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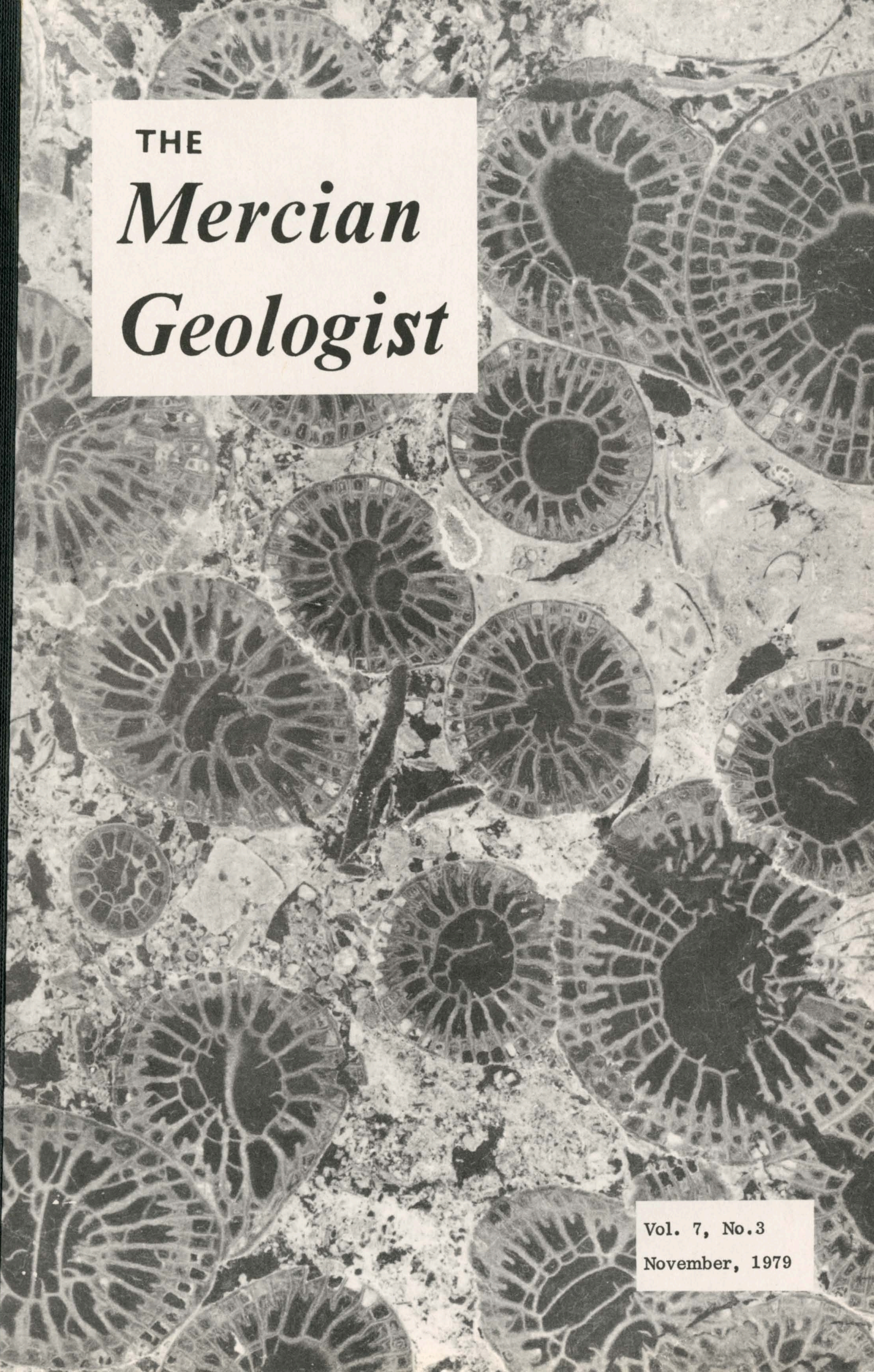

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Front Cover: *Diphyphyllum* sp. Coombs Dale, Derbyshire. D_2 Carboniferous Limestone. Cf. cover Vol. 7, No. 1.

STUDIES OF *KIRKIDIUM KNIGHTII* (J. SOWERBY) FROM THE UPPER BRINGEWOOD BEDS NEAR LUDLOW, SHROPSHIRE.

by

Helen E. Boynton

Summary

Studies of disarticulation, orientation and size were made of the species of the pentamerid brachiopod *Kirkidium knightii* (J. Sowerby) from twelve localities near Ludlow, Shropshire. Using tracings made directly from the rock face at two localities and tabulated field data collected from ten localities, percentages of disarticulated and split valves, positions of orientation and variations in size were calculated. It was concluded that *K. knightii* disarticulated fairly easily first along the hinge line and then was broken along a line between the internal septa, the spondylium being the stoutest part of the shell which often remained after other parts of the shell were abraded away. Orientation appeared to be fairly random, whereas size showed relation to the sediment in that the larger shells were found in the carbonate-rich rocks and the smaller shells in the more silty limestones often on the margin of the shelf region.

Introduction

After a study of the shells of the *Cyrtina* [*Davidsonina*] *septosa* band in the Lower Carboniferous of Derbyshire (Sadler, 1964) the opportunity has now been taken to extend the technique to the Upper Silurian (Ludlovian) shell beds containing the pentamerid brachiopod *Kirkidium knightii* (J. Sowerby). Holland, *et al.* (1963) recorded the species as being common in the Upper Bringewood Beds near Ludlow, and Newall (1966) noted it was confined to particular beds or units. Accordingly this area and stratigraphical division were chosen for the study and a record made of the orientation, distribution and size of over 1,400 shells and shell fragments from an area comprising some 15 sq. km in order to try to determine the conditions of their deposition.

Geography and Stratigraphy

The main exposure of limestones and silty limestones containing *Kirkidium knightii* are to be found in an area north-west, west and south-west of Ludlow (text-fig. 1). Occasional specimens have been recorded from other outcrops of the Upper Bringewood Beds and from other stratigraphical horizons in the Ludlovian and Wenlockian but these are not considered here.

The Upper Bringewood Beds vary in thickness from 0 to 50 m, (Alexander, 1936). They are well developed at Leinthall Earls Quarry (locality 8) where there is a shallow anticline exposing a thickness of 40 m. The beds are massive and nodular limestones, with varying amounts of silty and muddy material, and the fossils generally occur in bands. Newall (1966) divided the beds into three main types of faunal units: *Conchidium* (*Kirkidium*) *knightii*, coral, and *Atrypa-Strophonella* units, all named after the dominant characteristic fossils. In this paper particular attention is paid to the *Conchidium* (*Kirkidium*) units.

Mercian Geol. Vol.7, No.3, 1979, pp.181-190, 3 text-figs.

Palaeogeography (Upper Silurian)

As the massive and nodular limestones of the shallow shelf sea area are traced westwards to the margin of the deeper basinal region they pass into more silty limestones and finally into siltstones (Earp & Hains, 1971, fig. 35); Lawson, (1973b) showed this facies change in the Aymestrey area. Boulder beds are present in places in the basin facies and these have been interpreted as deposits transported down submarine canyons, the heads of which are located at the shelf margin (Whitaker, 1962), in the area immediately north and east of Leintwardine to the west of Ludlow (text-fig. 1). *Kirkidium knightii* has been recorded from siltstones of the basin facies at Bank Wood (264909) near Bishop's Castle by Allender (1960), but as the horizon at this locality is within the Middle Elton Beds, below the Upper Bringewood Beds, it is not detailed in this survey.

I have found a small specimen of *K. knightii* in the silty matrix between boulders in the boulder beds at Newton Lane, Lingen (377686) and suggest that it had probably been transported down a submarine canyon from the shelf region to the east.

Morphology of *Kirkidium knightii*
(text-fig. 2)

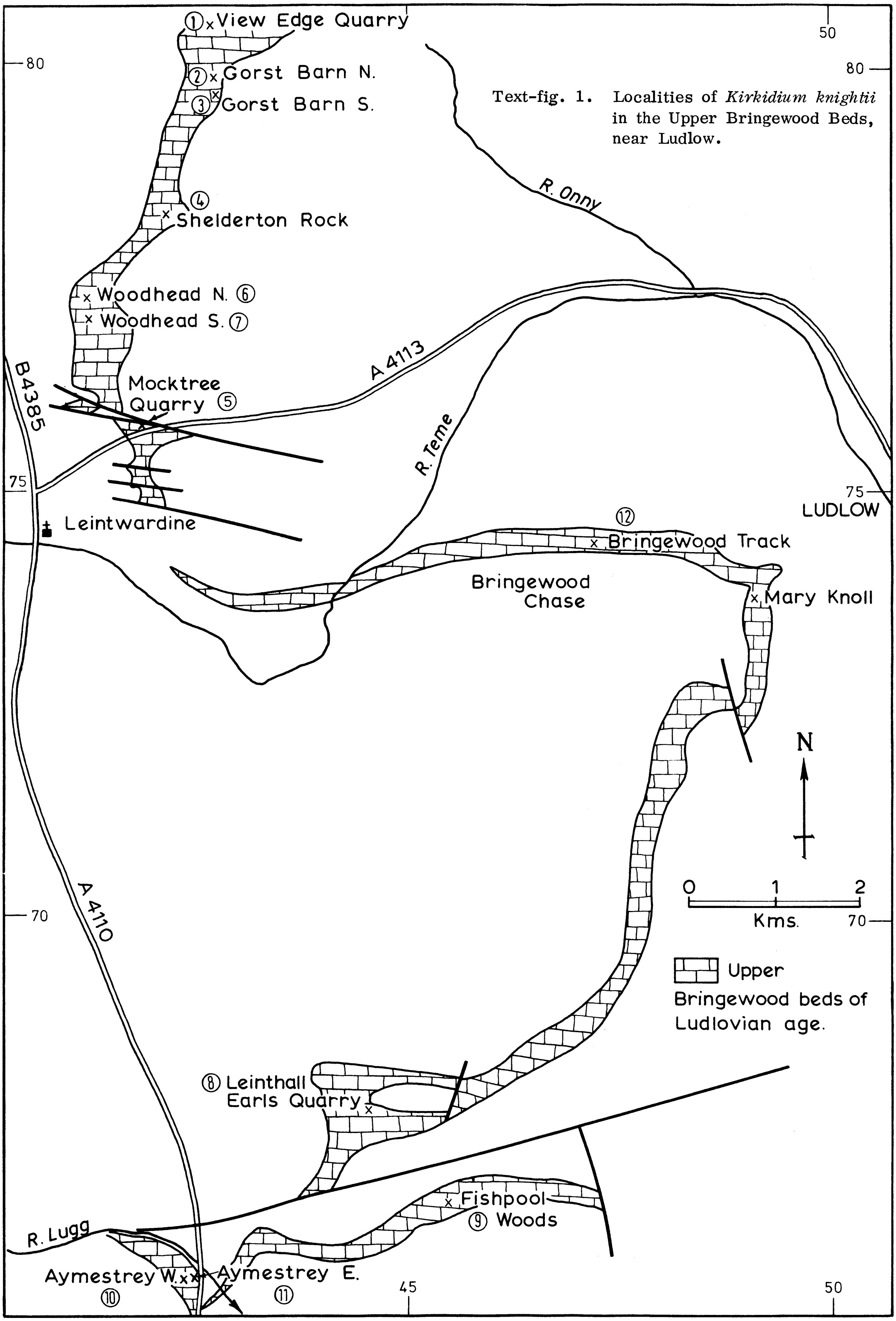
K. knightii is a large, thick-shelled brachiopod which is ovate or longitudinally oval in shape and often as wide as long (average size 5 cm by 5 cm). The shell is impunctate. The pedicle valve is more convex than the brachial valve and has a large incurved umbo. The brachial valve is oval in shape with a slight central depression running longitudinally. Surfaces of the valves are ornamented by numerous simple angular ribs, one or two bifurcating. Internally the dental plates of the pedicle valve converge in a trough-like shape for half the depth of the valve and this continues as a strong median plate made up of two septa which extends for two-thirds of the distance of the valve, towards the anterior margin. This internal structure is called the spondylium. In the brachial valve two much smaller, separate longitudinal septa extend from the hinge plate anteriorly to about half the length of the valve (text-fig. 2, no.4).

There is some variety in the shape of the shell and in the ribbing. This was illustrated by Lamont (1965) who suggested that the variation might have a palaeoecological significance. He said that coarse ribs appeared to indicate development in well-lit, shallow and wave-disturbed waters while more transverse forms with fine ribs predominated in muddy or silty waters where there was less water movement. He did not give reasons for these deductions.

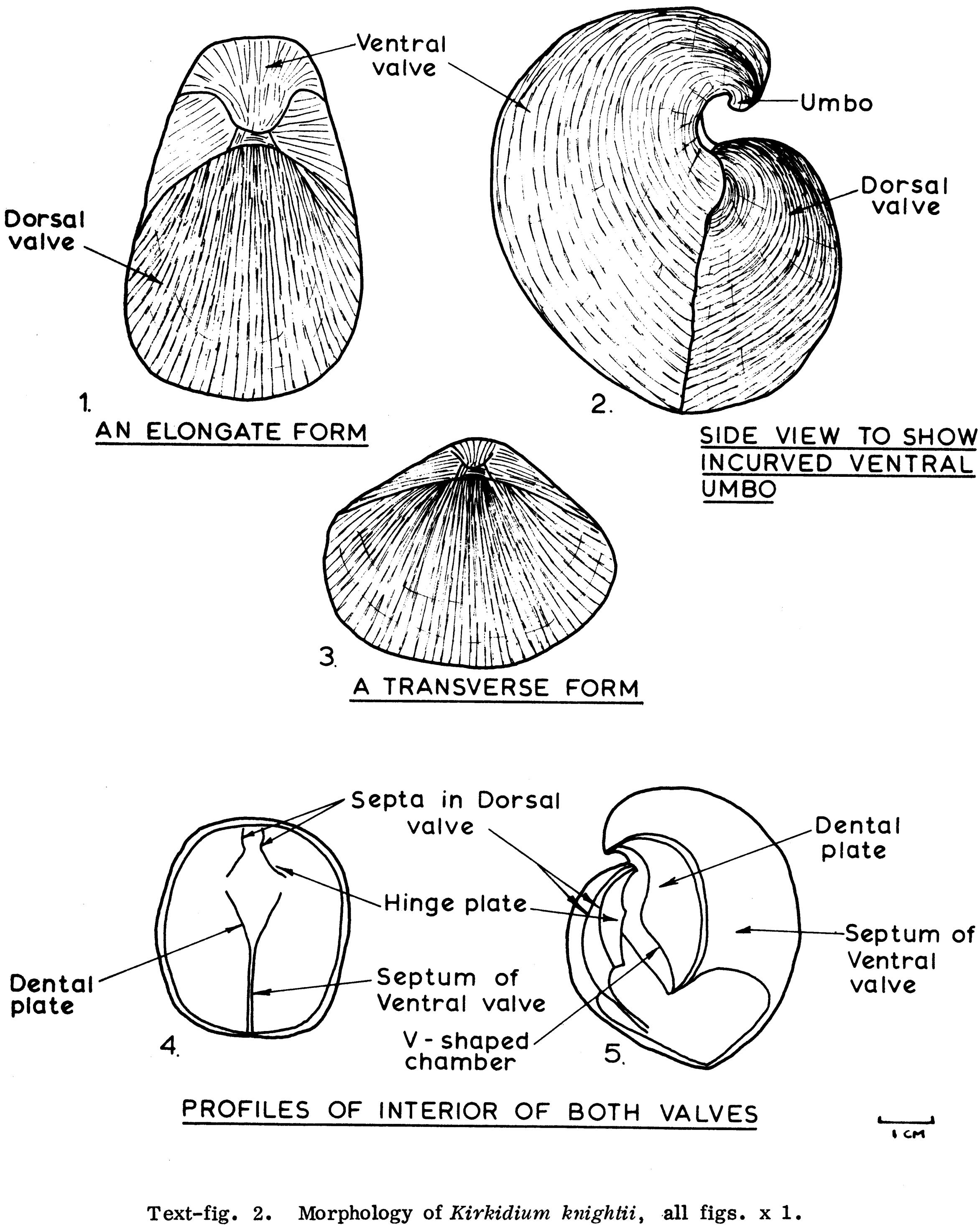
Method of study

Because of the difficulty of extracting individual specimens tracings of outlines of shells, shell fragments and corals were made onto paper directly from rock faces exposed at right angles to the bedding. By this means the exact position of each shell, its correct orientation, the state of disarticulation and size (as measured along the longest dimension visible) were recorded. This method of study, the same as that used for studying the *Cyrtina septosa* band in Derbyshire (Sadler, 1964) was used at two localities, View Edge Quarry (425806) and near Gorst Barn, north of Springhead Gutter (425789) which is referred to as Gorst Barn N.

At View Edge Quarry where the band attains its maximum thickness of 4 m a tracing was made which measured 6 m in length and 0.6 m in height. It illustrated 614 shells and shell fragments. Text-fig. 3 shows a small part of the tracing. A smaller tracing was made at Gorst Barn N. where 532 shells and shell fragments were recorded.

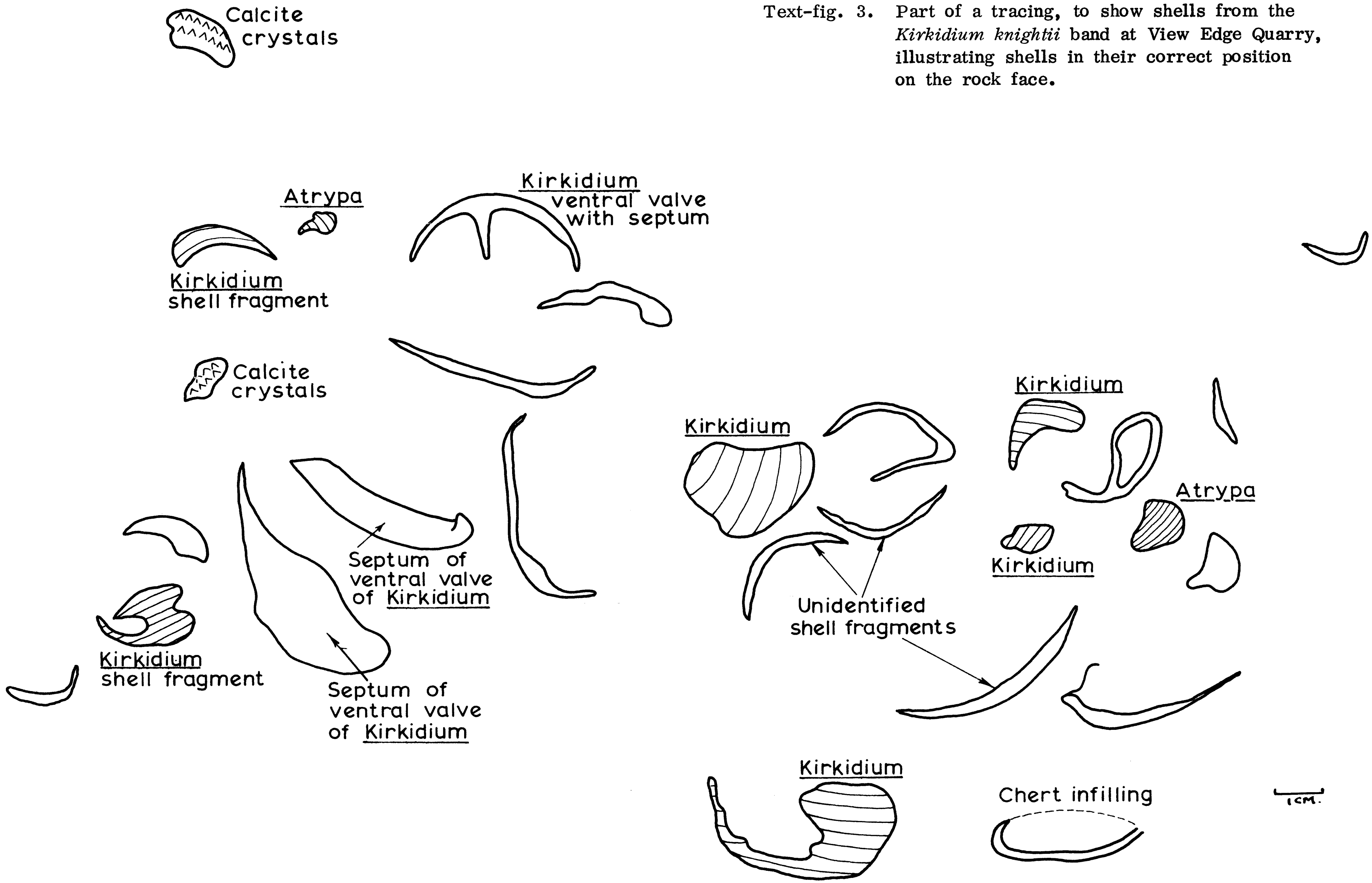


Text-fig. 1. Localities of *Kirkidium knightii* in the Upper Bringewood Beds, near Ludlow.



Text-fig. 2. Morphology of *Kirkidium knightii*, all figs. x 1.

Text-fig. 3. Part of a tracing, to show shells from the *Kirkidium knightii* band at View Edge Quarry, illustrating shells in their correct position on the rock face.



Locality	Total no. of shells counted	Total % of *K. knightii* in fauna	% of *K. knightii* showing *Orientation*			% of *K. knightii* showing *Disarticulation*			% of *K. knightii* showing *Size*			Grid Reference
			⌣	⌢	Others	Art.	Disart.	unknown	"Small"	"Medium"	"Large"	
1. View Edge Quarry	641	32%	30%	19%	51%	2%	67%	31%	43%	54%	3%	425806
2. Gorst Barn N.	532	41%	68%	9%	23%	$\frac{3}{4}$%	97%	$2\frac{1}{4}$%	34%	62%	4%	425789
3. Gorst Barn S.	44	90%	55%	10%	35%	2%	85%	13%	32%	54%	14%	425788
4. Shelderton Rock	42	95%	$22\frac{1}{2}$%	$37\frac{1}{2}$%	40%	$2\frac{1}{2}$%	75%	$22\frac{1}{2}$%	30%	45%	25%	419779
5. Mocktree Quarry	16	100%	$37\frac{1}{2}$%	44%	$18\frac{1}{2}$%	6%	75%	19%	31%	69%	0%	416754
6. Woodhead N.	5	80%	25%	50%	25%	0%	75%	25%	100%	0%	0%	409768
7. Woodhead S.	10	80%	$62\frac{1}{2}$%	$12\frac{1}{2}$%	25%	0%	75%	25%	75%	25%	0%	409767
8. Leinthall Earls Quarry	74	91%	51%	22%	27%	$1\frac{1}{2}$%	91%	$7\frac{1}{2}$%	34%	$8\frac{1}{2}$%	$17\frac{1}{2}$%	442682
9. Fishpool Woods	28	100%	39%	18%	43%	0%	72%	28%	14%	61%	25%	451664
10. Aymestrey W.	16	50%	25%	50%	25%	0%	$87\frac{1}{2}$%	$12\frac{1}{2}$%	25%	$62\frac{1}{2}$%	$12\frac{1}{2}$%	421654
11. Aymestrey E.	12	100%	25%	58%	17%	0%	83%	17%	25%	75%	0%	422654
12. Bringewood Track	15	100%	33%	7%	60%	0%	80%	20%	90%	10%	0%	456736

Table 1. To show percentages of *Kirkidium knightii* in positions of orientation, the state of articulation and the size.

Key:
Art. = Articulated
Disart. = Disarticulated
⌣ = Concave side uppermost
⌢ = Convex side uppermost

At the remaining ten localities correct disarticulation, orientation and size were tabulated in a field note book. From the field data, collected either on tracings or in tables, from the twelve localities it was possible to calculate the percentages of shells of *Kirkidium knightii* which were disarticulated, the percentages of shells in the following positions ◡ (concave uppermost), ⌒ (convex uppermost), and others, and the percentages of shells in various size groups. Size groups as follows were used: (1) "small" shells, less than 3 cm, (2) "medium" shells, between 3 and 6 cm and (3) "large" shells, over 6 cm. Sizes were measured along the greatest dimension visible. The actual size of the fossil could not always be measured because only a small portion of the shell might be visible on the rock face. Therefore only a general idea of the size of shells in each fauna could be obtained because of this discrepancy.

At least one thin section of limestone from each locality was studied and at View Edge Quarry seven thin sections spaced at 15 cm intervals vertically were also taken, in order to note the approximate amount of silty material and the orientation of the intraclasts. At View Edge Quarry two thin sections showed microscopic detail below the band.

Results of View Edge Quarry and Gorst Barn N.

At View Edge Quarry and Gorst Barn N. tracings were taken from just below and from the *Kirkidium knightii* band. *K. knightii* was found together with *Strophonella euglypha* (Hisinger). *Gypidula lata* Alexander, *Sphaerirhynchia wilsoni* (J. de Sowerby), *Leptaena depressa* (J. Sowerby), *Favosites gothlandicus* Edwards & Haime, and *Heliolites interstinctus* (Linnaeus).

Percentages of disarticulated valves, different orientations and size according to the three groups described, were calculated from the tracings and the results recorded on table 1.

The percentages of *Kirkidium knightii* in these two faunas were lower than at the other ten localities because data were obtained below the band as well as from the band itself. At View Edge Quarry *K. knightii* made up 32% of the fauna and at Gorst Barn N. the percentage was 41%. 67% of the shells at View Edge Quarry were disarticulated and at Gorst Barn N. the percentage was 97%. Shells of the "medium" group of size made up 54% at View Edge Quarry and 62% at Gorst Barn N. "Large" shells gave small percentages at both localities, 3% at View Edge Quarry and 4% at Gorst Barn N. Orientation at both localities was random.

At View Edge Quarry it was noted that the base of the *K. knightii* band was distinctive with shells of *K. knightii* coming in abruptly with more calcium carbonate-rich rocks and a notable decrease in argillaceous material.

A small collection of specimens was made from Gorst Barn N. where the band is 1.3 m in thickness. It was noted that *K. knightii* var. *elongatum* was particularly common at this locality. The variety was described by Lamont (1965) as a narrow, elongate form with low convexity and fewer ribs.

Results from the other ten localities

At ten localities where the *K. knightii* band was less well developed and numbers of the species considerably fewer than at View Edge Quarry and Gorst Barn N., notes on orientation, disarticulation and size were tabulated in a field note book. From these notes and numbers, percentages of *K. knightii* in the total faunas were calculated and found to be high, ranging from 50% at Aymestrey W., to 100% at Mocktree Quarry. Percentages of disarticulated valves were also high ranging from 72% at Fishpool Woods to 91% at Leinthall Earls Quarry. Orientation was variable showing no distinct pattern. Figures for size showed largest percentages in the "medium" group at most localities, while "large" shells were present at three localities - $17\frac{1}{2}\%$ at Leinthall Earls Quarry, 25% at Fishpool Woods and $12\frac{1}{2}\%$ at Aymestrey W.

Interpretation of the results of the *Kirkidium knightii* survey

Disarticulation

After death a brachiopod will tend to disarticulate the two valves which become separated if subjected to water turbulence. Therefore a high rate of disarticulation indicates a death assemblange of fossils.

There are high percentages of disarticulation of *K. knightii* at all twelve localities indicating they are all death assemblages. Disarticulation appears to have taken place first along the hinge line, separating pedicle from brachial valve and then the valves are broken or split along the line between the internal septa particularly in the pedicle valve. This line (text-fig. 2, no.4) was probably a line of weakness which became exposed to water action after the two valves had separated. Numerous sections of pedicle valve spondylia are seen at most localities (text-fig. 3). *K. knightii* appeared to be a species which disarticulated and split fairly easily after death when subjected to water action.

Orientation

There appears to be no pattern in the orientation of brachial or pedicle valves of *K. knightii*. Valves are found in many positions including, concave side uppermost, convex side uppermost, , the hinge line uppermost , and the anterior margin uppermost . Newall (1966) believed that *K. knightii* lived with the pedicle valve lowermost and probably embedded in the sediment, . It is thought that individual valves arranged in random pattern in the *K. knightii* bands studied, may represent accumulations of shell debris by fairly turbulent water action not too far from the original life positions. There is no pattern of orientation as shown by the intraclasts as seen in thin sections, although there is perhaps a slight preferred orientation parallel with the bedding.

Size

The shells were divided into groups consisting of "small", "medium" and "large" shells as described in *Method of Study*, p.182.

Most shells fell into the "medium" group with numbers ranging from 10% at Bringewood Track to 75% at Aymestrey E. As many complete specimens of *K. knightii* would fall naturally into the "medium" group, this indicates that many of the shells have not been greatly comminuted into smaller fragments. "Small" shells and fragments make up the next most important group with numbers ranging from 14% at Fishpool Woods to 90% at Bringewood Track. Woodhead N. recorded 100% "small" specimens. In contrast, the highest numbers of "large" shells, 25% at Shelderton Rock, $17\frac{1}{2}$% at Leinthall Earls Quarry, 25% at Fishpool Woods and $12\frac{1}{2}$% at Aymestrey W. were all found to be localities where the limestones were rich in calcium carbonate and where small subhedral quartz grains and argillaceous material were less important. At Woodhead N. and Woodhead S., Aymestrey W. and Bringewood Track where the limestones were more silty and less rich in calcium carbonate the shells were definitely smaller in size. This indicates that *K. knightii* preferred conditions where calcium carbonate was more abundant in the sea water for the manufacture of its thick large shell. Woodhead N. and S. and Aymestrey W. are all on the margin of the shelf and basin facies where shelly limestones pass into siltstones of deeper water sedimentation. It appears that at this margin conditions were far less suitable for *K. knightii* which preferred the more carbonate-rich waters of the shelf region.

Conclusions

This study of *Kirkidium knightii* from the Upper Bringewood Beds near Ludlow has revealed interesting results which are summarized below:

(1) The base of the *K. knightii* band is, particularly at View Edge Quarry, distinctive with this species coming in abruptly with the onset of the more carbonate-rich rocks. *K. knightii* generally occurs with other brachiopods and some corals, although it forms the dominant element in the fauna of the bands.

(2) Nearly all the shells are disarticulated showing that the bands are composed of death assemblages. Many pedicle valves are then broken along the line between the two internal septa to show parts of the spondylia. The anterior margin of the shell is often worn away.

(3) Orientation appears to be random with shells in many different positions of fossilization.

(4) Size of shells shows some relationship to the sediments in which the shells are found. "Small" shells are found in more silty limestones often at the shelf margin and "large" shells are present in the shelf area where the limestones are more carbonate-rich. "Medium" shells form substantial percentages at most localities indicating that many shells had not undergone great comminution by water action.

(5) Shells of *K. knightii* probably accumulated in shell banks, similar to the mussel beds of today and they were fossilized not too far from their life positions. This is shown by the high rate of disarticulation but low rate of dispersal of the shells after disarticulation.

(6) In comparison, shells of the *Cyrtina septosa* band (Sadler, 1964) in the Lower Carboniferous of Derbyshire showed a high disarticulation rate, indicating that these were also death assemblages. In Derbyshire the survey also showed a random pattern of orientation but no relation of size of shells with sediment. After processing the data of 1964 by computer (Sadler & Merriam, 1967) it was deduced that water movement over the shelf region was more turbulent than over the shelf margin. It is hoped to process the data of *K. knightii* by similar methods in order to discover further evidence for sedimentation in the Upper Bringewood Beds of the Ludlow region.

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COPROLITES: A BRIEF REVIEW WITH REFERENCE TO SPECIMENS FROM THE RHAETIC BONE-BEDS OF ENGLAND AND SOUTH WALES.

by

Christopher J. Duffin

Summary

The morphological nature and the various interpretations of the provenances of spiral coprolites are reviewed. The suite of faecal structures found within the Rhaetic bone-beds is described, and four morphological coprolitic types recognized. These four types are assigned to selachian + palaeoniscid chondrostean, dipnoan, and indeterminate producers. Ichthyosaur coprolites remain to be identified from the ichnofauna. The problem of distinguishing between faecal structures and phosphatic nodules is briefly discussed. It is concluded that the spiral coprolites from the British Rhaetic are true enterospirae (fossilised small intestines).

Introduction

'Coprolite' is a term proposed by Buckland (1829) for structures interpreted as fossil faeces. The first description of coprolites appears to be that of Lister in 1678 (Hantzchel, *et al.*, 1968; Williams 1972), but Mantell (1822) was the first to suggest their animal origin. The problem of spirally coiled coprolites has been a topic of active discussion in recent years. This subject is briefly reviewed here, with particular consideration of the groups of fossil vertebrates to which spiral coprolites have been assigned as a result either of association or articulation. The more unlikely explanations of the provenance of these enigmatic fossils are considered, followed by a review of the evidence in support of the idea that spiral coprolites represent fossilised intestines. The coprolites of the British Rhaetic bone-beds are then described and discussed in relation to previous theories of coprolite origins.

Spiral coprolites - history of research

The morphology of spiral coprolites was the particular study of Neumayer (1904) who worked on a suite of specimens from the Permian of west Texas. Neumayer recognised two types, and introduced some descriptive terms which remain in current use in the literature. 'Heteropolar' designates spindle-like forms with relatively closely spaced turns concentrated toward the least pointed end of the specimen, which Neumayer called anterior. 'Amphipolar' forms possess relatively blunt ends, and the more widely spaced spiral turns are more regularly spaced along the entire or greater part of the length of the specimens.

Spiral coprolites have been assigned to a number of vertebrate groups.

1. Selachians

In an early account, Buckland (1829) assigned coprolites found in the Liassic strata of the Lyme Regis succession to the large marine ichthyosaurs on the premise that remains of this reptile and the examined coprolites are most common at coincident stratigraphical horizons. Buckland (1841) later noted the occurrence of a spirally coiled coprolite within the body cavity of an ichthyosaur from these beds. Woodward (1917) remarked that this coprolite is flattened and not conclusively shown to be present in 'life position'. Woodward also noted that the hybodont sharks *Acrodus* and *Hybodus* are common within this Liassic succession. He considered that sharks were the most likely candidates for the production

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pp.191-204, Plates 21 and 22.

of the spiral coprolites since all extant forms possess a spiral valve in their digestive tract. As further evidence in support of his conclusions, Woodward noted that similar spiral coprolites have been located in the body cavity of the Devonian ctenacanth *Cladoselache* (cf. also Dean 1893; Claypole & Wright 1893; Fritsch 1895). A similar conclusion was reached by Fraas (1891) who noted that although spiral coprolites are common in the German Muschelkalk and Keuper, ichthyosaurs are rare. Similarly, sites at which ichthyosaurs are common, such as Bad Boll and Holzmaden, yield only rare spiral coprolites.

In a classic work on the palaeoecology of a series of Pennsylvanian shales exposed in Parke County, Indiana, Zangerl & Richardson (1963) describe several types of faecal debris. These occur in association with a vertebrate fauna comprising at least a dozen elasmobranch genera, including *Petrodus* and *Listracanthus*, an acanthodian and several other indeterminate placoderms, and a crossopterygian. In addition to spiral coprolites with few inclusions, these authors also describe irregular, compact faecal structures showing shrinkage and degassing channels (the latter having developed during anaerobic decomposition, cf. also Zangerl 1971, p.1208). The recognition of separate food boli, differing in colour, density and inclusion composition, leads to the conclusion that the mass was located for some time in the gut or rectum of the host, with successive additions to the faecal bulk. Trains or splatters of coprolitic groundmass are also described. All three of the faecal structures mentioned above are assigned to the selachian component of the fauna on the basis of size relationships. Zangerl & Richardson (1963) also recognise oral ejecta (mildly disoriented and disarticulated complete prey specimens strewn with brownish ?coprolitic material) and gastric residues (vertebrate material intermingled with seemingly coprolitic groundmass, preserved as loosely strewn or pelletal masses).

G.R. Case (1967) figures spiral coprolites from the New Jersey Cretaceous, assigning them to the actinoprergians *Amia* or *Enchodus*, while Williams (1972, p.6) considers that the selachian components of the fauna are more likely candidates.

2. Palaeoniscid chondrosteans

Vetter (1881) and Eastman (1914) consider that spiral coprolites may also have been produced by palaeoniscids. As evidence in support of this, they cite the occurrence of a 'coprolite' within the body cavity of *Asthenocormus titanus* from the Bavarian Lithographic Stone. This species is now considered to be a pachycormid holostean (Lehman 1966, p.155), and the spiral structure interpreted as an air bladder.

Johnson (1934) reports spirally coiled coprolites from the upper part of the Weber Formation (Pennsylvanian), as exposed in Park and Chaffee Counties, Colorado. Measuring 0.64 cm to 1.64 cm in length, the coprolites are restricted to the black shales of the succession. The spiral coprolites are flattened, probably due to compaction, and contain scales, teeth, bone and shell fragments enclosed in a fine groundmass. Johnson considers these coprolites to be virtually indentical to those ascribed to *Palaeoniscus* by Price (1927).

3. Dipnoans

Matley (1939a) described coprolites first recorded by Oldham (1859) from the Maleri Formation of the Indian Upper Trias. These coprolites vary in length from an average of about 5 cm to a maximum length of 8 cm. They are of broadly oval cross-section and possess a smooth, polished, brown ferruginous coating. The smoothness possibly represents a mucous surface, and the colouration may be due to the nature of the enclosing matrix. The coprolites consist of a thin lamina of mineralised material wrapped spirally around itself in a closed coil of several overlapping turns, tapering toward the terminal end. The lamina varies in thickness from 1 mm to 3 mm. These coprolites lack visible inclusions of vertebrate remains. The groundmass is a "fine grained paste". From a chemical analysis of one of the coprolites, Matley concluded that the producers were vegetable or soft invertebrate feeders. The latter suggestion might seem more in accordance with the recorded calcium oxide percentage in these specimens.

Matley (1939b) also described spiral coprolites showing dessication cracks, from the Cretaceous of Pijdura. Since none of the Maleri Formation coprolites exhibit any indication of sub-aerial exposure, Matley considered that the producer was probably aquatic. The vertebrate fauna of beds of the Maleri Formation comprises several species of amphibian and reptile, in addition to the dipnoan *Ceratodus*. Of these forms, only the dipnoan is likely to have possessed a spiral valve in its intestinal tract. Matley concluded that the spiral coprolites of the Maleri Formation are confidently attributable to *Ceratodus*.

E.C. Case (1922 p.84) later assigned spiral coprolites from the Triassic of west Texas to dipnoans. These coprolites are 3.5 cm in length, and belong to the heteropolar type of Neumayer (1904).

Ochev (1974, p.253) described a series of coprolites collected from the basal Upper Triassic rocks on the north eastern shore of Lake Inder (Kazakhstan, U.S.S.R.). The beds also contain labyrinthodont, dicynodont, thecodont and theriodont remains. The coprolites described by Ochev were placed into three morphological groups which correspond almost exactly with the three types categorised from the Texas Trias by Case (1922). The spiral coprolites (heteropolar) forming one of the Russian groups contain inclusions of bone fragments, probably fish, and measure up to 3 cm in length. Ochev notes that dipnoans are found in Russian Platform deposits of similar age and implies that the coprolites which he describes may have been produced by such candidates. Realising that previous authors have considered labyrinthodonts as producers of spiral coprolites, he defers making a firm statement as to the nature of the producer in this instance.

4. Other groups

As mentioned above, certain authors have considered amphibians as likely producers of spiral coprolites. Neumayer (1904) concludes that the coprolites belonging to his larger heteropolar type were produced either by a juvenile *Eryops*, or by a smaller stegocephalian. He concludes that the amphipolar forms were produced by *Diplocaulus*, a nectridean. In reaching these conclusions he followed the lead of Gaudry (1887) and Ammon (1889) who also ascribed spirally coiled coprolites to labyrinthodont sources.

Rusconi (1949) refers certain spiral coprolites from the Middle Triassic deposits of Mendoza, Argentina, to a reptilian source. The coprolites often contain inclusions of ganoid scales, possibly referable to *Pholidophorus dentatus* Rusconi. The scales are often partially destroyed, and display some alignment to the spiral folds. On the basis that dermal scutes, which he ascribes to the large aetosaur *Typothorax punctatus*, are found in the same deposits, Rusconi concludes that the coprolites must have been produced by this fish eating reptile. From this assumption, he continues his extremely suspect process of logic to conclude that *Typothorax* was aquatic. In a revision of the aetosaurs of Elgin, N.E. Scotland, Walker (1962, p.194) makes no mention of this Argentinian material, and reaches the conclusion that, as far as the Elgin specimens are concerned, *Typothorax* was thoroughly terrestrial, possibly adapted for digging. Thus, the Mendoza coprolites are much more likely to have been produced by other, as yet undetermined elements of the vertebrate fauna from these beds.

A certain dichotomy of opinion has arisen concerning the precise relationships of spiral coprolites. Many authors have preferred to interpret them as fully extruded faecal structures, and hence coprolites *sensu stricto*. Others consider that they may represent the intestine, fossilised in its entirety. Williams (1972) reviews this dispute, offering new evidence based on a suite of spiral coprolites from the Lower Permian Wymore Shale, near Manhatten, Kansas. The review given by Williams is supplemented here.

In concluding that the spiral fossils found at Lyme Regis were faecal in origin, Buckland (1829) closely compared their structure with that of modern shark and ray intestinal passages. The spiral valves present in the digestive tracts of modern fish were recognised as belonging to two morphological types by Owen (Parker 1885); the longitudinal valve, comprising a flap of tissue running longitudinally along the intestine in a sinuous line (as, for example, in the Hammerhead shark, certain members of the Carchariidae, and also in *Bothriolepis* - Denison, 1941); the transverse valve, a highly variable feature comprising a screw-like flap of tissue descending the length of the intestinal case (Parker 1885).

Both Matley (1939a) and Price (1927) note that in addition to sharks, the lower actinopterygians and Dipnoi are the only extant groups to exhibit a spiral valve in the intestinal tract. The spiral valve is unknown in modern amphibians and reptiles.

Although Buckland was almost certainly wrong in concluding that spiral coprolites from the Lower Lias were produced by ichthyosaurs, his descriptions of the specimens are meticulous and highly accurate. He chose to attempt some explanation for many features ignored by other and later workers. Buckland states that the mucous membrane to the small intestine of the host transferred "a series of vascular impressions and corrugations" to the surface of the coprolite (Buckland 1829, p.195). He concludes that the faecal material was extruded and fully retained its spiral configuration inherited by passage through the small intestine. This explanation was accepted by Lea (1843) and many subsequent workers.

Dean (1893, p.117) states that the coprolite found within the body cavity of *Cladoselache newberryi* "furnishes a cast of the intestinal wall and gives direct evidence as to the presence of a spiral valve". Fritsch (1895) later interpreted coprolites found in the body cavities of four pleuracanth sharks as fossil small intestines, and extended this conclusion to include isolated bodies of spiral morphology. He later (Fritsch 1907) suggested the term 'enterospirae' for these forms.

At one point in his discussion, Neumayer (1904) compares the heteropolar coprolites to the intestinal structures of *Ceratodus*, suggesting that, since the spiral turns are consistently concentrated toward one end of the structure, they may represent fossilised intestines. He further suggests, though, that the faeces were deposited prior to fossilisation, and that the processes of diagenesis imparted the spiral banding.

Zangerl & Richardson (1963, p.142, and see also Williams 1972, p.4) mention the presence of a spiral coprolite in the pelvic region of a mutilated shark specimen from the Pennsylvanian of Indiana. They continue by considering that the isolated coprolites in the fauna were produced by sharks, on the basis of their size. Zangerl and Richardson conclude that the diversity of ejectal types found within the sequence which they studied reflect the diversity of microenvironments to be found in the small intestine. They notice that some of the spiral coprolites from Indiana possess well defined spiral structure (although not perfect), and some demonstrate incomplete spiral structure, while some specimens lack internal spiral structure entirely. They consider that faecal material of considerable plasticity would retain a spiral form when extruded into the rectum. Deviation from the plasticity optimum would result in either imperfect coiling, or total lack of spiral structure.

As mentioned above, many authors have referred to the intestinal tracts of modern fish in considering the origin of spiral coprolites. Buckland (1829) made Roman Cement casts of shark intestines, and Zangerl & Richardson (1963) made rubber casts. Williams (1972, p.9) searched the literature for information on modern shark faecal pellets, but was able to discover only that laboratory sharks eject liquid or loosely viscous faeces. My own enquiries of the London Zoo achieved the same results - shark faeces have never been observed (Vevers, pers. comm.).

Dean (1903) has figured spiral coprolites produced by *Protopterus*, the African lungfish, and Williams (1972, p.9) notes that the long nosed gar (*Lepisosteus osseus*) produces similar faecal pellets. Both of these examples of modern faecal structure belong to the amphipolar type.

Histological evidence

The specimens studies by Williams (1972) from the Permian of Kansas are all heteropolar. The specimens show whorl orientation comparable to that of a spiral valve. Some specimens show collapse structures at the posterior end, with a cavity formed inside the faecal mass itself, a configuration consistent with the morphology of a spiral valve. Williams also recognises mucosal folds on the exterior of the specimens. His most impressive evidence, however, lies in the thin sections which he prepared. Bifurcating mucosal folds arise from whorl interfaces in remarkable similarity of histological form to that of the spiral valve in recent elasmobranchs. Thus, Williams concludes that heteropolar coprolites are true 'enterospirae', and should be regarded as fossilised spiral valves. He concludes by assigning the specimens which he studied to pleuracanth selachians.

Broughton, Simpson & Whitaker (1977; 1978) describe a series of spirally coiled faecal structures from the Upper Cretaceous Whitemud Formation of Saskatchewan, Canada. Referring to previous work they consider that the perforations on certain of the specimens which they describe represent gas escape phenomena (cf. also Jepsen 1963; Zangerl, Woodland & Richardson 1969). Possible mucosal fold structures are present in certain of the specimens which they describe, in spite of their total replacement by limonite. This evidence favoured interpretation of the faecal structures as fossil intestines. Broughton *et al.* conclude (1978) that certain of the specimens represent fully extruded faecal masses since plant debris adheres to their surface. This suggests their deposition in an aqueous medium. The range of coprolitic form is accounted for by these authors with regard to variation in plasticity of the faecal material involved.

Further evidence in favour of interpretation that at least certain of the faecal structures preserved by the fossil record are fossil intestines is provided by Stewart (1978). He studied heteropolar spiral faecal bodies from the Niobrara Formation (Upper Cretaceous) of west Kansas. The presence of well defined mucosal folds in these specimens led Stewart to conclude that the faecal debris represent true 'enterospirae'. From an analysis of the contemporary fauna, he suggests that they form the record of a previously undetected selachian in the Formation.

Coprolite diversity from single horizons

It is regretable that the study of spiral coprolites has tended to eclipse the consideration of the range of their diversity in single faunas. This is partly due to the difficulty in distinguishing phosphatic nodules of coprolitic origin from purely diagenetic phosphorites. Most of the better documented coprolite assemblages come from deposits of the lower Mesozoic, particularly the Trias (see Häntzschel *et al.* 1968, and Neumayer 1904, Case 1922, Ochev 1974 considered above). A recent study considering a wide spectrum of faecal remains of Upper Triassic age has recently been published by Ash (1978). These coprolites, obtained from the Ciniza Lake Beds of the Chinle Formation of New Mexico, are divisible into two morphological groups; smooth coprolites, cylindrical to cigar-shaped, with occasional longitudinal and transverse striae, transverse ridges and spiral grooves; rough, flattened coprolites, of round to oval outline. The spiral coprolites appear to be amphipolar for the most part, with occasionally well preserved heteropolar forms. The internal spiral structure is invariably obliterated, although separate food boli are occasionally recognisable. Ash does not consider the problem of coprolitic versus enterospiral origin for the spiral forms, but appears instead to consider them all as fully extruded features. He speculates that the flatter specimens may have been fairly viscous and deposited from some height in the water column, while the more regular forms could have been defaecated closer to the sediment surface, in accordance with the previous suggestions of Waldman and Hopkins (1970). An interesting feature of the coprolites forming this association is the wealth of inclusions which they hold. These vary from bone and wood fragments, through spores to conchostracans (branchiopod Crustacea). In studying the lipid components of the coprolites, Weber and Lawler (1978) conclude that the specimens represent a digested concentrate of organic hydrocarbons, supporting the view that these specimens are faecal structures rather than being of inorganic origin.

Vertebrate remains found in association with the coprolites are rare in the Ciniza Lake Beds, but comprise amphibian and fish remains. It is likely that the spiral coprolites were produced by an as yet undetermined member of the fauna (Ash 1978, p.70). Considering the environment of deposition and the nature of many of the coprolitic inclusions, it may well transpire that the producer of the spiral faecal bodies was a dipnoan.

Faecal structures from the British Rhaetic

'Coprolites' are very common within the various bone-bed lithologies of the British Rhaetic. As a direct result of the sorting influence of the prevailing currents, a reduced ratio of 'coprolites' to other vertebrate remains is often present in well sorted, sandy bone-beds of Barnstone (Nottinghamshire) and Chilcompton (Somerset). The faecal structures of the various bone-beds of Rhaetian age often show a concentric structure and are divisible into four broad morphological types:

Type 1:

This group comprises large, brown, often tapered, ?amphipolar coprolites measuring up to 80 mm in length. Undigested fish remains are visible in the coprolitic ground mass, and are arranged concentrically in cross section. Coprolites in this group possess well defined spiral structure (plate 21, figs.1-5; plate 22, figs.8-9). The material examined includes material presently held in the National Museum of Wales (specimens G 2066 to G 2068 inclusive and Jackson Collection 22. 345.Gl - all specimens are from Lavernock Point) and the Bristol City Museum (cb. 4891, cb. 3916).

In thin section (plate 22, figs.8,9), the spiral structure remains obvious. The included vertebrate remains are often arranged either tangential or radial to the spiral coils, and may show some imbrication. Distinct food boli are discernible (plate 22, fig.9) as areas of differing colour and density in the section. The spiral structure is not perfect; the spiral turns are complete, but not perfectly concentric. This may be due to collapse of the structure during diagenesis, although it should be noted that no degassing channels are obvious in the thin sections taken. The collapse may well have been accentuated in its effects by compaction pressures from overlying sediments. There is no evidence for the presence of mucosal structures in the thin sections examined.

Type 2:

This group comprises light brown to black, elongate faecal structures with well defined spiral structure. The spiral coiling is amphipolar in most cases, but appears to be heteropolar in a few specimens (Bristol City Museum specimen cb. 4898). In these latter forms, the specimen is often incomplete, making their spiral configuration difficult to determine accurately. Faecal structures belonging to this group lack included vertebrate remains, and measure up to 3 cm in length (plate 21, figs.6-11). Examples of this coprolitic type include Bristol City Museum (henceforward abbreviated as BCM) specimens cb. 4898 and 4900. Type 2 coprolites tend to fracture easily, so hindering the cutting of thin sections.

Type 3:

Coprolites of type 3 are capsule shaped, lacking undigested vertebrate remains, and measuring up to 3 cm in length. The coprolites of this group do not show spiral coiling. Material includes BCM cb. 4897 (cf. also plate 22, fig.2,7). In thin section (plate 22, fig.7) the coprolites are seemingly structureless. The ground mass is fine-grained and there is some disseminated pyrite present. In the case of the specimen sectioned, a phosphatised skin is present around the whole specimen. This phosphatic coat is 0.5 mm thick, and is a product of diagenesis.

Type 4:

Flattened, shiny black coprolites measuring up to 3 cm across, often with included scales and teeth breaking the surface are allocated to type 4. The shiny black appearance of the specimens is due to phosphatisation (plate 22, fig.6). Material includes that figured in plate 21, fig.12; plate 22, figs.1,3 and 6, and also BCM cb. 4896 and P.23353 in the British Museum (Natural History). There is no trace of spiral structure in the coprolites of this group.

As yet, it is impossible to assess the relative abundances of these coprolite groups. Such a project would require the development of a vast amount of bone-bed material. It is noticeable, however, that the coprolites of groups (3) and (4) are by far the most common.

Discussion

Affinities of the Rhaetic coprolites

With reference to the literature survey above, and the anatomy of extant forms, it is likely that the hybodont and euselachiform sharks, the palaeoniscids, and the dipnoan represented in the Rhaetic bone-beds all possessed a spiral valve in their intestinal tracts. The spiral coprolites comprising types 1 and 2 are thus attributable to certain of these forms.

The sharks and palaeoniscids were well-suited to a predatory mode of life, and as such, probably gave rise to the coprolite of type 1. These coprolites contain undigested fish remains. In addition, coprolites possibly referable to this group may contain crustacean remains (Duffin, 1978).

The coprolites of type 2 lack undigested fish remains. *Ceratodus*, the dipnoan, with its crushing tooth plates, would appear to be the most suitable candidate to have produced coprolites in this group.

Ichthyosaur coprolites

Coprolites have been assigned to ichthyosaurs by Buckland, 1829; Prout, 1829; and Firtion 1938. Pollard (1968) studied the gastric contents of ichthyosaurs, and concluded that a diversification of feeding habits may have been present in Lower Jurassic ichthyosaurs. The coprolites described by Buckland (1829) would have been produced by fish eaters, whilst those ichthyosaur skeletons preserving a gastric mass packed with dibranchiate cephalopod hooklets, were invertebrate feeders. In a more thorough study of ichthyosaur stomach contents, Keller (1976) finds little evidence in favour of a fish diet for Lower Jurassic specimens from Germany. The possibility remains that these ichthyosaurs ate both fish and cephalopods, the cephalopod hooklets being retained in the stomach, instead of being defaecated with undigested fish remains. In either case, the prey is nektonic and the ichthyosaur an active predator.

Rhaetic ichthyosaurs were presumably also of nektonic feeding habits. Belemnites are not represented in the British Rhaetic, having their first appearance in the basal Jurassic beds, (Roger 1952, p.708). The invertebrate remains of the British Rhaetic, with the exception of ostracods, are all benthonic. It is unlikely that an ichthyosaur would prey on benthos. More feasible is that the Rhaetic ichthyosaurs were fish eaters.

It remains for ichthyosaur coprolites to be identified from the Rhaetic trace fossil assemblages, if present at all.

The problem of phosphatic nodules

The separation of coprolites from phosphatic nodules is exceedingly difficult. Little is known about the geology of these nodules, although the nature of phosphorites has begun to come under scrutiny in recent years (Antia 1979). Phosphatic nodules are suggested as being common in association with diastems, glauconite, areas of non-deposition of terrigenous material, and vertebrates, especially coprolites (Pettijohn, 1957). All of these conditions are present, or have been suggested as being present, in the Rhaetic bone-beds, so that it is quite probable that phosphatic nodules occur within it. Phosphatic nodules are reported to contain various organic remains, both vertebrate and invertebrate.

The coprolite types 3 and 4 are the most likely to be confused with, to include, or to comprise phosphatic nodules, since they lack a well defined spiral or other such characteristic internal organisation. The coprolites of type 4 are common and consistent in their structure, with inclusions of vertebrate remains breaking the surface. Certain other small, black, polished forms, apparently lacking significant amounts of inclusions of vertebrate material, probably represent phosphatic nodules. These forms are easily confused with the coprolites of types 3 and 4.

Specimen H38, in the Buckland Collection of Oxford University Museum, greatly resembles the coprolites of type 4. This specimen, from the bone-bed at the base of the Rhaetic succession of Aust Cliff, has its smooth surface broken by the presence of small lumps. A broken surface shows the inclusion of many structures not present in the coprolites of type 4. These structures include almost complete valves of bivalve molluscs, and small pieces of glauconite. Glauconite grains would not be expected in a coprolite, and the bivalves would be considerably triturated, if present at all. It is concluded that this specimen is indicative of one type of structure displayed by phosphatic nodules in the Rhaetic bone-beds, although it is not necessarily typical.

It is also interesting to note here that certain coprolites belonging to type 4 show unusual projections from the main body of the specimen. These projections are usually of flat aspect, although a few specimens do show thinner developments (plate 21, fig.12). The flattened projections on certain specimens often are present along the greater length of the structures, and may on occasion completely circle the specimen. Specimens of this nature may represent phosphate precipitation around a suitable nucleus, with preferential lateral growth along the sediment/water interface, or along bedding laminations.

Gindy (1978) made a recent study of the alpha radioactivity of constituent phosphate particles in Maestrichtian pelletal phosphorites from Egypt. He found considerable range of values of alpha radioactivity; the constituent particles in order of increasing radioactivity are 1, chert and quartz lithoclasts and cements; 2, vertebrate fragments; 3, colourless and clear collophanite pellets; and 4, pellets of assumed faecal origin. Both carbonaceous matter and calcium phosphate are concentrate collectors of uranium from solution. Gindy further notes that certain of the vertebrate fragments and possible faecal pellets showed the development of superficial films of increased radioactivity. He states that the following in a likely explanation of these results (Gindy 1978, p.544); "A film of mucilaginous cement deposited on the outer surface of some particles, a common feature of faecal matter, could have avidly collected any available uranium from sea water as well as from later intergranular solutions. This could have started during the early diagenesis of the pelletal phosphate and continued epigenetically for a long time afterwards."

It has so far not been possible to examine phosphate particles from the Rhaetic bone-beds for alpha radioactivity, so the distinction between phosphatic remains of faecal and inorganic origin remains obscure at the present time.

The problem of the origin of coprolites

The histological evidence offered by Williams (1972) and Stewart (1978) is overwhelming proof that at least some 'coprolites' are fossilised intestines. This histological evidence is so far true only for heteropolar forms. Spiral coprolites from the Rhaetic bone-beds are all amphipolar, and none shows evidence of the preservation of mucosal folds on the whorl interfaces in thin section.

The small intestine, when filled with food material, is the soft organ of the body most likely to be preserved in the fossil record. It is protected from external destructive processes for some time, depending upon the precise mode and site of death, while the processes of carcass decay are going on. The Kansas 'enterospirae' show consistent preservation of spiral valve histology. If the Rhaetic coprolites described above are indeed fossil spiral valve contents, then the lack of preserved mucosal remains must be due to the microenvironment in the centre of the coprolite at the time of burial, and during diagenesis. It may be that the spiral valves in the Kansas deposits were rapidly enclosed by sediment. Further decay of the walls of the spiral valves in the Rhaetic specimens may have been a feature of long exposure on the sea bed in reducing conditions.

The whorl orientation and surface features are certainly more explicable if the Rhaetic coprolites are spiral valve contents. It is unlikely that spiral structure would be retained by the contents of the intestines after squeezing through the sphincter at the base of the small intestine, and extrusion into the rectum. This is well illustrated by the rarity of spiral faecal bodies recorded from extant organisms which are known to possess a spiral valve in their digestive tract, and the difficulty faced in trying to produce fully extruded spiral faecal structures experimentally.

Thus, it is concluded here that the most likely explanation for the origin of the Rhaetic spiral coprolites described above, is that they are spiral valve contents, and should be regarded as true 'enterospirae'. It remains possible that certain specimens showing spiral configuration may represent fully extruded faecal material of optimum plasticity for subsequent shape retention.

The question remains as to whether these conclusions can be extended to include all coprolites as enterospirae. It is possible that all of the coprolites from the Rhaetic bone-beds are small intestine contents. Many specimens, especially certain of those belonging to type 3, are probably not, since they show evidence of total extrusion, such as a small twist at the posterior end, and occasional impact features. Thus, the remainder of the coprolites from the Rhaetic bone-beds quite probably includes coprolites *sensu stricto*, and small intestines. The lack of definitive structure in these forms obscures their precise origins.

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Explanation for Plate 21

Coprolite types 1, 2, 4

Fig. 1	Type 1 spiral coprolite, x 1. BCM 4891. Aust. Cliff, Avon.
Fig. 2 (a & b)	Type 1 spiral coprolite, x 1. G2066 Nat. Mus. Wales, Lavernock Point.
Fig. 3	Type 1 spiral coprolite, x 1. G2067 Nat. Mus. Wales, Lavernock.
Fig. 4	Type 1 spiral coprolite, x 1. BCM Cb.4893. Aust.
Fig. 5 (a & b)	Type 1 spiral coprolite, sliced, x 1. G2068 Nat. Mus. Wales, Lavernock.
Fig. 6	Type 2 spiral coprolite, x 1. BCM Cb.4892. Aust.
Fig. 7	Type 2 spiral coprolite, x 1. BCM Cb.4900. Aust.
Fig. 8	Type 2 spiral coprolite, x 1. BCM Cb.4898. Aust.
Fig. 9	Type 2 spiral coprolite, x 1. BCM Aust.
Fig. 10	Type 2 spiral coprolite, x 1. BCM Cb.4900. Aust.
Fig. 11	Type 2 spiral coprolite, x 1. BMNH P.23353. Aust.
Fig. 12	Type 4 coprolites, x 1. BMNH P.23353. Aust.

(BCM = Bristol City Museum, BMNH = British Museum (Natural History), Nat. Mus. Wales = National Museum of Wales, Cardiff).

Explanation for Plate 22

Coprolite types 1, 2, 3 and 4

Fig. 1 Type 4 coprolites, x 1. BMNH P.23353. Aust.

Fig. 2 Type 3 coprolites, x 1. BMNH P.23353. Aust.

Fig. 3 Type 4 coprolites, x 1. BCM Cb.4899. Aust.

Fig. 4 Assorted coprolites from Holwell fissure, Moore Collection, Bath Museum, x 1.

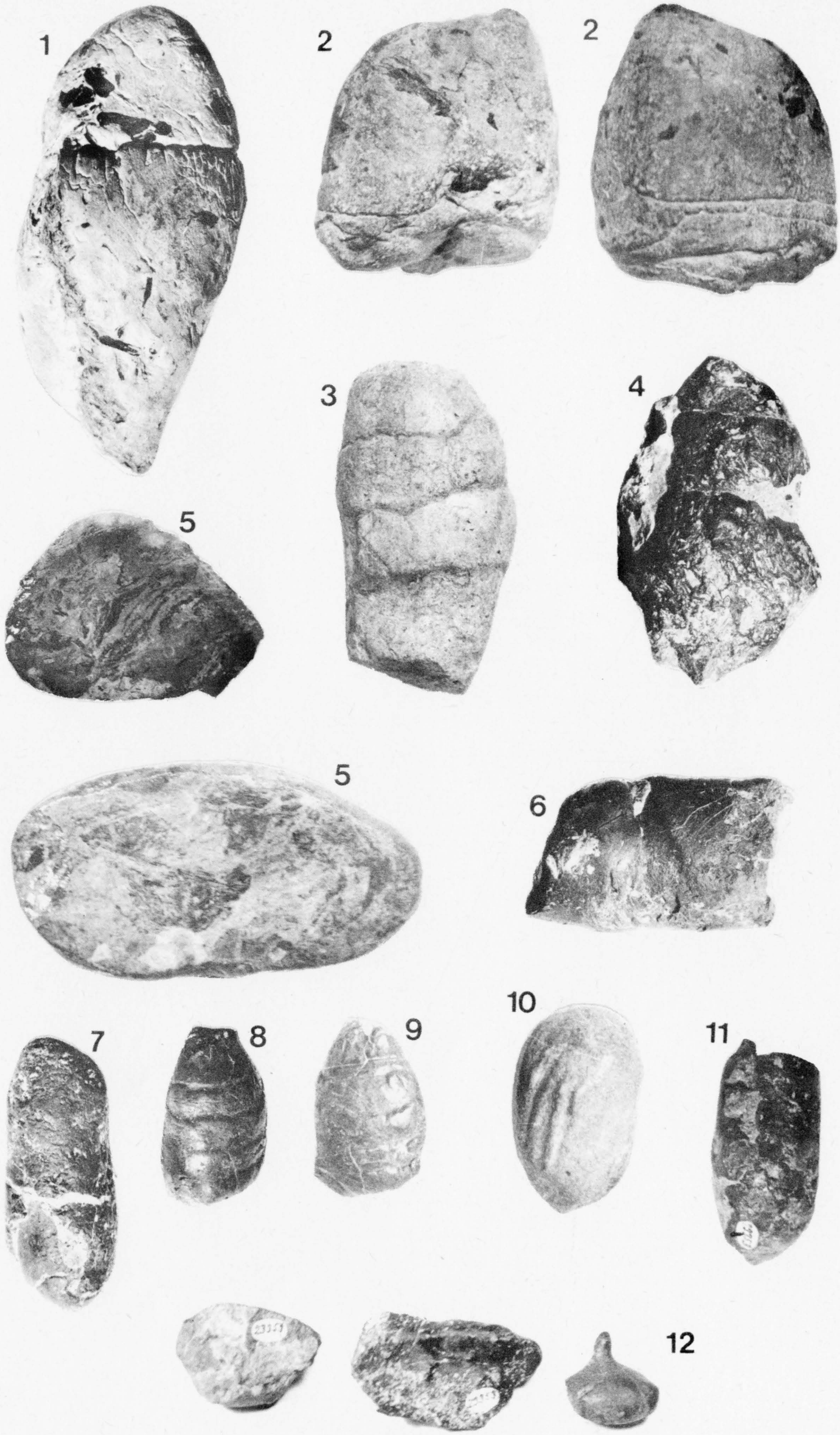
Fig. 5 Type 2 spiral coprolite in thin section (x 4). BCM Cb.4895. Aust.

Fig. 6 Type 4 coprolite in thin section (x 4). BCM Cb.4891. Aust.

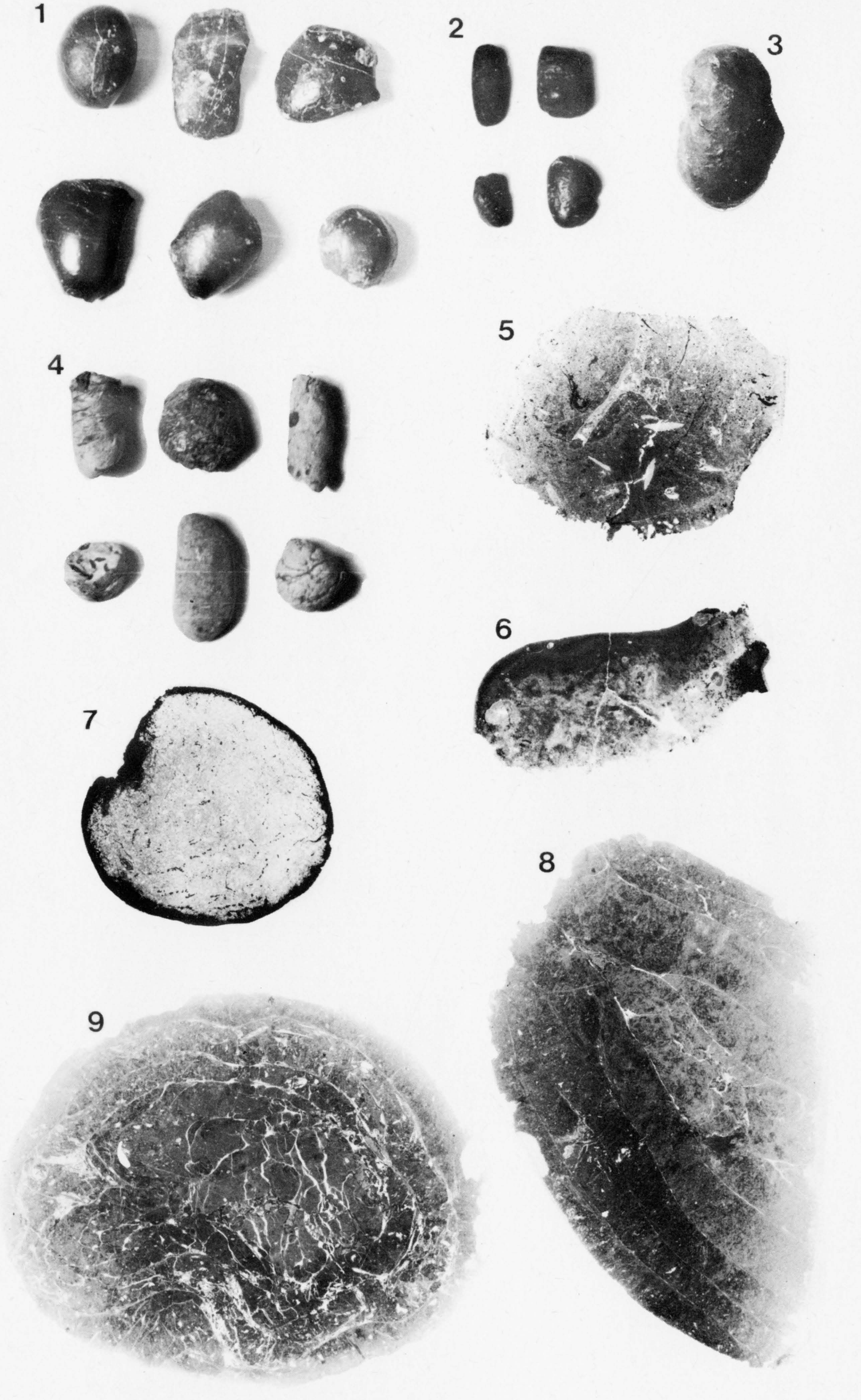
Fig. 7 Type 3 coprolite in thin section (x 4). BCM Cb.4894. Aust.

Fig. 8 Type 1 spiral coprolite in thin section (x $2\frac{1}{2}$). Nat. Mus. Wales, Lavernock. Longitudinal section.

Fig. 9 Type 1 spiral coprolite in thin section (x 2). Nat. Mus. Wales, Lavernock. Transverse section.



Duffin-Coprolites



Duffin-Coprolites

THE SURFACE TEXTURES OF QUARTZ GRAINS FROM A RHAETIAN BONE-BED, BLUE ANCHOR BAY, SOMERSET.

by

D.D.J. Antia and J.H. Sykes

Summary

The surface textures of detrital quartz grains in a Rhaetian bone-bed at Blue Anchor Bay, Somerset, have been investigated using a scanning electron microscope. The results show that there is a systematic change from the base to the top of the bed in the nature of the textures displayed by the quartz grains. Those from the basal clay-rich parts of the bed feature solution pits, while grains from the upper clay-poor parts of the bed display well developed euhedral overgrowths. The differences are attributed to *in-situ* diagenesis.

Introduction

Quartz grains in Rhaetian bone-beds are usually abraded and well rounded. They have been recorded from many localities, ranging across England and Wales, including Barnstone (Nottinghamshire), Barrow-upon Soar (Leicestershire), Westbury (Gloucestershire), Chilcompton (Somerset) and Lavernock (Glamorgan). Further examples including locality details have been presented by Sykes (1977). Rare bipyramidal quartz crystals have been recorded from Rhaetian bone-beds (Kent, 1970, p.365) at a number of localities including Barnstone (Duffin, 1978, pers. com.) and Blue Anchor Bay (Antia, 1979a, pl.18, fig.f). Such crystals arise as the result of quartz overgrowths around an original quartz nucleus. They have been recorded from a number of bone-beds including those of the Silurian in Britain (Antia & Whitaker, 1978, pp.121, 123-127; Antia, 1979a, pp.115, 169) and bone-beds in the Devonian of the U.S.A. (Wells, 1944, p.283).

In Silurian bone-beds (e.g. the Ludlow Bone-Bed) some of the euhedral crystals pre-date the formation of the deposit and bear surface abrasion features (Antia & Whitaker, 1978, pp.132, 133, 135, 136). Others have no abrasion features and nucleate around quartz grains, suggesting that they have grown in the bone-bed after its deposition. At the present time there are no adequate descriptions of euhedral quartz crystals from a Rhaetian bone-bed and consequently it is not known if they were reworked from a previous sediment or whether they have grown *in-situ* in the bone-bed. Reworked grains should be identified by their abraded surfaces.

Conversely, if the quartz euhedra were precipitated in the sediment after it was deposited, then a complete continuum ranging from original quartz grains and silica coated quartz nuclei through to perfect euhedral quartz crystals could be expected to occur, in which quartz euhedra increase in abundance towards the more porous base or top of the deposit. If, however, the relative abundances of the various diagenetic quartz morphotypes remain constant throughout the deposit then they could either have been derived from an older deposit (cf. Wilson, 1979) or have formed as diagenetic precipitates within the bone-bed. This study seeks to determine which of the explanations is most applicable to the quartz euhedra in the bone-bed under review.

Stratigraphy

Exposures of the Rhaetian beds at Blue Anchor Bay have been described by Richardson (1911, p.17) and also by Elliot (1953) and Macfayden (1970, p.225). Richardson recorded three bone-beds: 'Basal Bone-bed' (no. 33), 'The Clough' (no. 27) and 'The Bone-bed' (no. 15) near the top of the Westbury beds.

In a recent investigation into the nature of British Rhaetian bone-beds (Sykes, 1977), a large number of quartz crystals were noticed in part of the uppermost bone-bed (Richardson's bed 15) at Blue Anchor Bay (ST 042432). This bone-bed is 0.28 m thick and has been divided into five distinct parts (Table 1) (Sykes, 1977, p.231). Samples from parts 'a, c, d, & e' were disaggregated in acetic acid, washed and dried. The finer particles were removed by washing the grains in petroleum spirit and the coarser fraction (above 250 microns) separated by sieving. Several random samples were taken from each part and examined under a binocular microscope. The number of grains in each sample were counted in respect to their possession or lack of crystal faces also with regards to the amount of crystalline pyrite present. In each part of the bed averages of the relative contents were calculated over the various samples and the amounts expressed in percentages (table 2).

Scanning electron microscope (S.E.M.) analysis

Fifty quartz grains were randomly selected from each part of the bed listed in Table 2. These grains were then mounted on the S.E.M. stubs with either silver dug (parts d & e) or Pritt (parts a & c) and gold splatter coated to a thickness of 350 Å. The grains were then examined on a Cambridge 600 S.E.M.. After examination the grains were removed from the stubs and cleaned using first acetone and then hydrogen peroxide. The majority of the grains are now deposited with the Ludlow Museum; specimen nos. SHRCM G05501-4.

Most of the external surfaces of the quartz grains were covered by diagenetic overgrowths which appear to have been precipitated on more rounded quartz nuclei. Some of the grains are affected by silica solution which has removed the primary abrasive features and caused pitting. The exoscopic features of the grains are described as follows.

1. Primary crystal overgrowths, pl.23, figs.1,2 & 3

   Many of the quartz grains observed from parts 'd' and 'e' possess euhedral crystal faces. These vary in shape from compact grains to elongate, bipyramidal, euhedral crystals, some of which have prism faces. Some of the compact grains have crystal faces without a clear crystallographic orientation, while some of the more euhedral grains have prism faces which are poorly defined or are smothered by bulbous overgrowth.

   The quartz grains show three stages of diagenetic overgrowth around an original, compact spheroidal quartz grain (text-fig. 1, fig.A).

   a Silica sheet layering on the external surface of the grain (pl. 23, fig.7, text-fig.1, fig.B). These sheets are in optical continuity with the host quartz grain.

   b Polarisation of quartz growth to produce a c-axis aligned along the quartz grain and to allow development of pyramidal crystal faces at either end of the grain (pl. 23, fig.3, text-fig.1, fig.C).

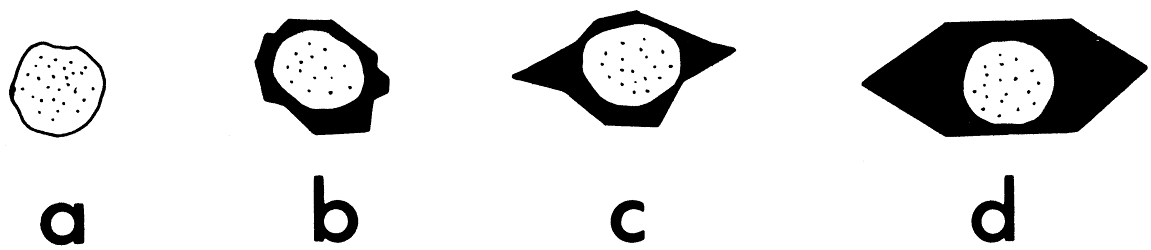
   c Enlargement of the pyramidal faces until the pyramid diameter equals or exceeds the grain diameter. This is followed by development and growth of the prism faces (text-fig.1, fig.D).

Table 1. Description of bone-bed, parts 'a' to 'e'

Part	Thickness	Description
e	up to 120 mm	A massive, calcareous sandstone, enriched in vertebrate remains.
d	50 mm	A calcareous sandstone, enriched in vertebrate remains and containing thin layers of black shale limestone.
c	70 mm	Alternating layers of black shales and sandstones with vertebrate remains.
b	up to 30 mm	A layer of 'beef' calcite ($CaCo_3$).
a	18 mm	A calcareous, sandy bone-bed containing shell and silt laminae.

Table 2. Distribution of crystalline pyrite and quartz crystal faces in the coarse fraction of the bone-bed

Part	Without crystal faces	With crystal faces	Crystalline pyrite
e	23%	74%	3%
d	33%	62%	5%
c	73%	19%	8%
a	94%	0%	6%



Text-fig. 1. Deduced stages in the development of quartz euhedra

Fig. a. Original quartz grain (shape unknown).

Fig. b. Quartz grain coated with silica sheets producing crystal faces on the grain's surface (most common in parts 'a' and 'c').

Fig. c. Polarisation of crystal growth and the development of crystal faces (most common in parts 'd' and 'e').

Fig. d. Development of prism faces connecting the pyramid faces (most common in parts 'd' and 'e').

2. Secondary crystal overgrowths (pl.23, figs.6 & 8)

On one quartz grain from part 'e', a small euhedral crystal growth was observed encrusting a primary overgrowth crystal face (pl. 23, fig.8). On another grain from the same part of the bed a more complex pattern of secondary crystal overgrowth was observed (pl.23, fig.6). On some grains the growth of silica sheets appears to post-date the development of euhedral crystal faces within the bone-bed (pl.23, figs.4,7 & 9).

3. Diagenetic solution (pl.23, fig.5)

Silica solution features are present throughout the bone-bed though they are most pronounced at its base, in part 'a'. A thin section of this part (Sykes, 1977, pl.16, fig.5) shows that most of the silica solution features appear to be related to the growth of the calcite matrix during 'late' diagenesis.

Typical examples of pitting due to silica solution within the bone-bed are illustrated in pl.23, fig.5.

Discussion

The association of pyrite, apatite and black shale has been noted in bone-beds throughout the geological record and may indicate the presence of high negative Eh (-200 to -300) and a pH of 6 to 8 in the sediment pore waters during diagenesis (Baturin, 1971, p.61; Burnett, 1977, p.820-821; Antia, 1979a, pp.107, 124). If this sediment was also undersaturated with respect to Ca^{2+} and CO_3^{2-} ions, then diagenetic gypsum and/or quartz may have precipitated within the sediment (Burnett, 1977, p.821; Briskin and Schreiber, 1978, pp.47-48; Antia, 1979b, p.M1, M3).

Observations (Sykes, 1977, p.232) show that the mean grain size of the sand fraction of the bone-bed increases upwards. This trend, coupled with a decrease in its clay and limestone content towards its top (Sykes, 1977, p.231), shows that the initial post-depositional porosity of the bone-bed also probably increased towards its top. The increase in porosity coincides with a change in quartz grain shape (Table 2) and a decrease in the incidence of solution features.

A possible explanation is that silica was removed from some of the quartz grains and clay minerals in the bone-bed by upward percolating pore waters and concentrated in the upper porous layers of the bone-bed beneath the overlying impervious clays. In this context it is interesting to note that clay minerals may actually enhance solutions of quartz (see Blatt, Middleton & Murray, 1972; Pettijohn *et al.*, 1972) and that the presence of a clay mineral matrix will inhibit growth of cement. The pore water solutions may then have become supersaturated with respect to silica and precipitated as silica sheets in the lower porosity layers of the bone-bed (parts 'a' and 'c') and quartz crystals in the higher porosity layers (parts 'd' and 'e'). Silica may also have been derived from the impermeable clays overlying and underlying the bone-bed.

Elsewhere in the geological column similar relationships appear to occur between porosity and quartz crystal growth. For example, the Ludlow Bone-Bed at Netherton (King & Lewis, 1912) grades upwards from vertebrate rich clays to a vertebrate sand (Antia, 1979b). These vertebrate sands had a higher initial porosity than the vertebrate rich clays and the contain diagenetic, euhedral, quartz crystals. Such crystals are not present in the lower porosity clays.

Conclusions

The quartz grains in a Rhaetian bone-bed at Blue Anchor Bay, Somerset, have diagenetic quartz overgrowths. These overgrowths are restricted to silica sheets in the lower porosity, vertebrate rich clays and limestones but form euhedral crystal overgrowths in the higher porosity, vertebrate rich quartz sands of the upper layers of the bone-bed.

Acknowledgements

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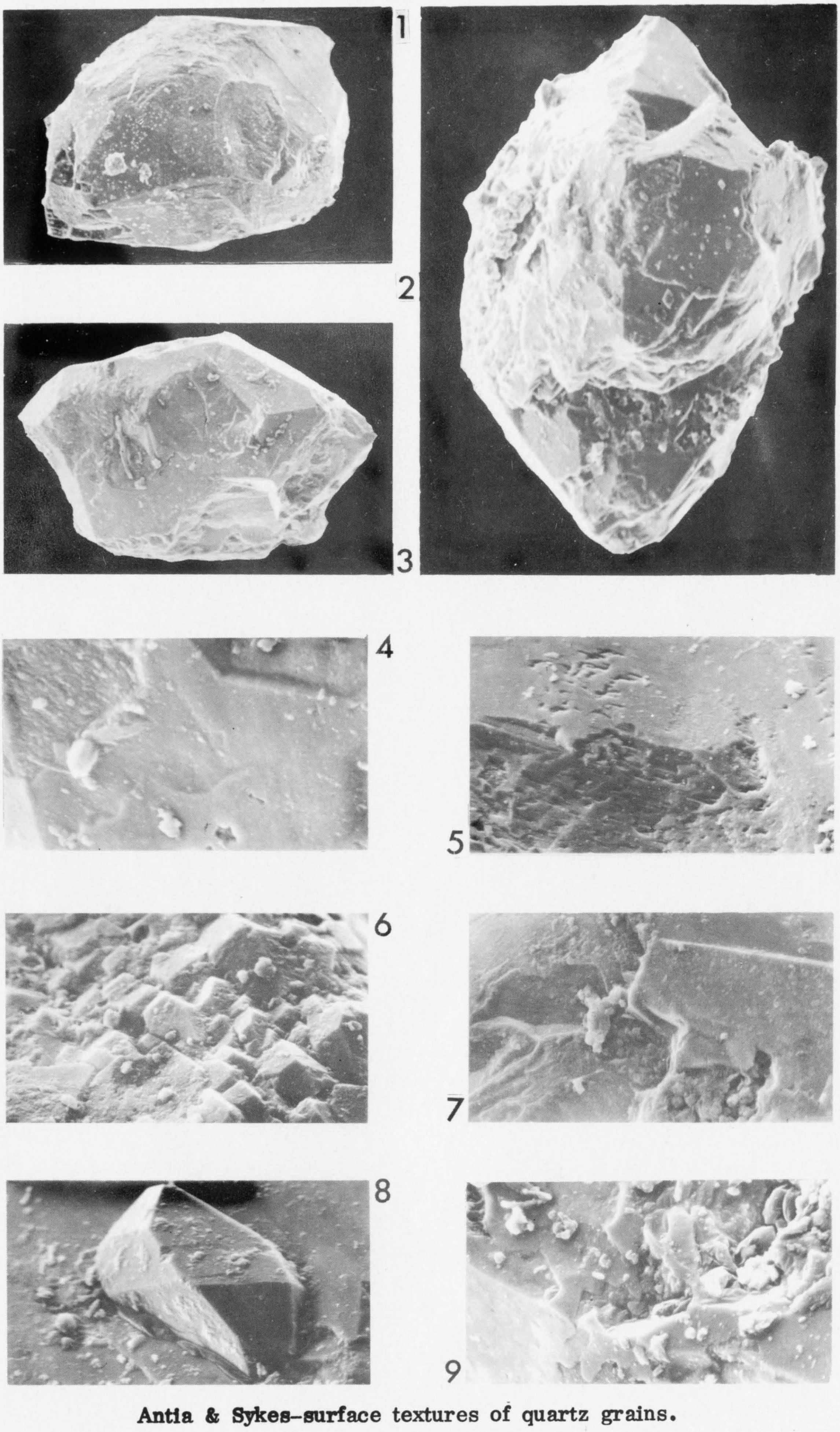
Explanation for Plate 23

1 - 9 Quartz grains and surfaces from a Rhaetian Bone-Bed at Blue Anchor Bay

1. Angular, compact, high sphericity grain (x 150).
2. Modified, compact grain, showing the development of crystal faces (x 80).
3. Compact grain completely enclosed within a quartz overgrowth (x 80).
4. Silica sheeted surface (x 600).
5. Silica surface showing solution pits (x 600).
6. Quartz overgrowth on a grain (x 500).
7. Silica sheeting on a grain surface (x 600).
8. Quartz overgrowth on a grain surface (x 1000).
9. Silica sheeting on a grain surface - note the various angles of the sheet faces (x 700).



Antia & Sykes–surface textures of quartz grains.

INVESTIGATING THE AGE OF A PENNINE LANDSLIP

by

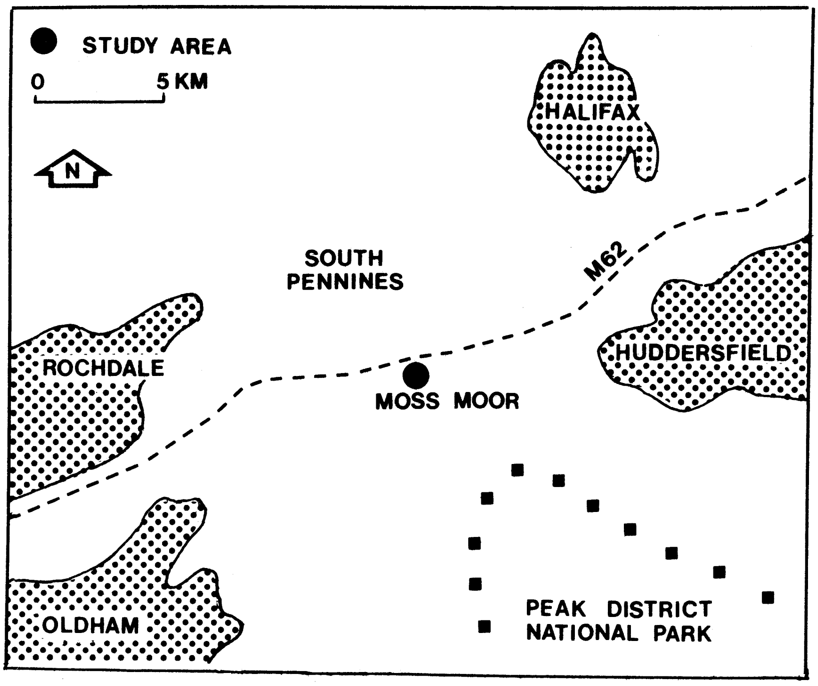
Roderick Muller

Introduction

Slope instability has produced both ancient and recent landslips of considerable areal extent within the Pennines. In studying slips of substantial age the time of occurrence has largely been a matter of inference. Until the advent of pollen analysis there were few methods by which these processes of past millenia could be dated with reasonable accuracy. The problem concerning the age of landslips cannot be severed from the causes generating them and for this reason some questions pertinent to the factors of displacement are considered in this study of a landslip at Buckstones Moss, West Yorkshire.

"The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands
Like clouds they shape themselves and go."

Lord Tennyson



Text-fig.1. Location of Moss Moor.

Buckstones Moss (SE 005139) is an isolated upland region and a constituent part of Moss Moor, text-fig. 1, situated 16 km due west of Huddersfield. The area of landslipping (SE 014143) is unnamed and for the sake of convenience is termed the Buckstones Landslip. Buckstones Moss attains a height of 473 m and comprises an escarpment with a dip 9° to the NNW. The gentle arching of the Pennines with its many minor anticlines and synclines has given rise to a complex series of cuestas often referred to as "edges". Here the edge is formed by the massive Midgley Grit and the dip-slope has been dissected by the headwaters

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1979, pp.211-218, 3 text-figs.

of the River Ryburn, a tributary to the River Calder. The result of this erosion has been the production of a large cuesta stretching in a shallow, concave arc for 3.2 km along the northern margin of the moss, and backed by the gritstone erosion-scarp of Moss Moor. Generally speaking, this Moor rests on the softer shales, mudstones, flags and fireclays of the Millstone Grit Group (Upper Carboniferous), while the scarp is of a more massive nature (Wray *et al.*, 1953). The slipped mass extends along the cuesta for almost 1 km., but only the westernmost sector is described in this paper.

The peripheral upland areas, which were never glaciated throughout the Würm/Weichsel stage (Raistrick 1933, 1934), reveal but few exposures of the underlying solid geology except were stream courses have become deeply entrenched. Invariably there is a considerable development of rotted and kaolinised grit debris, and isolated pillars or collections of weathered grit are characteristic of the moors as first noted by Hull (1869). The frequency of their occurrence is in itself confirmatory evidence of the unglaciated nature of these moorlands, and detached blocks have been transported by subsequent landslips and solifluction movements (Bairstow 1902). Interestingly, it was near Buckstones Moss that Hull incorrectly interpreted the fragmented blocks as erratics. This litter of grit is clearly reflected in such a place name as "Buck-stones" perceptively noted by Crossland (1902).

Existent relationships between landslips, free-faces, tors, shattered blocks, and solifluction deposits emphasise the probability that such features within the Pennines may be a by-product of a much larger scheme of slope evolution before the present climatic regime (Bass 1954, 1956; Loundsbury 1963; Linton 1964). Landslips are frequent wherever a prominent scarp of grit overlies a thick mass of shale, and the possibility that some of them were formed either in Pleistocene times or during a succeeding phase gave genesis to this investigation.

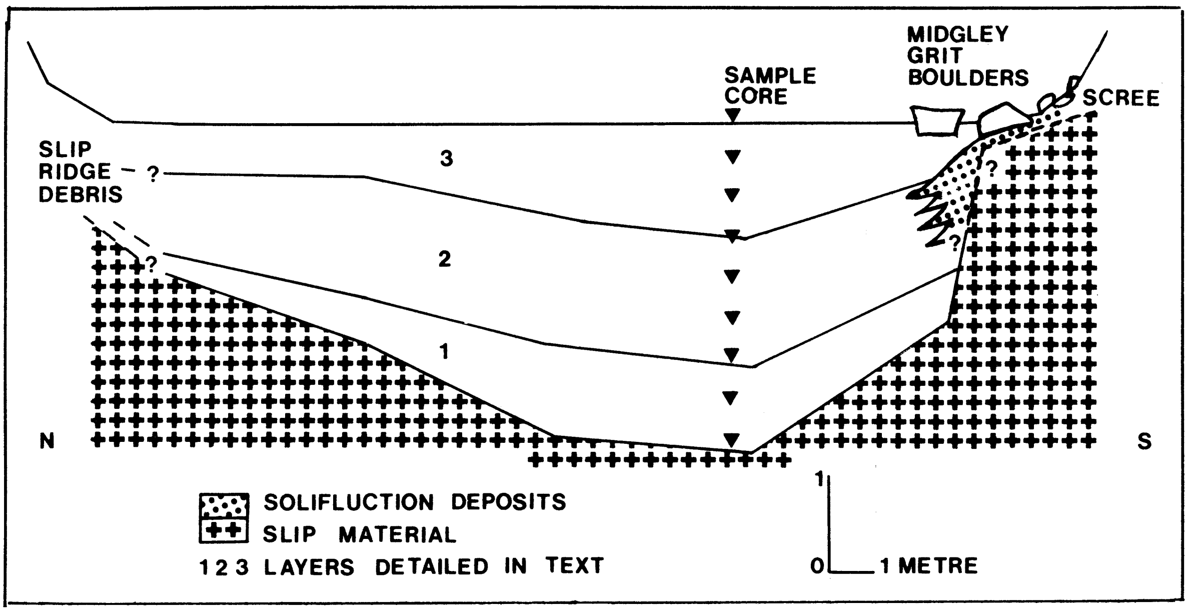
Only brief reports have appeared regarding the age of ancient landslips, and few special researches employing the techniques of pollen analysis have been devoted to this problem (Morariu 1964; Franks and Johnson 1964; Johnson 1965).

Pollen grains may be identified significantly from the Jurassic System onward, but their value is more spectacular when establishing environments and relative dates for the Quaternary. Pollen analysis (palynology) is based on the principle that wind pollinated vegetation produces pollen in considerable quantities, and that the annual pollen 'rain' is added to the accumulation of stratified sediments especially in bogs and lake beds. Pollen is robust and, if the sediments are poorly aerated or acidic, may be preserved quite well. Shape is diagnostic of the species which produced it, and the laminae of sediments thus hold a chronological and environmental record for a region. The retrieval of samples must be done without contamination and a careful record made of levels. Chemical treatment of each sample is undertaken in the laboratory to rid it of extraneous material. Identification and counting of pollen grains for each level leads to the construction of a pollen diagram which can be subdivided according to acknowledged pollen zones. The late and post-glacial periods of the Quaternary have been divided into 8 major zones, and using radioactive methods now have absolute dates. An insight into climate, vegetation, prehistoric settlement, environment and processes is thus provided. Pollen analyses are published in numerous books and journals, but a wider description of principles and applications may be had by referring to Davis (1963), Faegri and Iversen (1964), Crabtree (1968), and Pennington (1969).

As far as the Buckstones Landslip is concerned, some minor rockfalls, due to physical weathering, occur along the main scarp of Moss Moor Edge, but there is no evidence to suggest the recent splitting-off of massive debris from the scarp. Apart from the gritstone scarp, the whole area of slipping is completely covered by moorland vegetation, and the undulating topography of the landslip rubble has been superimposed by a drainage system of intermittent peat-moor streams. Furthermore, auger probes on some of the slip ridges encountered a stiff clay material to 14 cm in depth and this, together with the related features, indicates the passage of considerable time. Thus, a recent historical age is out of the question for it becomes immediately apparent in the field that, morphologically, the landslip is not a recent feature.

Along the whole interior section of the slip, and that part nearest the scarp face, are to be found both large and small depressions. Within the larger depressions correspondingly large and small hollows can be located which have, since the time of movement, been infilled with water and a miscellany of material. A suitable site for the collection of pollen samples was found near the western end of the slipped material.

The site is an oval-shaped basin with a level, vegetated floor of *Eriophorum* sp., *Juncus* sp., and *Empetrum* sp., and bordered on its periphery (and therefore completely isolated from subsequent drainage erosion) by ridges of slipped material from the abutting middle scarps to the south. The floor of the depression measures 50 m x 15 m. Towards the eastern section there exists an all-season pond with the dimensions of 13 m x 8 m and a depth of at least 3 m. Due to a vigorous hydrosere the pond is now diminishing in size. Within the depression there is evidence of the progressive stages of infill to the aquatic environment and thus, at an earlier stage in the evolution of the basin, the pond would have extended over a far greater area. A transect was taken across the depression and the data obtained from 7 probes provided the information for text-fig. 2.



Text-fig.2. The Landslip Depression.

From this illustration it will be seen that throughout the history of its infilling the basin has become markedly stratified, except against the precipitous southern slopes where what appears to be downwash from the scarp slopes together with rockfall boulders of Midgley Grit interrupt the succession to a slight degree. Deposits for pollen analysis were taken from a Hiller (sampler) boring 85 cm from the transect, and an identical succession to the other transects was obtained at this point. The greatest depth was in fact met by the auger at this boring where an impenetrable substratum was reached at 335 cm.

Obviously the period between the occurrence of the Buckstones Landslip and the initiation of the pond and *Sphagnum*-*Eriophorum* spp. marsh within the depression represents a somewhat variable element and one which could reflect in the dating. Nevertheless, a pollen analysis of the deposit within this hollow might offer a more absolute age to the landslip since it is clear that the depression itself could only have been produced *after* the slip movement and, consequently, an *upper date* for the displacement can be obtained. Since an upper date to the landslip was the objective the basal sediments were of prime interest and, once a depth of 300 cm had been exceeded, Hiller samples were taken every 5 cm.

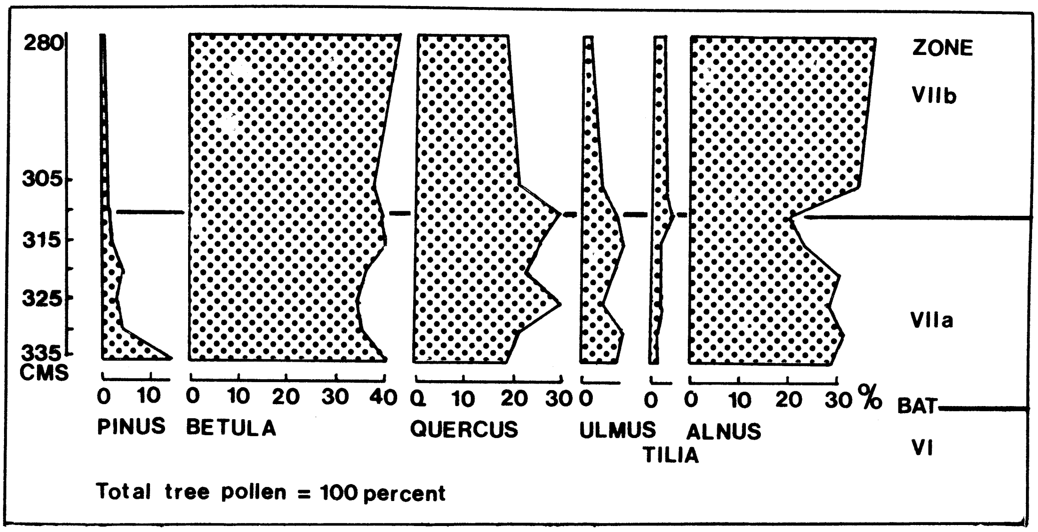
The succession at the site, although showing variations in stratification over short vertical distances, can be subdivided into three main stratified layers, (table 1), but it is the basal layer which is, in the context of this report, of most importance. This layer consists of an amorphous and highly humified dark-brown peat with some occasional *Sphagnum*, overlying a coarse or gritty sandstone.

Table 1 - Succession of deposits at the Buckstones Site

Depth (cm)	Description	Layer
000-103	Alternating layers of highly humified and fairly humified *Eriophorum* peat with abundant *Sphagnum*	3
103-123	Fairly humified *Sphagnum* peat with abundant *Eriophorum* rootlets	
123-182	Less humified peat with less *Eriophorum*	
182-229	*Sphagnum* peat not highly humified	2
229-252	Fresh *Sphagnum* peat	
252-335	Amorphous highly humified peat	1
335- ?	Mineral substratum	

One should consider at this point that a time-lag in deposition would have been present, although in terms of the pollen diagram and dating attempt this would probably be very small. A time-lag in deposition could have been caused by the existence of the local acidic rocks, for an abundance of $H+$ ions would ensure acidic water within the depression so that only siliceous micro-organisms and acid-tolerant plants would have thrived at the onset. Thus the basin, with no base-seeking plants such as sedges and some weeds, would have seen only slow accumulation. One may broadly conclude that this is an *Eriophorum–Sphagnum* bog since the mass of peat has been produced by an abundance, if not dominance, of such vegetation. The lowermost layers of the peat were not dominated in such a manner, thus according with the widespread observation that bog *Sphagnum* and *Eriophorum* do not grow directly on a mineral base.

Since the prime interest of the investigation was to obtain an upper age for the onset of deposition, and thus an upper age for the landslip, the methods used were far from the refined techniques employed in specialist pollen analysis. It was hoped that an answer to the main problem could be achieved by using the simplest methods on a number of samples. No attempts have been made to discuss the results in relation to the general forest history of the region or the vegetational colonization of displaced rubble. The arboreal pollen curves are shown in text-fig. 3 and provide a framework to which we may attach our conclusions as to the phases of local ecology, since tree data alone can form a link in the general sequence of events in post-glacial time. These events are further expressed in pollen zonation schemes as outlined by table 2.



Text-fig.3. Pollen frequencies.

Table 2. Post-glacial climatic periods

Climate		Zone	Period	Date (B.C.)
Cool and wet	Oceanic	VIII	Sub-Atlantic	
				c. 500
Warm and dry	Continental	VIIb	Sub-Boreal	
				c.3000
Warm and wet	Oceanic	VIIa	Atlantic	
				c.5500
Warmer than before and dry		VI, V	Boreal	
				c.7600
Sub-Arctic		IV	Pre-Boreal	
				c.8300
	Late Glacial	III	Younger Dryas	

(Sources: Godwin 1956; Pennington 1969) (Radiocarbon dates)

With reference to text-fig. 3, certain points can be noted concerning the tree pollen curves. *Pinus* (pine) shows a fall from possibly high Boreal values to a more or less steady and low level around 3% through zone VIIa. *Betula* (birch) shows its characteristic reversion to higher values beginning above the transition zone with maximum values around 35% appearing quite consistently from the Boreal-Atlantic Transition through to zone VIIb. *Quercus* (oak) shows a rise from this supposed Boreal-Atlantic Transition with two peaks: one of which occurs in mid-zone VIIa; the other at the transition with zone VIIb. A familiar decrease towards the upper part of the diagram is noticeable. *Ulmus* (elm) has low values and never exceeds 8%. The "elm decline" which marks the boundary between VIIa and VIIb is clearly discernible. *Tilia* (lime) is recorded low down in the succession and may indicate that the Boreal-Atlantic Transition has not quite been fully reached. A gradual increase to a maximum around the "elm decline" is evident. *Alnus* (alder) reaches a characteristic maximum following the elm horizon. Changes are apparent around the Boreal-Atlantic Transition (B.A.T.) and at the elm horizon, but the time-scale is much compressed and fluctuations in the pollen curves should be regarded as slow swings.

If we accept that the landslip took place after the Boreal-Atlantic Transition then it is possible to suggest that the displacement took place somewhere around 5500 BC. Although radiocarbon dates have eroded some confidence in the age of this transition, students of Holocene history generally take the boundary between the Boreal and Atlantic periods as *circa* 5500 BC. Bearing in mind the delay in deposition, and the short basal hiatus caused by acidic rocks, it is reasonable to assume a similar date for the Buckstones Landslip.

The zonation scheme used herein is based on the traditional "Blytt-Sernander boundaries' as applied in some form by most palynologists. Analysis of the Buckstones site is thus based on well established documentation of vegetational change and boundary criteria for this latitude and altitude. Recent work with 14C has generated problems in assigning 'traditional' dates to boundaries. There now exists sufficient evidence to show some discrepancies between published dates and 14C measurements. The provision of a reliable calibration curve for 14C together with research into regional, topographic, climatic and edaphic influences on vegetational change are still being undertaken. Consequently, all the dates recorded in this paper are interim suggestions based on published palaeoecological evidence. For a discussion of these and related problem see: Smith & Pilcher (1973).

Post-glacial variations in climate raise several interesting points: The role played by water in the mechanics of landslips has already been noted (Sharpe 1938; Terzaghi 1950; Gifford 1952; Young 1972), but it is rather intriguing to realise that during the very termination of the Boreal Period, and throughout the Atlantic Period, climate became markedly maritime. Indeed, various workers have noted the marked climatic shift at this point in time caused by the continuing eustatic rise in ocean levels and the creation of both the North Sea and Baltic Sea (Willett 1950; Godwin *et al.* 1958; Zeuner 1958; Manley 1959; Lamb 1966). This more oceanic clime, coupled with a suggested more southerly track of depressions, would have provided an increase to precipitation amounts and triggered a general rise in ground-water levels. Conway (1954) has shown how, in the Pennines, this increase in both rainfall and ground-water allowed the expansion of 'blanket' peats at the expense of established wet alder and birch woods. Perhaps this increase in available water is the very ingredient we are looking for as a major participatory factor in slope failure at Buckstones around 5500 BC.

The relationships between significant processes and prevailing climate are discussed in length by Stoddart (1969). It could be an interesting exercise to perform pollen analyses upon many more Pennine landslips because if the conditions for displacement seem to be of a similar nature can there be any reason for not suggesting a peak of slip activity on the post-glacial time-scale? This proposition could be most attractive, particularly when one visits and considers the morphological characteristics of the numerous and ancient Pennine slips. Unfortunately the idea of any further analyses is beyond the scope of this study, but if reference is made to palynological investigation of a landslip in Derbyshire a highly interesting correlation is found (Franks & Johnson 1964; Johnson 1965). It has been shown of the Charlesworth Landslip (SK 015915) that it has very similar features to that of Buckstones, and the onset of deposition within a slip-zone depression has been dated at 5200 BC. This is a close date to that of 5500 BC for Buckstones. Dare we, from only two approximations, infer a peak of Pennine landslipping? The answer, however tempting, remains to be established.

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DINOCYSTS FROM THE UPPER KIMMERIDGIAN (*PECTINATUS* ZONE) OF MARTON, YORKSHIRE

by

Leslie A. Riley

Summary

Two dinocyst assemblages (comprising 32 species) are reported from the Upper Kimmeridgian (*pectinatus* Zone) of Marton, Vale of Pickering, Yorkshire. The assemblages, which constitute the first published record of Kimmeridgian dinocysts from northern England, are similar to those reported by Riley (1974) from the type *pectinatus* Zone of southern England. Allocation to the *Pareodinia mutabilis* (dinocyst) Zone of Fisher & Riley (1979) is indicated. The new combinations *Egmontodinium ovatum* (Gitmez & Sarjeant), *Kleithriasphaeridium telaspinosum* (Riley) and *Lithodinia areneosa* (Muir & Sarjeant) are proposed. *Fromea warlinghamensis* Gitmez & Sarjeant is treated as a junior synonym of *F. amphora* Cookson & Eisenack and existing Kimmeridgian records of *Cyclonephelium distinctum* Deflandre & Cookson and *Oligosphaeridium pulcherrimum* (Deflandre & Cookson) Davey & Williams are considered to be doubtful.

Introduction

During the course of a larger study on Upper Jurassic microplankton, two samples were collected from the Kimmeridge Clay of Yorkshire by Dr. R.C.L. Wilson (Dept. of Earth Sciences, Open University) and made available to the present author for palynological analysis. The samples were obtained from a brickpit, referred to as the Golden Hill Pit, by Cope (1974), lying approximately 0.5 km to the southwest of the village of Marton (Grid. Ref. SE 725828), in the Vale of Pickering. The two samples were collected from Beds 16 and 17 (Cope, 1974), and are assigned to the *pectinatus* Zone of the Upper Kimmeridgian.

Assemblage details

After standard palynological preparation, the two samples yielded organic residues composed of abundant amorphous organic matter in association with large quantities of exinite, the bulk of which is in the form of dinocysts. The dinocyst assemblages are moderately well preserved, although certain forms exhibit signs of diagenetic degradation. Evidence for the latter is clearly indicated by distortion and rupture due to contained framboidal pyrite. Associated structured palynomorphs include moderate numbers of miospores (chiefly of gymnospermous affinities) and microforaminiferal test-linings in association with rare acanthomorph acritarchs and *Pterospermopsis aureolata* Cookson & Eisenack. Small amounts of terrestrially derived humic materials are also present.

The two dinocyst assemblages are so similar in composition as to constitute one dinocyst association. With the exception of fairly numerous, but indeterminate specimens attributed to the genera *Gonyaulacysta Cribroperidinium* and, to a lesser extent, *Cleistosphaeridium*, the dinocysts recovered are represented by the following species:

Apteodinium granulatum Eisenack 1958
Cassiculosphaeridia magna Davey 1974
Chlamydophorella cf. *discreta* Clarke & Verdier 1967
Chytroeisphaeridia chytroeides (Sarjeant 1962) Downie & Sarjeant (1964) 1965 emend. Davey 1979b
Cyclonephelium hystrix (Eisenack 1958) Sarjeant & Stover 1978
Dingodinium albertii Sarjeant 1966

Mercian Geol. Vol. 7, No. 3, 1979, pp. 219-222

Egmontodinium ovatum (Gitmez & Sarjeant 1972) comb. nov.
E. polyplacophorum Gitmez & Sarjeant 1972
Epiplosphaera reticulospinosa Klement 1960
Fromea amphora Cookson & Eisenack 1958
Glossodinium dimorphum Ioannides *et al.* 1976
Gonyaulacysta cladophora (Deflandre 1938) Dodekova 1967
G. deflandrei Riley 1979
G. jurassica (Deflandre 1938) Norris & Sarjeant 1965
G. longicornis (Downie 1957) Sarjeant 1969
G. nuciformis (Deflandre 1938) Sarjeant 1968
G. perforans (Cookson & Eisenack 1958) Sarjeant 1969
G. setcheyensis Sarjeant 1976
Hystrichodinium pulchrum Deflandre 1935
Kleithriasphaeridium telaspinosum (Riley 1979) comb. nov.
Leptodinium arcuatum Klement 1960
Lithodinia sp.
Oligosphaeridium pulcherrimum (Deflandre & Cookson 1955) Davey & Williams 1966 *sensu* Ioannides *et al.* 1976
Pareodinia ceratophora Deflandre 1947 emend. Gocht 1970
P. mutabilis Riley 1979 (= *Imbatodinium* cf. *villosum* of Gitmez & Sarjeant 1972
Psaligonyaulax cypraea Ioannides *et al.* 1976
Prolixosphaeridium granulosum (Deflandre 1937) Davey *et al.* 1966
Scriniodinium inritibilum Riley 1979 (= *Scriniodinium* sp. A. Ioannides *et al.* 1976)
Senoniasphaera jurassica (Gitmez & Sarjeant 1972) Lentin & Williams 1976
Sentusidinium echinatum (Gitmez & Sarjeant 1972) Sarjeant & Stover 1978
Systematophora areolata Klement 1960
S. orbifera Klement 1960

Stratigraphical discussion

Comparable, and in many instances, almost identical dinocyst assemblages, have previously been reported from the type *pectinatus* Zone of southern England, the Argiles de Wimereux (Upper Kimmeridgian) of northern France (Riley 1974), the Kimmeridge Clay Formation (*pars*) and its lateral lithological equivalents of the North Sea Basin (Fisher & Riley 1979) and the upper part of the Helmsdale Boulder Beds succession in northeast Scotland (Riley, unpubl. reports).

Of particular stratigraphical significance is the presence in the Marton assemblages of *Egmontodinium ovatum*, *E. polyplacophorum*, *Gonyaulacysta deflandrei*, *G. longicornis*, *Kleithriasphaeridium telaspinosum*, *Oligosphaeridium pulcherrimum* sensu Ioannides *et al.* and *Pareodinia mutabilis* - a dinocyst association which clearly indicates an age within the limits of the *Pareodinia mutabilis* (dinocyst) Zone of Fisher & Riley (1979). The additional record of *Gonyaulacysta jurassica* would restrict this further to that of the *Gonyaulacysta jurassica* Subzone age; a dinocyst subzone which is considered by Fisher & Riley (1979) to be essentially of *pectinatus* (ammonite) Zone age.

The occurrence of *G. jurassica* at this stratigraphical level is of particular interest and is considered by certain palynologists to be the result of reworking. Davey (pers. comm.) considers *G. jurassica* to range no younger than Lower Kimmeridgian, whereas Brideaux (1977) considers the upper limit of the species to be either Lower, or basal Middle Kimmeridgian. Gitmez & Sarjeant (1972) and the present author (1974 and herein) have, however, recorded *G. jurassica* (albeit in very low numbers) from Middle and Upper Kimmeridgian sediments, whilst Brideaux & Fisher (1976) report the species as rare from the Middle and Upper Kimmeridgian of the northern Canadian mainland. In addition, occasional records of the species have been reported by the present author (unpubl. reports) from the Upper Kimmeridgian of northeast Scotland and the Central Graben area of the

North Sea Basin. Reworking cannot adequately explain all of these post-Lower Kimmeridgian records of *G. jurassica* and, although Brideaux's (1977) comment that the species only rarely occurs above the *autissiodorensis* Zone is accepted, it is maintained that the upper limit of the range of the species is within the *pectinatus* Zone of the Upper Kimmeridgian.

Taxonomic discussion

Kimmeridgian records (Riley 1974, Ioannides *et al.*, 1976) of *Cyclonephelium distinctum* Deflandre & Cookson 1955 are considered to be of doubtful attribution and, on morphological criteria, allocation to *C. hystrix* (Eisenack 1958) Sarjeant & Stover 1978 seems more probable.

The genus *Egmontodinium* Gitmez & Sarjeant 1972 is to date represented by three species - *E. polyplacophorum* Gitmez & Sarjeant 1972, *E. torynum* (Cookson & Eisenack 1960) Davey 1979 and *E.* sp. A Davey 1979. A fourth species is considered to conform with the diagnosis of the genus and the following taxonomic combination is proposed:

Egmontodinium ovatum (Gitmez & Sarjeant) comb. nov. = *Systematophora ovata* Gitmez & Sarjeant 1972, p.237, pl.14, figs.1-3. Kimmeridgian.

Fromea warlinghamensis Gitmez & Sarjeant 1972 is treated herein as a junior synonym of *F. amphora* Cookson & Eisenack, 1958.

The species ?*Hystrichodinium telaspinosum* Riley 1979 is now considered to represent an ancestral Jurassic species of the genus *Kleithriasphaeridium* Davey 1974 and the following taxonomic combination is proposed:

Kleithriasphaeridium telaspinosum (Riley) comb. nov. = ?*Hystrichodinium telaspinosum* Riley 1979 (in press). Upper Kimmeridgian/Middle Volgian.

The genus *Meiourogonyaulax* Sarjeant 1966 is considered by Gocht (1975) to be a junior synonym of *Lithodinia* Eisenack 1936 emend. Gocht 1975. This is endorsed by the present writer and the following taxonomic combination is proposed:

Lithodinia areneosa (Muir & Sarjeant) comb. nov. = *Meiourogonyaulax areneosa* Muir & Sarjeant 1978, p.197-198, pl.1, fig.1; text-fig.1. Callovian.

The dinocyst cited herein as *Lithodinia* sp. is conspecific with *Meiourogonyaulax* sp. Gitmez & Sarjeant 1972.

The Kimmeridgian specimens described and illustrated by Ioannides *et al.* (1976) as *Oligosphaeridium pulcherrimum* (Deflandre & Cookson 1955) Davey & Williams 1966 are considered to have been wrongly assigned to a post-Jurassic species. They are significantly different in morphological detail from the Australian type material of *O. pulcherrimum* and almost certainly represent a new species. Similarly, the specimen attributed to *O. pulcherrimum* by Gitmez (1970) may well be conspecific with the species illustrated by Ioannides *et al.* (1976) and reported herein.

Senoniasphaera jurassica (Gitmez & Sarjeant 1972) Lentin & Williams 1976 may be a junior synonym of *Lithodinia staffinensis* (Gitmez 1970) Lentin & Williams 1977 and a re-study of the type material of these species is accordingly needed.

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EXCURSION REPORT

QUATERNARY TERRACE SEDIMENTS OF THE MIDDLE TRENT BASIN

Leaders: P.F. Jones, C. Salisbury
J.F. Fox, W.A. Cummins

Sunday, 10th July 1977

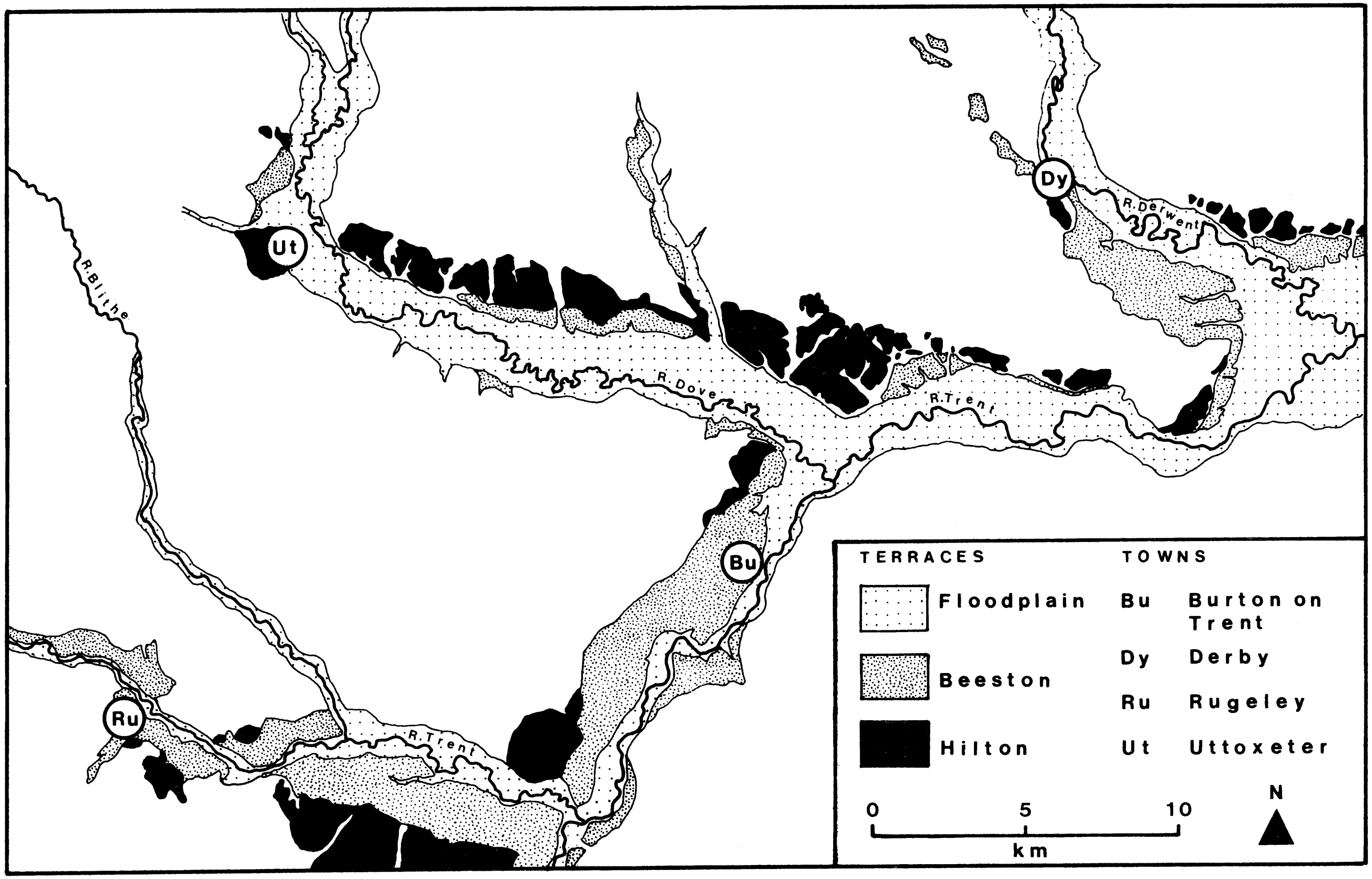
Introduction

The River Trent is a principal river of the English Midlands. It transects the Triassic lowlands of southern Derbyshire and Nottinghamshire in a wide valley flanked by terraces. The terraces comprise discountinuous patches of sand and gravel with relatively level surfaces. They form prominent morphological features at heights of up to 90 ft above the modern floodplain. Following the work of Clayton (1953) three major terraces are generally recognised, text-fig.1, although some of these are locally composite. Traditionally the terraces have been interpreted as representing the remnants of former floodplains which were left behind when the river was forced to cut down to a new level following successive episodes of rejuvenation. In this way, each terrace has been regarded as a single morphostratigraphic unit capable of being dated on the basis of its relative height above sea level. However, considerable disagreement has persisted over the age, origin and even the number of terraces. Recent evidence suggests that the terrace stratigraphy is far from simple (Jones and Derbyshire, 1977). The purpose of this field excursion was to give members of the Society an opportunity to assess some of the evidence for themselves through the examination of temporary sections in the terrace sediments provided by current industrial workings. By this means, it was hoped to demonstrate the amount of useful information that may be obtained from the careful monitoring of gravel workings over a period of time. Since all industrial excavations are necessarily destructive to the surface morphology and sub-surface geology, it is vital that as much information as possible is recorded at the time of excavation. The excursion leaders wished to emphasise that there was a pressing need for more extensive site documentation of this type.

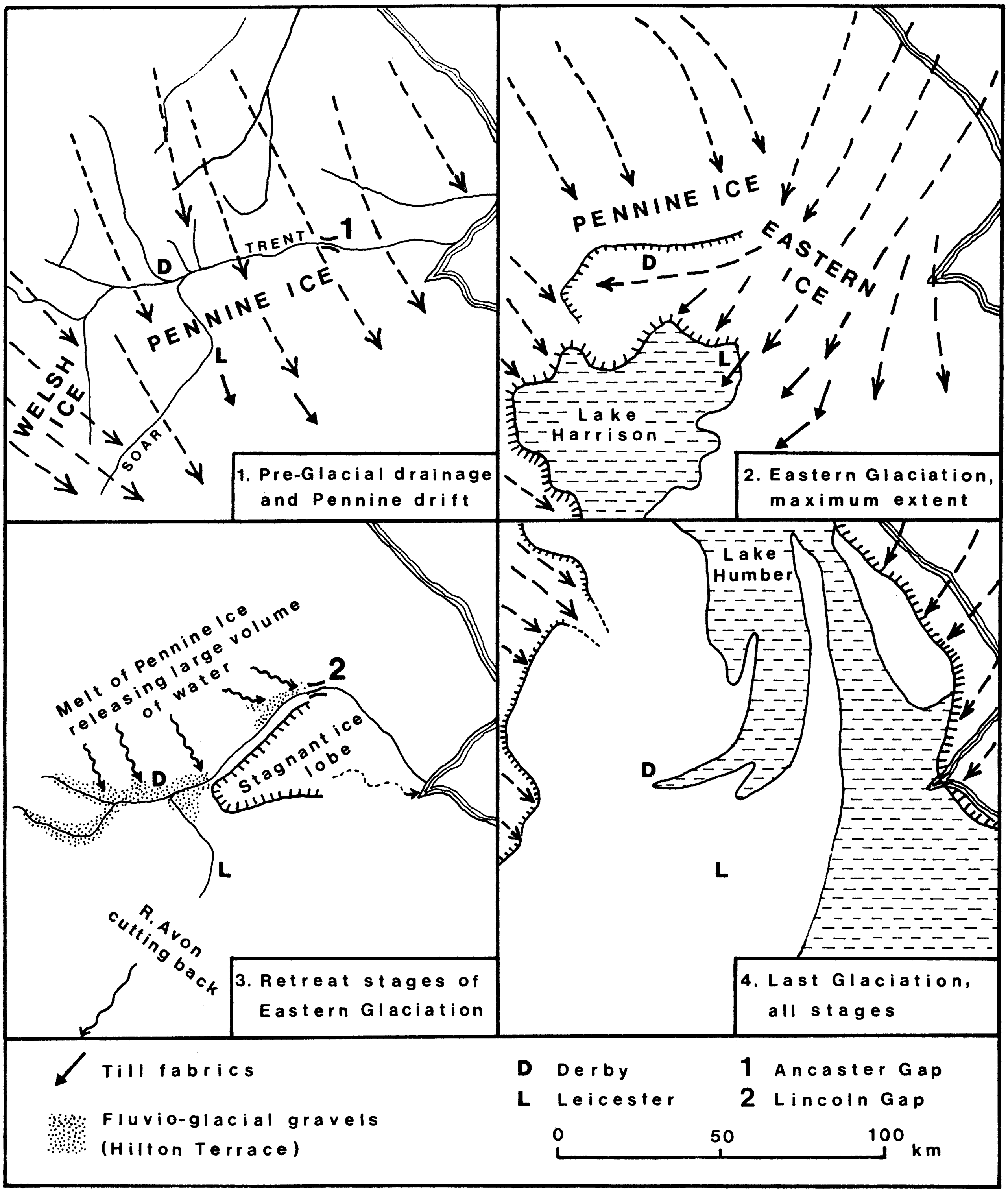
Quaternary evolution of the River Trent

The circuitous and often anomalous route followed by the River Trent between the south-western Pennines and the Humber reflects the complex history of environmental change during the last 2 million years. Although the river's early development is obscure and somewhat speculative, it is clear that the final evolutionary stages are intimately associated with the sequence of late Quaternary glaciations.

The penultimate (Wolstonian) glaciation appears to have caused considerable derangement of Midland's drainage. According to Posnansky (1960) and Straw (1963), the former valley of the River Trent between Long Eaton (SK 5033) and the Wash was deeply gouged by the advancing ice and, during deglaciation, the gouged area was occupied by a large stagnant ice lobe. The Trent was thus unable to re-establish its earlier course across the Vale of Belvoir, and supplemented by meltwater from the decaying ice sheets, eroded a new valley along the north-western edge of the ice lobe, text-fig.2. This route was maintained after the ice melted and now takes the form of an anomalous NE-SW 'trench' aligned obliquely across the Keuper Marl dip slope between Nottingham and Newark. During the melting process, vast quantities of sediment were washed from the ice fronts to form extensive sand and gravel spreads. As the rivers cut down into their valleys these spreads were left as high level terraces. They are particularly prominent on the north side of the River Dove near its confluence with the Trent, where they constitute the composite Hilton Terrace, text-fig.1.



Text-fig. 1: Distribution of 'river terraces' in the Middle Trent Basin.



Text-fig. 2: Glacial chronology of the Middle Trent Basin (after M. Posnansky 1960)

During the ensuing Ipswichian interglacial, temperate conditions prevailed. As a result, river gravels containing a fauna indicative of warm climatic conditions were deposited. At Derby, in 1973, temporary excavations into these gravels revealed the remains of hippopotamus, elephant, rhinoceros, brown bear, red deer, hyaena and bison (Jones & Stanley, 1975). Similar faunal assemblages have been discovered in excavations at Trafalgar Square in London and at other Ipswichian sites in southern Britain.

The Ipswichian interglacial was succeeded by the Devensian cold stage. Ice sheets were mainly restricted to northern Britain, but the English Midlands were subjected to severe periglacial conditions. At this time considerable modification of earlier deposits took place, both by cryoturbation (disturbances related to freezing ground) and as a result of solifluction (mass movement of material downslope). Furthermore, significant changes of sea level caused substantial down-cutting by the rivers. This probably accelerated the erosion of neighbouring upland areas and led to the formation of river terraces in a much degraded landscape.

Comparatively little dissection has taken place in post-Devensian (Holocene) times. The most notable development has been the deposition of alluvium on the floodplains of the modern river valleys. At the present day the River Trent is a rather sluggish stream. Only in periods of flood does it possess sufficient energy to transport coarse detritus. Consequently, deposition of the thick and extensive sheets of gravel which lie beneath the floodplain must have largely occurred when the river was in a more active and higher energy condition; possibly towards the close of the Devensian glacial episode (approximately 10,000 years ago) when the melting of ice sheets and permafrost would have produced a greatly increased discharge. Since that time the river has continually eroded and progressively re-worked these deposits while meandering across its floodplain. Periodic overbank flooding has been responsible for the surficial spreads of alluvium which now obscure the gravels. Much of the alluvium may be derived from soil washed off the interfluves into the valleys as a result of man's clearance of the forests during historical times.

Excursion details

1. Chellaston Quarry (SK 385301)

Inside the quarry, Mr. Jones outlined the general sequence of Quaternary events in the Middle Trent area. The party then had an opportunity to examine the bedrock geology (Keuper Marl) and overlying glacial drift. The former represents the substrate over which the River Trent now flows, while the latter illustrates the material from which the terrace sediments have been largely derived.

The Keuper Marl comprises a sequence of reddish brown mudstones and siltstones with several beds of gypsum. This formation has been examined at other localities on previous excursions by the Society (see, for example, Taylor & Houldsworth, 1973). However, many of the party were intrigued by the variability of the gypsum present at Chellaston, and specimens of alabaster, satin spar and selenite were avidly collected. Attention was drawn to solution marks on the surfaces of gypsum nodules, and it was suggested that selective sub-surface solution of gypsum horizons could be the explanation of various topographic depressions in Keuper Marl areas.

The glacial drift dates from the penultimate (Wolstonian) glaciation and rests on an irregular surface of Keuper Marl. The south-eastern face of the quarry showed a 10 m thick section of drift. This consisted of a basal clayey gravel containing fragments of red mudstone, and an overlying complex of tills containing lenses of sand, sandy gravel and relatively stone-free clays. The tills contained erratics of both northern (Carboniferous) and eastern (Mesozoic) derivation, and some time was spent discussing the implications of this varied suite with respect to the glacial chronology of the region. A particularly notable feature of the erratic suite was the remarkable abundance of derived fossils, and various members of the party collected specimens of bivalves (*Gryphaea*, *Cardinia*, *Lima*, *Nuculana*), amonites (*Dactilyoceras*, *Amaltheus*, *Schlotheimia*), corals (*Montlivaltia*, *Syringopora*, *Lithostrotion*), crinoids (*Pentacrinus*) and belemnites. Mr. Jones mentioned that the quarry was the last surviving brick-pit in Derby and regretted that it was scheduled to close in September 1977.

2. Etwall Gravel Pit (SK 275300)

Here the party examined gravels ascribed to the Hilton Terrace which reaches its maximum development in this area. The terrace feature had already been noted on the north side of the Swarkestone-Willington road en-route from Chellaston. The Hilton Gravels represent the highest (oldest?) terrace sediments along the River Trent. Previous conflicting views have attributed them either to normal fluvial aggradation (Clayton, 1953) or to glacifluvial deposition (Stevenson & Mitchell, 1955). As a partial compromise Posnansky (1960) suggested that the Hilton deposits represented 'outwash aggradation terraces' initiated during the retreat stages of the Wolstonian glaciation and completed during the ensuing Ipswichian interglacial.

The gravels were poorly stratified and highly disturbed in a form suggestive of severe periglacial disruption. They made a strong contrast with the the lower-lying terrace and floodplain sediments. It was mentioned that lumps of 'boulder clay' had been recorded in the Hilton gravels during earlier excavations (Posnansky, 1960). Members of the excursion examined a discontinuous surficial layer of pebbly clay and there was much discussion (particularly amongst the leaders) whether this constituted a till or a solifluction earth. The problem was unresolved. Nevertheless it was noted that the apparently simple planar surface of the terrace is misleading since it obscures a complex internal structure.

The party then proceeded via Willington and Repton to Ingleby which is situated on the southern bluff line of the Trent valley. Lunch was taken at the John Thompson Inn, Ingleby, SK 354269, in warm sunshine and pleasant surroundings.

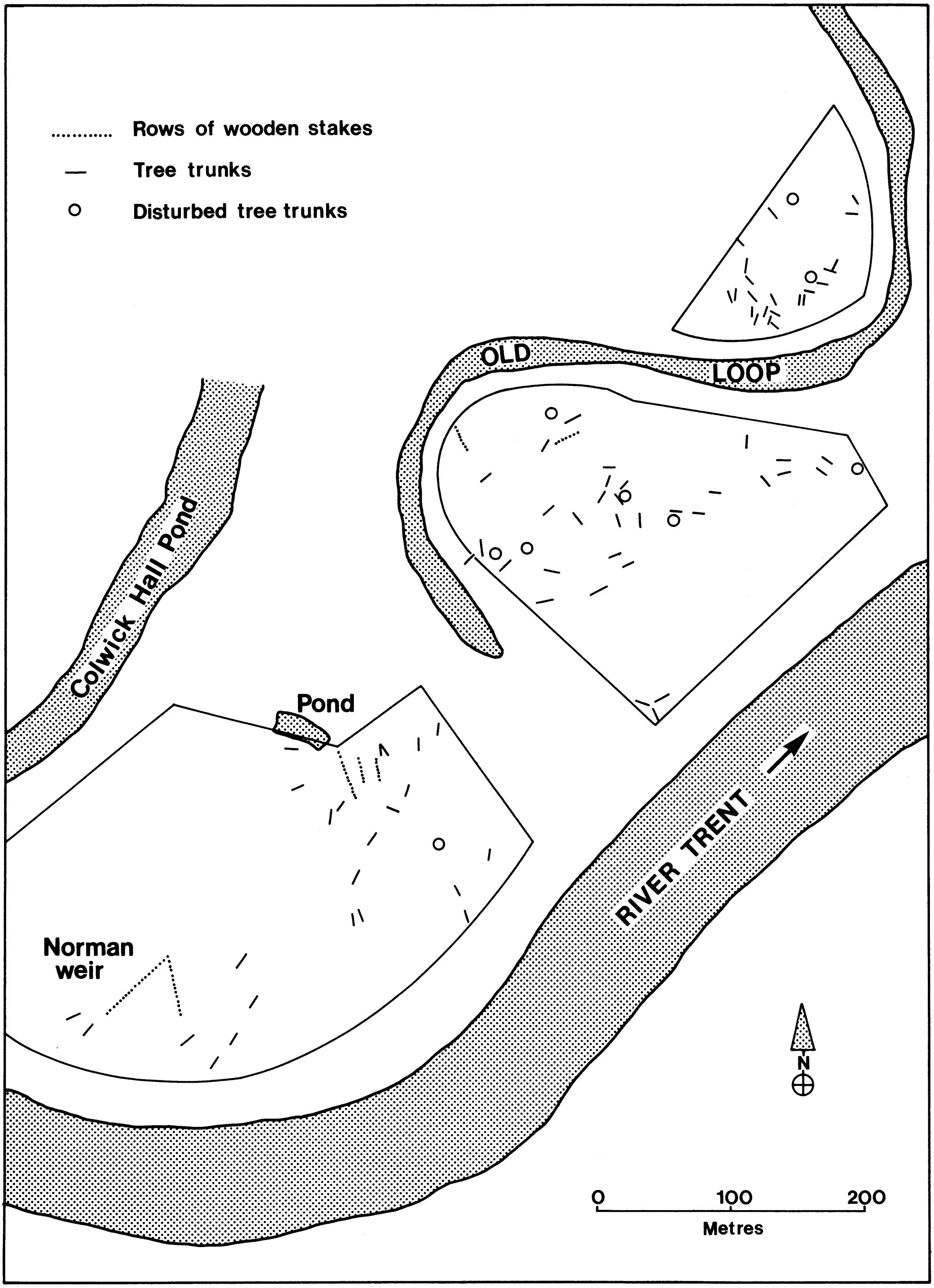
3. River Trent, Ingleby (SK 356270)

After lunch the modern floodplain of the River Trent was viewed from a vantage point on the Ingleby-Swarkestone road. Dr. Cummins briefly outlined the process of fluvial sedimentation and, in particular, discussed the activities of the meandering River Trent. The party's attention was drawn to the active erosion taking place on the outside of a large meander loop, and to point bar deposition occurring on the inside. Recent overbank flooding had added a thin layer of silt and clay to the surface of the floodplain.

The coach and following vehicles then travelled via Swarkestone and Chellaston towards Borrowash, SK 4134. This involved a transect of the Allenton Terrace of the lower Derwent Valley, which is a correlative of the Beeston Terrace of the River Trent. Unfortunately, no exposures in this terrace were available for examination. Previous excavations at Allenton, SK 3732, and Boulton Moor, SK 3831, had revealed Ipswichian mammalian remains (Jones & Stanley, 1975). Before the coach departed from Ingleby, members of the excursion had an opportunity to examine some of the mammalian remains in a "roadside display" provided by Mr. M.F. Stanley of Derby Museum.

4. Church Wilne Gravel Pit (SK 449318)

The route from Borrowash to Church Wilne took the party over representatives of all three terrace features on the northern side of the Derwent valley. Church Wilne lies on the floodplain of the River Derwent near to the confluence with the River Trent. Floodplain sediments and subjacent glacial deposits were examined. The former consisted of brown silty alluvium (1.0 m) overlying coarse sandy gravels (1.5 - 2.0 m) with large-scale cross-bedding. A black organic silty clay occurring beneath the alluvium and occupying a wide sinuous channel in the gravels was interpreted as being an infill of an old meander cut-off. Fragments of Mediaeval pottery, obtained from the clay, indicated that the channel had been active within historical times. Thin lenses of dark organic silt at the base of the gravels have recently yielded a radiocarbon date of 10,320 ± 160 BP (Birm-818).



Text-fig. 3: Distribution of tree trunks and wooden structures found in Colwick gravel pits, Nottingham.

The glacial deposits fill a deep buried channel beneath the floodplain sediments. They form a complex assemblage of tills, gravels, silts and clays, and are probably of Wolstonian age. Unfortunately, because of high groundwater levels, these deposits were not readily accessible on the day of the visit.

5. Colwick Gravel Pits (SK 604388)

Colwick was reached via Long Eaton, Beeston and Nottingham. This route followed the anomalous SW-NE valley of the River Trent. Gravel pits adjacent to the river were examined by walking from the Holme Sluice Road to Colwick Hall. Most of the older workings are now flooded but the southern pit was dry at the time of the visit. The floodplain deposits seen here were similar to those at Church Wilne. However, an interesting feature of this locality was the presence of large flat-lying tree trunks, and members of the excursion examined several of these *in situ* on the floor of the pit.

Dr. Salisbury explained that over 90 trunks had been recorded at Colwick, and the majority of these were oak. They were all tall, straight, forest-grown trees, often with the roots and branch stumps attached. The virtual absence of sap wood suggested that the trees had been dead for some time before deposition. The trunks occurred mainly in the lower 3.0 m of coarse, cross-stratified gravels. In plan, they formed a broad meandering band in which their long axes tended to lie parallel to the river valley, text-fig.3. In general, their roots pointed upstream. It was thus concluded that the trunks were water borne, before being emplaced in the bed-load deposits of an earlier meander of the River Trent (cf. Cummins & Rundle, 1969). Dr. Salisbury speculated that, since oaks were intolerant of flood water, a stand of these trees had been killed and eventually swept away during a period of particularly severe flooding. He briefly described the dendrochronological work which he is currently carrying out on the trunks, and stated that this might eventually provide evidence for the rate of movement of meanders.

Mr. Fox outlined the archaeological attractions of the site. In 1973 a unique Norman fish weir had been excavated which yielded a radiocarbon date of 1105 A.D. ± 70 (HAR-846). It stood in the lowest 2 m of gravel and 200 m away from the modern course of the Trent. Fragments of a similar structure were available for examination by the party. Members were also shown an impressive collection of archaeological objects recovered from the pits. These ranged in age from Neolithic to 18th Century, and served to emphasise the fact that constant re-working of the floodplain deposits has been taking place throughout Holocene times. As a consequence, the depth and position of movable artifacts now bears little relationship to chronology.

The excursion ended with some members finding difficulty in tearing themselves away from the archaeological remains provided by Dr. Salisbury and Mr. Fox. A vote of thanks was made to all four leaders and the coach then returned to Nottingham and Derby.

Acknowledgements

The leaders wish to thank Chellaston Brick Company, Redland Gravel Limited, and Hoveringham Limited, for kindly allowing the Society to have access to their respective sites.

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WEEKEND EXCURSION TO LUDLOW

Leader: John Norton 5th-7th May, 1978

The meeting was attended by about 25 members, who were accommodated at the Cliff and Croft Hotels, Dinham. On Saturday, 6th May, we met at the County Museum's Natural Sciences Department in Old Street, Ludlow at 9.30 a.m. for a brief talk in the lecture room on the geology of the Ludlow Anticline area.

The Wenlockian and Ludlovian rocks of the Ludlow district were deposited in a shelf area of the sea, which towards the end of Ludlovian times became shallower owing to the uplift which continued into the Downtonian, when brackish, fresh-water and land deposits were laid down. The north-east to south-west strike of the Silurian rocks, so evident along Wenlock Edge, is disturbed in the vicinity of Ludlow by folding to the west of the town into an anticline which plunges underneath the Old Red Sandstone. It is now very much denuded and as its component rocks are alternating soft shales or siltstones and hard limestones, the landscape shows escarpments where limestone outcrops occur and valleys or step features in the shales.

One of the reasons for the introductory talk was to discuss the revised classification of Ludlovian rocks in their type area. The new revision made by Professor C.H. Holland, Dr. J.D. Lawson and Dr. V.G. Walmsley replaces the old classification of Sir Roderick Murchison, made during the first half of the last century when he divided the Ludlovian into Lower Ludlow, Aymestry Limestone and Upper Ludlow.

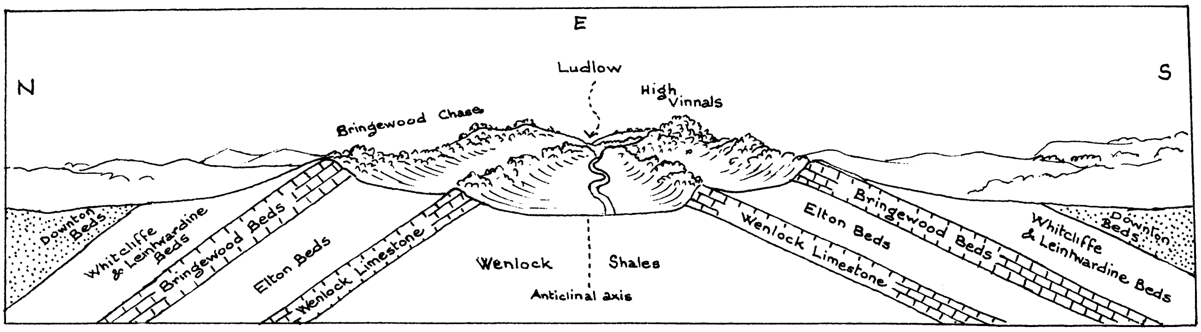
For a long time, geologists realised Murchison's old divisions were quite inadequate. The revised classification, based mainly upon fossil content, consists of the Eltonian, Bringewoodian, Leintwardinian and Whitcliffian stages; these, in turn are subdivided into beds. The name Aymestry Limestone disappears from the revised classification because it is diachronous and therefore, does not represent a bio-stratigraphical unit. It may still, however, be referred to lithologically as a limestone development which occurs about the middle of the Ludlovian in the area. The syncline which corresponds with the Ludlow Anticline covers the Craven Arms - Downton - Leintwardine district.

We commenced our excursion by taking the road through Bromfield and made our first stop at Downton Gorge, where we saw the River Teme flowing through a deep channel below the impressive, high, massively jointed limestone cliffs of the Upper Bringewood Beds. These Bringewood Beds correspond in general with Murchison's Aymestry Limestone, however, in some localities, he had also included calcareous Lower Leintwardine Beds. We crossed over the river to the south bank and climbed to a viewpoint on Bringewood Chase, collecting fossils on our way, which included specimens of tabulate and rugose corals, the brachiopods: *Kirkidium* (*Conchidium*) *knightii*, *Gypidula lata* and *Strophonella euglypha* also the trilobite *Dalmanites myops*.

The glacial deposits of the Wigmore-Leintwardine area are particularly interesting and from the viewpoint, we obtained an excellent prospect over the Vale of Wigmore, in glacial times, occupied by a large lake, of which the shorelines can still be seen. It was pointed out that the original course of the River Teme may have been southwards through a gap at Aymestrey but when access to this became blocked, the river flooded those parts of the Vale of Wigmore, which were free of stagnant ice and spilled eastwards carving out the picturesque Downton Gorge.

Our next stop was Leintwardine, when the party climbed to the Church Hill Quarry. Unfortunately, this famous 'Starfish quarry' has long since, for the greater part, been filled in; although, occasional specimens of *Furcaster leptosoma* and *Lapworthura miltoni* still turn up when careful search is made. About a hundred years or so ago, the quarrymen did a good trade selling fossil starfishes to tourists. At the time these rocks were being deposited, the area occupied a position somewhere near the edge of a continental shelf. Dr. J.H. McD. Whitaker of Leicester did some splendid work on the Leintwardine district, showing how in higher Lower Leintwardine times, submarine canyon heads existed. The channels which lie parallel to each other contained a particularly interesting fauna, including echinoids, asteroids, phyllocarids, eurypterids, annelids and xiphosurids. Graptolites and small orthocones from these localities often show a definite orientation in their alignment.

Travelling on to Wigmore, a stop was made at the Compasses Hotel, where we ate sandwiches, and obtained liquid refreshment. From the hotel car park, we had a splendid view of the Ludlow Anticline, where we were standing on low ground of comparatively flat Wenlock Shales. Two horse-shoe shaped escarpments opened in front of us, the nearer being of Wenlock Limestone with a step feature in the softer Elton Beds between it and the further escarpment on the skyline of Bringewoodian and Lower Leintwardine Beds (text-fig.1).



Text-fig. 1. Sketch section across the Ludlow Anticline

We followed the road towards Ludlow almost along the anticlinal axis and paid a visit to some roadside quarries in Wenlock Limestone. These rocks were deposited away from the reef area, and fossils are not common. Possibly, the water may have contained too much suspended sediment for corals and other reef-building organisms to have thrived, or perhaps, water may have been deeper than was favourable for their growth. In one of these quarries, we saw an interesting fault with a slickensides feature and in another higher up, observed the junction to the Lower Elton Beds marking the beginning of the Ludlow Series.

A short detour through the forest then took us to a fossiliferous exposure in Middle Elton Beds, the soft blue-grey soapy shales containing many trilobites mostly *Dalmanites myops*, although, a few fragmentary odontopleurids were also found. There is a fairly abundant graptolite fauna here, including *Neodiversograptus nilssoni*. Other fossils included orthoconic cephalopods, bivalves and gastropods. We then returned to the road and examined Upper Elton Beds at Gorsty, where flaggy siltstones yielded many specimens of *Monograptus tumescens*. As we had already examined the Bringewood Beds, at Downton Gorge, the party decided to pass roadside quarries in these beds and to proceed up the succession to a roadside quarry in calcareous siltstones of the Lower Leintwardine Beds, where we saw a shelf fossil assemblage consisting chiefly of the brachiopods *Isorthis orbicularis*, *Sphaerirhynchia wilsoni* and *Dayia navicula*. Other fossils here included bryozoans, gastropods, bivalve molluscs and small eurypterid fragments. We did not find the tabulate corals *Favosites* and *Heliolites* from these beds, whereas they are plentiful from the Bringewoodian, no doubt, due to some environmental control. The Upper Leintwardine Beds on the trail are less calcareous and distinctly more flaggy than the lower division, and contain an interesting fauna with trilobites and the large ostracod *Neobeyrichia lauensis*.

The Lower Whitcliffe Beds were examined at roadside exposure and on Whitcliffe itself, where members of our group noted the bedding to be thicker and more irregular than in the Leintwardine Beds, and calcareous nodules and honeycombing were absent, but sphaeroidal jointing occurs. It was also commented on that there is a marked change in fauna and many fossils common in the Leintwardine Beds were missing, such as brachiopods of the genera: *Atrypa*, *Shaleria* and *Leptaena*, but *Protochonetes*, *Camarotoechia* and *Salopina* had become very common. There is an increase in the numbers of bivalve molluscs such as *Fuchsella amygdalina* and cephalopods are quite plentiful. Examination of the character of the Whitcliffe Beds indicated a shallowing of the sea. Fossils are numerous often occurring in layers or lenses, probably due to current washing.

In Ludford Lane, the position of the Ludlow Bone-Bed is clearly defined by a recess where collectors have for many years, obtained specimens. We tried to be careful not to add too much to this erosion process, but did obtain a few small pieces with the aid of a long chisel. In these samples, we were able to examine the skin studs and cutwater spines of small fishes. The Bone-Bed was probably deposited in very shallow water, and consists of organic debris deposited along a strand line winnowed by a retreating sea. We were now back at Ludlow, where the members kindly entertained the leader and his son at the Cliff Hotel, providing an excellent and very welcome dinner.

On Sunday morning, we journeyed through the ancient market town of Much Wenlock to Farley Quarry, where we were able to compare the Wenlock Limestone with that seen the day before on the Ludlow Anticline. In contrast, to that at ludlow, the rocks at Farley are extremely fossiliferous and it was possible for us to examine corals and other reef-building organisms *in situ*. Excellent corals and stromatoporoids were collected, also some splendid specimens of gastropods of the genus *Poleumita*. Our next stop was to the Acton Arms, Morville, where we enjoyed a picnic lunch. Here we met the Tarrant brothers, Peter and Mark, who have for many years, collected important 'fish' specimens from the Old Red Sandstone of South Shropshire and they accompanied us to Monkhopton where some fish fragments were collected in a stream where cornstones of the Ditton Series, lower group, are exposed. Specimens included fragments of *Traquairaspis symondsi* and acanthodian scales and spines.

After a rather lengthy journey over the 'Old Red,' we saw the Carboniferous Limestone at Oreton but owing to lack of time, did not stop to examine it. Eventually, the party arrived at Titterstone Cleehill roadstone quarries, where an impressive dolerite sill intrudes into rocks of the Coal measures. A discussion took place about the possible source of the dolerite, which is the famous 'Dhustone,' from which, in the past, many of the sets for city roads were made. Fashioning these was an extremely skilled job, the Old Cleehill set makers starting work at a very early age to become expert. It was at one time, suggested that there may have been a volcanic plug in the middle of Cleehill, but this is now disproved. Brown Clee has similar igneous sills, which, no doubt, were derived from the same source as those on Titterstone.

The leader would like to thank members of the party for being so kind in providing lifts for his young son Mark and himself and for their wonderful enthusiasm and co-operation in every way.

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SOME FEATURES OF THE HEATH AND FEN OF SOUTH LINCOLNSHIRE

Leader: D.N. Robinson Sunday, 11 June, 1978

The purpose of the excursion was to demonstrate certain glacial and post-glacial features of South Lincolnshire, with particular reference to Fenland deposits and the sequence of drainage and land reclamation in historic times.

The excursion started at the Glebe Quarry, Colsterworth (SK 898242), by permission of the Church Commissioners. This is a worked out but unrestored ironstone quarry (last worked 1943) with a 10 acre water-filled gullet and 30 acres of hill and dale. There is an exposure with the sequence of Lincolnshire Limestone, Lower Estuarine Beds (ferruginous sands, sandy clay and dark grey shale - a lagoonal series with slow and interrupted deposition in a wide coastal zone of mud flats and sands) and Northampton Ironstone (rich brown sandy rock with prismatic 'boxes' of hard brown and black ferric oxide; deposited in shallow seas swept by sand laden currents in which ferruginous sands and siliceous ironstone accumulated; fossils rare or absent). The main exposure is at the western end of the gullet but the Lower Estuarine Beds are largely obscured.

The central section of the quarry face exposes a sand and gravel filled pre-glacial valley, part of a system formerly draining the Lincolnshire Limestone. Infilling occurred by spring melt from local snowfields under periglacial conditions. Advance of the Wolstonian ice sheet covered the feature with deposits of chalky boulder clay, much of which has been removed on development of the present drainage system.

Tomling Hole Sinks (SK 967259), was visited by permission of Mr. F.B. Wakerley, Burton Coggles; here there is a blind valley in boulder clay. It has a 20-30 ft incised inner valley within the broad trough, with impressive miniature meanders leading to a series of a dozen sink holes. The largest are 5-6 ft. deep. During late autumn the stream slowly advances down the valley, overtopping successive swallets towards the blind end. In rare conditions and for periods of a day or so there is a lakelet 400 yds. long, 30 yds wide and up to 30 ft. deep. From April the boulder clay dries out and cracks so as to absorb rainfall without leaving a surplus for run-off. The valley and funnel-shaped sinks were examined.

Sink holes are generally towards the thinning edges of boulder clay cover of the Lincolnshire Limestone, but a number in the Burton Coggles area are also fault-guided. It is suggested that fissures in the limestone below the clay cover were opened by periglacial action, exploited by meltwater run-off in late and post-glacial times.

The route proceeded via Burton Coggles to Corby Glen, crossing the southward-flowing R. Glen incised (probably initiated, like the Eden, as an ice-edge drainage channel) into Lincolnshire Limestone. It then crossed Cornbrash and a small tributary of R. Eden which has been dammed to form the lake in Grimsthorpe Park, part of Capability Brown's landscaping of 1772. Much of the Park is on a boulder clay capped spur between the valleys of the Glen and Eden. The road round the north end of the Park provided good views of Grimsthorpe Castle, the main part of which was "an extempore building set up of a sudden by Charles Brandon, Duke of Suffolk" to entertain Henry VIII in 1541. The great north front was designed by Sir John Vanbrugh in 1722.

From Grimsthorpe through Edenham to Toft, the route crossed lightly incised meanders of the R. Eden three times before turning east to cross the gravel and boulder clay capped ridge of Kellaways and Oxford Clay which separates the valley from the Fen edge and gave good views across Thurlby Fen. In the Fen edge villages the mixture of limestone and brick buildings was noted.

The route followed the Fen edge to Langtoft, with Oxford Clay to the west and Fen-edge gravels to the east. Just south of Thurlby and one field from the road to the east is the line of the Roman Car Dyke, a catchwater drain. At Kent's Bridge the A15 crosses the R. Glen there having turned to flow north-east.

During the Ipswichian Interglacial sea level reached a maximum height of 70 ft OD, that is flooding the Fenland basin up to the clay edge in this area. The Fen-edge gravels, widening southwards from 1-5 mls. and some 10-20 ft. thick, are relatively coarse and composed of rounded pebbles of flint, Jurassic limestones and Bunter pebbles derived from the former boulder clay cover to the west. They were laid down in relatively quiet shallow water conditions, with long extensions (like the one to Crowland) marking the position of stronger seaward currents. Near the top of the gravel is a driftwood horizon - a foot or more of pebbly sand full of blackened and broken fragments of wood.

There are extensive workings in the Fen-edge gravels east of Baston and Langtoft with an opportunity to view the ARC Eastern pit at TF 140140, which has been worked down to the underlying Oxford clay.

Towards the end of the Bronze Age (1000-800 BC) land sinking ceased and rose by about 2 ft. which put the inner Fenland basin beyond reach of the tides. Here the upper peat accumulated in a broad zone up to 5 mls wide over the next 1000 years or so to a depth of 3-5 ft, but this has shrunk since reclamation and drainage. In Deeping Fen the peat is only about a foot thick and mostly mixed with clay due to deep ploughing.

At the Baston Fen Nature Reserve (Lincolnshire and South Humberside Trust for Nature Conservation) the party was met by Mr. E.J. Redshaw, the voluntary Reserve Warden. The 90 acres of permanent grass between the R. Glen (which flows between high banks and above level of surrounding land) and the Counter Drain, was formerly a wash or flood reservoir for the R. Glen and is still occasionally used for that purpose in the winter. The R. Glen is about 10-12 ft OD and the Counter Drain 4-5 ft OD compared with a land level of 3-4 ft OD. Borrow pits along the Glen bank are permanently flooded and a shallow mere has been excavated in the peat.

In the 8th century the fens were described as a "hideous area of huge bigness ... oft-time clouded with mist and dark vapours, having within it divers islands and woods as also crooked and winding rivers." Camden in the 16th century recorded that "Deeping or 'deep meadow' is the deepest of all the fenny country, and the receptacle of many waters." Around Crowland the land "is so moory that you may run a pole into the ground to the depth of 30 ft and nothing is to be seen on either side but beds of rushes ...." For most of this period the 30,000 acres of this fen were held in common by the towns of Deeping, Spalding, Pinchbeck, Thurlby, Bourne and Crowland.

The main drainage of Deeping Fen was achieved between 1632 and 1637 by Adventurers including Sir Philibert Vernatti, after whom the Vernatt's Drain takes its name. All new drains were cut by hand - by Dutch workers and Scottish and Irish prisoners of war. But, despite windmills, the fen still flooded with water. Various improvements were made through the 18th century, including two large scoop wheels or 'Dutch Engines' for lifting water into the Vernatt's Drain.

Finally, in 1801, an Act of Parliament was passed for draining, dividing and allotting Deeping Fen. It was the works resulting from this Act which created the present pattern of drainings, roads and farms. Even so, the improvement was not permanent as pumping was still by windmill, of which there were 50. Steam power was required and the two steam engines, driving scoop wheels, commenced work at Pode Hole in 1827.

The level of Deeping Fen today is less than 5 ft above sea level, and in normal times the water in the R. Welland and R. Glen is as much as 10 ft higher. Maintenance of their banks is therefore of vital importance in the drainage system. In fact the whole of Deeping Fen has to be pump drained; there is no natural gravity discharge. In 1665 the peatlands were about 6 ft higher than the siltlands and have shrunk about 12 ft in the last 300 years due to drainage and agriculture.

Pode Hole Pumping Station is the key to the drainage of Deeping Fen. Here drainage waters from the North and South Drove Drains accumulate in the basin, and the water level is normally 1-2 ft *below* sea level. The water is raised nearly 14 ft by pumps into the Vernatt's Drain where it flows by gravity to the tidal outlet at Surfleet Seas End. The Deeping St. Nicholas Pumps, which came into service in July 1965, are capable of pumping over 283,000 gallons of water a minute and were made by Gwynnes Pumps Ltd. of Lincoln.

The route proceeded alongside the Counter Drain to Pode Hole and then through the Spalding suburb of Little London on to Cradge Bank which follows the foot of the Welland Bank to Four Mile Bar, where the road ascends onto the bank. Here good views were obtained of the R. Welland and the Washlands between the Welland and the New River at Brotherhouse Bar. These washlands were deliberately created as natural flood reservoirs. In winter they would freeze and made Cowbit and Crowland Washes famous for fenland skating. They were also much used for fishing and wildfowling. One method of wildfowling was the use of a huge punt gun, mounted either on a punt in water or on a sled on skate runners on ice. Traditionally the washes were under grass, but the Brotherhouse electric pumping station was built in 1969 to improve the drainage of the upper Welland washes and enabled them to be brought under cultivation.

By a bend in the bank a pond, known as a Gull, indicated the site of a former breach in the bank. Flood water pouring out of the Welland, which flows at about 15 ft above sea level in times of flood, burst through the bank and cascaded into Deeping Fen 10 ft below. The gull would have been caused by the resulting scour.

The Roman coastline of what is now the Fens consisted of a series of silt and saltmarsh 'islands' in an arc from Wainfleet to Holbeach on which were saltmaking sites. With the post-Roman lowering of land level, the sea flooded further into the Wash throwing up a bank of silt against the islands to create the 'Townlands' on which Anglo-Saxon and Danes could settle (including Gedney - 'Gydda's island'). From this base a series of intakes were made - of the Fen inland and of saltmarsh to the seaward - thus developing very elongated parishes.

The route crossed Great Postland to Gedney Hill and then followed 14 miles through the parish of Gedney: via Leedsgate (Les Gates) and crossing the old Fen Dyke, Ravens Dyke and Gedney Fen, via Gedney Broadgate to Gedney on the silt bank and crossing the Hargate (now followed by the A17); via Gedney Dyke and past two clear saltern mounds (the debris of medieval salt making) and crossing the Common Fen Dyke (the coastline in 1307) at Black Barn; across Gedney Marsh (reclaimed by 1700) to Gedney Drove End, crossing the reclamation of 1793 to Boatmere Haven, with reclamations of 1865 to south and 1875 to north.

The inlet of Boatmere Haven had been closed off by a reclamation bank in 1977/78 but leaving a strip of saltmarsh still to the seaward. The party were able to walk onto the sea bank to obtain a clear view of the bunded reservoir of just over 1 hectare constructed to east of the R. Nene on Westmark Sand. From the vantage point of the sea bank it was possible to point out sedimentation processes in the inner Wash and discuss the problems of reclamation, barrage and bunded reservoir construction.

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EXCURSION TO THE ASHBOURNE AREA

Leader: T.J. Charsley Sunday, July 2, 1978

The object of the excursion was to sample some of the lesser-known geology around Ashbourne, particularly those areas which have recently been the subject of primary mapping by the Institute of Geological Sciences.

Kniveton (SK 206 494)

The party walked across the fields from Brookhouse Farm to an exposure of a highly altered amygdaloidal porphyritic olivine-basalt. This was formerly regarded as a dyke (Green, *et al.*, 1869), but recent mapping has shown it to be concordant with the surrounding sedimentary rocks, though whether it is a lava flow or a sill has not yet been resolved.

The basalt, which has a thickness in the stream of 17.5 m, is exposed in a rather weathered section (SK 2060 4939) through Visean P_1 rocks of the Widmerpool Formation, which here consists of alternations of mudstones with graded beds of limestone of probable turbiditic origin. The section showed a number of beds of limestone with coarse bioclastic material at the base grading up into calcisiltite or calcilutite. The few current directions measured support the conclusions of Weaver & Stanley (1977) that palaeoflow and mineralogy are consistent with an origin to the southeast, possibly from the Charnwood Forest massif.

Punches Dumble (SK 191 482)

The first section (SK 1911 4813), in Namurian turbidites, showed some 6 m of alternating mudstones, siltstones and sandstones, with just over 50% mudstone. The sandstones are very fine- to medium-grained and quartzitic, and are in some cases graded. Their most characteristic feature is the presence of a variety of sole markings, mainly groove and load casts, with some prod marks and possibly unroofed sand-filled burrows. These features together with the cross-lamination observable in some units and the general poor degree of sorting are typical of turbidites. Measured current structures indicate flow towards the NNW.

The reddish colouring of the rocks is regarded as staining below a former Triassic cover, and the basal Triassic unconformity crops out 350 m SE from this locality. The rocks in the Dumble, which dip 14-22° ENE, lie on the western limit of a syncline having a N-S axis and a wavelength of about 350 m.

Two fossiliferous horizons, within the *Eumorphoceras bisulcatum* (E2a) Zone, are exposed along the stream course (at SK 1910 4815 and SK 1909 4807 respectively), and a number of intrepid fossil hunters, braving rubbish, mud and water, were rewarded with fair specimens of goniatites and bivalves.

Ashbourne (SK 1765 4657)

The party visited an exposure in the gardens of the old Ashbourne Grammar School, by kind permission of Mr. and Mrs. Bowden, to see a 3 m section in cemented gravels. The gravels consist of angular to well-rounded blocks, cobbles and pebbles of Carboniferous limestone with a few Carboniferous sandstone, quartz, quartzite and black chert pebbles. The matrix consists mainly of coarse quartz sand and the whole is strongly cemented by calcium carbonate. The gravels are poorly stratified and poorly sorted, and are regarded as being the product of a high energy fluvial environment, probably laid down as braid bars.

Six separate occurrences of the gravels have been located aligned in a general N-S direction across the west side of Ashbourne. These deposits lie about 15 m above the flood plain of the Henmore Brook at heights decreasing from about 360 ft AOD in the north to 425 ft in the south over about $1\frac{1}{4}$ miles. Their height indicates that they pre-date the Mayfield Terrace of the River Dove which may be equated with the Beeston Terrace (Ipswichian) of the Middle Trent (Jones & Stanley, 1974).

The gravels are thus either the equivalent of the Hilton Terrace of the Middle Trent and of Wolstonian age, or, if they pre-date the till on the ridge above the school, they are pre-Wolstonian and the earliest Pleistocene deposits known from this part of the Midlands.

Limestone Hill area (SK 136 463)

Several sections were examined on and around Limestone Hill, a knoll-reef of Chadian (C_2S_1) age, which also formed a feature, later to be buried by sediment, in the sub-Triassic landscape. Sections along the stream course were seen showing local variations in the basal part of the Hawksmoor Formation, itself part of the Sherwood Sandstone Group. A thin bed containing silicified limestone clasts of probable local derivation was seen (SK 1382 4612) in a sequence of about 4 m of dark red-brown fine-grained micaceous silty sandstones with yellow mottles. Slightly upstream (SK 1383 4617), ten separate mudstone units, some showing silt laminae, in a sequence of interlayered mudstones and sandstones point to an origin for the sequences as fluvial channel sands with overbank deposits of silt and mud.

A basal Triassic conglomerate was seen at SK 1371 4637 where it consists of angular silicified limestone clasts up to 22 cm in diameter, set in a very fine sand matrix with secondary carbonate cement. The conglomerate rests on a part of the Widmerpool Formation in which limestone is dominant (c. 80%), formerly referred to as the Bull Gap Shales (Parkinson & Ludford, 1964) of Upper B_2 age.

After examining the site of a shaft, sunk in 1820 as part of a lead mining project (Porter & Robey, 1972), the party climbed Limestone Hill. Evidence of mineralisation was seen on the hillside including dolomitisation, blocks containing disseminated galena and a large boulder of finely crystalline baryte. The hill is surrounded by soft Triassic sandstones of the Hawksmoor Formation which give way at the top of the slope to well cemented coarse-grained, commonly pebbly, sandstones of the Hollington Formation.

Stanton Quarry (SK 123 466)

Little is now to be seen in the quarry, which was visited with the permission of the owners, Mr. and Mrs. Lucking, of the former extensive workings for building stone, but at a rock known as the "Tor" baryte veining and cementation of the sandstone was demonstrated. The control on the baryte mineralisation was regarded as partly structural and partly caused by the capping effect of the overlying Mercia Mudstone Group. A small pond in the quarry probably overlies an impermeable marl band, a feature of the Hollington Formation, but a previously-recorded exposure of mudstone could not be located on this occasion due to the thickness of the undergrowth. A member of the party reminded those present that the quarry was the location for the labyrinthodont holotype *Cyclotosaurus leptognathus*, formerly known as *C. stantonensis* (Paton, 1974), the skull of which now resides in the British Museum (Natural History).

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BOOK REVIEWS

CLAYTON, A.R., 1979. The Sand & Gravel Resources of the country around Bawtry, South Yorkshire; Description of 1:25,000 Resource Sheet SK 69. Miner. Assess. Rep. Inst. Geol. Sci. No. 37. ISBN 0 11 884053 3. £5.75.

This report is one of the latest in a series by the Industrial Minerals Assessment Unit of the Institute of Geological Sciences and deals with the Sand and Gravel resources of the area around Bawtry in South Yorkshire.

Sand and Gravel production in Britain exceeded 117 million tonnes in 1976 and the total annual take of land for quarrying is currently about 2,500 ha. It was against this background that the Industrial Mineral Assessment Unit was established to identify and assess potential workable deposits with a foreseeable use as aggregate. Such deposits are technically defined as resources and a clear distinction needs to be made between these and reserves, the latter being those deposits which have been proven to be economically viable under present day conditions. This remains quite firmly the responsibility of the extractive industry, the surveys undertaken by the Institute of Geological Sciences on the other hand are designed to improve our knowledge of national resources for the long term.

The report is clearly intended for the local and government planning officials, professional geologists and the extractive industry in general and not the amateur geologist. It contains an account of the survey procedure and techniques and much detailed information, all clear and well presented. The report loosely falls into two parts. The first contains a brief section describing in turn the geology of the area (with particular emphasis on the drift deposits) the composition of the sand and gravel, a description of the $2\frac{1}{2}$" geological map which accompanies the report and the results of the borehole survey together with a description of what are referred to as "Resource Blocks". The area has been divided into eight of these blocks and for each the geology of the deposit is described, overburden and mineral thicknesses assessed and volume and gradings computed. A simple statistical approach is adopted in computing these figures but no allowance is made for any possible constraints on working and hence the estimated volumes bear no relation to the amount that can be extracted in practice. The danger is that a false impression can be given of large tonnages when in reality recoverable content may be small. Regrettably this has led many involved in the sand and gravel industry to treat the exercise as of academic interest only and argue that it would prefer to see the IGS concentrating its resources on producing good quality maps and leaving the industry to locate and assess deposits.

The second part of the report contains the detailed logs of 87 boreholes and these records account for 75% of the total volume. It is questionable whether this detail is necessary, an abridged form with details available separately on request might be a better alternative and would help to keep the costs down. It is interesting to note that the boreholes were completed in late 1974 and the early part of 1975. Four and a half years seems a long time to produce a report of this nature and if the format could be simplified or reduced, a shorter publication period may be achieved.

The area covered in the report has been extensively worked for sand and gravel since the turn of the century and these workings now cover approximately 750 ha. In the circumstances brief mention of reclamation and restoration aspects might have been appropriate and certainly a section on hydrogeology would not have been out of place.

R. J. Hawkins

H.H. SWINNERTON and P.E. KENT. *The Geology of Lincolnshire.* Second Edition with revisions and additions by Sir PETER KENT. Lincolnshire Naturalists' Union. Lincoln 1976. £3.45

The first edition of this book, under the joint authorship of Professor H.H. Swinnerton and Dr. P.E. Kent, appeared in 1949. The need for a revised edition has come about in no small measure as a result of the subsequent activities of Sir Peter Kent himself. During the intervening years he has added considerably to knowledge of Lincolnshire geology and we are grateful that he has found time also to update this useful little book.

At first glance this new edition is an improvement on the original. New features are the pleasing front cover colour photograph, a geological map and fifteen black and white plates. The general format and chapter headings are much as before but skilful recasting and concise writing have allowed much new information to be included without increasing the size of the book. Several chapters are devoted to the Mesozoic rocks from the Rhaetic through to the Upper Cretaceous. In most of these the extent of the revision is considerable with added refinement of detail and discussion of major changes, for example the recognition that the lower part of the Spilsby Sandstone belongs to the Jurassic. The number of text-figures in these chapters is not significantly increased but in general they adequately supplement the descriptive stratigraphy. Inevitably there are fossil names in profusion but regrettably no overall taxonomic revision has been attempted. One wishes also that room could have been found for a few more illustrations of common fossils.

Later chapters deal with the Tertiary Landscape, Structure, the Pleistocene, Post-Glacial History and Economic Geology. The Pleistocene chapters in particular have been extensively revised and contain some new figures and a useful chronological table. A short final chapter comments on Geological Conservation and provides a field-work code, a necessary inclusion nowadays.

The book is remarkably free from irksome printing errors but there are a number of inconsistencies due to a certain unevenness in the revision. On page 18 we read (with some relief) that the Rhaetic must now be accepted as belonging to the Trias; it is so placed in Table II but in the column accompanying the map (Fig 1) it is included in the Jurassic. On page 13, and again on page 27 there is confusion in the naming of the Lower Liassic ammonite *Schlotheimia angulata* and of the corresponding ammonite zone. On page 76 we read, surprisingly, that there was no life on the planet in Pre-Cambrian times. More seriously, it is to be regretted that the author chose to retain virtually unchanged certain of the introductory chapters originally written by Professor Swinnerton. In Chapter 3, on the Age and Arrangement of the Rocks, most of the ages given on the column (Table 1) differ considerably from current versions of the Phanerozoic time scale, and on page 7 the term formation is misleadingly referred to as the rocks laid down during any one period of time. Revision of this chapter and of Table II, to come into line with modern stratigraphical nomenclature, would have been timely. Chapter 5, on the Natural History of the Mesozoic, contains a brief outline of Professor Swinnerton's classic work on the evolution of *Gryphaea* without the addition of any reference to later quite different views about oyster evolution. Somehow its inclusion here seems less relevant than it was in 1949.

The out-of-dateness which thus pervades parts of the early chapters is unfortunate, but should detract little from the usefulness of this otherwise excellent book. It is attractively produced, very readable and remarkably comprehensive for its small size. Although not intended as an excursion guide it will undoubtedly be carried in many a pocket or rucksack and should be indispensable to all who pursue their geological activities anywhere between the Humber and the Wash.

A.M. Honeyman

FOSSIL COLLECTING by F.G. DIMES and R.V. MELVILLE, KTG Series

E P PUBLISHING LTD (WAKEFIELD) 1979 36 pages
WITH FIGS, DIAGRAMS AND MAPS PRICE 60p

This booklet has been written for the beginner of whatever age. The discernable theme throughout is that of reconciling the best interests of both the increasing number of people taking part in fossil collecting and the countryside itself which has suffered the depredations of unthinking collectors. The booklet has the imprimatur of the Palaeontographical Society and has been written by two veterans in the field of practical fossil collecting.

The result is a worthwhile distillate of practical advice from which both the novice and the advanced collector will benefit. An introductory eight pages define fossils and detail how and where they are to be found. A further five pages deal with how to extract the fossils from the host rock. Eighteen pages are devoted to identifying fossils to a level which will be adequate for most amateurs. The chosen representative samples of the fossils the collector is likely to meet are liberally illustrated with photographs and annotated line diagrams. The bulk of the excellent photographs are by the Institute of Geological Sciences.

The small bibliography will suffice for most purposes, but unusual finds are always worth bringing to the attention of the specialists.

A 'Code of Conduct' insisting on a responsible use of the countryside is inserted as a timely reminder at the end of the booklet. On the back cover is a useful coloured stratigraphical column listing the main fossil bearing rocks.

P.I. Manning

Secretary's Report for 1977

This will be my last annual report to the Society, and it is with great pleasure and satisfaction that I can say that 1977 has been a year of vigorous activity and enthusiastic support. There have been fifteen meetings, nine indoors and six in the field, all well attended and enjoyed. The lecturers whom we have invited to speak to us have all mentioned with appreciation the interest shown by our members, and the leaders of our excursions have expressed their pleasure in leading such keenly interested parties.

The indoor meetings comprised an Annual General Meeting and Collectors' Meeting, a Presidential Address, a joint meeting with the Matlock Field Club, an Annual Dinner, four lectures from visiting speakers and an evening devoted to demonstration of laboratory techniques. There were four day field meetings, a weekend field meeting, and for the second time, a meeting which lasted a week.

At the Annual General Meeting in March, the serving officers were elected to hold office for a further year and four Ordinary Members of Council retired, to be replaced by four newly elected members.

A vote of thanks was proposed to the retiring members, Mr. R.C. Gratton, Mr. N. Green, Mr. D.N. Robinson and Mr. M. Stanley, each of whom had rendered particularly valuable service during his term on Council.

When the business was concluded, a Collectors' Meeting followed. Exhibits had been arranged earlier in the evening, and in the happy, relaxed atmosphere, characteristic of this meeting, members enjoyed a tour of the wide variety of geological items. A list of exhibits follows:

1.	A.E.G. Allsop	"Let's go to the Isle of Skye again."
2.	M. Beaumont	Collection of geological books.
3.	P. Binks	Rocks and minerals mainly from the Peak District.
4.	M. Boneham	"What can it be?" Geological quiz.
5.	D.S. Buist	Columnar sandstone from Kilchallan Bay.
6.	J. Cantrill	Crystals great and small.
7.	W.A. Cummins	(a) Working model of tectonic plates of the East Pacific. (b) Collection of metamorphic rocks.
8.	J. Hayes	Photographic slides of the Edinburgh field excursion.
9.	R.J. Hawkins	(a) Collection of geological instruments. (b) Collection of "The British Geologist".
10.	Cahit Helvaci	Borate minerals from Turkey.
11.	N. Leiter	Collection of old geological books.
12.	D.M. Morrow	Some British granites.
13.	S. Penn	Photographic slides of fossils.
14.	G.S. Robson	Random gleanings.
15.	J.W. Smith	(a) Geological map of Mount Vesuvius with lava and ash samples and thin sections. (b) Photographic slides of the Edinburgh field excursion.
16.	H. Sykes & M. Williams	Collection of Pleistocene mammal bones.

17.	F.M. Taylor	(a) Mineralised Carboniferous Limestone with malachite, azurite and baryte from Cannington Park, Somerset. (b) An algal limestone with corals, Treak Cliff, Derbyshire.
18.	The Editor	Complete series of "The Mercian Geologist".
19.	Dept. of Geology	Examples of fossil preservation.

At the meeting, Mr. J.H. Sykes again offered for sale a stallful of delectable specimens, fossil and mineral, and his business premises were as popular as ever. His total profit amounted to £18.30 and this sum he later donated to the Society's Trust Fund, bringing his total contribution to the fine sum of £143.40. Mr. Sykes thanks members for their generous donation of specimens and their unfailing support of his sale. The Society in turn is very grateful to Mr. Sykes, who gives a great deal of his time to the receiving, storing, mounting and presenting of his wares, thus making considerable contribution to our funds.

In April, Mr. J.B. Delaire came to speak on the subject of ichthyosaur remains. He conveyed to his audience his own keen interest in these ancient creatures, and, indeed surprised his hearers with the wealth of fascinating information which he possessed. His lecture was copiously illustrated by photographic slides and a fine collection of fossil bones.

The weekend field meeting in May was centred in South Wales, the first time the Society has ventured into this beautiful part of Britain. We were fortunate to have for leader Dr. J.D. Weaver of Derby College of Technology, whose knowledge of his home ground was extensive and detailed, and who gave the party a thorough introduction to the most interesting geology and lovely scenery of the North Crop of the South Wales Coalfield.

Also during May a meeting was arranged for the Association of Teachers of Geology, to which members of the Society were cordially invited. The meeting was held in Derby College of Technology and was practical in nature, with the object of demonstrating basic laboratory techniques. This is the first occasion such a meeting has been held and it was a most successful experiment. We are grateful to the staff and technicians who gave their time.

The June meeting was in the hands of Dr. N. Aitkenhead and Mr. I. Chisholm, both of the Institute of Geological Sciences, who led a large party to the Lathkill Dale and Pilsbury area. It is always a privilege to have demonstrated the latest investigations and conclusions by the survey officers who have worked in the area.

An unusual and interesting day was spent in July visiting the Quaternary terrace sediments of the Trent Basin around Derby and Nottingham. There were three leaders on this occasion, Mr. P.F. Jones of Derby College of Technology, who showed and described the various terraces of the River Derwent; Dr. W.A. Cummins of Nottingham University, who demonstrated river habits and sedimentation; and Mr. J.L. Fox, who led the party to Colwick, Nottingham, for a wide succession of items of geological and archaeological interest. We had with us also Dr. C. Salisbury, who described his work in dendrochronology, in connection with fossilised tree trunks at Colwick.

Late in July, the week excursion took place, this time centred in Ayrshire. The party was accommodated in the Craigie College of Education, Ayr, among delectable surroundings, and we were deeply grateful to Dr. E.N.K. Clarkson of Edinburgh University who kindly arranged the week's activities. Not only this, Dr. Clarkson stayed with the party, led the first three excursions, to the beautiful areas southwest of Girvan, to the Craighead limestone inlier, to the incredible graptolite-rich valley near Moffat, known as Dobb's Linn, and in the evenings presented a lecture to describe and discuss the geology of the day. Following this, Dr. W.D.I. Rolfe of the Hunterian Museum, University of Glasgow led a marathon excursion to study the Silurian beds of the Hagshaw Hills; Mr. S.K. Munro of the Institute of Geological Sciences, Edinburgh, showed the Scottish Carboniferous of the Ardrossan area; and finally Dr. B. J. Bluck of the Department of Geology, University of

Glasgow crowned the week with a splendid day among the beautiful rocks of the Ballantrae volcanic complex. We acknowledge our gratitude to all our leaders for this fine week's excursion to such a fascinating corner of Scotland.

The Society does not meet during August, but in September Professor J.E. Prentice of King's College, University of London met a very large party in the Manifold Valley to examine limestones of varying facies at Ecton Hill and in Narrowdale. Professor Prentice pointed out the characteristics and relationships of bedded and reef limestones, and showed how an environment could be inferred by studying bedding types and conditions of fossil deposition.

A visit had been planned in October to visit certain exposures on the new motorway which was under construction near Chesterfield. At the last moment, however, this had to be cancelled, and Dr. F.M. Taylor of Nottingham University stepped gallantly into the breach with a substitute excursion to the Cromford and Wirksworth area. This proved a most enjoyable day, which the party spent in a secluded world, surrounded by fog, but if the views were restricted, the geology was excellent.

The indoor meetings of the winter season began in November with a lecture on the metamorphic rocks of southern Norway. The speaker was Dr. D. Field of the Department of Geology, Nottingham University, who had himself carried out research in this area. In his interesting address, he discussed regional variations in the degrees of metamorphism and related dehydration of rocks to a deep-seated position in the earth's crust.

In December, Dr. B.J. Bluck, who had, during the summer excursion, introduced the Ayrshire party to the rocks of the Ballantrae volcanic complex, came down from Glasgow University to describe them to the Society, and to link them to the theory of plate tectonics. This latter has always been a favourite subject with the Society, and members entirely filled the large lecture theatre to hear Dr. Bluck speak of the unique sediments of southern Ayrshire, and give his interpretation of them.

The Society met twice in January, first when Dr. P.H. Bridges of Derby College of Technology gave a lucid account of the evolution of the Welsh basin. This lecture was doubly appreciated in its corollary to Dr. Bluck's exposition at the last meeting.

A week later, a meeting was held jointly in Matlock with the Matlock Field Club, when three geological films were shown. Two were issued by the National Coal Board, the first gave an interesting report of the new coalfields at Selby and Belvoir, and the second a reassuring account of the reclamation of old coal tips, "eyesores to assets". Less comforting was the third, a BP film entitled "Energy in Perspective", which presented a sobering picture of the lavish wastage of natural fuels during the present century. An official from the N.C.B. was present to lead a discussion.

The Annual Dinner was held in February in the Staff Club of the University of Nottingham. Dr. Taylor again kindly made all the arrangements. This meeting held all its usual warmth and good companionship, and after dinner the party adjourned to a private room for further refreshment.

The Presidential Address next evening had for its subject economic geology in neolithic Britain. The Society was aware already of Dr. Cummins' researches concerning the source rocks of neolithic stone axes, and it was of enormous interest to hear him link the factory sites with the areas in which the axes are found, and suggest probable trade routes between the two.

We are very grateful, not only to our President, but to all our speakers for such a fine series of lectures.

Our excursion leaders, too, merit our most grateful thanks. We cannot be unaware of the busman's holiday our leaders take when, after lecturing or surveying all week, they give the whole of one of their free days to share with us their expert knowledge and experience.

In connection with excursions, one point has been particularly stressed this year, the use of safety helmets when visiting quarries. Since the 1974 Health and Safety at Work Act, quarry owners and managers have been responsible for the safety of visitors to their premises. Naturally, as a result of this, certain restrictions have been imposed, one of them being the wearing of safety helmets. Indeed, some quarry owners refuse admission unless helmets are worn. The Society has, consequently, acquired a stock of these which may be bought by members at any meeting.

The Society continues in its policy of conservation of geological sites, and is vigilant in ensuring that all new members are provided with a copy of its Countryside Code. Certain of our members have offered their services in patrolling the Wilcockson Geological Nature Reserve at Duckmanton, and the Society has donated £20 to help in the production of a booklet to describe its geological features.

Eleven monthly circulars were sent out during the year, a necessary and valuable means of communication with members and, indeed amongst members. Increasingly members have used the circular to obtain information or assistance, and the Secretary may be contacted at any time. It is, however, an appallingly expensive item, costing almost £18 every month in postage. And this cost would be considerably greater if it were not for the help given by individual members who receive several circulars and most kindly deliver nearby ones by hand. This service is enormously appreciated and further volunteers would be welcomed.

It was understandable that after doubling our annual subscription we should lose some members. A small number of institutions left us with some regret and some of our Juniors did not renew their membership, but the great bulk of our members accepted the increase as unavoidable, and we were delighted to welcome many new members. It is with sadness that we recall the death of two of our most longstanding members, Mr. R. Wilmot and Mr. Edmund Taylor, the Society's first Treasurer and a well known figure at all our gatherings.

The state of membership at the end of the year was as follows:

Honorary	Ordinary	Joint	Junior	Institutional	Total
2	276	118	19	112	527

Council met on six occasions during the year to arrange programmes, discuss policy and deal with any business. Although there is a gradual change in the composition of Council over the years, it maintains a wonderfully helpful character and spirit of co-operation. As secretary for eight years, I have had tremendous help and support.

After experiencing such an auspicious year as 1976, the unhappy Editor could only expect vicissitudes to follow, and after publishing Volume 6, No.2, early in the year, he met with delays and disappointments on every hand. In spite of all endeavour, he did not succeed in producing Volume 6, No. 3, until the close of 1977.

The travelling Society exhibit has been much in evidence during the year. Upon completing its tour of museums and libraries in Lincolnshire, it embarked on a tour of those of Leicestershire. It was shown at the conference of United Kingdom Geological Societies in Swansea, and we were gratified to receive an invitation from the Assistant County Librarian to place it on show in the Nottinghamshire County Library in Angel Row. We give our thanks to Mr. M. Stanley who has kindly taken on responsibility for its travels and its maintainance.

Perhaps the most unexpected occurrence of 1977 was the bequest of £1,000 to the Society from the will of Mr. A.E. Frost, unknown to the Society, but described by his solicitors as interested throughout his life in science. The Society was most grateful at this time of desperate inflation to accept this handsome bequest.

In conclusion, I offer the Society's warm thanks to Professor Lord Energlyn and to the University of Nottingham for the free use of their fine premises for our activities, and for my own part, my sincere gratitude to the Society and to Council for a most happy and rewarding term of office.

My best wishes to Mrs. Wright, my successor.

D.M. Morrow

THE MERCIAN GEOLOGIST

Journal of the East Midlands Geological Society

The journal first appeared in December 1964 and since that time 26 parts, comprising 6 volumes have been issued; the last, Vol.7, No. 2, in April, 1979. The Mercian Geologist published articles especially on the geology of the Midlands of England, but other articles have been published which are of current interest to geology generally. Contents include original papers, review articles, biography, bibliographies, excursion reports, book reviews and the Secretary's report on Society activities.

For Contributors:

Authors intending to submit manuscripts of papers for publication in the Mercian Geologist are asked to follow the format of papers included in a recent number of the journal, and if possible to provide two copies. As the journal is read by Members with a wide spectrum of geological interest and ability, authors are asked to ensure adequate introductions for their papers, particularly, if the subject has not been reviewed in the journal over the last few years. The paper should be complete in itself, without the need of the reader to refer to specialist journals not easily available to the average Member of this Society. It follows that the length of the paper may be greater than that published by some other journals but authors are asked to be as lucid and concise as possible and to avoid repetition.

Text-figs. normally occupy a full page of the journal, but part diagrams can be fitted into the typed page. Double page diagrams have been published with a single fold but each printed page has to be folded by hand. The standard reduction by our present printing process is approximately x 0.75. Thus the optimum size for the original diagram, including space for caption, index and explanation if required on the diagram, should be 285 x 190 mm. (285 x 380 mm with a single fold). Greater reduction is possible but care must be taken with the original to ensure that at the final reduced size (230 x 155 mm; or 230 x 310 mm) the smallest letters are no smaller than 1 mm and that there is a similar minimum spacing between letters and lines. Bar scales (metric) should be provided as the exact reduction cannot be guaranteed.

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