Such shales appear to form during the early stages of transgression in fully marine but intensely anoxic conditions.

Sunday, 31st July

Leader: J. I. Chisholm, British Geological Survey, Keyworth, Nottingham.

The aim of this day's excursion was to demonstrate lateral changes in the sandstones and mudstones of the Millstone Grit and Coal Measures, and to show how these can be explained by the building out of successive delta systems into the sedimentary basin.

1. Hebden Bridge: Lower Kinderscout Grit

The Lower Kinderscout cyclothem crops out extensively in the valley sides around Hebden Bridge. At Hell Hole Quarry (SD 985 277) near Heptonstall, giant cross-beds near the top of the grit are up to 10m or more high, with internal erosion surfaces showing that the river transporting the sand had a variable discharge, perhaps adding to the foresets during rare floods (McCabe, 1977). Massive or vaguely flat-bedded sandstones are visible in a quarry lower down the slope (SD 988 274). An excellent view of the surrounding valley sides here enables the lateral and vertical relationships between softer siltstones (smooth slopes) and harder sandstones (projecting crags) to be appreciated. The massive sandstones form "pods" or narrow channel-like bodies less than 0.5km wide at various levels in the background siltstone, and the giant cross-beds appear to lie in a shallower channel about 3km wide cut across the top of sandstone pods and background siltstones alike.

The sequence is thinner than in the well-known sections around the Kinderscout Plateau in Derbyshire and differs in one important way — there is no equivalent here of the turbidite fan sandstones that form a prominent unit (the Shale Grit) near the bottom of the cyclothem in Derbyshire. An earlier belief (Ramsbottom, 1969, fig. 5) that the Todmorden Grit of Hebden Bridge is equivalent to the Shale Grit has proved mistaken (Ramsbottom, 1977, p.276). There are one or two marine bands of R_{1c} aspect above the Todmorden Grit (Lloyd and Stephens, 1931), dating it as late R_{1b} or earliest R_{1c}, whereas the Shale Grit appears to be entirely in R_{1c}, so is likely to be younger. A sandstone probably belonging to the Todmorden Grit is exposed in a small quarry

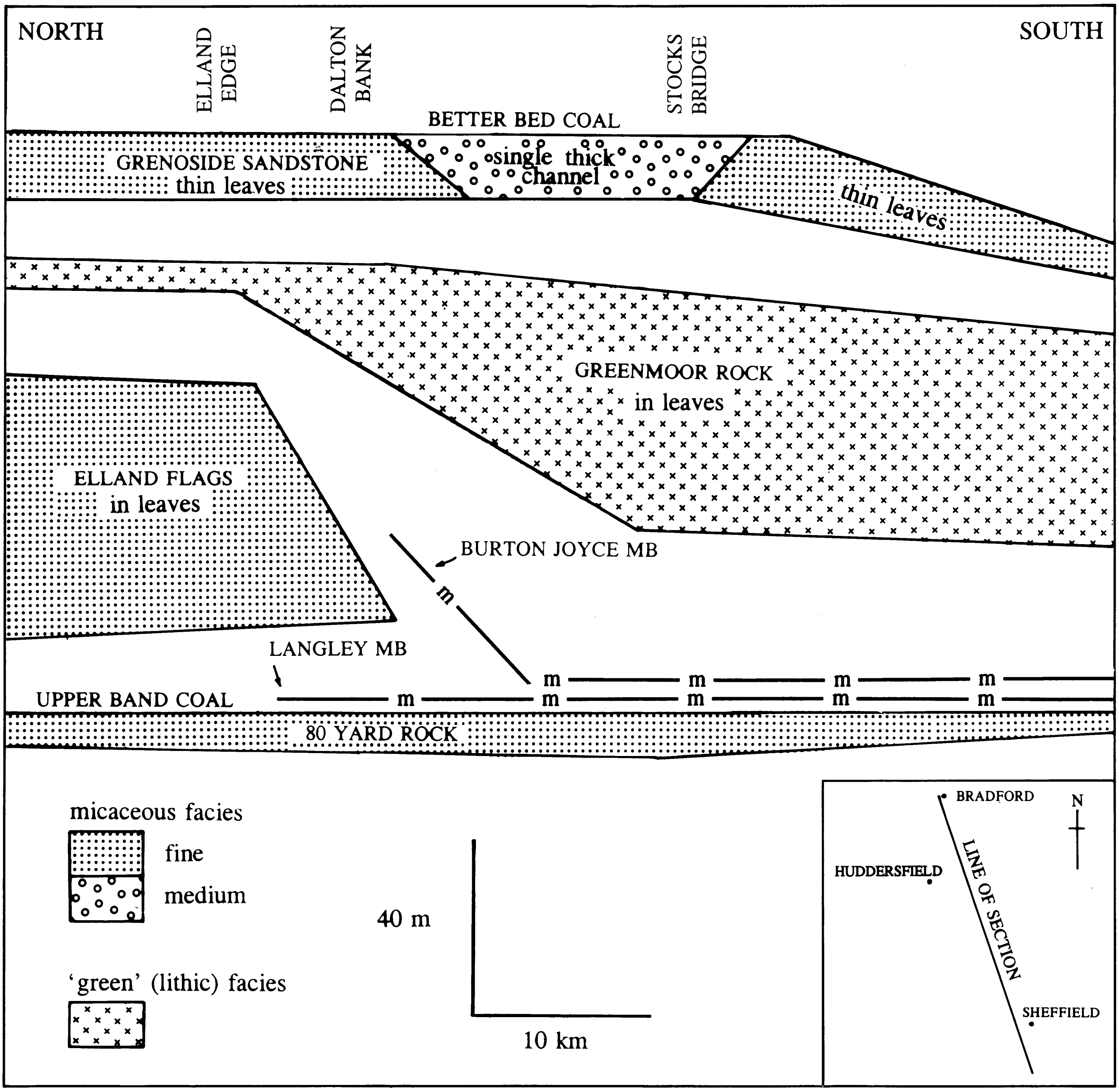

Fig. 1. Schematic diagram illustrating the stratigraphical relationships of sandstones in the Lower Coal Measures of the Cental Pennines.

(SD 985 274) by Mytholm Church. It is massive, with a strongly fluted base eroded into dark siltstone.

The accepted "turbidite-fronted delta" model of Collinson (1988, fig. 9.4) for the Kinderscout cyclothem can be applied here on the assumption that the Shale Grit turbidite fan was only deposited in the deepest parts of the basin, well to the south of Hebden Bridge. The sandstone pods are interpreted in the model as feeder channels leading down the delta slope and into the turbidite fan, and the giant cross-bedded sandstones are seen as the deposits of a river channel that advanced across the earlier deposits of its own delta, cutting down into these as it went. Only minor changes of sea level are envisaged in the Collinson model.

The more recent ideas of sequence stratigraphy suggest that there may have been larger and more frequent sea level changes than previously thought, and lead to alternative interpretations of the relationships seen in the Hebden valley sides. The older model can easily be taken apart on this basis, but if we want to put another one in its place we need to know how many times the sea rose and fell, and by what amounts, during the Kinderscout cyclothem. This knowledge is not yet available, but some suggestions can be made. The sandstone pods might be shallow-water channels that pushed through the delta front deposits during floods, and were sealed up immediately after. The giant cross-beds could be resting in channels incised during a drop of sea level, and filled during a subsequent rise. Hampson (1994) has suggested that incision and backfilling could have happened several times in the Kinderscout Grit, as sea level rose and fell.

2. Elland to Stocksbridge: Elland Flags, Greenmoor Rock and Grenoside Sandstone

The relationship between these sandstones in the Lower Coal Measures has recently been clarified (Chisholm, 1990). The Elland Flags of West Yorkshire were previously thought to pass laterally southwards into the Greenmoor Rock of South Yorkshire (Bromehead *et al.*, 1933; Davies, 1967) but it is now clear that the Elland Flags die out southwards near Huddersfield, and that the Greenmoor Rock thins northwards over the top of them. The Grenoside Sandstone of South Yorkshire is now known to lie below the Better Bed Coal, not above it. These stratigraphical relationships are shown in Figure 1. The same regional study shows that the Elland Flags deltas entered the Pennine Basin from the north but did not get very far, the Greenmoor Rock deltas advanced across the whole basin from the west, and the Grenoside Sandstone came in from the east. The westerly-derived Greenmoor Rock sediments have a different character from the other two units — they are less micaceous, and have a greenish look when weathered. They obviously came from a different source terrain, but the location of this is still a puzzle. Thin sections of sandstones show a high proportion of lithic grains of fine mica and chlorite, perhaps pointing to a source land of Lower Palaeozoic greywackes and slates.

At Elland Lower Edge (SE 128 218) the top of the Elland Flags is exposed. The characteristic micaceous nature of these deposits is well seen here. Cross-bedded and ripple-laminated mouthbar sandstones pass up into siltstones of inter-distributary bay facies, overlain by wave-reworked sands showing hummocky cross-stratification. The wave reworking can be related to the extent of the open water that lay to the south of the delta front at that time — this bay stretched at least as far as the Midland Barrier at Charnwood, a distance of 90km. Elland Edge provides an excellent viewpoint, from which can be seen the Elland Flags escarpments running north and south from the Calder Valley, brickpits dug into the Lower Coal Measures mudstones below the scarp, and the Rough Rock dip slope below the mudstones.

At Dalton Bank another excellent viewpoint is located on the escarpment of the Greenmoor Rock. A quarry on the face of the bank (SE 174 187) shows a good example of the lithology — it is ripple-laminated, but is much less micaceous than the Elland Flags and has a greenish tinge. The greenish colour is most obvious in interbedded siltstones and mudstones. On the skyline to the west is a saddle-shaped outlier of Rough Rock. Nearer to hand, to the south-west, Grenoside Sandstone forms tree-covered dip slopes shelving eastwards into the Yorkshire Coalfield, and the same bed caps an outlier of Greenmoor Rock at Castle Hill. At Dalton Bank the Grenoside Sandstone only forms an inconspicuous ridge on the hillside above the Greenmoor Rock dip slope — the different expression in the landscape is due to lateral variation in the sandstone. The prominent dip slopes to the south are developed where the Grenoside Sandstone forms a single thick leaf of medium-grained cross-bedded sandstone, probably a river channel deposit.

At Stocksbridge a new road cutting (SK 299 988) exposes this channel facies in vertical cliffs. The Greenmoor Rock is also well exposed in old rail cuttings at a lower level (SK 297 987), showing its characteristic greenish look.

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SECRETARY'S REPORT FOR 1993/1994

The Society has again had a most wonderful year with 19 new members and one new institution having joined. Membership now stands at 392 individual members plus 81 institutions. It is my sad duty to record the deaths of four of our members, Mr. Ian Gott, Mr. R. Bean, Dr. Roger Gunn and Dr. Neville Green, the last two having been founder members of the Society. Our sympathy and condolences are extended to all their families.

Our programme of events has included nine indoor meetings, three full-day field meetings, two evening excursions and a residential weekend in the Forest of Dean.

Last year's Annual General Meeting was enlivened by a thoroughly entertaining talk from John Martin of Leicester Museum on the "Art" of Palaeontological Reconstruction. He showed how the artistic depiction of a dinosaur by a particular scientist, such as Richard Owen, could influence public and scientific interpretation of the beast in question for a considerable period of years.

Later in March Dr. Robin Wingfield of B.G.S. lectured to us on the topic of Sea Level Changes since the last glaciation with particular reference to the raised beaches around the Celtic and Irish seas.

The first two field meetings of the year were evening excursions, the first being to the British Gypsum Quarry at Cropwell Bishop. It was a perfect May evening with 56 members in attendance, and our leader for the visit was Ted Moczarisk, a geologist with B.G.S. Once he had overcome his amazement at the number of participants, Ted gave us a most educational guided tour of the huge new working of the Cropwell Bishop pit.

The second evening event, in mid-June, again took place on a superb evening. It was an idyllic geological walk from Hartington through Biggin, Wolfscote and Beresford Dales led by our President Neil Aitkenhead and our Field Secretary Ian Sutton, and was thoroughly appreciated by the 32 members who were there. This time we got back to the cars before the moon came up!

The Forest of Dean was the venue for our annual residential weekend field course, the party being based at an excellent hotel near Ross-on-Wye. The participants very much appreciated the most able leadership of the course by Dr. Paul Coones of Oxford University, who knew the area intimately having lived there for many years and having studied its geology in some considerable detail.

On Sunday, 18th July, David Thompson of Keele University led a well attended excursion to the Clive and Grinshill areas of Shropshire to examine the Permo-Triassic of the South Cheshire Basin and to view the famous Murchison's Dykes. David's fund of historical as well as geological knowledge enhanced a most enjoyable day.

After our Summer break, we recommenced activities with a day excursion to the Coventry area led by John Rees and David Bridge of B.G.S. Attendance for the trip was disappointing because of a delay in publicity that resulted from permission being denied for the party to enter one of the main quarries. This was a great shame because those of us who did attend enjoyed an extremely well led trip proving that despite their name, the so-called "Barren Measures" of the Warwickshire Coal Field were far from lacking in interest.

The Autumn lecture programme commenced in October with a talk in inimitable style by Tony Waltham of Nottingham Trent University on the Caves of Xingwen in China. He described the ongoing environmental conflict between local mining activities and conservation of the spectacular karst scenery of the area.

On a clear but bitingly cold day in late October, we had our last field excursion of the year with Eric Robinson of the G.A. taking us on one of his famous London walks, in the area south of the Thames between Tower Bridge and London Bridge. His wealth of knowledge about the building stones and the industrial and architectural history of the area was greatly appreciated by the large number of members on the trip. It was an excellent day.

We were pleased to be able to hold our November meeting in Derby by courtesy of the University, where Dr. Stan Salmon of the Geology Department gave a most interesting lecture on the varied plutonic igneous activity exhibited in the rocks of the Channel Islands and the closely associated areas of South Normandy and Brittany.

The pre-Christmas meeting in December was, as ever, extremely well supported and we were rewarded with a fascinating insight into the number and variety of projects which have been undertaken by the British Geological Survey over the years and the way in which the funding for these projects has had to change. The speaker was Dr. Rob Evans of the Survey, and I am delighted to say that both he and his wife have since become members of the Society. The lecture was followed by the usual Christmas buffet which was much enjoyed by all, the food and wine both disappearing very rapidly.

To the new year, when Dr. Susan Rigby of Leicester University came to talk to us about graptolites. She presented new evidence showing such similarities between the graptolites and present day pterobranchs that it can now quite viably be argued that graptolites are still alive and well and with us today. It was an excellent lecture which was most professionally presented.

And so to the last meeting of the year, Neil Aitkenhead's third Presidential Address for which he chose as his topic, the Birth, Life and Death of the Derbyshire Carbonate Platform. The topic and the speaker were clearly popular as there were so many members in attendance (102) that we had to repair at the last minute to a larger lecture hall in order to accommodate everyone. It was a most coherent and educational account of an area well known and loved by many, detailing the evolution of the platform from early Courceyan times through to its demise with the development of black shales (the Longstone Mudstones). These were deposited during a sudden rise in sea level which made life no longer viable for the calcareous fauna upon which carbonate production is dependent. The evening and the Society's year were most appropriately concluded with a superb buffet meal at Nightingale Hall, Nottingham University, attended by some 60 members.

Seven Council meetings have been held during the year and six Circulars published, and once again we are indebted to Mrs. Joan Bush for all the hard work she puts into production of the Circular.

One initiative launched by the Council this year is the inauguration of an Annual Study Travel Award for a student of pre-undergraduate level living in the East Midlands Area and studying geology or an associated Earth Science subject. The award will be worth £250 to the winner, together with one year's free membership of E.M.G.S. £50 will be given to the student's School or College to be spent on furthering the study of geology. This award will be funded from Trust Fund money, the objectives being the encouragement of geological studies and publicity for East Midlands Geological Society.

Only one issue of the Journal has been published — number 13(2) in July, but 13(3) is anticipated very shortly. Sales of the off-print of The Sandstone Caves article written by Tony Waltham for volume 13(1) have been excellent, and I feel that all those involved in promoting and distributing the booklets for sale should be sincerely thanked for all their hard work.

The Society has recently invested in a new (and much more easily carried and erected) display stand, which is available to be used at appropriate events. One future event I would like to bring to members' early attention is the British Association Meeting which is to take place at Loughborough University in early September 1994, with Society involvement.

Our Treasurer, Jack Fryer, has again been responsible for organising our programme of indoor meetings. This year our thanks to him for all his unstinting efforts over many years on the Society's behalf should be particularly recorded, as Jack is retiring from both posts on Council at this Annual General Meeting.

Ian Sutton has continued to organise our programme of field meetings and the standard and diversity of our excursions continues to be excellent. He is to be thanked for his sterling efforts.

We continue to be indebted to the many ordinary Society members who regularly help with the refreshments at our indoor meetings or deliver the Circular and Journal. Their assistance is greatly valued and appreciated as has been the help of my own Secretary, Celia Morris, over the six years I have enjoyed being your Secretary.

The Society continues to appeal to a wide audience of professional and amateur geologists and to a wide age range. Long may it continue to thrive.

Susan M. Miles

BOOK REVIEWS

The Sun and the Rain

FRAKES, L. A., FRANCIS, J. E. and SYKTUS, J. I. *Climate Modes of the Phanerozoic*. 1992. Cambridge University Press, £40 hardback, 274pp. ISBN 0 521 36627 5.

This is a brave attempt to write a small book on a very large subject, and it will undoubtedly be useful to students and teachers seeking an overview of palaeoclimates. Its scope is impressive; from the late Precambrian glaciation to the Holocene warming, with a final chapter on the causes and chronology of climate change. The theme is global climate; inevitably, there is no space for local or regional case histories. Except in the last chapter and to an extent the section on the Quaternary, the emphasis is descriptive; climates are inferred from the geological record rather than predicted from modelling. Deliberately, there is no attempt to provide a general introduction to the various methods used to reconstruct palaeoclimates, and it is assumed that readers will already have some familiarity with Earth history. The climate modes featured in the title are recurring episodes of warm and cool global climate recognized by the authors. They do not coincide with system boundaries, nor with Fischer's well-known Icehouse and Greenhouse divisions: warm, early Cambrian to late Ordovician; cool, late Ordovician to early Silurian; warm, late Silurian to early Carboniferous; cool, early Carboniferous to late Permian; warm, late Permian to middle Jurassic; cool, middle Jurassic to early Cretaceous; warm, late Cretaceous to early Tertiary; cool, early Eocene to late Miocene. The description of the late Cenozoic cool mode is continued in a separate chapter (late Miocene to Holocene) and, of course, the available information for this time period vastly exceeds that for all the rest of the Phanerozoic put together. As the authors recognize, any attempt to impose divisions on a continuum is bound to be to some extent arbitrary, and it remains to be seen whether the modes proposed will be found generally useful. They are certainly thought-provoking; are they cyclic (regular in time, controlled by some as yet unknown driving force), or merely random fluctuations about a mean nearly-steady state, with no regularity in time or intensity? I, for one, continue to find the lack of directional trends in climate, surface chemistry and tectonics during the Phanerozoic more striking than the changes that have occurred; how on earth has the system not run wild (Gaia survived), with so much going on? As the authors point out, even asteroid impacts didn't change things all that much. Life shows direction, all right; but that is another story.

There are some problems with the approach adopted. It is unfair to blame the authors for the deficiencies of their data; they rightly draw particular attention to the problems caused by inconsistent time scales. It is obvious that there is an information deficiency for the early part of the record, and from the text-book writer's viewpoint, overload in the Quartenary. (To try to follow the Younger Dryas saga, you need a subscription to *Nature*, not a textbook; I really think the Quaternary can only be done in a book of its own). So perhaps the middle chapters are the best. But I think some guidance to methodology should have been provided. As it is, references to problems with particular methods (oxygen isotope palaeotemperatures, for instance) are scattered through the text, and there seems to be no place where the issues are fully set out. In later chapters there is much reference to the carbon cycle and its involvement with climate via the CO_2 content of the atmosphere. I doubt if much of this could be followed by anybody coming new to the subject. Try p.149, for example. We are switched rapidly from bubbles in ice cores, which measure atmospheric CO_2 more or less directly, to benthic foraminifera, and there seems to be a muddle between carbon depletion and carbon 13 depletion. We are then told the whole subject is complex, and are switched again to carbon isotope fluctuations (in what?) and their correlation with orbital parameters. Then back to ice cores. The carbon cycle also figures prominently, but to this reader not altogether coherently, in the discussion of mechanisms in the final chapter.

So what climate indices can we trust, and which can be quantified (not the same thing, necessarily)? It would be good to have the authors' views. Here are a few of mine, and I claim the indulgence of being only a reviewer. Glacial tillites — fine; about the best we have for early times. Glacial dropstones — some OK. Glendonites — probably OK, could do with more discussion here. Oxygen isotopes in carbonates — very convincing in the Cenozoic where we have both surface and deep foraminifera and asssured preservation; so we can get global temperature gradient as well as value, and quantify it; much more work needed for earlier times, especially the early Palaeozoic, but a signal is certainly there if we can read it right. Cenozoic and Cretaceous floras (leaf physiognomy, tree rings) — very good; give information on humidity as well as temperature, almost uniquely. Distribution of sedimentary rock types (evaporites etc.) — relevant, but resolution very coarse and affected by many non-climatic factors. Most fossil distributions — likewise.

Geological and palaeontological climatology has produced many convincing examples of environmental interpretation on a local scale, for instance the second author's elegant studies on the Purbeck of southern England and on polar forests (far more elegantly written, too, than the often turgid prose of the present volume). But adding all these up to a global whole seems at present impossible. So the search is on for indices of global environmental state and change, and these must come, it seems, from geochemical studies of palaeo-oceans or palaeo-atmospheres, for the sea and the air encircle the globe and nourish its inhabitants. At what stage do we stop collecting information and start modelling from it? Can we take Berner's CO_2 models as data, and can we deduce climate from them? Probably not yet, but they are at least as convincing as Exxon's sea level curves, and as worth using to test against one's own data. This review, like the book, raises more questions than it answers; there is much still to do, and let us hope that the book inspires a new generation to do it.

John D. Hudson

All about Everything

EMILIANI, C. *Planet Earth: Cosmology, Geology and the Evolution of Life and the Environment.* 1992. Cambridge University Press, £55 hardback, £19.95 paperback, xiv + 719pp. ISBN 0 521 40123 2 (h/b), 0 521 40949 7 (p/b).

Those of us who were undergraduates and A level students further back in time than we may care to remember will recall that most text books tended to be parochial. Many could appear to be rather turgid, especially if the book was being consulted out of necessity rather than out of interest. However, in recent years many more integrated books have appeared, the authors perhaps aiming at a more aware readership but also, no doubt, trying to avoid producing updated versions of "the same old thing".

There is no doubt that the content of *Planet Earth* is diverse, and the book is divided into discrete sections. It begins with a description of the origin of the Earth according to various religions. It compares the Asiatic religions which weren't, and probably still aren't, concerned with natural phenomena with the religion created by the Greeks which attempted to interpret and explain. Emiliani certainly seems to admire the Greeks for Greek etymology makes several appearances. It is not fundamental, for instance, to be able to spell "diamond" in faultless Greek, but the spelling is given on page 186 should the reader be interested. This first section continues with a list of those who Emiliani considers to be his top twelve scientists of all time, and concludes with a section on various units of measurement.

Part II deals with matter and energy. It is Emiliani's opinion that "Elementary particles and the four forces of nature are . . . so fundamental . . . that it should be an intrinsic part of any introduction to science", a statement with which many would agree. Radiometric dating methods are amongst the subjects covered as well as angular momentum, bonding and sub-atomic particles. Part III is entitled "Cosmology". Starting at the Big Bang, it discusses all objects to be seen, and inferred, in the sky. The history of astronomy is covered as well as distance measurement in the universe.

Part IV is a 200 page section about Geology. All aspects appear to be covered, including sections about the atmosphere and the hydrosphere. Part V, entitled "Evolution of Life and Environment", is marginally shorter, principally biological in content and historically organized. Part VI traces significant scientific achievements from the Minoan civilisation more or less up to the present day through brief biographical details of around 300 scientists.

Finally Part VII is phenomenal as well as being extremely useful. It comprises two appendices and is 100 pages long. There are tables of constants, every conversion factor one could hope for, elemental electron structure, isotope charts, mineral composition charts, a long table of chemical formulae and much more.

There is a lot of basic science of all types in this book, and all readers will find some, but not necessarily the same, parts to be rather heavy going. However, Emiliani usually manages to prevent interest from flagging for too long. The chapters are well subdivided, and there is an abundance of line diagrams, monochrome photographs and tables, so full pages of text are uncommon. Some parts of the text are anecdotal, but they are no less interesting for that. For instance, almost a page is taken up by an account of the various misfortunes that befell many successive owners of the Hope Diamond. In other cases photographs with short subscripts are used to save space by obviating the need for text, as with the two pictures of an Egyptian obelisk. One picture was taken after the obelisk had been in the desert for 3,000 years; the second picture was taken 100 years later after the obelisk had been subject to the ravages of New York's atmosphere.

Also, there is a "Think" section at the end of each chapter. Here, questions are posed relating to the subject matter of the chapter, but usually bearing little relation to its actual content. The diversity of these "Think" sections is high, from the easy (pumice is highly porous so why does it float in water?), to the hard (how much energy is expended in raising a salt dome of given dimensions?), to the downright obtuse (estimate the mass of your body and calculate how long you would last if you were a virtual person), but the section is always interesting, and it does make the reader think. Questions are often posed that would keep discussion groups going for hours.

Anyone absorbing all the details of this book will have a good grounding in the basics of all the sciences. In fact, it is difficult to think of any subject that has been totally left out. However, such a reader will become aware that he will know just enough about anything to realise that he is an expert at nothing. The problems set out in the "Think" sections will reinforce this view. To cover the amount of ground that Emiliani has done in this book is quite extraordinary, but the depth of coverage of the many and diverse topics must be variable. The section on the origins of life and evolution is very good, but there are also many dated palaeontological line drawings particularly in a chapter that Emiliani describes as "rather boring". Perhaps Emiliani's enthusiasm was beginning to diminish at this point, but maybe it is a subconscious suggestion that the principles of macropalaeontology have not changed as much as those of other branches of science.

Planet Earth is a book that can be read from start to finish and it is also a book that can be dipped into almost anywhere. There is much here to educate and also to entertain, as well as most comprehensive and useful appendices. It is refreshing to come across a book that does not deal with one science in isolation, but covers several subjects and interrelates them. This book cannot, of course, replace any "single subject" books because, although it has the breadth of coverage, it cannot have the depth. However, *Planet Earth* should stimulate, and even rekindle, interest in subjects which may be on the fringe of, or even outside, one's specialism and inspire the reader to find out more.

There are, however, quite a few spelling mistakes. There is one in the first paragraph on page 1 and the captions to both photographs on facing pages 144 and 145 contain spelling errors. To criticise such a marvellous book in this way may at first sight seem petty, but as one branch of modern educational thought believes that it is not necessary for a student to be able to spell correctly, these errors in the text of Emiliani's book merely highlight the fact that *Planet Earth* contains something for everyone.

Robert E. Brown

Setting the Scene

WHITTOW, J. *Geology and Scenery in Britain*. 1992. Chapman & Hall, London. £19.95 paperback, xii + 478pp. ISBN 0412443805.

The author of this new publication was responsible for the revision of three classic Penguin books, *Geology and Scenery in England & Wales*, *Geology and Scenery in Scotland* and *Britain's Structure and Scenery*. All of these are now very much dated both in content and style and *Geology and Scenery in Britain* has been published to replace all of these out of print publications.

The book is divided into 18 chapters, 17 of which address geology and scenery in a regional context, although it could be argued that some of these chapters do not include the most natural of regions from either a geographical or a geological viewpoint. The text is clearly written by a geographer rather than a geologist and consequently the geomorphological aspects receive somewhat more detailed attention than the geological, and in many places human influences come to the fore. This is not a criticism but merely a statement of fact. It would be almost impossible to present a manageable text which dealt in sufficient detail with both. As Britain must have a justifiable claim to some of the most varied scenery and geology for any area of comparable size in the world. Having read and enjoyed the text, it became clear that the book was written primarily for a lay readership. It introduces the relationship between geology and scenery in a simple and extremely readable form and in most chapters there are also references to the human impact on the landscape. It is a clear indication of geographical bias when East Anglia and the Fens are given as much treatment as the geological haven of the Lake District! Although I have made some criticisms from the geologist's viewpoint, however, I anticipate that the book will be well received by the laymen travellers who will find the content rewarding when the scenery of many places they are visiting needs explanation in relation to the underlying strata.

It is useful to find a good bibliography at the end of each chapter. These are through necessity not comprehensive, but some are not up to date and how could such well known authors as R. J. Firman be unfortunately mis-spelt (page 209)! My other criticisms are largely confined to the text figures and plates. I welcome the presence of block diagrams showing the relationship of geological structures to the underlying geology, but there are many other places in the text where such diagrams would have been useful but do not appear. The choice of geological sketch maps also seems to have been somewhat haphazard, and some that do appear refer to detail in small areas whereas the text itself generally gives a much broader treatment. The black and white plates quite simply do not always do justice to some magnificent geological and geomorphological features. Many readers will, however, appreciate the use of clear and informative diagrams and geomorphological sketch maps, and having in many ways been critical I must conclude with my positive feelings about the book. I would happily recommend it to laymen who wish to know something about Britain's wonderful landscapes and who wish to recognize the basic relationships between the scenery and the underlying geology. It is a book uncomplicated with technical jargon and is very likely to stimulate many into deeper studies.

Ian D. Sutton

Stress and Strain

TWISS, R. J. and MOORES, E. M. *Structural Geology*. 1992. W. H. Freeman and Company, New York. £47.95 hardback, xii + 532pp. ISBN 0 7167 2252 6.

Many readers will be well aware that I'm not a structural geologist. However, I have to lead undergraduate field trips and I have to talk to the students about all aspects of the geology we see, and I also have to admit to a lifelong fascination and bewilderment with geological structures. So, when the specialist structural geologists I approached to review this book turned down the commission, I gladly, if a little timidly, took on the task myself. Somewhat daunting, as I was faced with 532 large-format pages, crammed with detailed text, intricate diagrams and mathematical formulae; but I knew that I would learn a great deal.

The job turned out to be even more rewarding than I anticipated, for this is a handsome book, beautifully produced with clear line diagrams and excellent photographs. It tackles its subjects thoroughly, shirking nothing, and making the reader well aware that proper study of structures involves some advanced mathematics, particularly continuum mechanics. However, the authors adopt an approach of descriptive geology first, leading into the quantitative theory; they emphasize the point that an intuitive and geometric understanding of structures is a necessary solid foundation for more advanced analyses. So, in general, the text allows you to delve as deeply as you wish; you can stop at the descriptive stage, or move on into the experimental interpretations and mathematical theories. Some of the more esoteric mathematics is separated out into boxes for the connoisseurs; I won't reveal how much they meant to me!

The book is intended for students, and chapters 1 to 17 constitute the core of structural geology. The text begins with techniques, including methods of data recording and the nature of data (observational, orientational and geophysical), then follow large sections on brittle deformation (joints and faults) and ductile deformation (folds). Chapters 18-20 are concerned with rheology and the last two chapters cover tectonics, although the authors note that they have a companion volume on *Tectonics* in preparation. Throughout, theoretical discussions of structures are linked with actual examples, predominantly, but by no means exclusively, drawn from North America. I have only one minor quibble; there are so many illustrations that sometimes the text and figures get out of phase, necessitating repeated irritating page turning.

So, I liked this book. It provided me with new information on structures at every level, from the molecular to the global. If my mathematics were stronger, it might even have turned me into a structural geologist! In any event, when next I wax eloquent in the field about the propagation of joints or the niceties of *en echelon* tension fractures, any students who have read this review will know where I gained my insights.

Richard J. Aldridge

Croeso i Cymru

WOODCOCK, N. H. and BASSETT, M. G. (Eds). *Geological Excursions in Powys, Central Wales*. 1993. University of Wales Press, Cardiff. £12.95 paperback, 366pp. ISBN 0 7083 1217 9.

This book is divided into fifteen chapters of geological excursions, typically between ten and twenty pages in length, following a useful section on "Codes of Practice" and a general introduction to Powys.

The excursion chapters comprise, with the author/s in parenthesis: (1) The Ordovician of the south Berwyn Hills (Brenchley); (2) The Ordovician and Silurian of the Welshpool area (Cave and Dixon); (3) The Wenlock and Ludlow of the Newtown area (Cave, Hains and White); (4) Wenlock turbidites between Radnor Forest and the Newtown area (Dimberline and Woodcock); (5) The Machynlleth and Llanidloes areas (Leng and Cave); (6) Llandovery basinal and slope sequences of the Rhayader district (Waters *et al.*); (7) The Ordovician of the Rhayader district (Wilson *et al.*); (8) The Ludlow and Pridoli of the Radnor Forest to Knighton area (Woodcock and Tyler); (9) The Precambrian and Silurian of Old Radnor and Presteigne (Woodcock); (10) The Ordovician igneous rocks of the Builth Inlier (Bevins and Metcalfe); (11) The Ordovician and Llandovery in the Llanwrytd Wells to Llyn Brianne area (Mackie); (12) The Silurian of the Newbridge-Builth-Eppynt area (Bassett); (13) The Silurian of the Wye Valley south of Builth (Cherns); (14) The Old Red Sandstone of the Brecon Beacons to Black Mountain area (Almond, Williams and Woodcock), and (15) Carboniferous Limestone of the North Crop of the South Wales Coalfield (Dickson and Wright).

This book contains well-illustrated excursion guides, including clear maps, stratigraphical sections, simplified geological panels. The photographs are of variable quality. If guidebooks such as this are to include photographic plates, then they should be of high quality and printed on appropriate paper, or otherwise omitted. But this is a minor gripe in what is a useful book for anyone interested in studying the geology of Powys. I have actually used the book on a couple of occasions and I certainly found it helpful in locating sections and gaining a rudimentary understanding of those stratigraphical intervals. I can recommend this book to anyone interested in the geology of Powys, either as a field guide or simply as a source of additional information.

Kevin T. Pickering

Constructive Guidance

WALTHAM, A. C. *Foundations of Engineering Geology*. 1994. Blackie Academic & Professional, Glasgow. £9.95 softback. 88 pp, 211 figures and photographs. ISBN 0 7514 0071 8.

In the not-too-distant past, Engineering Geology used to be the course that was thrust upon the junior assistant lecturers, possibly as their first experience of teaching. Consequently, most courses must have been nervously dull or downright inappropriate. Almost as much could have been said for the text-books which existed at the time; most were dryly factual or barely differed from what was offered as physical geology to all geology undergraduates. Just as a new sense of realism has transformed the appreciation of engineering and applied geology within our science, so a new generation of textbooks has arrived on the scene. These provide varying approaches to the task of registering the inherent interest that lies within the subject, and at the same time, supply the basic facts. In its approach and presentation, this book succeeds at several levels.

First, the text is broken up by maps and diagrams at frequent points. These fit snugly within the text because, for the most part, they have been drawn specially for the purpose. Apart from giving an overall smoothness to the book, the diagrams provide a focus upon the main themes being dealt with. Finding texts dense with data difficult to absorb, I myself appreciate this graphic presentation, and I am sure that this will be the experience of the many overseas students who are so numerous in our applied science courses.

'Easy bites' represents the second success of this book. After ten double page spreads dealing with basic geology (Igneous Rocks, Surface Processes, Geological Structures etc.), there follow short sections dealing with distinct topics such as Groundwater, Coastal Processes, Rock Excavation, and Tunnels in Rock. Other sections deal with practical problems such as Site Investigation Desk Study or S I Geophysical Surveys, emphasising that these are areas of work which students will be expected to undertake as soon as they begin to practise on graduation. Equally useful is the subdivision of discussion of Subsidence into Subsidence on Clays, Subsidence on Limestone, and Subsidence over Old Mines, as each of these sections addresses the problems and the means of coping with them as self-contained exercises. Would that all geological problems were so neatly packaged for our everyday life!

A third appeal is topicality. Several of the examples are drawn from well-known major disasters, but there are also examples that have only just appeared in the daily press, such as the Scarborough landslide of 1993 or the coastal collapses in the Isle of Wight. While these cases will undoubtedly date, they give a freshness and relevance that can be maintained in future reprintings.

Not myself a specialist engineering geologist, I have had the satisfaction of being able to pass comment upon the New Australian Tunnelling Method as it became a matter of national discussion, simply because on page 77 the method is summarized, with its advantages and strengths analysed. I feel equally informed on the matter of strength testing, not, of course, to the extent of carrying out such work, but at least to having some idea of the limits set and the standards expected.

There are two final areas in which this book succeeds where others fail. It was Dr Johnson who said "There is no branch of learning in so few hands as knowing when to have done". Comprehensive as this account is, it is also brief, filling only 88 pages including a six-page index. Equally welcome to the student must be the price, which is accordingly modest and within the reach of a limited budget. This is, however, not just a student textbook, but a book which all geologists could own to advantage.

Eric Robinson

NOTES FOR CONTRIBUTORS

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INDEX

Index to Volume 13 Parts 1 to 4
September 1992 to March 1995

Compiled by R. E. Brown

Author Index

General Index

Palaeontological Index

NOTES

Contents