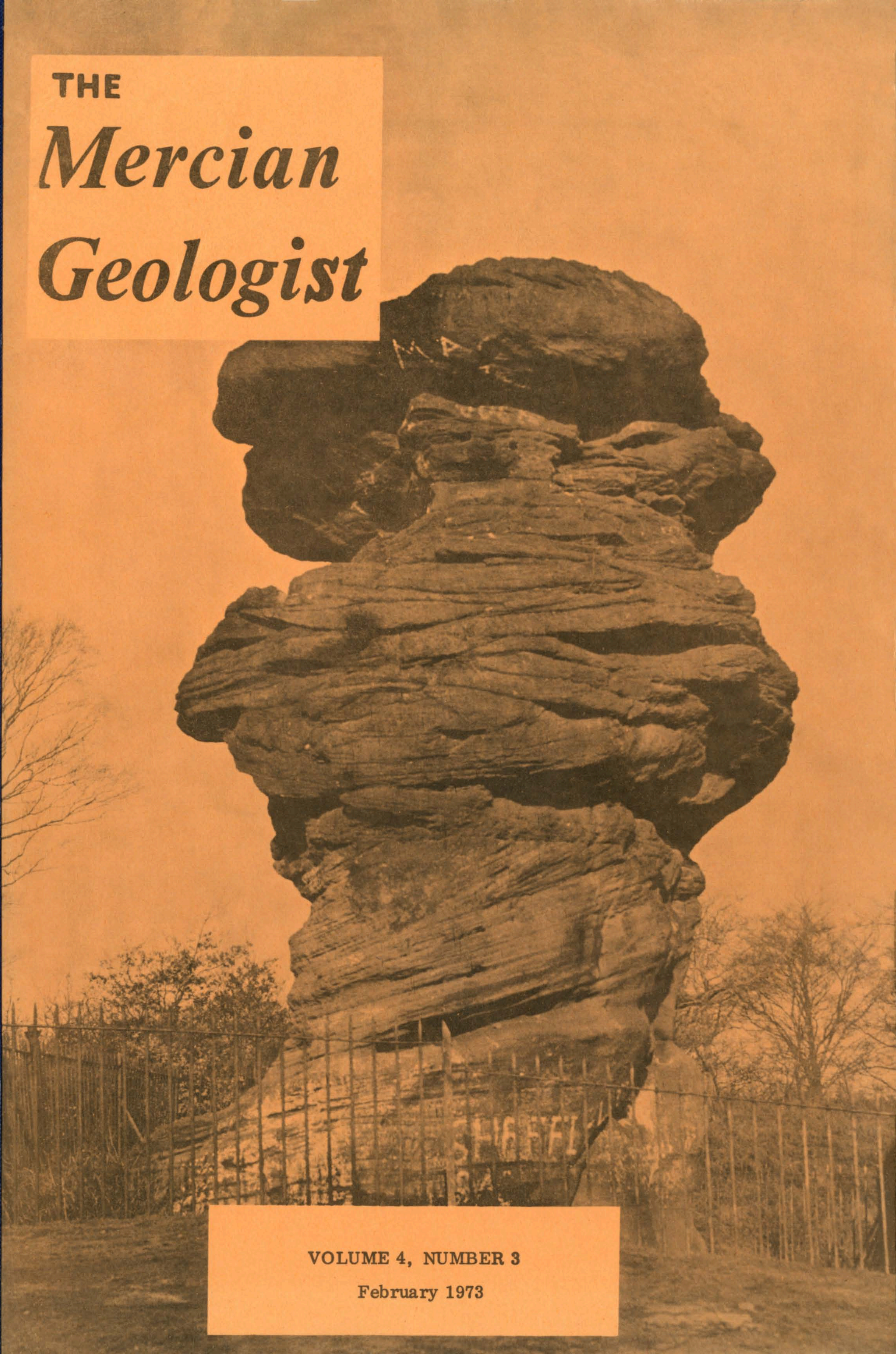
# THE Mercian Geologist



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Front cover: The Hemlock Stone. An isolated stack of cross bedded Bunter Pebble Peds, with barite cement (see Taylor and Houldsworth, this issue, page 174). The origin of the stack has been attributed to marine, glacial and sub-aerial denudation by various authors (see Shipman, 1884, Trans. Notts. Nat. Soc.) and as a quarry remnant (Stukely, 1709). The name suggests celtic witchcraft activities and is probably of great antiquity. Comparable pillars of Lower Keuper Sandstone are found elsewhere. Photograph by A.R.E. Houldsworth.

# THE PERMO-TRIASSIC/UPPER CARBONIFEROUS UNCONFORMITY AT SWANCAR FARM, TROWELL MOOR, NOTTINGHAMSHIRE

by

F.M. Taylor and A.R.E. Houldsworth

## Summary

The occurrence of Mottled Sandstones overlying, unconformably, well jointed brown sandstones, micaceous siltstones and shales, at an old quarry near Swancar Farm, Trowell, Nottinghamshire, is considered to be an example of the local Permo-Triassic/Upper Carboniferous unconformity as yet undescribed. The base of the Permo-Triassic rocks, in this area can now be extended further to the west in a small down-faulted block.

## Introduction

During the search for sandstones containing barite in the area west of Nottingham, the disused quarry (SK 491393), 400 metres west of Swancar Farm, on the east side of the Nottingham Canal, was examined in detail. The discovery of an unconformity in the south east face of the quarry is the subject of this paper. The most recent publication on the area is the 6 inches to 1 mile map, Geological Survey Sheet, SK 43 NW (Dunham 1969) which follows Gibson (1910) and Shipman (1889) and does not show the presence of red beds or the unconformity in this quarry.

## The south-east face of Swancar Quarry

The following sequence of rocks is exposed in the south-east face of Swancar Quarry. (text-fig. 2).

| | | |
|---|---|---|
| Mottled Sandstones | Soft, dark red and yellow mottled, fine-grained sandstones. Coarse, friable, buff sandstone up to 10 cms. thick. | Up to 13 metres exposed. |
| | - - - - - - - - - - Unconformity - - - - - - - - - - | |
| Lower Coal Measures, above the Low Main Coal. | Hard brown micaceous medium-grained sandstones with a weathered top, up to 4 metres exposed.<br>Purple and green micaceous siltstones and shales 1 metre<br>Hard brown micaceous sandstone, 1 metre<br>Purple and green micaceous siltstones and shales. Up to 1 metre seen. | Up to 7 metres exposed. |

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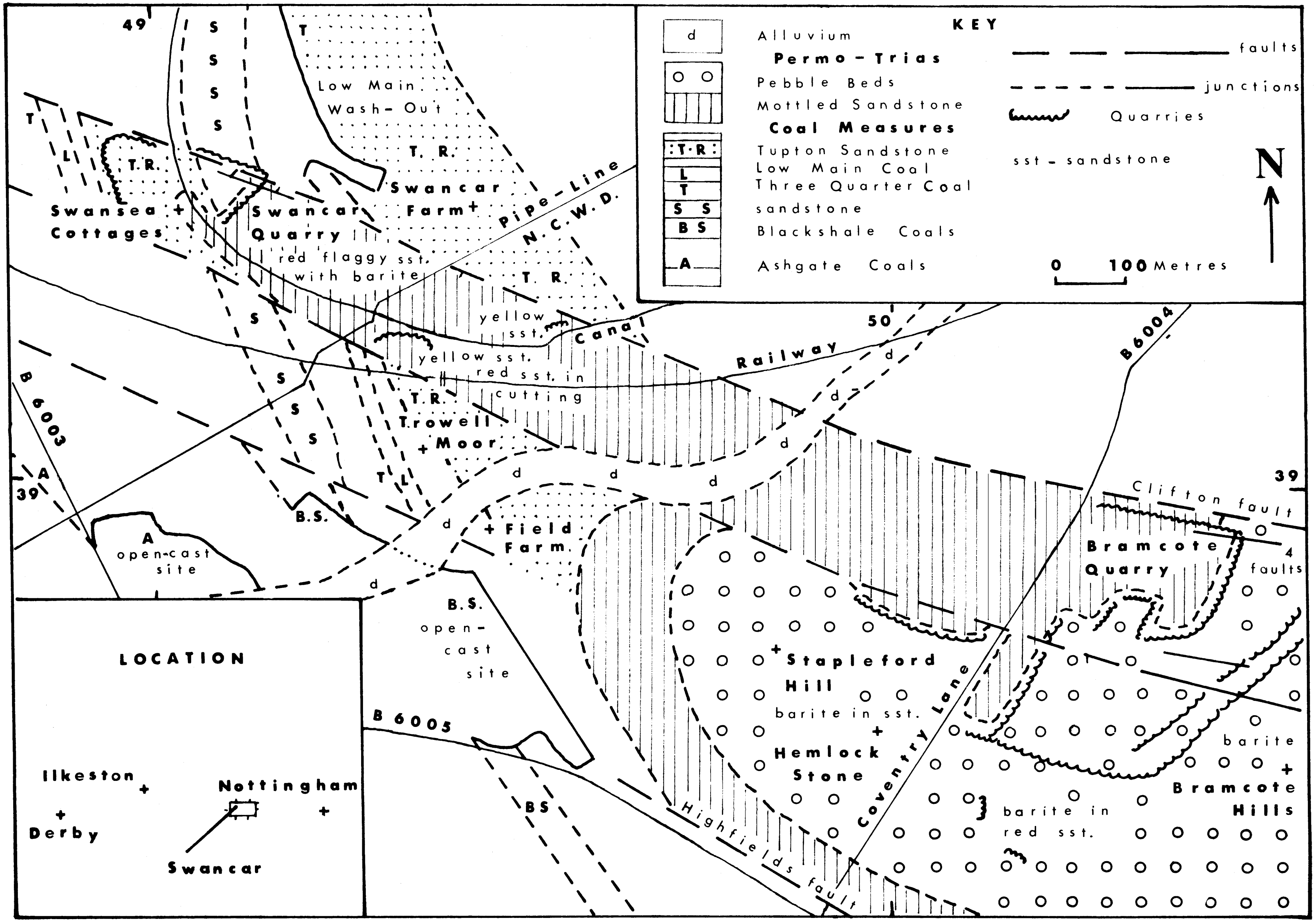

Figure 1. Geological map of the area between Swancar Farm and Stapleford Hill, Nottinghamshire.

Figure 1 The small fault at the north-east corner of the south-east face of Swancar Quarry. Well jointed Coal Measure sandstones can be seen below the fault; soft red and yellow sandstones above.

Figure 2 South-east face of Swancar Quarry showing the unconformity, marked by inverted 'V's. Note the cross-bedded Permo-Triassic sandstones above and the massive Coal Measure sandstones below.

The upper set of beds are lithologically similar to the lowest beds seen in the old Bramcote sand quarry (SK 501389), on the west side of Coventry Lane and are considered to be the Mottled Sandstones of the local Permo-Triassic sandstone sequence. The age of the lower set of beds is in doubt, for the Clifton Fault (text-fig. 1) separates the rocks of the south-east face from Coal Measures sandstones seen elsewhere in the quarry and lithologically the two quarry faces are disimilar. The ground immediately to the north of the quarry was investigated and eventually excavated, as an open-cast coal site and the occurrence of the Three-Quarter Coal and the Low Main (Tupton) Coal, with wash-out structure, and the Tupton Sandstone were proved by the National Coal Board. South of the Clifton Fault these sandstones and coals are faulted to the west, as shown on the Geological Survey map (Dunham 1969). The whole of the Swancar Quarry is shown on this map in a sandstone above the Three-Quarter and Low Main Coals. As drawn on text-fig. 1, the Clifton Fault or possibly one of its subsidiary branches is thought to pass through the north-east corner of the quarry hidden by debris and slip material at this point, but the fault will affect the age of the sandstones underneath the unconformity on the south-east face. So far we have no evidence to prove their stratigraphical position, but consider that the rocks will be above the Tupton Sandstone.

The Mottled Sandstones are predominantly red but with yellow streaks and patches and are without pebbles. The sequence commences with a thin but persistant bed of friable buff sandstone, often containing a yellowish mineral, not yet identified, encrusting the sand grains. Weathered grains of galena may be found in sand filled cracks in the top surface of the Coal Measures sandstone below. Barite cement results in less friable sandstones occasionally. The coarse sandstone passes upwards into typical fine-grained red sandstones with marl partings only a few mm. thick and coarser sandstones lenses somewhat variable in thickness and grain size. The sandstones are strongly current bedded, (Plate 11 fig. 2) and at least six ripple-marked surfaces have been noted. Barite is present in the coarser sandstones resulting in the presence of much harder thin seams of sandstone, variable in thickness and lateral extent, which stand out as small ledges on the weathered quarry faces, (Plate 12 fig. 2). Where the marl layers are well developed, the Mottled Sandstones have a laminated appearance.

The Coal Measures rocks are well jointed sandstones, micaceous siltones and shales. The sandstones are more compact and buff to brown in colour, contrasting with the red sandstones above. In hand specimen the Coal Measures sandstones appear to be without barite, but small grains may occasionally be found in the rocks immediately below the unconformity. In thin section, felspar can frequently be seen and is a distinguishing mineral. The micaceous siltstones and shales form a contrasting unit (Plate 11 fig. 1), the abundant mica producing a fissile rock. The finer grained rocks are frequently coloured red, green or purple, a common alteration phenomenon of Coal Measures rocks close to the Permo-Triassic unconformity.

## The unconformity

The exact line of the unconformity, in the quarry face, is difficult to see from a distance and does not photograph well. (Plate 11 fig. 2). There is no basal breccia or conglomerate visible in the quarry face, although blocks of breccia, unfortunately not in place, were seen near the lane adjacent to Swansea Cottages (SK 490393). The unconformity is marked by a thin friable sandstone which transgresses the underlying hard sandstone. The latter has a weathered top and is discoloured in places although not to the same extent as the finer-grained siltstones and shales below. The unconformity was also seen in a temporary exposure behind Swansea Cottages. Here the soft red beds were deposited in a small, steep-sided channel eroded into the hard sandstone.

## Red beds east of the quarry

In an effort to trace the Mottled Sandstones eastwards from the Swancar Quarry across fields and a small valley, to link up with outcrops mapped on Stapleford Hill (SK 498387), test pits were dug to sub-soil and rock depths, on a 10 metre grid basis. The occurrence of barite in red flaggy sandstones, below soil level was taken to indicate the outcrop of the Mottled

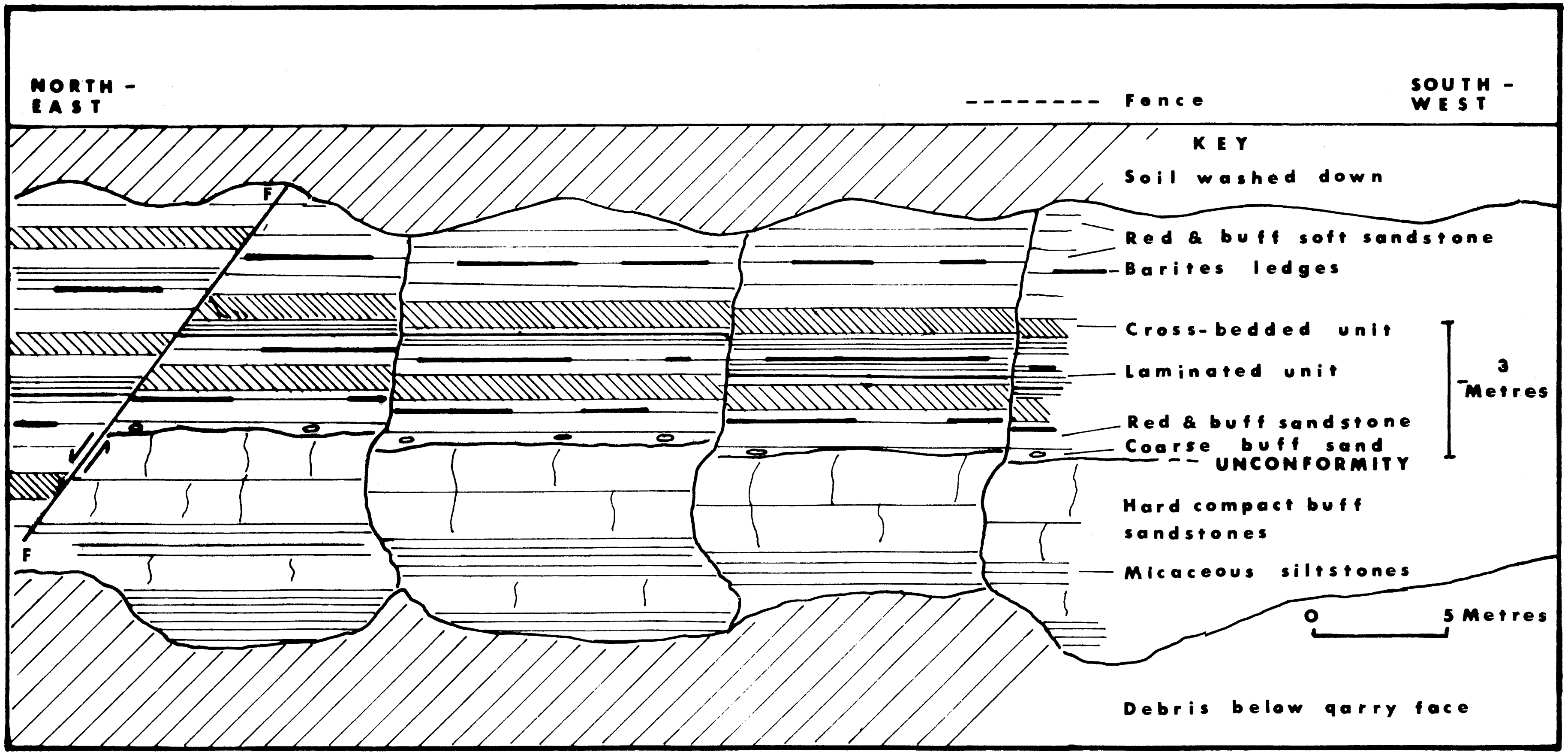

Figure 2. Diagram representing the succession in the south-east face of Swancar Quarry, showing the position of the unconformity and the lithological contrasts above and below it. The rock layers above the unconformity are thin and are not drawn to scale.

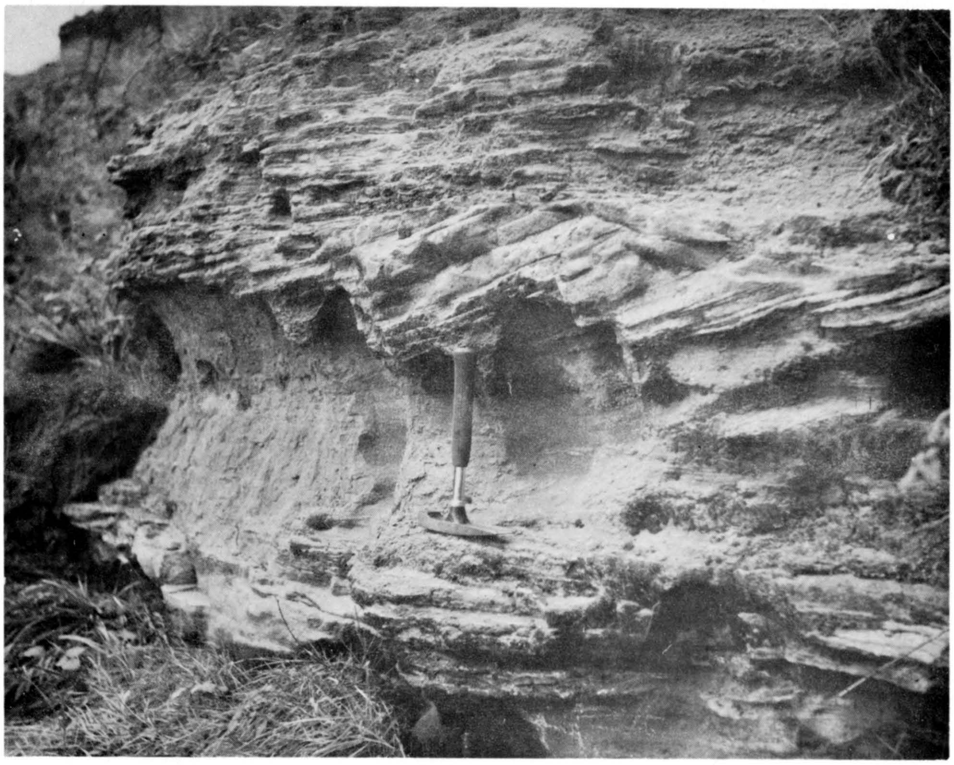

Figure 1 Old quarry face (SK 493392) in yellow cross-bedded sandstone, with prominent ledges cemented by dolomite and barite.

Figure 2 Swancar Quarry. South-west end of south-east face showing red and yellow mottled sandstones with ledges of harder rock cemented with barite.

Sandstones. In many places the soil was brown, sandy in part, clayey elsewhere and probably derived from weathered Coal Measures, the result of downwash from the higher ground north of the Clifton Fault, not of tipping during open-cast excavation, since we were assured by the National Coal Board's records of the site and by Mr. R. Moss, owner of Swancar Farm, that no such tipping had occurred in that area. These excavations showed that the Clifton Fault lies a few metres south of the line chosen by the Geological Survey Officers (Dunham 1969) and is in line with the north-east corner of Swancar Quarry.

South and south-west of Swancar Farm, red beds are clearly indicated by soils containing fragments of red flaggy sandstone with barite, which also appears as a rubbly or nodular component of the soil due to its insolubility. Barite cemented flaggy sandstones with thin interbedded grey-green clays were exposed in a trench excavated for a mains water pipe-line, (Nottingham Water Department, River Derwent Abstraction Scheme) excavated in 1968. Further excavations on the site have revealed the presence, at the junction of a red clay overlying yellow sandstone, of a fibrous mineral similar to gypsum in crystal form, which on subsequent analysis, proved to be barite.

An old quarry (SK 493391) south of the canal, exhibits a sequence of current bedded soft yellow sandstones (Plate 12 fig.1), cemented in part by dolomite. Small scale asymmetrical ripple marked surfaces, with dessication cracks are visible. On the north side of the Nottingham Canal the same beds were noted beneath red sands with barite in a recent trial bore-hole for the proposed route of the M. 42, Birmingham - Nottingham Motorway. Similar beds close to the Clifton Fault were seen in a now in-filled quarry (SK 495392) south of Swancar Farm. Finally, red beds with barite have been located in the nearby railway cutting (SK 494392).

Dolomite is not unknown from the lowest horizons of the Mottled Sandstones and was used by Swinnerton (1948) and others as evidence for the Upper Permian age of the rocks. The lithology and colour of the sandstones in the old quarry south of the canal is so unlike anything else in the area as to suggest possible age differences or de-colourisation by frictional heat from adjacent fault planes.

The stream at Field Farm, (SK 495389) flows in a small drift-filled valley, which separates the Swancar Farm area from the main outcrops on Stapleford Hill. At its lowest possible position, on Stapleford Hill, the unconformity is still too high topographically, to be joined directly with that north of the stream and a fault is therefore inferred between the two outcrops. A fault, in approximately the correct position was encountered in old workings in the Kilburn Coal and is shown on the old Geological Survey, six inches to one mile, map (Gibson 1910). This fault was also seen in the trench excavated for the mains water pipe just north of the railway line.

## Faulting

The three faults described from the Swancar area, the Clifton Fault, a small fault a few metres to the south, and the fault forming the southern boundary of the Permo-Triassic outcrop, can be traced eastwards to the new Bramcote Sand Quarry, (SK 504387) on the east side of Coventry Lane and further east across Wollaton Vale to Nottingham University (Taylor 1965). Exploratory investigations from the sand quarry, fix the Clifton Fault along the lane leading to Moor Lane Farm (now a Restaurant). There are four closely spaced, vertical faults in the north-east corner of the quarry, which together are the equivalent of the one seen in Swancar Quarry (Plate 11 fig.1) although here, small adjustment faults can be seen to leave the main structure. The southern boundary fault of the extended Permo-Triassic outcrop can be traced across the northern flank of Stapleford Hill and was located towards the southern end of the new Bramcote Sand Quarry, where it is located within the Pebble Beds outcrop. In the lower part of the quarry, the fault seemed insignificant, with a fracture zone only 50 mm. wide and no visible displacement. At higher levels in the quarry and further to the east, the fracture zone was more extensive, over 5 metres wide, mineralised, and in the centre, there was a well developed fault breccia. The fault has now been traced across the top of the quarry for a distance of over 50 metres. The throw of the fault, as shown by the displacement of a bed of pebbly sandstone containing large marl fragments was 6 metres. The main fault plane showed vertical slickensides. A further fault, 13 metres north of the above fault, displaces the same bed, vertically, 1.7 metres.

## Conclusions

With the discovery of red beds in the Swancar Quarry area, the outcrop of Permo-Triassic rocks can now be extended approximately 700 metres west of the main outcrop on Stapleford Hill, in a downfaulted block. The unconformity of the red beds on local Coal Measures is well displayed in Swancar Quarry.

## Acknowledgements

The authors wish to acknowledge the very generous help and permission to excavate, made readily available to them by Mr. R. Moss of Swancar Farm, Trowell. Records kept by the National Coal Board, Open Cast Division, Cinderhill, and those kept by the Nottingham City Water Department have been made freely accessible to the authors and information given on the various sites has been used in this publication. Permission given by the Midland Road Construction Unit, Matlock, to examine bore-hole cores and general discussion with their geologist, Dr. D. Buist, is acknowledged. Mr. E. Winks and Mr. P. Spencer have helped collect field samples, which have been used in collating evidence for this paper.

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# THE DISTRIBUTION OF BARITE IN PERMO-TRIASSIC SANDSTONES AT BRAMCOTE, STAPLEFORD, TROWELL AND SANDIACRE, NOTTINGHAMSHIRE

by

F.M. Taylor and A.R.E. Houldsworth

## Summary

The geographical and stratigraphical distribution of barite, in an area to the west of Nottingham, is described. The association of the mineralisation with faulting is considered significant. Other locally occurring minerals are mentioned and it is concluded that there is a restricted region of intense barite mineralisation in a severely faulted area. The origin of the barite is still in doubt.

## Introduction

The knowledge that barite is to be found in the sandstones of Bramcote and Stapleford Hills (SK 500387) dates from papers by Clowes (1885 - 1893). Most references, for example, Blake (1892), Gibson (1908), Lamplugh (1910), Edwards (1951) and King (1966), are merely records of its occurrence and give little evidence for its geographical and stratigraphical distribution. The discovery of barite in sandstones excavated from a trench for a mains water pipe, near Swancar Farm, Trowell, led to a review of the literature and the realisation that there was little detailed information published. Using the Bramcote and Stapleford Hills area as a centre, a wide search was undertaken of all exposures available at the time, to determine the geographical and stratigraphical distribution of the mineral. At the same time, other geological evidence was assembled, much of it already known, with the hope that something new would turn up to shed light on the origin of the barite in this area. The work was stimulated by the account of the mineralised Triassic sandstones of Alderley Edge, Cheshire, by Warrington (1965).

## Detection of barite

This section is included mainly to assist Members of the Society to look at Permo-Triassic sandstones and observe even small amounts of barite in the rocks and perhaps record the data for a wider survey of the distribution of this mineral.

Sandstones containing over 25% barite are easily recognised in hand specimen (Plate 13 fig. 2), tabular crystals up to 20 mm. in length standing out on the weathered surfaces. On freshly broken surfaces, there is a characteristic reflection from the crystal and cleavage faces, varying in intensity on rotation of the specimen, the well known phenomenon of 'lustre-mottling'. Most of the crystals are pink, but some are buff or white. The specific gravity of the sandstone is high, between 3.2 and 3.7, compared with 2.6 for a sandstone without barite. The mineral is almost insoluble in normal ground water and the soils derived from these sandstones have a characteristic rubbly or nodular appearance.

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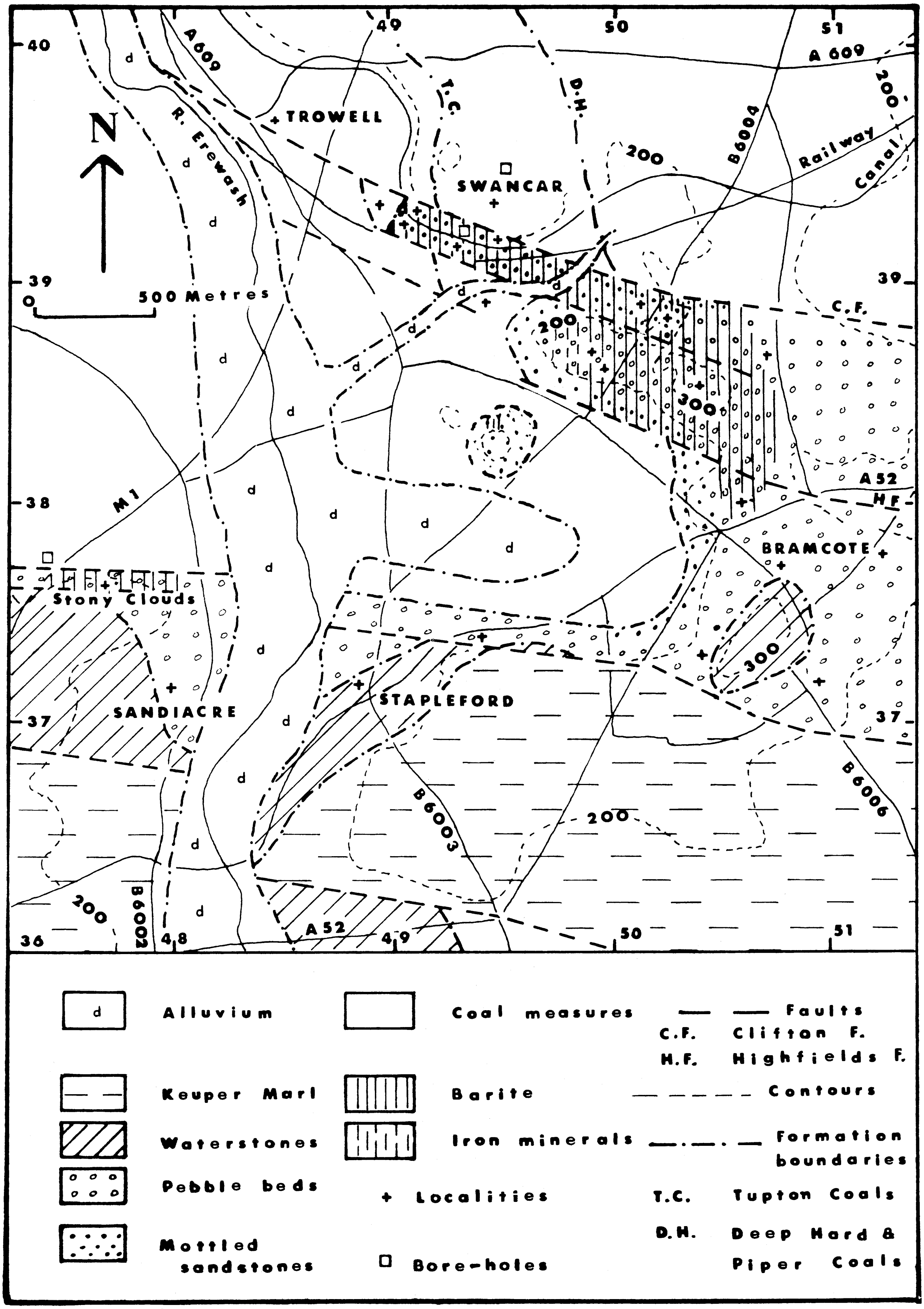

Figure 1. Geological map of the Bramcote, Stapleford, Trowell and Sandiacre area, to show the distribution of barite in Permo-Triassic sandstones.

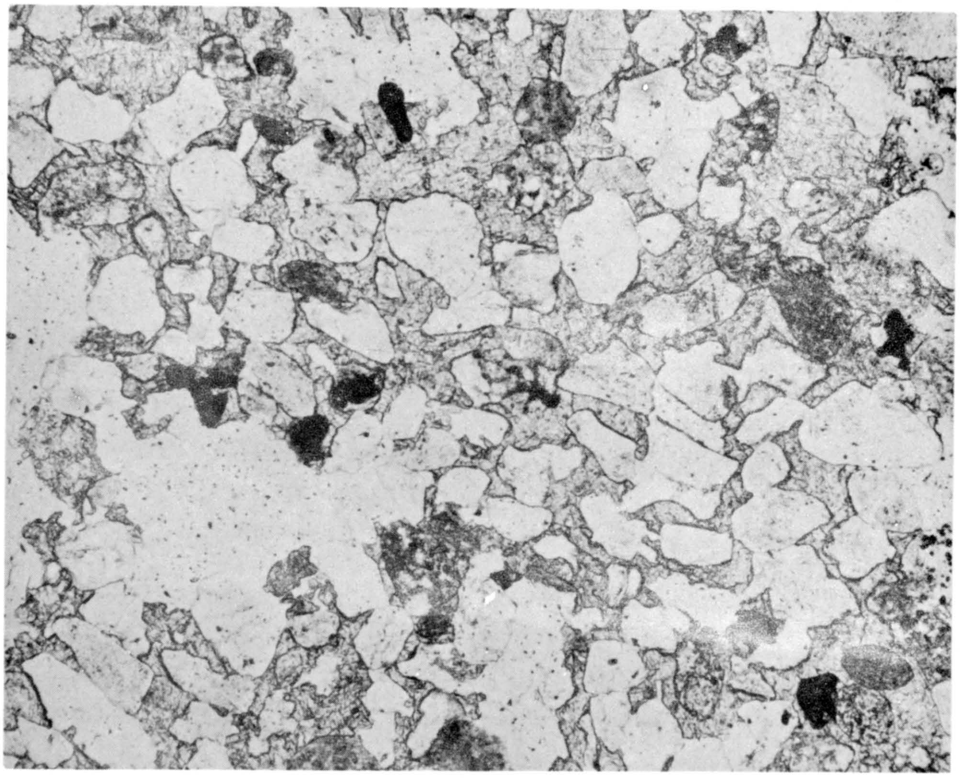

Figure 1 Photomicrograph of thin section of sandstone cemented with barite. Note the sharp crystal boundaries and the barite which appears grey.

Figure 2 Block of sandstone with 30% barite, developed in the rock as large tabular crystals, standing out on the weathered surface.

The mineral is less obvious in sandstones with between 25 and 10% barite. When the bedding is well developed, the sandstones are flaggy. Barite fills the pore spaces and encloses quartz grains in large irregular crystals. The sandstone is well cemented compared with rocks without barite and possess a characteristic pinkish colour. In this section (Plate 13 fig. 1 and cover of Mercian Geologist Vol. 1, No.4), the well marked boundaries of the crystals are due to the high refractive index of barite compared with quartz, whereas the polorisation colours (birefrigence) are about the same as quartz. The specific gravity of the rock is now between 3.0 and 3.2 .

A barite percentage, less than 10%, was more difficult to determine. Initially specimens were analysed for barium using the Philips X-Ray Fluorescence Spectrometer at the Department of Geology, University of Nottingham. For speed of operation, known high and low percentage barite sandstones were used as standards. In addition specific gravity determinations were made for many of them, although values below 2.8 may not be of significance, since iron oxide coating the sand grains may produce a similar result. Thin sections were made of a number doubtful samples. Eventually, with experience, it was possible to detect in hand specimen as little as 5% barite.

It is realised that strontium sulphate, celestine, has similar density and optical properties to barite. Investigations are progressing to determine the possible extent of celestine in the sandstones or the substitution of strontium for barium in the barite.

## The distribution of barite

### Geographical distribution

The areal extent of barite (text-fig.1) lies mainly between the Clifton and Highfields Faults, but there are small outcrops to the south of the Highfields Fault at Crow Hill (SK 505380) and a small outlier (SK 496384) 560 metres south-west of Stapleford Hill, where a small hill is being developed as the Albany Housing Estate. In the first case, weathered sandstones contain abundant barite material and in the second, flaggy sandstones in house foundation trenches in the northern part of the outlier, only, contained a small amount of barite. In the main area of Bramcote and Stapleford Hills, sandstones rich in barite form the higher ground, the best samples being obtained above the British Industrial Sands' Quarry, Bramcote (SK 504387) and close to the summit of Bramcote Hills. Two small abandoned quarries (SK 501385) on the west flank of Bramcote Hills, about midway in the Pebble Beds sequence contain sandstones with large barite crystals. These quarries are at about the same horizon as those forming the Hemlock Stone, which also has layers of sandstone well cemented with barite.

South of Derby Road (A.52), sandstones of the same type, outcrop at Bramcote Village (SK 509372), Bluebell Hill (SK 505375) and in Stapleford at quarries below Bob's Rock (SK 492373), but barite has not been found. These exposures are adjacent to the Beeston Fault, a major dislocation comparable with the Clifton and Highfields Faults to the north. The sandstones are not mineralised in the vicinity of the Beeston Fault and no barite was observed in a temporary exposure of the fault, south of Bramcote Village. Many other exposures have been examined, including quarries and roadside exposures in the vicinity of Sandiacre Church (SK 480372) and road cuttings at Cow Lane (SK 512378) and Moor Lane (SK 508388), both near Bramcote. In none of these localities do the sandstones contain any significant amounts of barite. A record of this mineral at Bramcote Hall, (Gibson, 1908), has not been confirmed. It is possible that there may be confusion here with the new Hall built on the south side of Bramcote Hills, where barite is seen, and the old Hall in the village. The same author recorded barite as far east as Wollaton Vale, but the present work records the distribution only as far as Moor Lane (text-fig. 1).

On the west side of the Erewash Valley, sandstones containing up to 10% barite have been found at Stony Clouds (SK 477377). The Pebble Beds at this locality dip steeply to the south and there is extensive faulting (Dunham 1969). A northern boundary fault is similar in effect to the

Clifton Fault downthrowing to the south, against Lower Coal Measures to the north. The southern boundary fault is a small structure, separating the Pebble Beds from the 'Keuper Basement Beds' (Taylor 1965) and also downthrowing to the south. A number of cross-faults divide the sandstones into small outcrops. There appears to be no continuity of outcrop across the Erewash Valley and the structures may be more complex than is shown in text-fig.1.

## Stratigraphical distribution

Of all the Coal Measures rocks in the vicinity, coarse grained sandstones were thought most likely to contain barite. The nearest exposures of such sandstones are the north-east face of Swancar Quarry (SK 491393) and the old quarry (SK 489393), immediately to the west near Swansea Cottages. The first is a coarse sandstone below the Tupton Sandstone, whilst the second is probably the Tupton Sandstone itself (Taylor & Houldsworth, 1972 fig.1). Acting on information received from Mr. R. Moss, the remaining sections of a bore-hole core drilled in 1934 were discovered under a hedgerow at Swancar Farm. The bore-hole passed through the Tupton Sandstone north of the Clifton Fault. None of these samples, from close to the Clifton Fault, contained barite, nor did other samples from close to the southern boundary fault or those from further afield, as far north as the type locality of the sandstone near Chesterfield, Derbyshire. The only Coal Measures sandstones that contained a small number of barite crystals occurred immediately below the unconformity in Swancar Quarry. Barite was located on joint surfaces on the north-east face of this quarry at a point closest to the Clifton Fault.

Barite is found in the Permo-Triassic sandstones immediately above the unconformity. The Mottled Sandstones are mainly fine-grained with thin marl seams. The barite occurs as a cement in the sandy layers, in thin seams up to 20 mm. thick and is best developed in the coarser beds. The mineral can be found in the Mottled Sandstones throughout the area between the Clifton and Highfields Faults wherever the beds are exposed, but the best locality is at the north end of the Bramcote Sand Quarry. The rocks, here, are close to the Clifton Fault, although it is not exposed in the quarry, and are much less friable than is usual for the Mottled Sandstone Formation. Elsewhere, the mineral occurs impersistently, binding the grains together and imparting a pinkish tinge to the rock at maximum concentration.

As the grain size of the sandstones increases, the Mottled Sandstones pass upwards into the Pebble Beds. Large barite crystals are developed in the coarser beds. Pebble Beds with well developed barite crystals occur midway in the sequence, at the Hemlock Stone and two small quarries on the west side of Bramcote Hills; higher in the sequence at the top of the Bramcote Sand Quarry. The top bed of the Pebble Beds contains the largest number and biggest pebbles and has been shown by Swinnerton (1948) and others, to contain a calcite cement in many places. Barites occurs immediately below this bed. The Hemlock Stone illustrates the irregular vertical distribution of the barite which accounts for the stark weathered appearance of this isolated stack (cover of this issue) and of quarry faces which have been left to weather for a number of years. Wind, rain and frost action, remove the finer, softer, uncemented beds, leaving the well cemented layers projecting as ledges (Taylor & Houldsworth, 1972 Plate 13 fig.2).

It is concluded that porosity of the sandstones, increasing with grain size, is a controlling factor in the occurrence and growth of barite crystals.

## Barite and sedimentation

As seen at the present time, the Mottled Sandstones and Pebble Beds are essentially arenaceous deposits, with thin beds of marl. Swinnerton (1948) records a marl bed near Blidworth, Nottinghamshire, over 1 metre thick, but this thickness is exceptional. In our area, marl occurs in the Mottled Sandstones in thin seams only a few mm. thick, well displayed on the north side of Stapleford Hill, and in the Pebble Beds, mainly as marl fragments. These fragments are all that remain of, formerly, more extensive layers, which may have included evaporite minerals, that were eroded with deposition of succeeding sandstone layers. Most of the sandstones are cross-bedded (see cover of this issue) but more regularly bedded sandstones are present in the Mottled Sandstones. No detritial grains of barite have been seen and it is concluded that the mineral developed within the sandstones after deposition. This results in the flaggy sandstones characteristic of parts of the Mottled Sandstones and the more massive beds within the Pebble Beds Formation. Barite fills the available pore spaces enclosing quartz grains and in the coarser sandstone with maximum porosity tabular crystals are formed. A fibrous form of barite, from a locality to the south of Swancar Farm, (Taylor and Houldsworth 1972) was interbedded with marl layers. Infilled dessication cracks in the marl underlying the barite were preserved. It is possible that his form of barite is a pseudomorph after gypsum.

## Barite and structure

The maximum development of the barite mineralisation is restricted to the area between the Clifton and Highfields Faults in the Stapleford and Bramcote Hills area (text-fig. 1). Both the faults can be traced for a considerable distance between the Trent and Erewash River Valleys, yet the barite mineralisation is largely restricted to the area under consideration. The Clifton Fault hades to the south, whilst the hade of the Highfields Fault is to the north. It is possible that at depth the two faults meet and become a single fracture. There are a number of subsidiary faults in the same area, some of which have been described by Taylor and Houldsworth (1972). Stapleford Hill and Bramcote Hills are separated by an erosion hollow and similar topographical features occur on Bramcote Hill, all of which may be controlled by faults. Although some of the mineralisation can be found to the south of the Highfields Fault, it very quickly dies out in that direction. Unfortunately, in the Bramcote area there are no Permo-Triassic rocks north of the Clifton Fault and the only evidence that this structure may be connected directly with the mineralisation is the occurrence of barite on joint surfaces of the sandstone noted on p. 174. There is a complete absence of barite in any of the fault planes seen in the Bramcote Sand Quarry although sections of the two main faults have not been available for study, in the Bramcote - Trowell area. The Stoney Clouds area, Sandiacre, with 10% barite in the sandstone, is again situated in a faulted locality.

## Comparison with Alderley Edge, Cheshire

The mineralisation of the Lower Keuper Sandstones of Alderley Edge, Cheshire, is described by Warrington, (1965) and Warrington and Thompson (1971). A further visit was arranged to study barite mineralisation of this area in detail. Although the age of the mineralised rocks of Alderley Edge differs from that in the Bramcote and Stapleford Hill area, the barite mineralisation shows many similarities. The development of crystals in the most porous sandstones is identical in the two areas and there are also large faults present. On Alderley Edge there is extensive copper mineralisation, traces of which can be located throughout the area at the present time. These minerals are largely absent from the Bramcote area. Warrington (1965, p. 127) considers that the Alderley deposits are epigenetic in character, possibly from an acid igneous mass at depth.

## Other minerals

Calcite is significant as a cementing mineral in some of the Permo-Triassic sandstones. It has been found in fault planes often accompanied by dolomite lining the cavities of geodes. Calcite is the more common cementing mineral of the top bed of the Pebble Beds Formation.

Various iron minerals occur as principal cementing materials but excessive amounts can be found on the west face of Stapleford Hill, in the form of limonite. Some sandstones possess a green iron mineral, not identified, although tested for copper.

Because of the record of a copper mine in the area, (Gibson 1910) on the north side of Stapleford Hill, a careful search was made for copper minerals without success. Gypsum has only been recorded in a bore-hole drilled close to the fault north of Stony Clouds at the side of the M.1. Motorway (Midland Road Construction Unit, Matlock, M.42 exploratory bore-hole) on joint surfaces of the Crawshaw Sandstone. It is common in the Keuper Marls to the south. (Taylor 1965). Its presence may be inferred in marls within the Pebble Beds, from the occurrence of fibrous barite.

## Origin of the barite

Although mineralisation of the Hemlock Stone was known before 1880, Clowes (1889 - 1895) was the first to test the mineral and identify it as barium sulphate. In his papers, he drew attention to the insolubility of barite in ground water and concluded that the mineral must have been precipitated from a chemical reaction, suggesting the oxidation of barium sulphide, a more soluble mineral, or the double decomposition of barium carbonate and calcium sulphate, both soluble. Warrington (1965, p.127) considers that the Alderley deposits are epigenetic in character, migration of the mineralising solutions being assisted by faulting. The syngenetic origin of minerals, including barite, deposited from hot springs and brines has been reviewed in papers by King (1966) and Dunham (1970) and with reference to modern examples by Degens (1969).

We have found no new evidence which can be used to assist in the choice between any of these possible origins for the barite. There is some calcium carbonate in the rocks which would favour Clowes' hypothesis of double decomposition if the calcium carbonate could be proved to be the result of this reaction. There would still be the need to account for the source of barium carbonate. There are two possible sources of calcium sulphate. The first is the Keuper Marl, which almost certainly covered the area above the Pebble Beds prior to erosion but it is possible that gypsum was precipitated in the marl layers of the Pebble Beds and became incooperated with the succeeding sandstones on resumption of normal sandstone deposition. Our fragments of fibrous barite is the sole evidence for this idea.

## Conclusions

In the Permo-Triassic sandstones, west of Nottingham there is a concentration of barite in the Bramcote and Stapleford Hills area. Barite occurs throughout the sequence, but is particularly well developed in the coarser sandstones of the Pebble Beds. The Bramcote and Stapleford Hills are bounded by two important faults with a number of smaller ones, one of which has been shown to contain iron and carbonate minerals, but no barite. The absence of barite in the sandstones associated with the Beeston Fault emphasises the restricted distribution. Similar mineralisation at Stony Clouds, is well developed and may be independent of that of the Bramcote area. The presence of copper minerals at Alderley Edge, Cheshire, reduces the development of barite to secondary importance in most accounts, but the barite mineralisation is comparable with that at Bramcote.

The origin of the barite is still in doubt, but its occurrence in well faulted areas suggest that the faults are not incidental but have aided the migrating mineralising solutions. Calcium sulphate was possibly available and may have been one of the minerals involved in the formation of barium sulphate but there is even less evidence for barium carbonate (Clowes 1889) or barium chloride (Dunham 1970) as a source of the barium.

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# THE CARBONIFEROUS LIMESTONE OF MONSAL DALE, DERBYSHIRE

by

Nicholas J.D. Butcher and Trevor D. Ford

## Summary

The sequence of the Carboniferous Limestone Beds of the $D_2$ subzone, occurring above the Millers Dale Beds, is described and mapped in detail for the first time. The sequence consists largely of two divisions, the Monsal Dale Group below, totalling some 660 feet (200 m), and the Ashford Beds above, totalling 145 feet (44 m). Both thin south eastwards. The Monsal Dale Group is redefined to include the Station Quarry Beds of Cope (1933) which are not separable from the overlying beds over much of the area. The Upper Millers Dale Lava is thus within the lower part of the Monsal Dale Group. This lava is correlated with the Upper Fin Cop Lava of Bemrose (1907). The Monsal Dale Group contains several marker coral beds at Upperdale, Hob's House and White Cliff, and the Rosewood Marble Bed provides another useful marker. The Ashford Beds are thought to be equivalent to the Eyam Limestones. Within the Monsal Dale Beds some limestones with abundant *Gigantoproductus* are shown to be slumped or turbidite horizons of little value in correlation. Numerous other slumps and turbidites are noted, in a quasi-basinal environment. Scattered *Lingula* valves in these "basinal" limestones are thought to have originated from an epi-planktonic environment. Sedimentological and structural notes are included and an appendix provides a guide to the sections seen in the abandoned railway cuttings.

## Introduction

Although Monsal Dale is visited by numerous geological parties, and the section therein was part of the "type" section described by Sibly (1908), no detailed geological map he published of the Dale and the details of the sequence published by various writers leave many discrepancies. The present paper attempts to fill the gap. The field mapping was carried out by the first author, under the guidance of the second, as part of his undergraduate course at the University of Leicester, during 1969 and 1970. Thus presented here for the first time are a detailed geological map of Monsal Dale (Fig. 1) and a statigraphical correlation and lithofacies chart (Fig. 2).

Monsal Dale lies on the eastern flank of the "Derbyshire Dome" of Carboniferous Limestone. It forms part of the valley of the River Wye, here incised some 500 feet (150 m) below the plateau. The hillsides are thickly covered with Pleistocene screes, and often densely vegetated, whilst the plateau is almost entirely covered by a drift of residual soils, chert gravels and occasional patches of till. The only reasonably continuous section in the area is that along the railway cuttings (Fig. 4) which, until abandonment a few years ago, were effectively inaccessible.

## Previous Research

The "current" Geological Survey map of the area is Old Series Sheet 81SE, published in 1852 and revised in 1867. The Institute of Geological Sciences are currently remapping the area and the sheet and memoir immediately to the north have recently been published (Sheet 99; Chapel-en-le-Frith; Stevenson and Gaunt 1971). Subsequent to the Old Series map and Memoir (Green 1869 and 1887), Bemrose (1907) gave a comprehensive description of the

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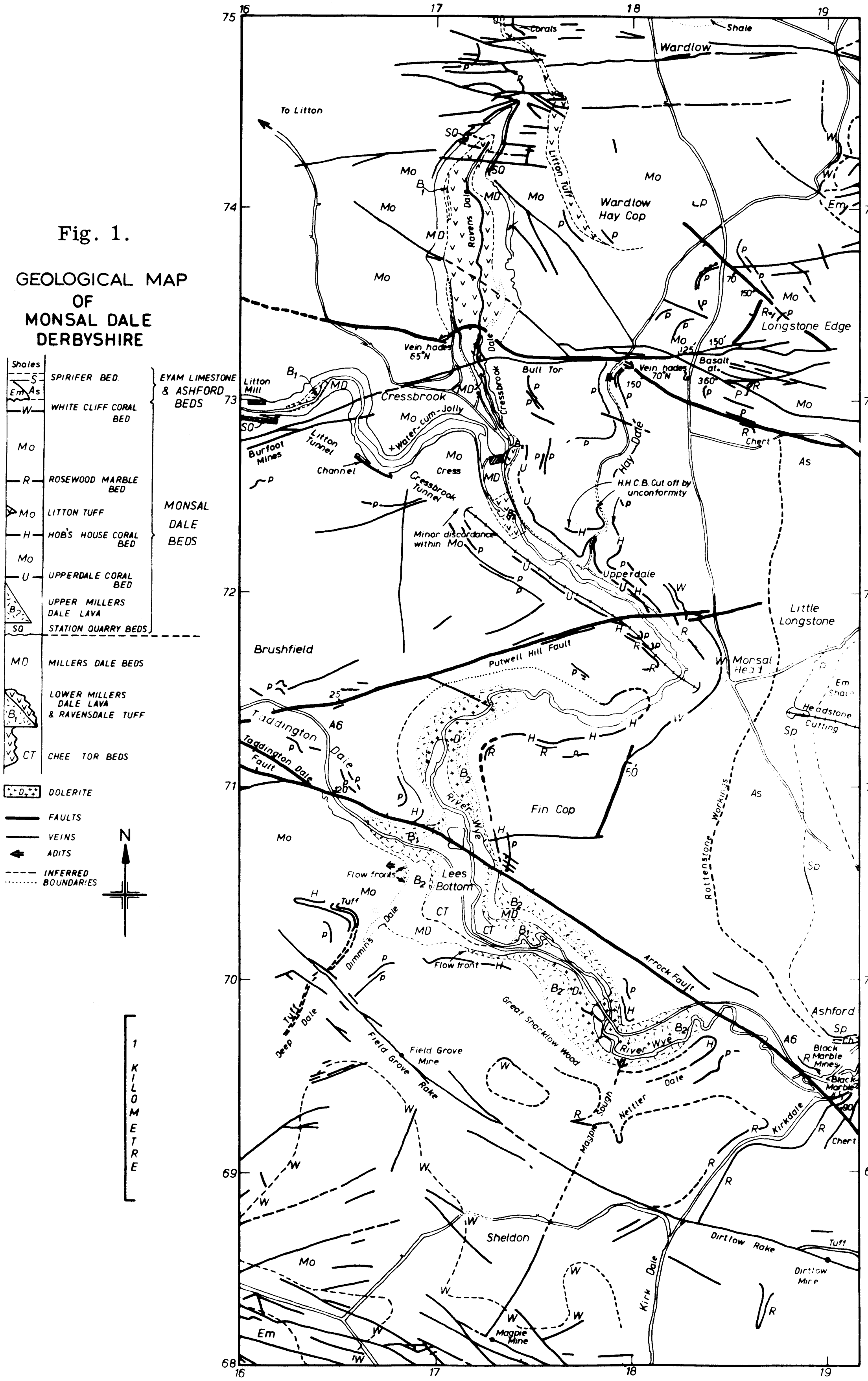
1973, pp. 179-195

Fig. 1.

GEOLOGICAL MAP OF MONSAL DALE DERBYSHIRE



distribution and petrography of the igneous rocks, though he left some outcrops uncorrelated. Sibly (1908) used the Wye Valley, including Monsal Dale, to establish sub-divisions of the Dibunophyllum Zone, $D_1$, $D_2$, and $D_3$. Following this, Cope (1933, 1937) described a 'standard' Wye Valley succession with sub-divisions named from the Millers Dale area. Shirley and Horsfield (1945) described and gave a detailed map of the succession in the Eyam area to the north-east, and Shirley (1958) has described the Monyash area to the south. Stevenson and Gaunt (1971) have included descriptions of the sections at the head of Cressbrook Dale, on the northern margin of the present area, and the mineralogy of some of the clay wayboards

Thus Monsal Dale lies in between areas with detailed maps. Although the sequence has been outlined by the above, by Eden (1954) and again by Cope (1958 and 1967), there are differences between the accounts, particularly in the placing of certain coral marker beds. For example, Cope placed the Hob's House Coral Band at less than 100 feet above the Upper Lava whilst Eden placed it 200 feet above; Cope's estimate of the thickness of the Monsal Dale Beds was less than 400 feet, whilst Eden's estimate was 500 feet.

Unpublished work by Taylor (1957) and Cockbain (1957) has added some detail on the corals and sedimentology. More recently Walkden (1970) has described the sedimentology of some sections along the railway, and the mineralogy of some of the clay wayboards (Walkden 1972).

## The Stratigraphic Succession

The formational names introduced by (Cope 1933, 1937 and 1958) are retained herein, though with some revision of thicknesses and boundaries as discussed below. The full succession is:-

| | | | Thickness |
|---|---|---|---|
| $P_2$ | Eyam Group | Viséan Shales | . . . ? . . . |
| | | Ashford Beds | 145 feet (44 m) |
| $D_2$ | Monsal Dale Group | Monsal Dale Beds | 500 feet (150 m) |
| | | Upper Millers Dale Lava | 0-100 feet (30 m) |
| | | Station Quarry Beds | 0- 63 feet (20 m) |
| $D_1$ | Bee Low Group | Millers Dale Beds | 75-150 feet (23-45 m) |
| | | Lower Millers Dale Lava | 0- 80 feet (24 m) |
| | | Chee Tor Beds | . . . . . |

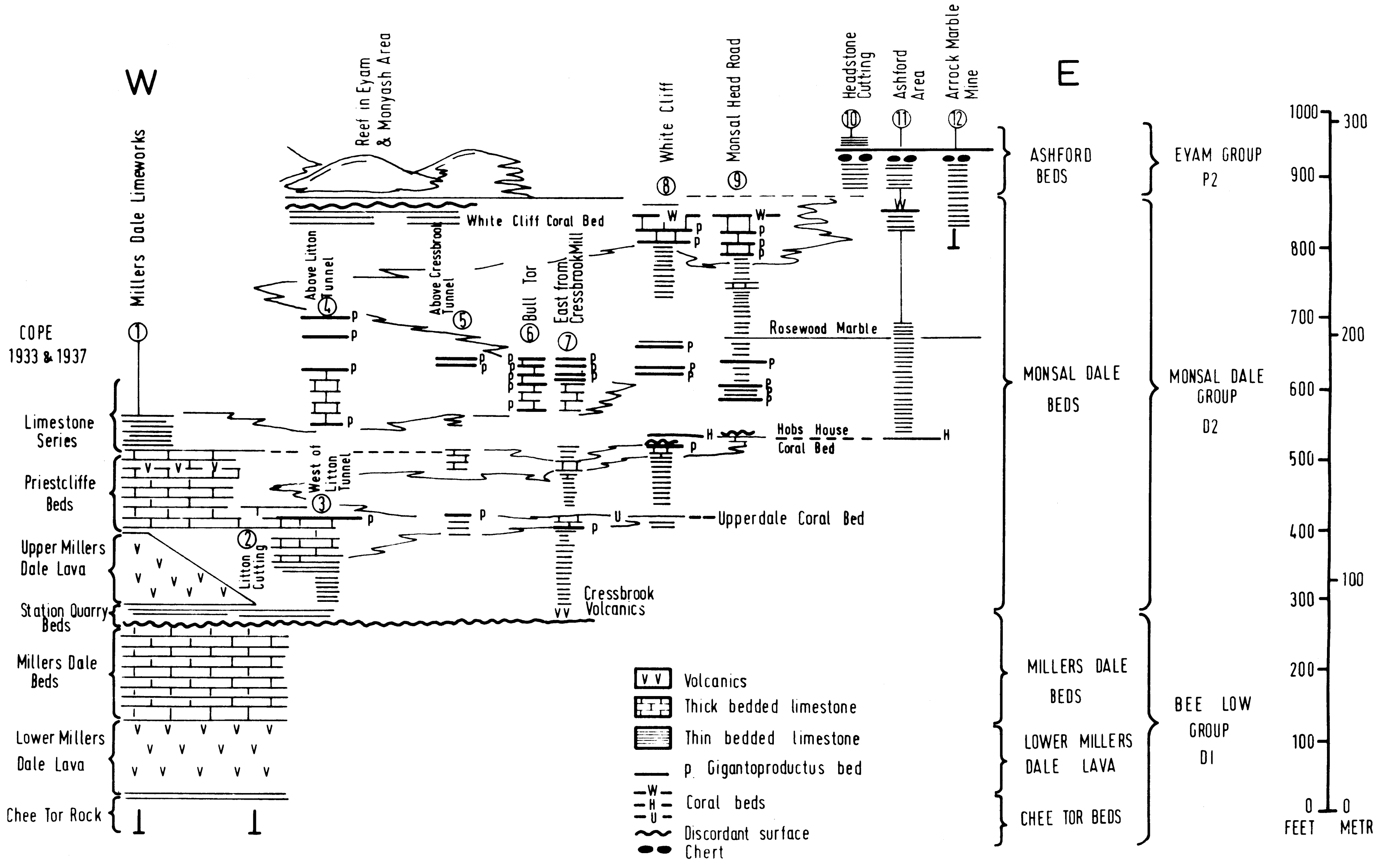
### The Bee Low Group

*The Millers Dale Beds and Lavas.* The Millers Dale Beds rest on the Lower Millers Dale Lava in Millers Dale, indifferently exposed near Litton Mill. The lava was correlated by Shirley and Horsfield (1945), on rather insecure evidence, with the Ravensdale Tuff in the upper part of Cressbrook Dale. New exposures have now been located, which show basalt resting on tuff with intercalated limestone beds at SK 171741; exposures at SK 171734 and SK 172741 are among landslips which have slid on thin tuff horizons.

The Millers Dale Beds are massive cliff-forming limestones with poorly developed bedding except at the top, where a coral bed with abundant ***Lithostrotion junceum*** (Fleming) is present. Overlooking Water-cum-Jolly a mound-like structure is present (SK 165729) and although difficult of access, it appears to be made up of bioclastic debris, presumably the result of current action. An abrupt lithological change from the massive limestones of the Millers Dale Beds to the thinly bedded Station Quarry beds was taken as the top of $D_1$ by Cope (1933) and this horizon was also noted in Cressbrook Dale by Shirley and Horsfield (1945).

The Millers Dale Beds dip eastwards beneath the valley floor near Cressbrook Mill but reappear in the Lees Bottom inlier as cliffs around the foot of Dimmins Dale and in Lower

Fig. 2. SUGGESTED STRATIGRAPHIC AND LITHOFACIES CORRELATION IN THE MONSAL DALE AREA



Taddington Dale. Indifferent exposures in faulted ground at the foot of Fin Cop show two lava flows and a dolerite sill. The lower flow is clearly seen to occur beneath massive Millers Dale Beds and is thus tentatively correlated with the Lower Millers Dale Lava. It appears to die out southwards, with a flow front exposed immediately north of the mouth of Dimmins Dale (SK 170704). Detailed mapping has shown that much of the flat ground here is not, as previously thought, underlain by basalt, but by limestones of the Chee Tor Beds. In the absence of the Lower Lava the Millers Dale Beds rest directly on Chee Tor Beds.

The Millers Dale beds are here approximately 75 feet (23 m) thick, in contrast to 150 feet (45 m) in Millers Dale itself.

## The Monsal Dale Group

*The Station Quarry Beds.* Described from Millers Dale Station yard by Cope (1933, p. 134) these thinly bedded limestones with *Saccaminopsis* bands are about 25 feet (8 m) thick, and rest non-sequentially on the Millers Dale Beds. The top of the Station Quarry Beds was here taken at the base of the Upper Millers Dale Lava, but the lava dies out eastwards, and the Station Quarry Beds are then indistinguishable from the upper part of the Monsal Dale Group.

In the Litton tunnel (east) railway cutting (SK 166727) the channel noted by Cope (1933, p. 132) shows Station Quarry Beds unconformably lying on Millers Dale Beds with a bed with frequent *L. junceum* at the top. A lens of limestone pebbles in a pyritic green clay lies at the bottom of the channel. However, near Cressbrook Mill, horizontal thin-bedded limestones without *Saccaminopsis*, rest directly on Millers Dale Beds. Much further to the north, in upper Cressbrook Dale (SK 173745), Station Quarry Beds with *Saccaminopsis* are seen to be 63 feet (20 m) thick, more than double the thickness in the type section. Along the east side of Cressbrook Dale, the Station Quarry Beds can be seen to thin from 63 to 40 feet (20-13 m) southwards. Dip readings taken above and below the Station Quarry beds along the Dale suggest that they thin out and may be banked against an incipient Longstone Edge monocline.

Some difficulty has been encountered in relating the above observations with the sections described by Cope (1933, 1937) in the Litton railway cutting (SK 157730) and east of Taddington (SK 153712). In the former, a study by Walkden (1970) has confirmed Cope's opinion that the flow front of the Upper Millers Dale Lava rests on top of Station Quarry Beds, and has basal Monsal Dale Beds banked against it. This seems to be the case near Taddington also, though the Station Quarry Beds are insufficiently exposed for definite conclusions to be drawn.

In the Lees Bottom inlier it has not been possible to differentiate the Station Quarry Beds from the overlying part of the Monsal Dale Beds owing (a) to the absence of *Saccaminopsis* bands, (b) to the absence of the normally intervening Upper Millers Dale Lava along most of the south-west side of the inlier, and (c) to the very indifferent exposures at this general horizon, with considerable scree cover. If present, the Station Quarry Beds, sensu stricto, can be no more than a few feet thick.

As the Station Quarry Beds can thus only be mapped and recognized as a distinct unit over a small area, the present authors agree with Stevenson and Gaunt (1971) that henceforth they should be regarded as no more than a sub-unit at the base of the Monsal Dale Beds. The Upper Millers Dale Lava thus occurs at an horizon within the lower part of the Monsal Dale Beds.

*The Upper Millers Dale Lava.* Although the lava was over 60 feet (18 m) thick in the type area, Cope (1933) described sections which appeared to show that this lava died out eastwards near Litton Mill (SK 157730) and in Taddington Dale (SK 151712). To the north the flow is present in Tideswell Dale but not in Cressbrook Dale. These observations allow an apparent eastern boundary to the flow to be drawn showing a lobate extension down the Priestcliffe syncline. Only two feet of tuff are seen at the appropriate position in the western mouth of Litton tunnel (SK 162729) but vesicular basalt and tuff totalling 20 feet (6·5 m) appear, resting directly on the Millers Dale Beds, at the mouth of Cressbrook Dale (SK 173726). Either these are a flow unrepresented elsewhere, or they cut out the Station Quarry Beds to rest conformably on Millers Dale Beds. In view of the thickness variations of the Station Quarry Beds in Cressbrook Dale, the latter alternative seems much more likely, and the Upper Millers Dale Lava is thus regarded as having been cut out by unconformity in the Litton tunnel area. The green clay filling the channel in the Litton Tunnel east cutting thus appears to be a relic of the lava.

In the Lees Bottom inlier, the Upper Fin Cop Lava of Bemrose (1907) appears at a position equivalent to the Upper Millers Dale Lava. It is seen to be 38 feet (11•5 m) thick on the south-western spur of Fin Cop. North-west of Black Rock Corner (SK 177700) the lava rests directly on the Millers Dale beds, but at the Corner itself a dolerite sill some 60 feet (18 m) thick appears. The contact between dolerite and basalt is a crumbly altered horizon, suggestive of subsequent intrusion, rather than a coarsely crystalline core to a flow. Both sill and lava die out westwards along the south side of the inlier, in Shacklow Wood, which contains an exposure inferred to be a flow-front facing westwards (SK 172702). The flow makes a brief re-appearance on the spur between Taddington and Dimmins Dales (SK 168705), with flow-fronts to both north and south. The flow and sill are both seen again in the northern margin of the inlier (SK 172714).

The three flow-fronts which together could be taken to indicate an irregular flow margin across the south-western part of the Lees Bottom inlier and the observations described above around Cressbrook Mill allow a new distributional analysis of the Upper Millers Dale Lava to be made; it can be inferred that a tongue, or complex of tongues, of this lava extend from Millers Dale to Lees Bottom under the Brushfield plateau. Furthermore, observations in old lead mines to the south of Lees Bottom, beneath Sheldon, allow a further extension of this flow to be outlined. At Field Grove Mine (SK 170695) the flow is absent, but in Sheldon Shaft (SK 176688) the flow (and sill?) are at least 138 feet (42 m) thick. The Magpie Sough (drainage level) (SK 176690 to 178696) was driven through basalts dipping gently northwards, but in the Magpie Mine Shaft (SK 172682) only a thin tuff at 480 feet (148 m) depth appears at the appropriate position. A rise in the True Blue Mine (SK 178680) penetrated the base of the flow. The flow was also seen, 110 feet thick (33 m), in Mogshaw Mine (SK 196678) and it appears to be the lowest of the three flows seen in Dirtlow Mine (SK 190685) still further east.

Neither the old mining records, nor the mines themselves, permit the recognition of the Station Quarry Beds sensu stricto, so that the Upper Fin Cop Lava, herein correlated with the Upper Millers Dale Lava, may either rest on these, or may be unconformable on the Millers Dale Beds. Alternatively, the Upper Fin Cop Lava may be a separate flow at the horizon of the unconformity recognized further west between the Station Quarry Beds and the Millers Dale Beds. The field evidence is incomplete but the present authors prefer the first alternative, the correlation with the Upper Millers Dale Lava.

*The Monsal Dale Beds.* Cope (1937) described the sequence above the Upper Millers Dale Lava in Millers Dale as composed of two units, the moderately thickly-bedded Priestcliffe Beds below, about 120 feet (36 m) thick, and a Cherty Limestone Series, nearly 400 feet (120 m) thick above. In Monsal Dale, however, it has not been possible to separate these two divisions, as thinly-bedded cherty limestone make up the bulk of the succession of some 500 feet (150 m) of beds. There is ample field evidence around the Brushfield plateau that there is a gradual change of lithofacies, with massive non-cherty limestones inter-fingering with the thin cherty beds. This is indicated diagrammatically in Fig. 2. A number of well-known coral and Gigantoproductid horizons in Monsal Dale form good marker beds, but most die out westwards and only by projection of their horizons, using strike and dip, can their approximate position in the Millers Dale succession be estimated. Some are of limited lateral extent within Monsal Dale as well. Defining the relationship of these bands is made more difficult by the absence over part of the area of the Upper Millers Dale Lava and also by the Station Quarry beds being generally indistinguishable from the rest of the Monsal Dale Beds. A more easily defined horizon from which to measure is the top of the Millers Dale Beds.

Recently, Stevenson and Gaunt (1971) have separated the Monsal Dale Beds into Upper and Lower divisions with a boundary at an Upper *Girvanella* Band or at the top of the Litton Tuff where the former is absent. No *Girvanella* Band has been found in the present study and the Litton Tuff can only be followed for a short distance so that such a subdivision is impractical in the Monsal Dale area.

At about 130 feet (42 m) above the Millers Dale Beds is the Upperdale Coral Bed, consisting of 3 feet (1 m) of massive limestone with abundant silicified *Lithostrotion junceum* and, less frequently, *L. martini* Edwards and Haime and *Diphyphyllum lateseptatum* McCoy. This is well exposed at track level in the cutting immediately west of the old Monsal Dale station (SK 177720), and is well seen below the lip of the lowest scarp in Hay Dale (SK 178722). A similar but less crowded bed occurs at the top of the Millers Dale beds where they are cut into by the channel at the east end of Litton tunnel. At the east end of the Cressbrook tunnel (SK 172724) the Upperdale Coral Bed has apparently slumped and has become mixed with the normally underlying Gigantoproductid bed, with discordant junctions both above and below the combined bed.

60 to 80 feet (18-24 m) higher is the more widely developed Hob's House Coral Bed, 8 feet (2·5 m) thick and crowded with large *Dibunophyllum bipartitum* (McCoy) and less common *Diphyphyllum lateseptatum*, *Lithostrotion martini* and *L. junceum*. This can be traced all round that part of Monsal Dale below Monsal Head, but it is cut out by an unconformity west of Hay Dale at SK 177723. It re-appears above the Litton Tuff at the head of Cressbrook Dale, apparently being interrupted by slight upwarping of the Longstone Edge monocline. Near Monsal Dale station the Hob's House Coral Band is seen in the cutting close to the fault at SK 179718, but westwards it is lost beneath the scree on the hillside. From the Hob's House landslip the coral bed can be traced along the face of the Fin Cop escarpment. It is lost in places beneath scree but re-appears some 50 feet (12 m) above the Upper Millers Dale Lava at Black Rock Corner. The Hob's House Coral Bed is also exposed in the western part of Shacklow Wood (SK 172701) and at the foot of Nettler Dale (SK 184696). At several of these localities the contact with the beds above is an angular discordance, though it has not been possible to demonstrate the nature of the unconformity suspected. On the basis of thicknesses, this horizon seems to be equivalent to the change from the Priestcliffe Beds to Cherty Limestones in Millers Dale. About the middle of the Monsal Dale Beds is the thick Litton Tuff. Although 100 feet (30 m) thick at Litton, this has thinned to 42 feet at the head of Cressbrook Dale, and is last seen on the western slopes of Wardlow Hay Cop (SK 178738). As it is about 200 feet (60 m) above the Millers Dale Beds, its relationship to the Hob's House Coral Bed becomes of importance. A coral bed a few feet above it on Litton Edge and at Peters Stone, just beyond the northern margin of the present area, was correlated with the Hob's House Band by Taylor (1957) and by Stevenson and Gaunt (1971) but the fauna contains a much higher proportion of colonial corals and some uncertainty must remain as the bed cannot be traced along the length of Cressbrook Dale.

At the head of Cressbrook Dale, a layer of basalt some 6 feet (2 m) thick, occurs some 30 feet (9 m) below the Litton Tuff, but it cannot be traced into the present area, although Stevenson and Gaunt (1971) have shown that it thickens rapidly northeastwards, beneath Wardlow Mires (SK 185755).

Although neither the Litton Tuff nor the Cressbrookdale Lava can be traced at outcrop in the Monsal Dale area, it is of interest to note that two volcanic horizons are known in the sub-surface in the south of the area. In the Dirtlow Mine Shaft (SK 192684) there are two "toadstones" each about 30 feet (9 m) thick, one of which makes a brief outcrop east of the farmhouse. These volcanic horizons have also been seen in shafts on Mogshaw Rake (SK 192678 and 195678) and clay-wayboards (degraded volcanic horizons) at about the appropriate position are known in the Magpie and True Blue Mine shafts (SK 173682, 178680). A thin tuff was noted near the top of the Priestcliffe Beds above Millers Dale by Cope (1937, p.181). The true relationships of these scattered volcanic horizons are uncertain and correlation must depend on further underground mine exploration. Although no tuff is visible, the foot of the Hob's House landslip is at about the Litton Tuff horizon and a clay-wayboard at this horizon could well be the weakness causing the landslip.

In Monsal Dale itself, the Rosewood "Marble" (or Laminated Limestone) is the next higher marker bed in the Monsal Dale Beds. The Rosewood Marble is a slumped horizon about 3 feet thick. The thin laminae show a great variety of convolutions, overthrusts and minor folds, all on a miniature scale. Preliminary examination shows the orientation of the slumps to be highly variable, though there is a suggestion of movement down the present dip, i.e. into the Priestcliffe syncline. Further study of these is needed. The Rosewood Marble is 140 feet (42 m) above the Hob's House Coral Band in the cutting west of the viaduct (exposed at SK 182716) but only 85 feet (26 m) higher in the Hob's House landslip scar (SK 176713) a quarter of a mile to the south. The distinctive lithology can be traced southwards by means of fragments in the scree round Fin Cop into Ashford-in-the-Water (SK 189695), on the Arrock (SK 188691) and into Nettler Dale (SK 177693), where it was mined for ornamental purposes in the 18th and 19th centuries (Ford 1964). Northwards however, the Rosewood Marble Bed appears to die out. It is exposed near the foot of the road down into Monsal Dale (SK 183717) and scree fragments indicate its presence in the lower end of Hay Dale, but its only other known occurrence is in a faulted area at the western end of Longstone Edge (SK 187734).

About 180 feet (55 m) above the Rosewood Marble bed is the White Cliff Coral Bed. Strictly two beds, a few feet apart, these have abundant corals including *Lonsdaleia duplicata* (Martin), *Palaeosmilia regia* (Phillips), *Diphyphyllum lateseptatum* and *Orionastrea placenta* (McCoy). The latter allows correlation with the *Orionastrea* band in the Eyam area to the north-east (Shirley and Horsfield 1945), Stevenson and Gaunt 1971). Taylor (1957) distinguished two *Orionastraea* bands close together. In Monsal Dale, however, the two beds are only a few feet apart in White Cliff, and they can be followed along the top of the slopes around Monsal Head and north of Fin Cop but they have not been seen elsewhere. The White Cliff Coral Bed is not seen to extend much to the west beyond the fault above the Hob's House landslip, and it is too high stratigraphically to outcrop on the Brushfield plateau.

At Crossdale Head Quarry (SK 183831) an isolated exposure of a coral bed with abundant *Dibunophyllum bipartitum* may be equivalent to the White Cliff Coral Bed, but it is in faulted ground and its fauna is dominated by Clisiophyllids. Both Cope (1933) and Taylor (1957) correlated this bed with the Hob's House Coral Bed, but later Cope (1958, 1967) referred it to the White Cliff Coral Bed, though Stevenson and Gaunt (1971) appear to accept Cope's earlier suggestion (1933).

A number of scattered localities have the same appearance and contain the same corals on the plateau south of Monsal Dale, around Sheldon. Although the band cannot be traced directly in the field, scattered blocks in walls suggest that its outcrop is much as shown on the map (Fig. 1).

The total thickness of the Monsal Dale Group, if the Upper Millers Dale Lava and the Station Quarry Beds are included, reaches 660 feet (200 m) but there is thinning in a south-easterly direction and between Lees Bottom and Ashford the total thickness is probably not more than 400 feet (120 m).

## The Eyam Group

*The Ashford Beds.* Definition of the top of the Monsal Dale Beds and the base of the Ashford Beds raises problems. To the north-east of the present area the Monsal Dale Beds are covered unconformably by the Eyam Limestones, of crinoidal mound and flat-reef facies (Shirley and Horsfield 1945); Stevenson and Gaunt 1971). These are a small but variable distance generally about 30 feet (9 m) above the *Orionastrea* band and in places cut it out by unconformity on the western end of Longstone Edge, according to Shirley and Horsfield. This "reef" facies of the Eyam Limestones has not proved to be present around Monsal Head and no unconformity has been seen. The lower slopes of Longstone Edge do, however, show an apparent transition from one lithofacies to the other, in much faulted ground. The crinoidal mound facies reappears in the extreme south-west of the area, between Sheldon and Monyash, though neither an unconformity nor the *Orionastrea* band has been detected before Lathkill Dale is reached (Shirley 1958). The intervening area contains a thin-bedded "basinal" equivalent, with two marker horizons. These basinal beds were referred to as the Ashford Beds by Cope (1958) though at present no basal boundary to these can be mapped and the line on the map has been inserted purely on the geometrical relationships of the marker beds.

The Ashford Beds contain a distinctive bed crowded with *Spirifer trigonalis* (Martin), exposed in the Headstone cutting (SK 188714) and on the Arrock at Ashford (SK 192694). Rarely more than a few inches thick, this bed can be traced across the dip slope of Fin Cop by blocks in walls, and it is exposed briefly in Little Lane (SK 189705). It can also be traced along the strike to the north of Great Longstone, east of the area under consideration. The bed is generally less than 8 inches (20 cm) thick but crowded with single valves of *S. trigonalis* and other less common brachiopods, such as *Martina glabra* (J. Sowerby), *Productus productus* (Martin), and *Camarotoechia pleurodon* (Phillips).

By geometrical construction the Spirifer Bed is 280 feet above the Rosewood Marble, in Headstone cutting (i.e. 100 feet (30 m) above the White Cliff coral bed which is not exposed owing to the railway tunnel). On the Arrock, at Ashford, it is 240 feet (73 m) above the Rosewood Marble. On this basis the base of the Ashford Beds must lie in the 100 feet (30 m) of beds above the White Cliff Coral band, which can only be traced over a limited area in Monsal Dale. By projection, however, the base of the Ashford Beds is approximately equivalent to the Black Marble Beds in the Arrock Mine (Ford 1964). Only about six feet thick, the Black Marble Beds can be traced for a limited distance around Ashford, but on the adjacent higher ground their outcrop is marked by rottenstone (Ford 1967) and a line of workings can be traced largely by blocks in the walls, across Pennyunk and Greengate Lanes on the dip-slope of Fin Cop. Other occurrences of rottenstone in the walls and turf are around Dirtlow Farm (SK 187687) and near Mogshaw Mine (SK 182676). The base of the Ashford Beds is accordingly drawn just above this horizon.

The Black Marble beds at Ashford are crowded with small corals of the Cyathaxonid phase. Used to define a $D_3$ zone by Sibly (1908), these are here regarded only as a special faunal phase of upper $D_2$. The corals have been studied by Cockbain (1957).

A few feet below the Spirifer Bed is another distinctive marker, a thick bed of chert. Generally around 6 to 10 feet (2-3 m) thick, this has a lithology identical to the better-known Bakewell Chert, mined 2 miles to the east. The thick Chert has been both quarried and mined on the Arrock (SK 194695) and in the top of the Rookery Plantation (SK 192697). The Bakewell Chert is thought to be the same bed, and it is notable that a bed with *Orionastrea* was noted below it in the Endcliff at Bakewell (SK 213699) by Cockbain (1957) indicating the same relationship with the base of the Eyam Limestones as in the Ashford area. The Chert bed is poorly developed in the Headstone cutting and not seen to outcrop elsewhere in the Monsal Head area. It has not been traced on to the higher ground southwest of Ashford, but it is present again near Green Cowden Farm to the south-east (SK 199678).

The chert formerly worked at Chertpit Plantation (SK 187729) is in fact a crystalline quartz rock associated with mineralization and is in no way related to the Bakewell Chert.

Some 15 feet (4·5 m) beneath the Chert in the Headstone cutting there is a distinctive limestone conglomerate, with small limestone pebbles up to half an inch long. The conglomerate is about 3 feet (1 m) thick but it has not been seen elsewhere. A bed with scattered rootlets and coaly markings is present high in the tunnel mouth, and may be the equivalent of the Coombsdale Quarry coal near Stoney Middleton (SK 233748).

The Ashford Beds are thus taken as 100 feet (30 m) thick up to the Spirifer bed and a further 45 feet (14 m) of limestones are seen above this in the Headstone Cutting below thick shales, giving a total of 145 feet (44 m).

*Viséan Shales*: At the eastern end of the Headstone cutting, the highest limestones of the Ashford Beds are seen to be interleaved with and overlain by shales. The highest shale within the limestones is about 10 feet (3 m) thick and it yields many crushed fossils including abundant *Chonetes* sp., trilobites, ostracods and goniatites including *G. granosum* diagnostic of the $P_{2a}$ subzone (Cope 1967, p.3). The shales overlying the limestones are seen to a thickness of some 20 feet (6 m) and yield a more sparse fauna. As no discordance is visible it seems that these too are of upper Viséan age. No definition of the top of the Viséan is possible owing to the drift cover of higher beds.

## Regional Correlation

Correlation of the Monsal Dale succession with that to the west in Millers Dale, has already been discussed. To the north the Monsal Dale Beds have been mapped by Stevenson and Gaunt of the Geological Survey on the 1 inch to 1 mile Sheet 99. Their correlation charts and discussion only serve to show the difficulties inherent in attempting correlation within a complex of highly variable facies. Lithological types, Gigantproductid beds, coral beds and volcanic horizons are all impersistent and lenticular. Correlations are too often liable to be little more than of similar lithofacies rather than continuous horizons. As Taylor (1957) noted, it is unwise to make too emphatic a correlation until a full sedimentological analysis has been done. The only marker beds which seem to be reasonably secure between Monsal Dale and The Eyam-Stoney Middleton area are the Hob's House Coral Band and the *Orionastrea* Band, and of these even the former raises some doubts as discussed earlier in this paper. The two coral bands between these recognized in the Eyam area containing *Londaleia duplicata* and *L.floriformis* have not been recognized in Monsal Dale, though scattered corals occur in limestones at about this level. The Rosewood Marble Bed of Monsal Dale has not been seen in the area to the north.

As with the Monsal Dale Beds, detailed correlation of the Ashford Beds with the limestones of the Eyam Group in the area to the north is not possible. No single horizon seems to be common to both Monsal Dale and to the sections described by Stevenson and Gaunt (1971). To the south, a broad correlation may be made with the succession in the Lathkill Dale and Monyash area as described by Shirley (1958), though much detailed work remains to be done. Broadly, the Monsal Dale Beds appear to be equivalent to the Lathkill Limestones of Shirley (1958) and the Ashford Beds may be equated with the Cawdor Beds. Apart from the coral bed with *Orionastrea placenta* mapped high in the Upper Lathkill Limestones by Shirley, no marker beds have been found to be common to both areas and correlation is largely on lithological types and the similarity of the facies interdigitation in both Lathkill and Monsal Dales.

## Sedimentological notes on the Monsal Dale and Longstone Beds

As indicated on Fig. 2 and discussed briefly in the foregoing, there is a gradual facies change from the more massive Priestcliffe Beds and the Cherty Limestones in the west to the thinly-bedded Monsal Dale and Ashford Beds in the east. This is seen largely as an interfingering of thick limestones with abundant *Gigantoproductus giganteus* (J. Sowerby) with the thin fine-grained limestones and shale partings. Attempts at correlation within the region by Shirley and Horsfield (1945), by Taylor (1957) and by Cockbain (1957) all using *Gigantoproductus* bands have led to contradictory results. In the present study, wherever such a band was found its position in relation to the nearest marker bands was carefully plotted and thicknesses of intervening beds were measured. These observations have shown that there is in fact a variable number of lenticular *Gigantoproductus* beds. The railway cutting west of the Monsal Dale viaduct (SK 181717) shows two such beds, and in this clear section both are seen to be part of slumped horizons.

The *Gigantoproductus* valves are frequently separated and they are randomly orientated in a calcarenite matrix, which shows some evidence of grading. The base of the beds are channeled into the underlying thin dark limestones. These too show small channels at the base. The aspect of such beds is one of turbidite deposition. To the west in Millers Dale the equivalent beds are full of *Gigantoproductus* in life position, and all variants from life position to turbidite disorientation can be seen along the southern slopes of Monsal Dale, opposite Cressbrook, as noted by Walkden (1970). Shirley and Horsfield (1945) noted similar "Broken shell" horizons in the Eyam area to the north.

Slumped horizons which do not involve *Gigantoproductus* are also common, one large slump is just outside the east end of Cressbrook tunnel (SK 172724). The Rosewood Marble is a thin, slumped horizon of wide extent discussed earlier. The lower part of the Ashford Beds in the Headstone cutting show frequent slumps near the tunnel mouth. Among these are slumps which are deformed round apparently early-formed chert nodules. A slumped bed is also present in the roof of the Arrock Black Marble Mine. A full study of these slumps still needs to be made, but the impression gained is one of movement into the Priestcliffe syncline from all sides, but particularly from the west, i.e. down the plunge.

A number of the thin dark limestones of the Monsal Dale Beds contain *Lingula* or less commonly, *Orbiculoidea*, usually as single valves and certainly not in life position. These beds are well exposed in the roadside quarry below Monsal Head (SK 183717). As these are unlikely to be benthos of a turbidite environment and are equally unlikely in the more turbulent waters of the nearby massive flanking facies with *Gigantoproductus*, it seems possible that they represent epi-plankton which have fallen from drifting sea-weed.

Apart from the slumps and channels, the Monsal Beds show a number of marker coral beds. As already noted these have discordances above them, and these too may represent the onset of turbulent conditions and bottom-scouring after the deposition of the corals. The large solitary corals in the coral beds, particularly in the Hob's House Coral Bed, are lying prone, not in life position, and their epithecae are frequently abraded, so that an element of transport, possibly in turbid conditions, from adjoining shallow waters may be deduced. The solitary corals are sometimes seen to lie on top of colonial corals apparently in life position, though a hunt will still reveal a few colonies inverted, again suggesting transport. The coral beds also show sharp bottoms in places, supporting the concept of bottom-scouring before deposition, though commonly the corals are only in the top part of a massive bed a few feet thick. This is taken to suggest that the corals may have "floated" in the upper part of turbidity currents. Collectively there is a suggestion of cyclicity; with members developed in upward sequence:- (1) dark thinly-bedded limestone; (2) light massive limestone; (3) coral bed; (4) scoured surface; and return to member 1. This type of sequence is only to be expected in such circumstances and it is doubtful if any regional significance can be attached to it.

The facies changes described above indicate that the regional distinction between the reef facies of the Eyam Limestones and the thin limestones of the Ashford Beds seen in the latest Viséan were already being manifest in earlier $D_2$ times, and that the area of the Priestcliffe syncline was an area of relatively deeper water at the time of deposition. Taylor's unpublished work (1957) suggests that there may be similar "transported" facies in the down-warped area of Coombs Dale, to the north of the Longstone Edge monocline.

Diagenetic changes in the thinly-bedded limestones differ from those of the surrounding massive limestones in the much greater abundance of chert. Nodular and lenticular masses of black chert are developed throughout the thinly bedded limestones of both Monsal Dale and Ashford Beds. Silicification in the coral beds is different, being largely metasomatic replacement of the coral tissues. In the *Gigantoproductid* beds silicification is shown mainly by beekite sheaths around the brachiopod valves. The Bakewell chert is a silicification complex which requires a separate study. Nodular and metasomatic phases are present, and many vughs have a chalcedonic lining (cf. the chert at Ashford described by Orme and Ford, 1971). Apart from these, most of the Bakewell chert is laminated, with quartz layers of differing grain sizes apparently reflecting original depositional layering. The various types of chert and silicification are well displayed in the old railway cuttings.

## Structure

Three main structural elements are depicted on the structure contour map (Fig. 3). From north to south these are the east-west Longstone Edge monocline, the Priestcliffe syncline, and the Taddington-Bakewell anticline. The first of these, the Longstone Edge monocline, has been described by Shirley and Horsfield (1945) and need not be described further so far as the north-east of the area is concerned. From Cressbrook Dale westwards, however, this monocline is replaced by the Ravensdale Fault, with a downthrow to the south of 200 feet (60 m) in Cressbrook Dale. The fault also terminates the outcrop of the Tideswell sill further west. The sinuous course across Cressbrook Dale clearly indicates that it is a reversed fault dipping northwards, at angles between 50° and 65°, showing the same sense of movement as the monocline. On the western end of Longstone Edge the fault splits into a number of lesser faults, but no evidence has been found for the north-south fault mapped by Shirley and Horsfield (1945).

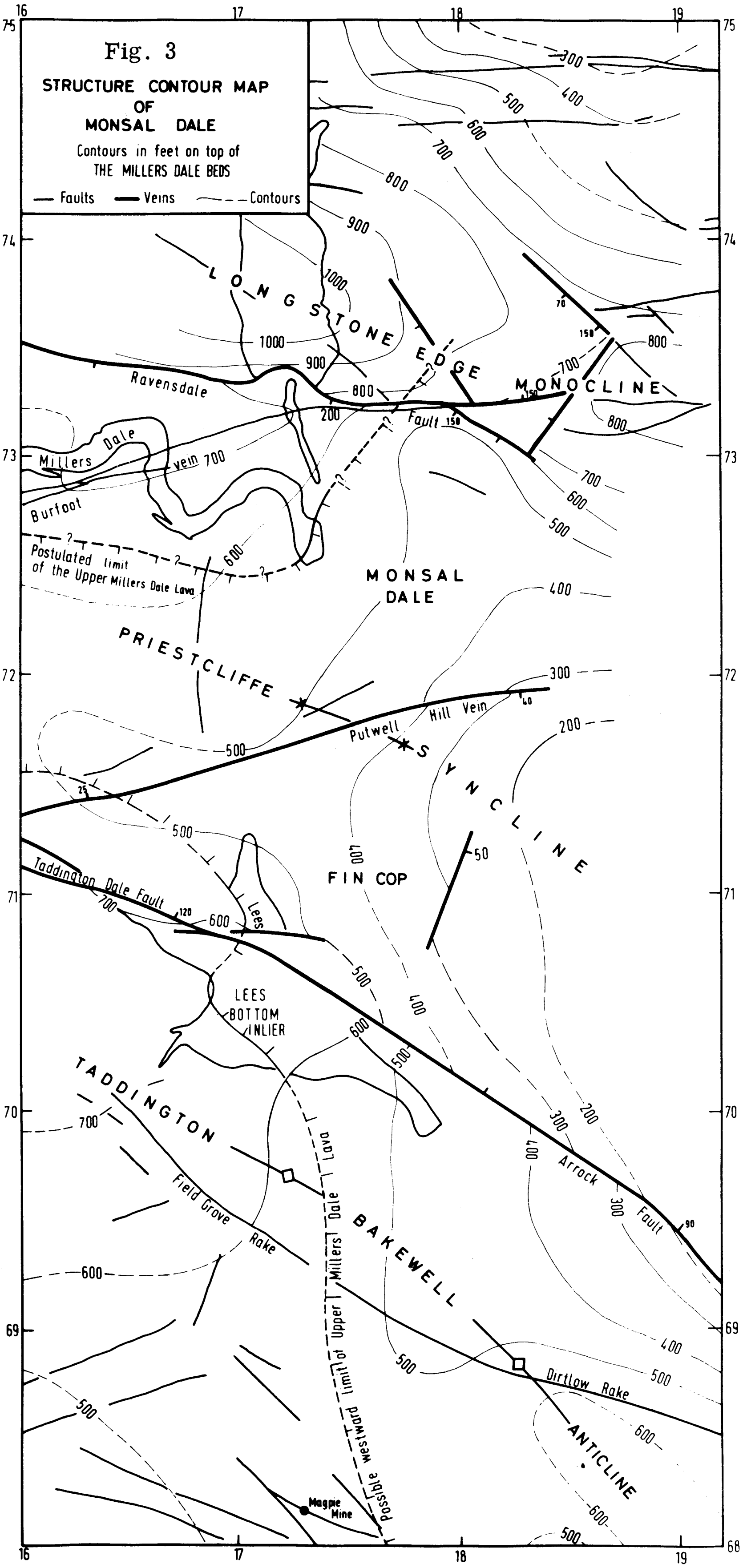


Fig. 3

STRUCTURE CONTOUR MAP OF MONSAL DALE

Contours in feet on top of THE MILLERS DALE BEDS

— Faults ▬ Veins --- Contours

A small area of upper Monsal Dale Beds is faulted down into the monocline on Rolley Low (SK 186735), and this is bounded to the north-west by a fault downthrowing south-west 150 feet (45 m). All these faults are mineralized, indicating a phase of tensional opening subsequent to the compressional reversed fault phase. Horizontal slickensides indicate a phase of wrench faulting also.

The Priestcliffe syncline proper lies to the west of the Monsal Dale area and appears to pass eastwards into the Chatsworth syncline affecting the Millstone Grit around Baslow and Calver. The name "Priestcliffe syncline" is here extended to include the Monsal Dale area. It has also been called the Bakewell syncline, but this name is inappropriate as an upwarp at Hassop station lies between the syncline and Bakewell.

The Priestcliffe syncline is crossed by a number of faults. The most northerly of these is the Putwell Hill vein which crosses the dale near Monsal Dale station with a WSW trend. Here it has a southerly downthrow of some 40 feet (12 m) but when traced westwards to Brushfield (SK 165714) it has a northerly downthrow of 25 feet (8 m). A SSW fault on Fin Cop (SK 174716) downthrows eastwards by 50 feet (16 m). The main fault crossing the syncline is that trending north-west from the Arrock at Ashford (SK 191693) for $2\frac{1}{2}$ miles towards Taddington. The downthrow is about 90 feet (18 m) to the north-east on the Arrock and about 100-125 feet in the same direction in Taddington Dale. It splits south of Brushfield and is less easy to define. The structure contours suggest a slight monoclinal flexure along the Arrock Fault, and there is some evidence indicative of thinning towards this flexure. Several parallel minor faults are to be found on Fin Cop. The fault is mineralized through most of its length. About half of a mile to the southwest, the parallel mineral vein system including Dirtlow and Fieldgrove Rakes is probably a fault, but the throw cannot be determined owing to the lack of marker beds. The veins around Magpie Mine also show evidence of faulting but again the throw cannot be determined, though it is apparently small.

The Priestcliffe syncline is diversified by a slight doming in the Lees Bottom inlier. The crest of this has almost horizontal beds in the mouth of Dimmins Dale (SK 169703), and the dying out of the Upper Millers Dale Lava flow here suggests that the dome was syndepositional. A more prominent structure occurs in an analogous position east of the present area, near Hassop station.

West of the present area, Cope (1937) described the Taddington anticline but this soon becomes indistinct and merges into the Taddington Dale fault and the domed Lees Bottom inlier. The Priestcliffe syncline is flanked to the south by a broad upwarped area forming part of the Bakewell anticline, which falls away southwards into the Lathkill syncline.

The structure of the area has been depicted on a structure contour map constructed for the only horizon clearly recognizable throughout the area, the top of the Millers Dale Beds. Although with limited outcrop in the south, its position can be estimated within insignificant limits from marker beds in the Monsal Dale Beds and from mine-shaft sections.

As has been indicated above, there is considerable evidence for the incipient phases of these structures having effects on contemporary deposition. The dying out of some lavas and the thinning of the Monsal Dale Beds appear to take place as structural highs are approached. For example, the Lees Bottom inlier shows slight doming which appears to have controlled the south-west flank of the Upper Millers Dale lava flow. The eastward thinning of the Monsal Dale Beds may reflect the direction of transport of the turbidite phase, with the thick proximal part in Monsal Dale itself, and the distal part around Ashford. Further studies of the sedimentology are needed.

The incipient tectonic phases may be summarized thus:-

(a) Post $D_1$ - pre $D_2$; as shown by the slight unconformity beneath the Station Quarry Beds. A gentle upwarping of the Longstone Edge monocline affected the distribution of these, the subsequent Upper Millers Dale Lava and some of the coral bands.

(b) Post $D_2$ - pre $P_2$; as shown by the unconformity beneath the Eyam Limestones in the northern extremity of the area, though no unconformity has been detected in the Monsal Dale area. Some evidence of slight emergence is shown by the rootlet markings and the limestone pebble bed in the Headstone Cutting.

No evidence of a post $P_2$ - pre $E_1$ phase of movement has been found.

Following the incipient stages, the main tectonic phases have been the Armorican movements, responsible for the main folding along east-west trends and presumably also responsible for the compressional reversed phase of the Cressbrook Dale fault. Compressional, wrench faulting followed by a tensional phase allowed mineralization, though there is ample evidence that this was poly-phase and overlapped with repeated movements in a lateral sense. There is no direct evidence for the age of mineralization though it is generally regarded as being of Triassic date (Ford 1969).

The mineral veins are largely seen on the anticlinal areas where crestal tension may have been a factor, though the apparently poor development in the syncline is perhaps illusory owing to the relatively poor exposures.

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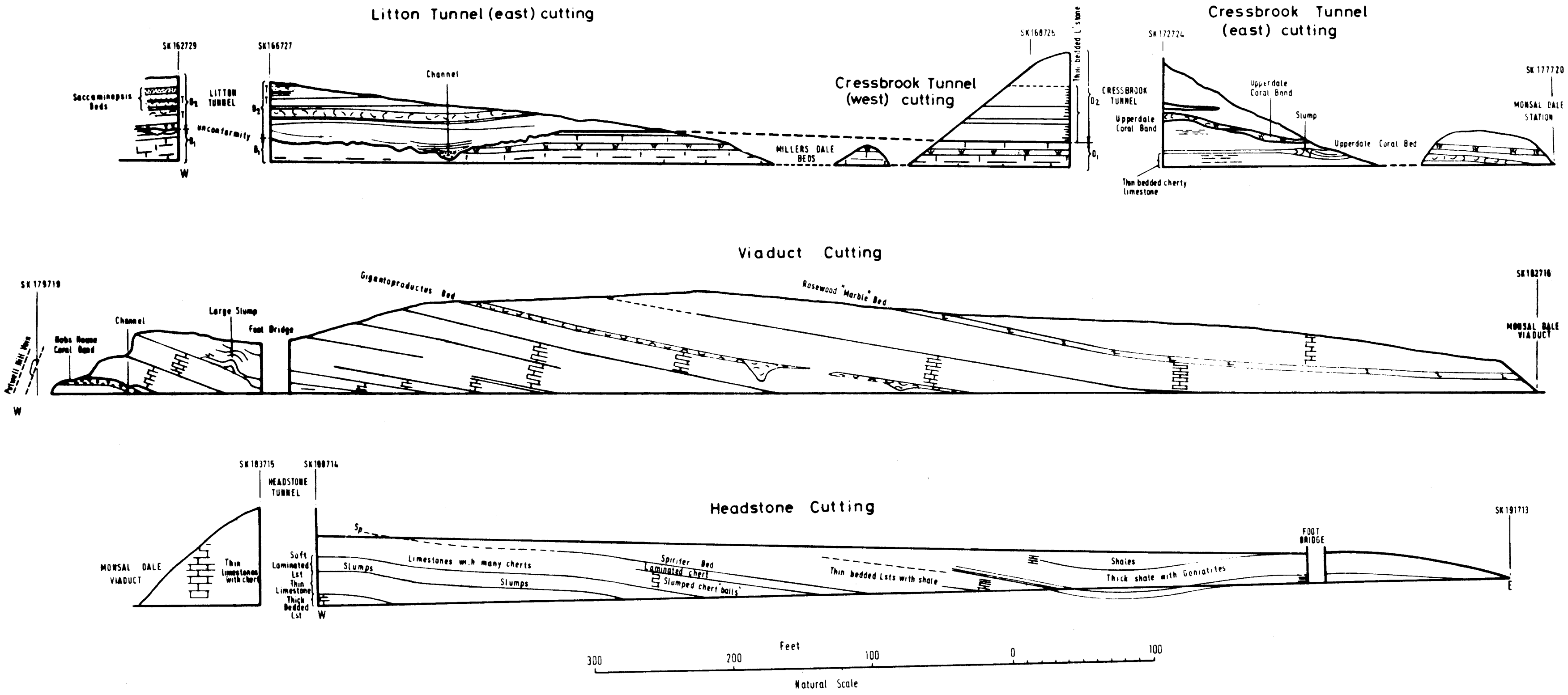
## Appendix

### Monsal Dale Cuttings Excursion

With the abandonment of the railway through Monsal Dale, the cuttings provide sections which make a most instructive excursion (fig. 4). The regional eastward dip allows the sections to be approached from either end, working downwards going west from Monsal Dale, or upwards going east from Millers Dale. The three railway tunnels are brick-lined, so that there are gaps in the succession. Each of the tunnels is about 500 metres long so that lighting is desirable to walk through; otherwise they must be passed by footpaths on the surface. The profiles illustrated in Fig. 4 are compounded from both north and south walls of the cuttings. The beds illustrated are present in both walls but are sometimes best seen on the south and at other points best seen on the north.

*The Headstone Cutting* (SK 191713 - 188714) may be reached by a footpath from Little Longstone. In it there are exposed about 145 feet (44 m) of Ashford Beds. At the extreme eastern end there are shales with calcareous nodules, and some evidence of mineralization. Under the bridge the first limestone beds roll through a small shallow syncline and a few yards to the west some 10 feet (3 m) of shale appears. The basal part of this yields many crushed fossils, mainly brachiopods and ostracoda, with some goniatites. About half-way

Fig. 4.


Litton Tunnel (east) cutting
SK162729
SK166727
Saccaminopsis Beds
T
$B_2$
$B_1$
LITTON TUNNEL
unconformity
W
Channel
MILLERS DALE BEDS
Cressbrook Tunnel (west) cutting
SK168726
Thin bedded L'stone
CRESSBROOK TUNNEL
$D_2$
$D_1$
Cressbrook Tunnel (east) cutting
SK172724
Upperdale Coral Band
Upperdale Coral Band
Slump
Upperdale Coral Bed
Thin bedded cherty limestone
SK177720
MONSAL DALE STATION
Viaduct Cutting
SK179719
Putwell Hill Vein
W
Hobs House Coral Band
Channel
Large Slump
Foot Bridge
Gigantoproductus Bed
Rosewood "Marble" Bed
SK182716
MONSAL DALE VIADUCT
SK183715
SK188714
HEADSTONE TUNNEL
MONSAL DALE VIADUCT
Thin Limestones with chert
Soft Laminated Lst
Thin Limestone
Thick Bedded Lst
W
Headstone Cutting
Sp
Slumps
Limestones with many cherts
Slumps
Spirifer Bed
Laminated chert
Slumped chert balls
Thin bedded Lsts with shale
Shales
Thick shale with Goniatites
FOOT BRIDGE
SK191713
E
Feet
300
200
100
0
100
Natural Scale

along the cutting is the Spirifer Bed, about 8 inches (20 cm) thick, and below it the rather inconspicuous Bakewell Chert, some 4 feet (1·2 m) of laminated siliceous rock. Many layers of black nodular chert occur in the beds below and on the north side of the cutting ball-shaped masses of chert show deformed slumps around them. The lowest beds seen are rather crumbly limestone with numerous small slumps. Fallen blocks around the tunnel mouth show rootlet markings.

*Headstone Tunnel West cutting* (SK 18715). The short cutting shows thin-bedded limestone alternating rapidly with layers of black chert over a thickness of some 50 feet (16 m) of the Monsal Dale Beds. The White Cliff Coral Bed may be found high above the tunnel mouth, almost at the lip of the escarpment.

*The Monsal Viaduct cutting* (SK 182716 - 179719), west of the viaduct, shows a most interesting section in the middle part of the Monsal Dale Beds. Almost the first bed seen on the south side is the Rosewood Marble Bed. About 3 feet (1 m) thick, it is somewhat hidden in the undergrowth, but rises gently along the cutting and its convolutions and slumps make a distinctive feature. About halfway along the cutting, a lenticular bed with many disoriented and separated valves of *Gigantoproductus* is seen to fill a channel on the north side of the cutting, and opposite it there are two small channels at the bases of thin dark limestones, presumably of turbidite origin. A little further along, a second channel with *Gigantoproductus* is seen on the north wall. Beneath the bridge, the dip steepens, and many joint faces are seen to be mineralized. High in the south wall is a large slump structure, and low down at the end of this face the Hob's House Coral Bed appears, though much obscured by mineralization. The top of the Coral Bed is cut into by a channel at one point. A few yards further is an opening (care!) into the Putwell Hill vein (sometimes known as Putty Hill Vein). Some 6 feet (2 m) of radiating crystals of dirty white calcite remain in place.

*Monsal Dale Station cutting* (SK 176721). Immediately behind the site of the station is a small exposure of Pleistocene till, apparently resting on a terrace of the River Wye. To the west of the station a low crag extends for some hundred yards alongside the old track on the south side. This shows the Upperdale Coral Bed about a foot thick in the upper part, consisting of abundant silicified *Lithostrotion junceum*, and a turbidite bed of disoriented Gigantoproductids in the lower part. These beds gradually rise westwards and reappear in the Cressbrook tunnel east cutting.

*Cressbrook Tunnel West cutting* (SK 168726) shows a section also containing a bed with many silicified *L. junceum*, but this is within the top of the massive Millers Dale Beds, and the base of the thin-bedded Monsal Dale Beds is a few feet higher up. The junction is sharp but not obviously discordant.

A few paces west of Cressbrook tunnel, there is a fine viewpoint looking down into the narrow part of Millers Dale known as Water-cum-Jully. Cliffs of massive Millers Dale Beds form the walls below railway track level. Away to the left is a mound-like structure in the top of the massive beds. To the right they dip beneath the Cressbrook volcanics at the foot of Cressbrook Dale.

*The Litton Tunnel East cutting* (SK 166727) shows the "wash-out" or channel, described by Cope (1933), in the south face. Here the basal Monsal Dale Beds, probably the Station Quarry division, (if *Saccaminopsis* beds are present they are inaccessible) rest on a greenish clay with limestone pebbles in the channel bottom. The channel is cut into the top of the Millers Dale Beds. Above the channel, thin-bedded cherty limestones are also discordant on the Millers Dale Beds. Some 20 feet (6 m) above the track are two thin Gigantoproductid turbidite beds, and two thin clay way-boards representing tuffs.

*The Litton Tunnel West cutting* (SK 162729) was described as Section I by Cope (1937). It shows an erosion surface on the top of the Millers Dale Beds, with a tuff over two feet thick above the tunnel mouth, which was not recorded by Cope as it was then walled up. This tuff is believed to be at the horizon of the Upper Millers Dale Lava and the Cressbrook volcanics. Above it are some 15 feet (5 m) of Station Quarry Beds with *Saccaminopsis* bands, a Gigantoproductid turbidite and another thin tuff.

Some 500 metres west of Litton tunnel is the Litton cutting described by Cope (1937), which shows the flow-front of the Upper Millers Dale Lava, here very much brecciated. The excursion may be continued into the Millers Dale Limeworks quarries above the track to the south and into Millers Dale Station Quarry, using the sections provided by Cope (1937).

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# CAUSES OF UNRELIABILITY IN MICROFOSSIL SAMPLES

by

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and

Anthony D. King

## Summary

Microfossil assemblages are not necessarily contemporaneous with the sediment from which they were collected; anomalous material can easily be present. This can be a result of natural contamination by processes such as recycling and stratigraphic leakage, which lead to a mixing of fossils from different horizons. Human errors in collecting, labelling and processing of fossil material can also result in contamination and unreliability of samples.

The possible causes of sample unreliability are discussed and ways of recognizing (and, where possible, avoiding) contamination are outlined.

## Introduction

Accurate and meaningful interpretation of microfossil samples requires the assessment of various possible sources of error. The interpretation and evaluation of an assemblage based solely on its contents can be as accurate as is humanly possible, yet can give erroneous results and conclusions.

Various factors can make a microfossil assemblage unrepresentative of the horizon from which it is supposed to come, thus making the conclusions obtained from the sample unreliable. These factors include contamination in the laboratory, mixing of assemblages in nature, and misplacing, misidentification or contamination of samples as a result of human error.

This paper is based upon research by the authors on several different groups of microfossils.

## Collecting of samples

Samples for micropalaeontological investigation can be collected by one of two methods; by hand, or by mechanical means.

### Hand Collected Samples:-

Samples collected by hand are usually collected from natural exposures such as streams and cliff-faces and such artificial exposures as excavations and road-cuttings.

Before undertaking systematic collecting in the field, the collector is best advised to study the succession thoroughly, so that he knows exactly from which horizon/zone etc. each sample came. The help of a local geologist as guide is especially advantageous when dealing with unfamiliar successions, particularly in foreign countries. Far too many cases have occurred of material being collected from either above or below the horizon from which the collector *thought* he collected it. Mistakes such as this can have serious repercussions by producing a false palaeostratigraphical picture.

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Often a certain element of statistical bias is introduced by collecting from the more obvious or easily accessible horizons rather than collecting uniformly. To guard against this, either fixed-interval sampling or random sampling should be undertaken. For detailed stratigraphic work, fixed-interval sampling is advisable, samples being collected at unit distances up the succession. This however is often impossible, because of changing lithology, lack of exposure, or sheer inaccessibility of outcrop. (For details of sampling techniques see, Cochran, 1963; Krumbein, 1965).

In certain areas, weathering diagenesis and metamorphism can present problems, due to partial or complete destruction of the fossils. Such processes include leaching, changes in the oxidation-reduction potential (Eh), changes in the hydrogen iron concentration (pH), and post-diagenetic alterations brought about principally by pressure, temperature and the introduction of new chemical substances (Tschudy, 1966).

The extent of weathering is controlled to some degree by lithology. Hard siliceous shales, limestones, and cherts are much more resistant than soft shales, clays and unconsolidated sediments. Sediments directly underlying bentonite beds are usually silicified and much more resistant to chemical and physical changes and are thus often a good source of organic-walled microfossils.

Removal of weathered and decayed surfaces of rocks is therefore an essential first step, prior to collecting samples. This removal of the surface layers also helps to avoid contamination by extraneous micro-organisms, e.g. modern pollen and spores which may adhere to the surface. Samples for palynological study must always have the surface layers removed or, if sufficiently consolidated, may be scrubbed and washed thoroughly with distilled water (Gray, 1965; Hay 1965; Wilson, 1971).

Where it is necessary to collect samples from beneath an overburden of soil or talus, a spade can be utilized to remove the overburden and expose the sediments. A screw auger can be utilized here, and also for collecting samples of unconsolidated sediments, although some mixing of material from different horizons always occurs.

Generally, unconsolidated sediments require special collecting techniques. These are best collected by forcing a clean plastic tube into the sediment, closing of the upper end of the tube then creates enough suction to retain a core of sediment when the tube is withdrawn. Again however, as with a screw auger, some mixing of material from different horizons can easily occur. (Faegri, and Iversen, 1965).

Mechanically collected samples:-

The most commonly encountered mechanically collected samples are termed 'well samples', these being retrieved in the drilling of oil wells. Samples from present day wells are usually of three types; conventional cores, sidewall cores and cutting samples. Cable-tool drilling is becoming increasingly rare, but is still being used for shallow oil wells in some areas and for water-wells.

Conventional cores are cylinders of the rock penetrated by the bit; taken by coring devices which replace the drilling bit when a core is required.

Sidewall cores are samples taken after a well has been drilled. A device with a number of hollow cylinders is lowered down the well to the desired depth; explosive charges then shoot the cylinders into the sides of the hole. Cable is used to connect the cylinders to the main coring device so that they can be retrived together with a plug of the sidewall.

Cutting samples are fragments of the rock produced by the rotary drill bit cutting its way through the rock. These fragments are brought to the surface by the circulatory fluid (either mud or water) used during drilling operations.

Conventional cores are the most reliable of these three types of samples. Even these however can be misleading, since fragments of rock can be knocked loose from upper sediments during the lowering of the coring device. In cores of a porous rock such as sandstones, a further source of contamination is that acid-insoluble microfossils may be forced in by pressure of the drilling fluid.

The main problem with sidewall cores is that a certain amount of drilling mud which cakes on the sides of the hole, may be retrieved. This mud may well contain microfossils from other levels, so anything which looks like caked mud should be carefully removed.

The most unreliable type of well sample, and unfortunately the most common, are the cutting samples. Exact depths of these are not easily known owing to the time-lag required for them to be circulated to the surface. Such samples are also susceptible to contamination due to cavings, lost-circulation (drilling fluid entering rock cavities) and additives in the drilling fluid. (Traverse *et. al.* 1961).

If wells are drilled with a gas rather than water or mud then more reliable samples can be obtained. Circulation of material to the surface is much quicker and caving is less of a problem as no swelling etc. (often due to wetting) of poorly consolidated sediments takes place.

Another type of sample is obtained from a shell and auger boring. This is commonly employed in site investigations in this country on poorly consolidated sediments, e.g. London Clay etc. This involves the repeated dropping of a steel cylinder which cuts its way through the sediment leaving a relatively undisturbed core. Undisturbed samples obtained for testing for engineering purposes are usually taken in 4" diameter thin walled steel sampling tubes, 18" long, sealed with wax and screw caps (commonly referred to as a U4). These usually provide reliable samples. Since the level of the sample is accurately known and these borings are usually cased throughout, thus eliminating the danger of caving. The outer layer of extruded samples should always be discarded as the steel tubes are reused for different jobs and they are not always thoroughly cleaned. Mr. C. King, of Paleoservices Ltd., found in one such sample from the London Clay, well preserved Kimmeridgian ostracods and foraminifera from a previous site investigation.

### Labelling of Samples in the field:

To minimise the risk of error, all samples should be numbered and labelled accurately whilst in the field; duplication of information in a notebook is advisable. Information such as locality, horizon (or measured distance/depth from a datum line), date and collector should be recorded and not just left to memory. Mislabelled or unlabelled samples, often a consequence of trusting to memory, can lead to completely erroneous conclusions and as often as not represent a waste of collecting time. The importance of accurate labelling cannot be overemphasised.

## Sources of Contamination

### Transport of samples:

Hard consolidated samples require the least care in packing and transport, provided that they are adequately labelled. If contamination during transport is suspected, they can easily be washed if they are required for palynological study.

Finely divided, friable and unconsolidated sediments however, require a great deal more care. Ideally, such samples should be thoroughly dried before packing and placed in leak-proof bags. At all costs loosely tied bags containing unconsolidated or friable material should not be placed side by side during transport; as spillage, from one to another can easily occur.

Bags of loosely woven material should not be used as they may allow dust, bearing contaminants, to pass through. Even finely woven bags have disadvantages, as dust can collect in the seams and corners. Ideally, each bag should be discarded after one use.

Strong polythene bags with well sealed joints are ideal for certain samples, although if used for palynological samples they can, when warm and containing moist material, act as incubators for bacteria and fungi which readily attack and destroy organic-walled fossils, and, also, destroy or render illegible labels placed inside the bag.

### Airborne Contaminants:

Airborne contaminants are most commonly of modern spore and pollen material. Contamination of this sort therefore only concerns the palynologist.

Obviously the ease with which modern contaminants are recognised depends upon the age of the spore-pollen material with which one is working. If the material is Recent or even near-Recent then the problem of differentiating modern contaminants is far more acute than when dealing with much older assemblages.

Ideally a palynologist should be familiar with what is likely to turn up in the air from the local flora. Greased plates are put out by some palynologists; these are examined at intervals to see what is in the air at the time.

When working with more ancient fossil spores and pollen, the problem of differentiating modern material is not very great. Modern spores and pollen differ from recent forms in body colour, sheen, and reaction to staining and are thus readily identified. Older sediments are nearly always compacted and, in the process, organic walled fossils are compressed, whilst modern material shows no compression.

Occasionally palynological samples may be contaminated in the laboratory by dust from other samples, particularly when samples are being crushed prior to chemical processing. This is a somewhat more serious problem and is much more difficult to resolve. To allow for such an incident occuring, it is advisable to keep abreast on what materials are being processed by colleagues in the laboratory. Palynological samples, for this reason, are best kept during the course of chemical treatment in covered beakers in a fume-cupboard with an air updraught continually switched on.

Calcareous nannoplankton present a problem as contamination due to airborne dust is very difficult to detect. Since they are very small (1 - 10μ being the norm) airborne chalk dust in the laboratory can contain many individuals in suspension (Echols and Levin, 1964). This dust can be trapped in crevices in the skin of the hands and under finger nails or even adhere to the surface of the skin itself. If more than one sample is being handled, then care must be taken to keep the hands clean by thorough washing (Hay, 1965).

Atmospheric contamination must have occurred throughout geological time, but this is a problem which is impossible to resolve.

### Contamination in the Laboratory:

The mains water supply to the laboratory, particularly if it has been stored in an open reservoir, is seldom free from micro-organisms: it often contains modern pollen and spores, dinoflagellates, desmids and diatoms and occasionally even fossil material. Such water is an obvious source of contaminants if used in the processing of palynological samples. To guard against this, distilled water should *constantly* be used in the palynological laboratory. Further more, all apparatus should be thoroughly cleaned out and rinsed in distilled water before use.

(a) *Palynomorphs.* Mortars and pestles used for crushing consolidated samples must be carefully scrubbed clean before and after use. Pitting of the pestle can easily result in material being trapped in the crevices, so ideally a damaged pestle should be discarded. A partial answer to contamination during crushing is to line the pestle with several layers of aluminium foil on heavy duty polythene, discarding and replacing the lining after each sample is crushed.

Glassware is a major source of contamination as palynomorphs tend to adhere to glass surfaces when wet. This is particularly true of pipettes whose small diameter makes cleaning of them difficult and it is perhaps advisable to use pipettes which can be discarded after one use (Wilson, 1971).

All glassware, including sinter funnels, used during the processing of organic-walled microplankton should be cleaned with a strong oxidizing acid, such as nitric acid or concentrated chromic acid. Ideally, glassware should be kept immersed in a bath of acid until needed. For calcareous nannoplankton hydrochloric acid should be utilized for cleansing purposes.

A further contamination risk occurs when commercial acids are used during processing. Sediments at the bottom of acid containers often contain spore and pollen material. To minimise this risk, it is preferable to use analar reagents which have a higher purity but, unfortunately, these are much more expensive than commercial acids. Alternatively, if this is impossible, acids should be poured carefully, taking care not to disturb the sediment, and the lees of the acid should be discarded.

(b) *Larger microfossils.* Sieves used in conjunction with the larger microfossils such as foraminifera often retain material trapped in the mesh which can contaminate other samples.

Two main types of sieve are commonly used, wet sieves and dry sieves. These are best cleaned by scrubbing thoroughly with a wire brush under running water.

When using wet sieves for concentrating calcareous foraminifera, a useful method (A.D.K.) is to immerse the sieve in a solution of methylene blue after each sample is sieved. This stains any adherent calcareous material blue so that residual contaminants can easily be distinquished from the contents of a later sample.

An ultrasonic cleansing tank, together with a non ionic detergent, should be utilized to clean all kinds of apparatus from microscope slides to sinter funnels. These are immersed in a water filled tank where electrically generated ultrasonic vibratory waves dislodge any adhering material.

(c) *Silicoflagellates.* These have been found as contaminants in Palaeozoic sediments from Norway (Sarjeant *pers. comm.*). The silicoflagellates are typically Tertiary forms so their occurrence, as the only microfossils in a Palaeozoic sediment warranted investigation. It was discovered that the sample was contaminated by an abrasive powder used in the laboratory as a cleaning and scouring agent. Whilst processing siliceous microfossils such as silicoflaggellates, abrasive powder containing finely divided silica should be carefully avoided.

## Sedimentary Contamination

### Reworking

Reworking is an integral part of sedimentation, involving the redeposition of older fossils into younger sediments. Problems caused by this are difficult and can occur in any type of sediment regardless of collecting techniques and scare taken whilst sampling.

Due to their small size, microfossils can readily be transported and deposited in clasts of original matrix, or as isolated individuals.

When reworked material occurs in the form of isolated individuals, they are usually corroded and less well preserved than contemporaneous fossils, although exceptions do occur. Well preserved Upper Jurassic microplankton have been found in an excellent state of preservation in Eocene (London Clay) assemblages (G.L. Williams, 1964), and reworked Chalk foraminifera are not uncommon at some levels in the Eocene (A.D.K.; Curry, 1952, p. 202). An abundance of reworked well preserved microfossils can dominate over the contemporaneous fossils and by their presence suggest an earlier incorrect age for the assemblage.

If fossils occur enclosed in particles of the original sediment (transported clasts), they may be redeposited in sediments of a very coarse nature; contemporary material being removed by winnowing and sedimentary sorting. Transported clasts are often readily identifiable in thin section.

Microfossil (and also macrofossil) assemblages can therefore be composed entirely of reworked material or a mixture of reworked and contemporary material.

Fuller discussions of this problem are presented by Muir (1967), Tschudy (1966) and Wilson (1964).

Stratigraphic leakage:

This is the direct opposite to reworking, in that it involves the deposition of younger fossil into older beds.

Stratigraphic leakage occurs when fossiliferous sediments are deposited in cracks, fissures, joints and solution channels in older consolidated sediments, e.g. Rhaetic material can be seen infilling crevices in Carboniferous limestone in the Mendips (For details concerning the collecting of fossils from fissures see Kermack, 1965).

Fortunately however, stratigraphic leakage seldom constitutes a serious problem to palaeontologists and is far less common than reworking. It can be guarded against by careful collecting of samples.

## Conclusions

When collecting and processing samples for micropalaeontological studies, the various possible sources of error and contamination must be borne in mind and where possible allowed for.

To quote from Funkhouser (1965), "If we find *Ulmus* in the Palaeozoic, we should not rush into print with an early record for angiosperms".

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# THE MID-$D_1$ UNCONFORMITY BETWEEN HARTINGTON AND ALSOP, DERBYSHIRE

by

Donald Parkinson

## Summary

It is argued that the unconformity above the $S_2$ inlier near Hartington is a northwesterly extension of the middle $D_1$ break east of Wolfscote Dale.

## The Wolfscote Dale area

In Wolfscote Dale on the north Staffordshire-west Derbyshire border there is a thick development of Carboniferous (Middle Visêan) Limestone of shelf (and in part reef) facies along the western boundary of the Derbyshire Massif. The lower part of this outcrop is a sparsely fossiliferous rock of fairly uniform character and a maximum thickness probably exceeding 800 feet, which was designated the Wolfscote Dale Limestone, and its age was attributed to the S Zone (Parkinson, 1950), but it was later shown (Parkinson and Ludford, 1964) to be of Lower $D_1$ age. It is succeeded by the Alsop Moor Limestone (Parkinson, 1950) of similar facies, which exceeds 500 feet in thickness on Wolfscote Hill. [I regret that in the 1964 paper the Alsop Moor Limestone was named in error the Alston Moor Limestone].

Westwards the Alsop Moor Limestone changes in character to become the massive Narrowdale Limestone of reef facies.

Southwest from Wolfscote Dale the Wolfscote Dale Limestone shows a gradual transition to the basin facies, with isolated developments of reef limestone. Eastwards it dwindles rapidly, and in a section between Biggin Dale and Coldeston the thickness has diminished to about 450 feet. Southeast of Coldeaton a fault running to Alsop en le Dale (Parkinson and Ludford, 1964, Plate 8) cuts out the remaining beds, and assuming a continuation of the thinning, the lower $D_1$ beds may be absent in the vicinity of Alsop.

In my 1950 paper (pp.283-4) I argued on various grounds that the attenuation of the Wolfscote Dale Limestone resulted primarily from overstep of the overlying Alsop Moor Limestone. The later work (Parkinson and Ludford, 1964) revealed a misinterpretation of an exposure high on the hillside east of the River Dove which caused some modification to but did not invalidate the earlier conclusion.

## The Hartington area

Northeast of Hartington, Sadler and Wyatt (1966) discovered an inlier of $S_2$ limestone which they subdivided into the Vincent House Beds and the Hand Dale Beds, the latter being overlain by $D_1$ shelf limestones, named the Lean Low Beds, which are in turn followed by the Upper Limestones, also $D_1$. The authors convincingly demonstrate an unconformity below the Lean Low Beds, which are 75 feet thick and contain a characteristic $D_1$ fauna, including ***Davidsonina septosa*** (Phillips). It is unlikely that these beds constitute the lower part of the $D_1$ Zone, since ***D. septosa*** does not appear until near the summit of the Chee Tor Rock.

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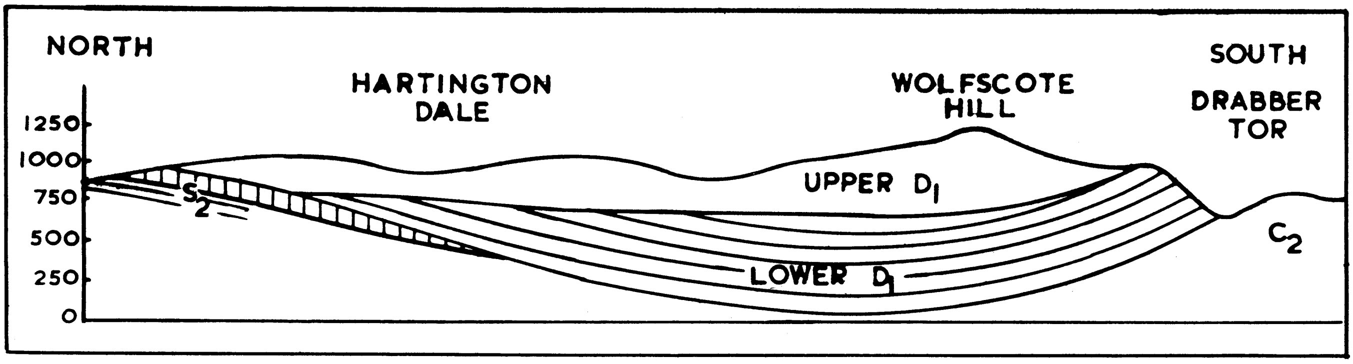

Figure 1. Generalised section to illustrate the relationships between the $S_2$ and the lower and upper $D_1$ beds. Vertical and horizontal scales the same.

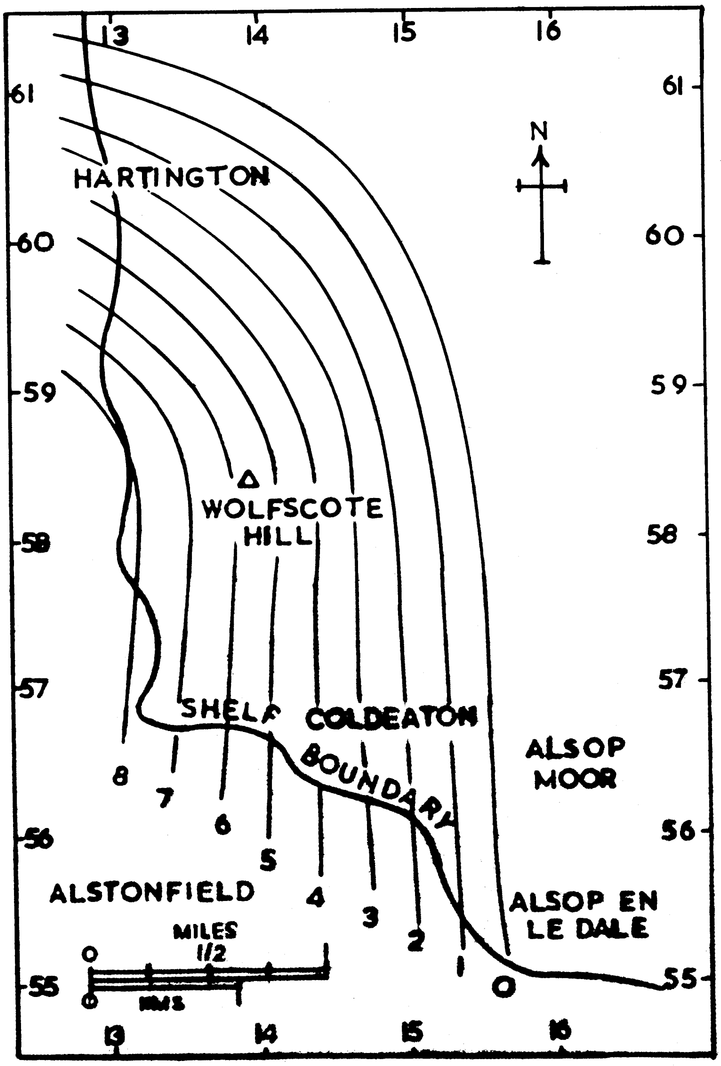

Figure 2. Isopachs at 100 ft intervals drawn on the Wolfscote Dale Limestone to illustrate the changing direction of the mid-$D_1$ axis of uplift.

## Interpretation of the Unconformity

I suggest that the Lean Low Beds are an extension northwards of the lower part of the Alsop Moor Limestone which, from the foot of Beresford Dale, I presume to be transgressive northwards over the whole of the Wolfscote Dale Limestone. This interpretation is illustrated by a generalized section (Text-fig. 1) which extends further southwards (though on a much smaller scale) than the more elaborate north-south section of Sadler and Wyatts' Fig. 3.

The unconformity can be further illustrated by an isopachite map. In Text-fig. 2 isopachs are drawn on the Wolfscote Dale Limestone, indicating a curved axis of uplift running from WNW-ESE north of Hartington to N-S south of Wolfscote Hill. (It is recognised, however, that the attenuation of the limestone may have been in part original). The map indicates that the axis of the earth movement is not related in direction to the shelf boundary.

South of Wolfscote Dale the $S_2$ beds are apparently absent and $D_1$ rests directly on (or $C_2 S_1$ strata. This involves the existence of an earlier unconformity. The age of this is probably pre-$S_2$ (see 1950 and 1964 papers).

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# A METHOD OF PREDICTING THE DENSITY OF FOSSIL CORALS

by

B.M. Abbott

Present work on the stability relationships between Silurian corals and their energy of environment is now under way. It was, however, first necessary to establish whether or not the homeomorphy shown by the modern scleractinian and Silurian tabulate analogues could be taken as a valid indicator of the animals energy of environment.

Since the density of the corallum would be a major factor in the organisms ability to withstand turbulence, a study of the relative densities of hemispherical colonies of *Platygyra lamellina* (Ehrenberg) and *Favosites gothlandicus* (Lamark) was made.

Unattached flat-based hemispherical growth forms were used for this study as they would form the basis of later experiments on models in flume tanks. The density of the corallum is not simply the density of the calcareous coenosteum, but must also include the density of the solids and liquids which filled the intra-skeletal voids. Resulting from post-depositional processes, the calcareous skeleton of *F. gothlandicus* had been recrystallized, and its intra-skeletal voids infilled by secondary calcite. A method had to be devised by which a fairly accurate statistical relationship between the two could be obtained. A large number of random sections were cut through several specimens of this species, and thin sections prepared. These were then photographically reproduced on heavyweight paper, at a magnification of 10 times. Because of the clear distinction between the intra-skeletal voids and the coenosteum, it was then a relatively simple, although time consuming, matter of cutting out with a scalpel, the paper which represented the original intra-skeletal voids, the weight of the remaining paper, representing the coenosteum, was then subtracted from the initial weight, and by converting these weights to percentages the relative volumetric development of each was given, see table 1.

Table 1

| Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Initial wt. in gm. | 12.22 | 11.97 | 11.36 | 12.47 | 10.96 | 8.18 | 12.84 |
| Final wt. | 5.25 | 3.79 | 5.62 | 3.29 | 5.34 | 2.86 | 5.13 |
| Wt. of paper representing voids. | 6.97 | 8.18 | 5.74 | 9.18 | 5.62 | 5.32 | 7.71 |
| % Coenosteum | 43% | 32% | 49% | 26% | 49% | 35% | 40% |
| % Voids | 57% | 68% | 51% | 74% | 51% | 65% | 60% |
| Coenosteum Ave. | = 39% | | Intra-skeletal voids ave. = 61% | | | | |
| | | | ∴ ± 1S = 86% | | | | |
| Stand. dev. | = 8.79 | | | | | | |
| | | | ± 2S = 100% | | | | |

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If these predicted values are then substituted in the following formulae the density of the coral colony can be calculated.

$$\frac{(\% \text{ of coenosteum x density}) + )\% \text{ of Intra-skeletal voids x Density})}{100} =$$

As there is no definite evidence whether the skeleton of *Favosites* was originally secreted as calcite or aragonite or as to the extent of the subsequent replacement of one by the other, a value for each polymorph is given. The density of the pore space material was arbitarily placed at 1.00, since these cavities in life were filled by sea water, which had a density greater than 1.00 (present sea water has a density of 1.03) and organic material whose density was slightly less than 1.00. This density has been used for both the modern and fossil specimens studied, so that the slight error inherent in this assumption would be common to both.

Density of *Favosites* if made of aragonite $= \frac{(2.94 \text{ x } 39) + (61 \text{ x } 1)}{100} = 1.76$

Density of *Favosites* if made of aragonite $= \frac{(2.71 \text{ x } 39) + (61 \text{ x } 1)}{100} = 1.67$

The examination of the modern coral *P. lamellina*, not only provided an instructive analogue, but also a method by which the accuracy of the photographic technique of estimating the void-coenosteum ratio could be checked. Four sets of experiments were run each consisting of 5 or more pieces of coral skeleton taken from various parts of the coral's coenosteum so that as representative as possible a sample of the colony could be made. The method was simply to heat the calcareous tissue to 110°C for a short while, allow it to cool in a desiccator to room temperature and then weigh each piece dry. The pieces of coral were then placed in distilled water and subjected to a vacuum by means of a High Vacuum Pump so that the air trapped in the voids could be removed and replaced by water. This process was repeated several times to ensure that as much air as possible was removed. The sample was then weighed wet, the increase in weight observed was due to the water filling the voids. This increase in weight is equal to the volume in cm$^3$ of the void space. The total volume of the sample was then established by the displacement method. By subtracting the volume of void space from the total volume the volume of coenosteum is obtained, see table 2. Since the extent of secondary alteration of aragonite to calcite could not be determined a value for both was calculated, and could be compared directly with those predicted for the fossil coral.

Table 2

| No. of pieces in sample | 8 | 4 | 8 | 5 | Ave. | Standard Deviation |
|---|---|---|---|---|---|---|
| Wt. of coenosteum dry gm | 62.3 | 41.39 | 86.28 | 71 | 65.24 | - |
| Wt. of coenosteum wet gm | 95.2 | 73.7 | 148.78 | 126 | 110.92 | - |
| Vol. coenosteum + water cm$^3$ | 59 | 50.7 | 113.5 | 99 | 80.55 | - |
| Vol. of water cm$^3$ | 32.9 | 32.31 | 62.5 | 55 | 45.68 | - |
| Vol. of coenosteum cm$^3$ | 26.1 | 18.39 | 51 | 44 | 34.87 | - |
| % of water | 56 | 64 | 55 | 56 | 57.75 | S = 3.7 |
| % of coenosteum | 44 | 36 | 45 | 44 | 42.25 | S = 3.7 |
| Predicted Density (Aragonite) | 1.85 | 1.69 | 1.87 | 1.87 | 1.82 | S = 0.07 |
| Predicted Density (Calcite) | 1.75 | 1.61 | 1.77 | 1.75 | 1.72 | S = 0.06 |

As can be seen from Table 2 the fossil coral appears to have had a less dense structure than the modern form by approximately 3%.

The density of the scleractinian coral predicted by the photographic technique was 1.93 for aragonite, see Table 3. There is a discrepancy of 6%, between this and the vacuum method most of which results from imperfections of the thin sections due to the delicate nature of the coral, or to a low value for the void space through incomplete evacuation.

Table 3

| Sample | 1 | 2 | 3 | |
|---|---|---|---|---|
| Initial Wt. | 7.66 gm | 11.99 | 8.04 | |
| Wt. of Coenosteum | 3.76 gm | 5.70 | 3.93 | |
| Wt. of voids | 3.90 gm | 6.29 | 4.11 | |
| % of voids | 51% | 53% | 51% | Ave. = 51.66% |
| % of coenosteum | 49% | 47% | 49% | Ave. = 48.34% |

S = 0.84

$$\therefore \text{ Density of Aragonitic coenosteum} = \frac{(48.34 \times 2.94) + (51.66 \times 1)}{100} = 1.93$$

$$\therefore \text{ Density of Calcite coenosteum} = \frac{(48.34 \times 2.71) + (51.66 \times 1)}{100} = 1.83$$

These observations, strengthen the hypothesis that the controls affecting unattached hemispherical growth form in modern seas can be extended to include extinct Silurian corals. Although as discussed elsewhere the secretion of the calcareous skeleton is controlled by the algal symbionts enclosed in the coral's soft tissue Abbott (1972), the close similarity of densities of the two homeomorphs would suggest that the environmental growth-form relationship of modern scleractinia provide a useful guide to the conditions under which the Silurian tabulate corals developed.

I gratefully acknowledge Dr. B. Rosen's assistance in identifying the modern coral which is now in the British Museum (Natural History) collection ref. No. 1972. 7. 27. 1 (ZOO)

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# THE CARBONIFEROUS LIMESTONE MARGIN BETWEEN CROWDECOTE AND HARTINGTON, DERBYSHIRE

by

A. Ludford, P. Madgett and Helen E. Sadler

## Summary

The Carboniferous Limestone margin is well exposed east of the River Dove from Crowdecote to Hartington, Derbyshire. Three distinct limestone facies are present; (i) shelf facies forming a large part of the outcrop, (ii) marginal facies including shell beds and reefs, (iii) basin facies partly equivalent to the other two facies and partly unconformable on them. The limestones of these three facies are thought to range from high $D_1$ to low $D_2$ ($P_1$). Namurian shales are unconformable on the limestones, or are faulted against them.

Structurally the northern part is relatively simple with some NW - SE faults. However, immediately north of Hartington the limestones are folded into an asymmetric syncline with a steeper western limb, and faulting is well developed with the larger faults trending N - S. The syncline is cut off by a fault just north of Hartington.

## History of previous work

The area described in this paper extends along the margin of the Carboniferous Limestone from Crowdecote (SK101652) in the north, south-eastwards for four and a half miles to Bullock Low (SK128601) immediately south of Hartington village. The Carboniferous Limestone near Hartington was first recorded by White Watson as far back as 1821 in a section from Bakewell to Hartington when he noted Aluminous Shales resting on Shell Limestone (Ford, 1960). In 1887, Green, Le Neve Foster and Dakyns described the area thus:- "At Crowdecote we found...... how complicated is the faulting along this line. At Ludwell is a very complicated bit. Opposite the mill the limestone was rising to the west steeply enough to carry it over the Yoredale shales on the opposite bank, unless a fault ran between. From Bank Top to Hartington there runs a clear line of crags of white limestone, dipping east at 25°, and with black shales abutting against them to the west; the boundary, therefore, for two reasons, must be a fault. This clear and undoubted line of faulted boundary ends at Narrow Dale." The interpretation of this description is seen on the Old Series Geological Survey Sheet 81 E.

Parkinson (1950), Prentice (1951), Parkinson and Ludford (1964) and Ludford (1970) all demonstrated that Namurian shales rest unconformably on the Carboniferous Limestone (Viséan) in the area immediately south of Hartington. To the north of Crowdecote a similar unconformity has been described by Hudson (1932), Holdsworth (1963) and Holdsworth and Trewin (1968).

The limestones to the south have been described by Parkinson (1950), Parkinson and Ludford (1964) and Ludford (1970). They indicated that three different facies i.e. basin, reef and shelf are present. To the north, Wolfenden (1958) mapped the area as far south as Pilsbury (SK118634), but concentrated his description on the shelf and reef (marginal) facies which crop out north of Crowdecote.

Sadler and Wyatt (1966) mapped an $S_2$ inlier within the shelf facies one mile east of Hartington and extended the area to include the Upper Limestones of $D_1$ age which crop out on the eastern edge of the region now described.

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## Stratigraphy

The three facies present within the area are shelf facies, basin facies and marginal facies including reef limestones, shell beds and dark-grey, bedded limestones.

### The Shelf Facies

These are a westward extension of those described by Sadler and Wyatt (1966) and Sadler (1966), and are typically well bedded, generally massive, pale-grey bioclastic limestones. They are calcarenites whose composition varies from highly crinoidal limestones with a few fragmented brachiopods, bryozoa and foraminifera, to rocks in which intraclasts predominate. Sorting is generally poor. Sparite is the usual cement and recrystallisation is common. Partial dolomitisation occurs near the fault zones.

### The Basin Facies

As Ludford (1970) found further south, the limestones belonging to this group are much more variable. They are thinly-bedded, dark grey limestones, usually associated with black, calcareous shales. They range from biosparites of calcarenite grade to bituminous micrites. Cherts were noted at one locality near the ford (SK 126620). Limestones of the basin facies (sensu stricto) are limited in their outcrop to fringe areas north and south of Ludwell and to somewhat larger areas around Banktop and Hartington village.

The unstable nature of the marginal area led to the interdigitation of shelf and basin facies. Steady downsinking helped the growth of reefs but periodic uplift and penecontemporaneous erosion of the reef limestone produced limestone conglomerates on the back-reef (leeward) side, as at Parks Barn (SK 121632). Thickly bedded, pale-grey limestones between the conglomerates were produced by biochemical deposition during the times of downsinking.

### Marginal facies

These are thought to have developed in a region of fluctuating conditions.

Reef limestones occur in the north and south of the area where they pass on the eastern side into shelf limestones. In the north they are typical apron reefs with dips away from the shelf (Wolfenden 1958). Judging by the cavity infillings of the shells, these dips are original, hence the term "apron reefs". South of Hartington, Bullock Low covers a belt some two hundred metres wide between the shelf facies and the overlying Namurian shales. The reefs here are similar to the Waulsortian 'reefs' of West-Central Eire described by Lees (1964). Petrographically both apron reefs and Waulsortian 'reefs' are calcite mudstones with varying amounts of recrystallisation. Shells and crinoid debris often occur in pockets. Laminae are common and probably result from recrystallisation of algae (Ludford 1970).

The bedded dark-grey limestones are seen to penetrate the reef limestone, as at Bridge End Crowdecote (SK 102650), or into the shelf facies as in the roadside exposure east of Pilsbury (SK 119634). In the Moat Hall syncline, dark-grey, fine or coarse grained crinoidal limestones are interbedded with pale-grey typical shelf facies and with shell beds. The shell beds are up to ten metres thick and are packed with brachiopods, mainly gigantoproductids of the latissimoid type. The fossils show varying degrees of attrition and the larger brachiopods rest predominantly with their concave side uppermost. Thin sections of the limestones indicate that they are fossiliferous micrites. Lack of sorting of the shells coupled with the presence of a micrite matrix signifies relatively quiet depositional conditions.

Details of the stratigraphy are best provided by subdividing the region as follows:

(i) From just north of Crowdecote (SK 101653) to immediately south of Pilsbury Castle Hills (SK 115639).

The junction between the reef limestones of High Wheeldon (SK 100660) and the Namurian shale to the west produces a strong topographic feature running NW - SE. In the vicinity of Crowdecote this line of contact continues but reef limestones are exposed west of it. This repitition of the reef limestone could be due to faulting, although there is no evidence, or it may signify a stratigraphically higher reef with an embayment of shale between the two reef zones. Green *et al.* (1887) proposed faulting to account for this extended outcrop of limestone, but did not then suspect a sub-Namurian unconformity. This feature is probably due to the exhumation of a pre-Namurian topography.

The bulk of the reef facies near Crowdecote consists of pale-grey, finely crystalline, unbedded limestone, but occasional bands of black, very fine grained limestone up to one metre thick penetrate the reef on the western flank. East of Crowdecote there is a rapid change from reef to shelf facies within a distance of a few metres. The shelf limestones here are pale-grey, massively bedded, poorly fossiliferous calcarenites dipping at 15° SW. The only fossil found in these bedded limestones which indicates a $D_1$ age is *Dibunophyllum bipartitum* (McCoy).

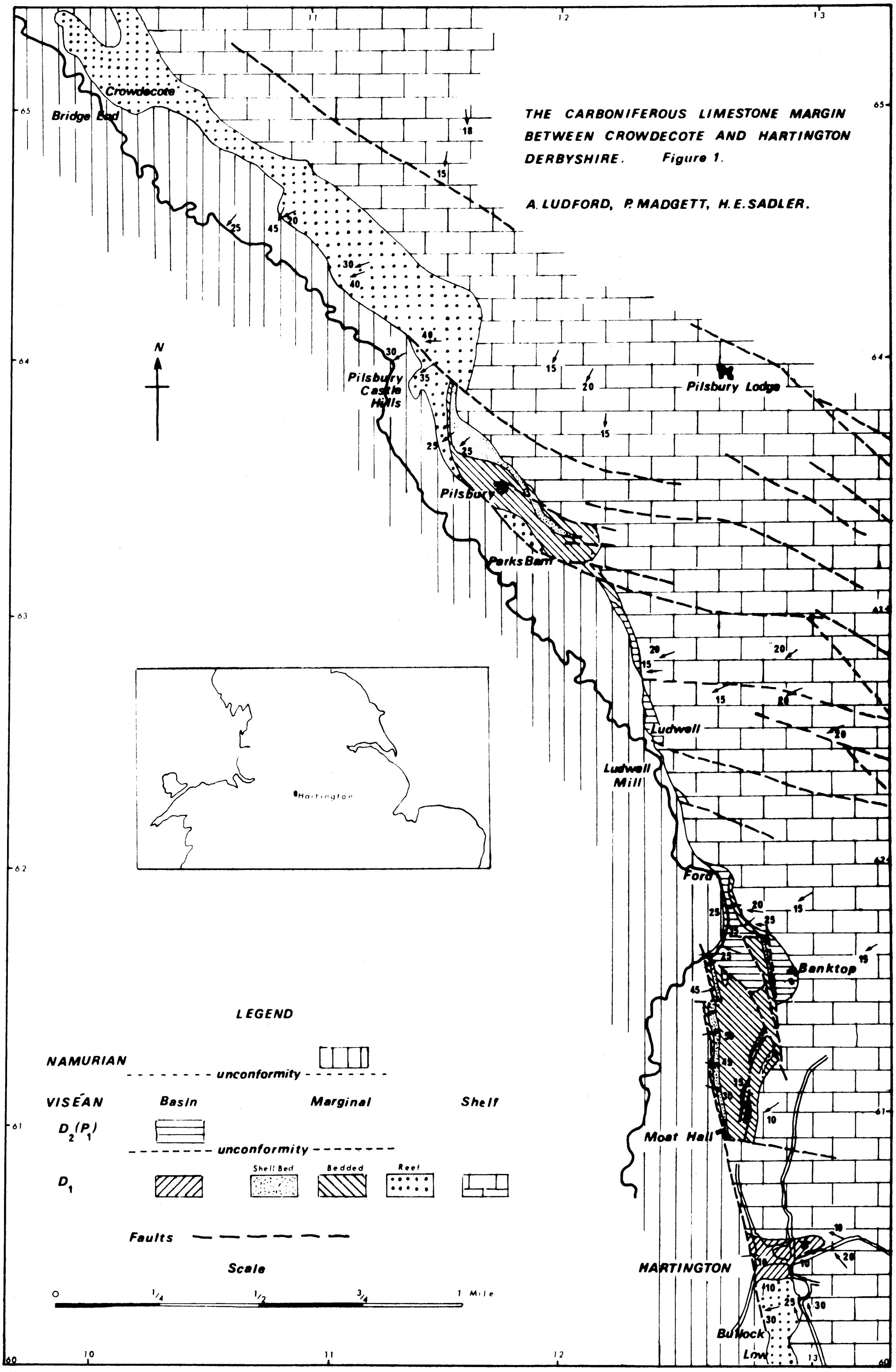
South of Crowdecote the shale/limestone junction again gives a marked break in slope. At one point (SK119645) along this feature purple-black shales dipping at 45° SSW are very close to fine-grained, grey and brown reef limestone dipping at 20° SW. This evidence suggest an unconformable junction. Further south at Pilsbury Castle Hills the limestone margin lies in front of the main reef belt, thus resembling Crowdecote. Evidence at the Hills suggests that they are natural extension of the main reef rather than faulted-off masses. Dips are approximately 30 - 35 degrees SSW. The reef limestones here contain a rich fauna of brachiopods, gastropods, lamellibranchs and occasional goniatites. *Davidsonina septosa* (Phillips), *Palaeosmilia murchisoni* (Edwards & Haime), *Dictyclostus semireticulatus* (Martin), *Gigantoproductus latissimus* (J. Sowerby), *Echinoconchus* sp., *Eomarginifera* sp. and a nautiloid were found at Pilsbury Castle whilst further north (SK111643) *Bollandoceras* sp. and *Bollandites* cf. *castletonensis* (identified by Dr. W.H.C. Ramsbottom) were collected from loose blocks.

### (ii) Pilsbury Castle Hills to Parks Barn (SK 121632).

In the north of this area the reef limestone outcrop gradually narrows, although it occurs along the line of the bridle path almost as far south as Pilsbury Farm. Everywhere the dip is to the SSW. Concomitantly with the decrease in the reef outcrop a shell bed develops and increases in thickness to the southeast. It is terminated on its northern side by a NW - SE fault. Due north of Pilsbury Farm the westward dip of this shell-bed would carry it below the apron reef. Just east of Pilsbury Farm (SK119634) two metres of black crinoidal limestone separate the shell bed from the overlying shelf facies. At Parks Barn the shell bed is partially silicified where it crops out on the crest of the hill north of a large gully. From this point eastwards the bed rapidly thins and disappears.

At the foot of the slope opposite Parks Barn, unfossiliferous limestone of reef aspect dips at 25° W. Between this reef and the shell bed, thickly-bedded, fine-grained, pale-grey limestones are interbedded with four bands of limestone conglomerate. The well-rounded pebbles have diameters of 20 - 50 mm, but one subangular block measured 250 m by 70 mm. Petrographically the pebbles are essentially micrites, and it is most likely that they were eroded from the reefs lying to the west and incorporated in deposits on the leeward side of the reefs. The intervening beds are fine-grained calcarenites with much recrystallisation. The absence of much reef at the surface is explained by the presence of a NW - SE fault which downthrows to the southwest. Breaks in the sequence are indicated by the fact that the conglomerates invariably rest on irregular surfaces, also at one point thinly bedded limestone dips at 20° W above a horizontal bed of massive limestone. The thicknesses of the conglomerates vary as they are traced along the sides of the gully but one measured section showed:-

| | |
|---|---|
| Conglomerate | 1 m |
| Massive limestone | 3 m |
| Conglomerate | 1.5 m |
| Massive limestone | 4 m |
| Conglomerate | 0.3 - 0.5 m |
| Massive limestone | 2 m |


THE CARBONIFEROUS LIMESTONE MARGIN
BETWEEN CROWDECOTE AND HARTINGTON
DERBYSHIRE. Figure 1.
A. LUDFORD, P. MADGETT, H. E. SADLER.
Crowdecote
Bridge End
Pilsbury Castle Hills
Pilsbury
Parks Barn
Pilsbury Lodge
Ludwell
Ludwell Mill
Ford
Banktop
Moat Hall
HARTINGTON
Bullock Low
Hartington
N
LEGEND
NAMURIAN
unconformity
VISEAN
Basin
Marginal
Shelf
D2(P1)
unconformity
D1
Shell Bed
Bedded
Reef
Faults
Scale
0
1/4
1/2
3/4
1 Mile
10
11
12
13
60
61
62
63
64
65

### (iii) Parks Barn south to the ford $\frac{1}{4}$ mile NNW of Banktop Farm (SK126619)

There is no reef limestone in this section, and, although two thin shell beds have been found, their lateral extent is extremely limited. Usually pale-grey limestones of the shelf facies are overlain unconformably by black limestones belonging to the upper part of the basin facies. Even the latter are cut out in several places by the sub-Namurian unconformity.

The relationship between the basin facies and the shelf is best demonstrated at Ludwell (SK 124625). Here unfossiliferous, well-bedded black limestones are seen to rest unconformably on very fossiliferous greybrown limestones from which a fauna of high $D_1$ age has been collected, including *Dictyoclostus semireticularis* (Martin), *Gigantoproductus* cf. *latissimus* (J. Sowerby), *Gigantoproductus* sp., *Productus productus* (Martin), *Rugosochonetes hardrensis* (Phillips), and *Spirifer bisulcatus* (J. de C. Sowerby). Along the banks of the River Dove similar black limestones are interbedded with black calcareous shales. Chert lenses occur adjacent to the spring (SK 126620) immediately north of a small anticline at the ford (SK126619). Occasional small productids and one specimen of a zaphrentid coral are the only fossils to have been noted. No microfossils have been seen in thin sections. East of the road sparsely fossiliferous limestones of the shelf facies dip 20° - 35° SW. They are probably equivalent to the Upper Limestone of Sadler and Wyatt (1966).

All dips measured in this section are westwards and at no point have any limestones been seen dipping eastwards as indicated by Green *et al* (1887).

### (iv) Banktop Farm to Moat Hall (SK 126609).

This is an area of marginal facies complicated by faulting and north-south folding. The main structural feature is an asymmetric syncline with dips up to 55° on the western limb and up to 25° on the eastern limb. A NW - SE fault terminates the structure to the north and an E - W fault limits it to the south. It is also cut off on both east and west sides by faulting. Instability is demonstrated by changes in the thicknesses of individual beds illustrated in a measured section just north of Moat Hall (Table 1).

| Western Limb | Eastern Limb |
|---|---|
| Dark grey, thinly-bedded, slightly bituminous limestone with thin argillaceous bands. 4 m. | Dark-grey, thinly bedded bituminous limestone and dark-grey coarsely crinoidal beds. 2 m |
| | Shell bed 3 m |
| Pale-grey, fine grained limestone with some darker bands 5 m. | Grey, crinoidal crystalline limestone 1 m.<br>Hard, splintery, fine-grained limestone. 2.5 m.<br>Grey, fine-grained limestone 1.25 m.<br>Ostracod bed 0.15 - 0.25 m.<br>Pinkish, crystalline limestone 2 m.<br>Dark-grey, fine-grained limestone 0.6 m. |
| Shell bed 10 m. | Shell bed 1.5 m. |
| Pale-grey, fine-grained limestone with some crinoidal debris. seen to 6 m. | Dark-grey, fine-grained limestone with crinoidal and shell debris. seen to 0.25 m. |

Table 1

This relationship is shown diagrammatically in fig. 3.

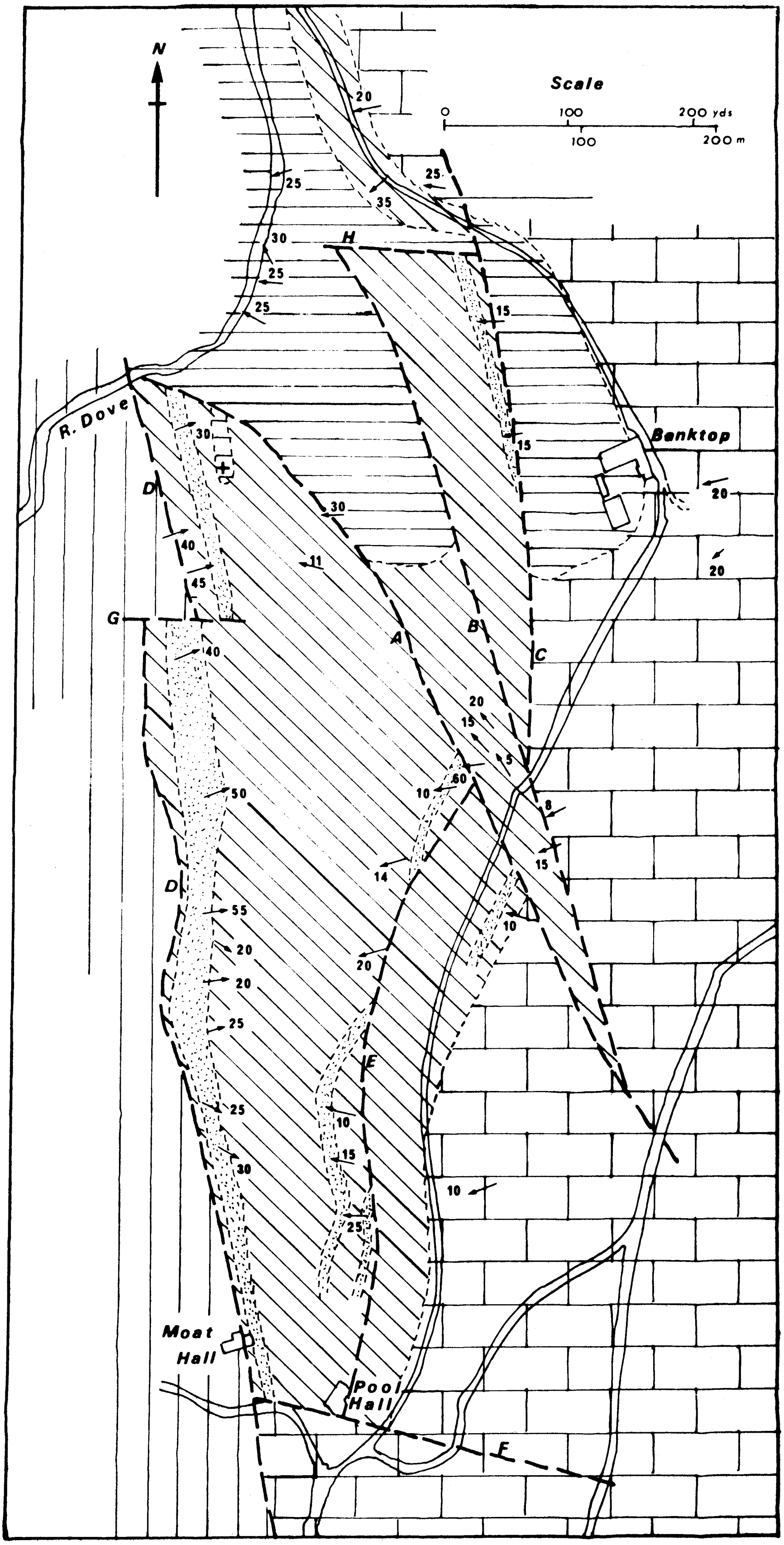


*Figure 2. Geology of the Moat Hall Syncline.*

*Key as Figure 1. A – H Faults – see text.*

The shell bed is packed with brachiopod valves, mainly productids, and include the following:- *Antiquatonia* sp., *Argentiproductus* sp., *Dictyoclostus semireticularis* (Martin), *Dictyoclostus* sp., *Eomarginifera setosus* (Phillips), *Gigantoproductus edelburgensis* (Phillips), *G. latissimus* (J. Sowerby), *G. praemoderatus* (Sarytcheva), *Linoproductus* cf. *corrugatus* (McCoy), *L.* cf. *hemisphaericus* (J. Sowerby), *Martinia glabra* (J. Sowerby), *Productus productus* (Martin), *P. productus* var. *hispidus* Muir-Wood, *Spirifer bisulcatus* (J. de C. Sowerby), *S. grandicostatus* McCoy, *S. trigonalis* (Martin) and *Spirifer* sp. *Carcinophyllum* sp. is the only coral found.

The centre of the syncline is occupied at the northern end by about one metre of black shales of upper basin facies. On the east the syncline is faulted against marginal facies exposed in a roadside quarry (SK 128612) where a thin shell bed is overlain by a thin band of black limestone.

Within the complex of three faults between Banktop and the northern end of the syncline there are pale-grey limestones with some darker, fine-grained beds. Occasional shell pockets with *Lithostrotion irregulare* (Phillips) occur. These limestones dip between 5° and 20° NW and pass westwards under a series of black limestones and calcareous shales dipping at 30° NW exposed in the banks of the River Dove. North of Banktop shales probably occur at the surface and form an impervious cover to any limestone, thus producing boggy ground. East of the Hartington - Pilsbury road the normal sequence of shelf limestones reappears with the massively-bedded rocks dipping 10° - 25° in a general southwesterly direction.

### (iv) Moat Hall to Hartington village.

The Moat Hall syncline is faulted off in the south by an east-west fault, and from here southwards there are very few outcrops. Shelf limestones crop out along the valley sides east of the village and also in Hide Lane north of the church. Dark greyish-brown limestones of the basin facies are exposed in the stream culvert in the village square. Below the southern side of the churchyard massive, pale-grey shelf limestones dip 10° WSW; these pass laterally into darker, fine-grained basin facies at the north gateway and below the west wall of the church. Stones taken from graves dug at the eastern end of the churchyard reveal specimens of both pale-grey limestones and dark-grey limestones with black shales suggesting intercalations of the shelf and basin facies just here. The presence of basin limestones as far as four hundred metres from the margin suggests a large embayment at Hartington at the time of deposition.

### (vi) Hartington to Bullock Low.

From the start of the footpath southwards to Dovedale the exposures indicate a facies change to one of reef limestone. The first hill, north of Bullock Low, is made up of a series of lenses, each with quaquaversal dips, and built one on top of the other to produce a small knoll. Bullock Low is similarly built but the two knolls are clearly separated, thereby indicating that they were discrete growths. Dips usually vary between 10° and 30° although one of 50° has been recorded; their original nature can be demonstrated in several places by the geopetal infillings. The following fossils have been recorded:- *Dibunophyllum bipartitum* (McCoy), *Lithostrotion maccoyannum* Edwards and Haime, *Gigantoproductus* sp., *Martinia glabra* (J. Sowerby), *Productus productus* (Martin), *Striatfera striata* (Fischer), *Endolobus* sp. and occasional fenestellid bryozoa. The reef limestones pass with gradual transition eastwards into the shelf facies near Reynards Lane.

## Age of the beds

The shelf limestones in the eastern part of the area are a continuation of the Upper Limestones of $D_1$ age (Sadler and Wyatt 1966), and the Alsop Moor Limestone (Parkinson 1950), to which Parkinson and Ludford (1964) subsequently assigned an upper $D_1$ age. The diagnostic $D_1$ forms collected in this survey include *Palaeosmilia murchisoni* (Edwards and Haime), *Dibunophyllum* cf. *bourtonense* Garwood and Goodyear, and *Gigantoproductus latissimus* (J. Sowerby).

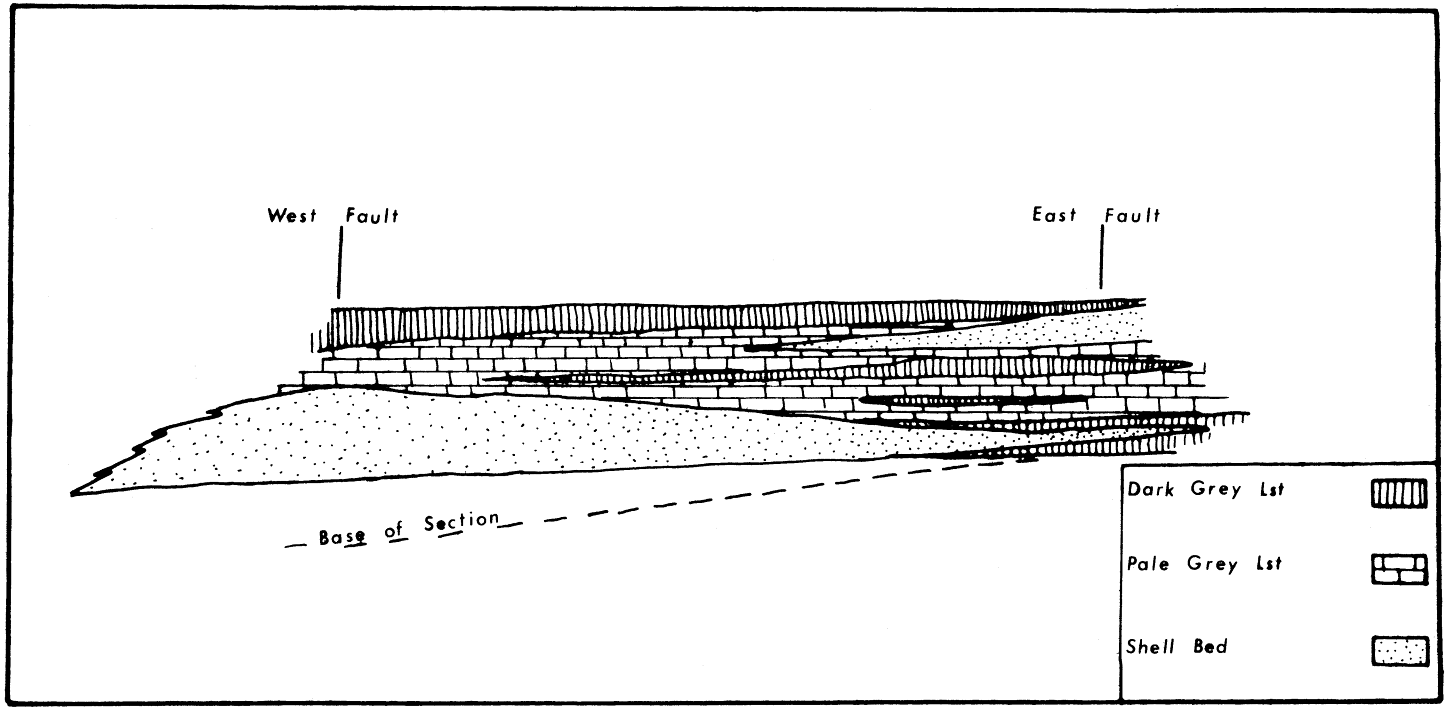


Figure 3.

Diagrammatic representation of the lithologies within the Moat Hall syncline

The marginal facies are of upper $D_1$ age. The general fauna of the shell bed is almost identical with that of a shell bed at Waterhouses which lies at the top of a richly fossiliferous high $D_1$ sequence (Ludford 1951). The reef limestones south of Hartington contain *Striatifera striata* which is rarely found much below $D_2$. Parkinson and Ludford (1964) showed that Pennilow is late $D_1$ in age, and as Bullock Low is separated from it by only a small gully, it is probably of the same age. The reefs at Pilsbury and Crowdecote include *Davidsonina septosa* and *Bollandites* cf. *castletonensis* thus equating them with the Upper $B_2$ reefs of Wolfenden (1958).

Beds of the basin facies are of two different ages. The larger outcrop at Hartington extends into and interdigitates with the shelf limestones and is therefore $D_1$ in age. Similarly, minor intercalations on the eastern side of the Moat Hall syncline are associated with the shell beds (see Fig. 3 and table 1). However, the higher beds consist of black limestones interbedded with calcareous shales and occasional cherts, which lie unconformably on fossiliferous shelf limestones (see Ludwell Section). Thus these latter beds cannot be older than Upper $D_1$ and are regarded as $D_2$ ($P_1$) in age.

The fissile black shales which crop out at various points along the River Dove are probably Namurian in view of their unconformable nature, although there is no palaeontological evidence. Holdsworth and Trewin (1968) note that the lowest Namurian beds in the vicinity of Dowel Dale to the north are of $E_2$ a.ii age.

## Structure

Over much of the area the limestones dip westwards from the Hartington $S_2$ inlier and only in the Moat Hall syncline is there any appreciable folding. Faults noted by Sadler and Wyatt (1966) can often be traced into the present area; these are normal faults which trend NW - SE in the northern part of the area and WNW - ESE in the central part. The Moat Hall syncline has a north-south axis in its southern part swinging to NNW - SSE at the northern end. Dips on the western limb range from 20° to 55° on bearings of 85 - 110, whereas on the eastern side the dips are lower, ranging from 10° bearing 260 at its northern end to 25° bearing 250 at the south. The northern end of the syncline is cut off obliquely by a NW - SE fault (fault 'A' fig. 2).

West of Banktop two sub-parallel NNW - SSE faults occur ('B' and 'C' fig. 2). They merge south of the farm and pass through a crag where they are reperesented by a calcite vein about 0.3 m thick. The main fault of the area ('D' fig. 2) is on the western edge of the syncline where it throws Visêan limestones against Namurian shales. Another fault ('F' fig. 2) running just north of west terminates the syncline to the south, but cannot be traced far eastwards; its throw is not less than twenty metres to the north. There are also two small faults in the area; one displaces the shell bed on the western side of the syncline ('G' fig. 2) whilst the other ('H' fig. 2) terminates the outcrop of the thin shell bed north of Banktop. Gentle folding may be seen in Hartington village whilst small scale folding in the black limestones occurs at the ford (SK 126619) where a small anticline has limbs dipping at 20° SW and 25° NW.

## Acknowledgements

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# APPLICATION OF TERRESTRIAL PHOTOGRAMMETRY TO EARTH SCIENCES

by

A.B. al Naqash

Following the recent paper by F. Moseley (1972) on the use of stereoscopic ground photographs in field geology, it was felt that some further information on the use of photogrammetry would be of interest.

## Introduction

Photogrammetry can be defined as the science of obtaining reliable survey measurements by means of precisely poisitioned photography in order to determine geometric characteristics, such as size, shape and position of the photographed object. Terrestrial photogrammetry has become indispensable to any kind of precise surface survey work. It can be said that this science has been employed for detailed geological and geomorphological mapping since 1901 (Pulfrich, one of the founders of stereophotogrammetry). The technique has been usefully applied in the Alps (Finsterwalder, 1954), Canadian Rockies (Konecny, 1964), and Alaskan highlands (Naqash, 1965).

The use of this kind of survey is to prepare accurate large scale topographic maps to assist in the quantitative assessment of the geological phenomena. Therefore, first-order accuracy photogrammetric instruments are required to plot the maps from this kind of photograph; thus, a network of base lines and triangulation stations should be established in order to get a reliable topographic map.

The basic equipment employed in this kind of survey is a Wild P-30 phototheodolite, which is a combination of a T-2 theodolite and a camera carrier. The theodolite section serves a triple purpose, i.e. for angular measurements in locating photographic stations and control points, for distance measurements, and for determining the desired orientation of the survey camera. The phototheodolite should be levelled and directionally oriented with respect to all base exposure stations before any photographs are taken.

## Practical Limitations of this Survey

Terrestrial photogrammetry can provide a substantially complete topographic picture, but to achieve this goal the whole terrain must be within view. This means that, if possible, photographic stations should be so situated as to permit full coverage of the terrain. It is an advantage to have little or no forest or woodland because it produces textural differences which cause distortion in the image position of the plotted surface. It should also be mentioned that this method has limitations when used in flat country without oblique vantage points. This is because the image scale of terrestrial photographs is fixed within narrow limits by the actual terrain configuration. Moreover, accuracy in determining planimetry and height is governed by the fact that in terrestrial photogrammetry camera stations lie directly in the plane of the ground, with the result that planimetric errors increase as the square of the distance from the base.

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# EXCURSION TO THE CASTLETON CAVES

Leader: T.D. Ford Sunday, 10th October 1971

Opening the excursion at Peak Cavern, it was explained that in spite of nearly two centuries of exploration of the Castleton Caves there were still many unsolved problems. Cavers dedicated to exploration in places difficult of access were still adding details to the story, but it was up to geologists to provide an explanation of why the systems had evolved in the way they had. Observation of detailed features, both above and below ground was necessary, and a careful assessment of processes past and present and their mutual interaction was needed before an approach to the whole story could be made. The Director explained that he had made some contributions to the present state of knowledge, but that much more research was needed. (see Ford 1967). The accompanying map (based on that in Ford (1967) by permission of the British Speleological Association) summarizes the state of knowledge concerning the distribution of underground passages. Links in drainage between cave systems which have been proved by dye tests are indicated, and the more important mineral veins are shown, as drainage undoubtedly used vein cavities for considerable distances though these were unlikely ever to be accessible. Altitudes of swallets, resurgences and of as many intermediate points as possible are given and these enable contours of a hypothetical water-table to be drawn, though it must be emphasized that this is not a boundary between a continuous zone of saturation below and a zone of percolation above as each drainage system is separate and follows its own independent channels sometimes crossing above or below another system.

The tourist part of Peak Cavern provided many interesting features. The large entrance chamber showed sections in lenticular "reef" limestones, cut by several vertical fractures. Solution had obviously allowed collapse of major blocks here. Much of the first part of the cave system beyond the Vestibule showed solutional development, and present day fluctuation of water levels indicates that this section has now long left the permanently submerged phreatic zone. Its relation to the valley profile outside was important, for if one restored the valley floor to some of the higher terrace levels seen further down the Derwent Valley, the Vestibule must have been submerged and functioning as a Vauclusian spring, with water rising to resurge perhaps 100 feet or more above its present altitude. When this phase had occurred was unknown, but the patches of scree cemented to the walls of the gorge outside the entrance indicated a former partial periglacial fill stage. The rope-walks in the entrance had been cut in a slope of scree and other debris, but without an archeological trench cut through the deposits, the story they might tell was not known.

Inside Peak Cavern, the Director outlined the events which led to the discovery of the inner passages by divers in 1949, and the subsequent relatively dry access which had been provided by draining the "Mucky Ducks". Further in, the main passages were developed mainly in widely spaced bedding planes dipping gently towards Castleton, and the stream had cut a vadose trench down from these. A clay fill stage had blocked many ancient passages, and this was now in process of gradual removal by the present drainage in places. Much of the inner cave was below Cave Dale, but this was regarded as a dry valley eroded on the surface in the periglacial conditions of the Last Glaciation, without regard to the cave beneath which was older.

On leaving Peak Cavern, the party paused to see the water flowing from Russet Well, situated on the east side of the Peak Cavern stream. Its catchment, however, is to the west, via Giants Hole and the other swallets, and through the inner parts of the Speedwell Cavern. In reaching Russet Well the water must flow beneath the Peak Cavern stream without mixing with it, thus emphasizing the discrete nature of such drainage systems. Russet Well did this by the water having utilized primary cavities in a mineral vein. In times of wet weather, snow melt etc., water backed up in both Peak and Speedwell Caverns, and overflowed as a mixed system via the now-blocked Peakshole Sough (a lead-miners drainage tunnel) and in the inner part of Peak Cavern.

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vol. 4, pp. 225-227.

The party then passed on to Treak Cliff Cavern. In contrast to the active system at Peak Cavern, Treak Cliff Cavern has been left high and dry by circumdenudation. It was discovered about 1750 by miners looking for Blue John Stone, the ornamental variety of fluorspar. The entrance tunnel leads straight into the old cave where Blue John is seen filling or lining the voids between boulders in the pre-Namurian boulder bed (Simpson & Broadhurst 1969). Ford 1969). Methods of mining were demonstrated and varieties of Blue John pointed out. In 1926 a breakthrough was made by Blue John miners into the inner caverns, Aladdin's Cave, Fairyland and the Dream Cave. Being in the solid limestone below the boulder-bed these are devoid of Blue John, but are well-decorated with multitudes of stalactites and stalagmites. Some of the new ideas of the formation of such speleothems were explained by the Director. Attention was also called to the ochreous clay on the floor of parts of the cave. There were several possibilities for the origin of this. Some could be insoluble residue from the limestone, but not more than a small proportion; some could be weathered shale from the former cover of Edale Shales; but a probable source for much of it was the former cover of loess which once overlay this area in late Pleistocene times.

Moving on to Giants Hole, the Director explained that this was but one of a series of swallet caves along the limestone margin. Several more lay to the west, and all engulfed small streams draining off the Millstone Grit of Rushup Edge. Their present position was clearly related to the shale margin having been eroded back from a former extent higher on the limestone. Old swallets should occur at higher levels but there was little evidence for these though some might be concealed beneath the loessic soil cover, and others had been so changed by mining that they were no longer recognizable. An important feature was that the swallets were mostly in hollows where solufluction debris off Rushup Edge had collapsed or been washed into pre-existing caves. Thus the present swallets were older than the solifluction sheet. Their drainage also penetrated right under the apparent topographic watershed which ran roughly southwards from Mam Tor. Giants Hole was the only one of the swallet caves which could be explored for more than a few hundred feet. The stream can in fact be followed for nearly a mile, to a depth of about 400 feet. Until recently this involved crawling through the body-tight Pillar Crawl and bailing out the Backwash Pool, but sufficient work towards opening the cave to the public had been done to make it an easy scramble. The party followed the stream passage noting features such as the scalloping of the rock surface by turbulence of the slightly corrosive waters draining Rushup Edge, and the former higher level of the stream cave system. Leaving the stream to pass through the former site of Pillar Crawl, the passage blasted through sheets of stalactitic fill was seen. From Pillar Hall onward the left-hand wall was seen to be a cemented stream-gravel fill, probably related to a different passage system active during solifluction and high run off stages. At Backwash Pool the former high-level of water was indicated by the undercut notch at head height! Rejoining the stream in Base Camp Chamber the high avens, well-decorated with stalactites, were thought to mark a strong joint system. Patches of old fill were seen cemented on the walls, and resistant chert nodules formed ledges. Exploration, on this occasion, stopped at the top of the 20 feet deep Garlands Pot, though the beginning of the narrow meandering Crab Walk could be seen below.

To close the day the party took advantage of an opportunity to visit Bagshaw Cavern at Bradwell. Descending the narrow stairway in the old mine workings by which the cave had been discovered, various features of mining were seen. The long silt-filled gallery to the Dungeon was traversed, and the former Pleistocene (?) fill stage was discussed. The more recently active passage near the Dungeon pot-hole was examined in more detail and much scalloping was seen, not only roof and walls, but also on fallen blocks. Finally the party squeezed by installments into Calypso's Palace, a stalactite Grotto formed in a calcite vein.

In closing the excursion the Director called attention to the simple facts that there was still a lot of exploration to be done before the cavers' dream of being able to go right through the systems was realised. There was also much geological and geomorphological research to be done before anything near a chronology could be established for the evolution of the cave systems. Many observations allowed a partial relative chronology to be worked out, but much more was needed, in particular some absolute dates. The party had doubtless realized that many of the old theories on the formation of cave systems were no longer tenable: members of the Cave Research Group of Great Britain were currently investigating details of how solution took place, of the rate of erosion, of the significance of mix-corrosion, of organic acids, and of the effect of the lithology of the limestone on the nature of caves. Finally, the Director pointed out that the party had had the opportunity of seeing both commercialized and semi-commercialized caves, and in the latter at least had been able to appreciate something of the nature of the obstacles found in cave exploration. They had also had the problems of safety in caving pointed out, but two points needed emphasizing again - good reliable lights and not too big a party!

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# THE GEOLOGY OF THE WYE VALLEY AND THE FOREST OF DEAN: A FIELD MEETING REPORT

Leader: Paul L. Hancock

Saturday, 5th June - Sunday, 6th June 1971

The purpose of the excursion was to examine the geology of the Wye Valley and the Forest of Dean, with a special emphasis, at the request of the Society, on the Old Red Sandstone. In the region covered by the excursion the general succession of solid formations, including principal lithologies, is after Welch and Trotter (1961), Allen (1964) and Gayer and Stead (1971):

| | Maximum thickness in metres |
|---|---|
| JURASSIC | |
| Lower Liassic (clays and thin limestones) | 15 |
| TRIASSIC | |
| Rhaetic (clays, shales and thin limestones) | 8 |
| Keuper | |
| Keuper Marl (red and green mudstones) | 91 |
| Dolomitic Conglomerate (conglomerates and breccias) | 9 |
| -------- major unconformity -------- | |
| CARBONIFEROUS | |
| Upper Coal Measures | |
| Supra-Pennant Group (mudstones, sandstones and thin coals) | 335 |
| Pennant Group (sandstones with subordinate mudstones and thin coals) | 244 |
| Trenchard Group (conglomerates, sandstones, and thin coals) | 107 |
| ------- minor unconformity -------- | |
| Carboniferous Limestone Series | |
| Drybrook Sandstones (sandstones) passing south into Drybrook Limestone (fragmental limestones and calcite mudstones) | 213 |
| Whitehead Limestone (limestones, calcite and dolomite mudstones) | 46 |
| -------- minor unconformity -------- | |
| Crease Limestone (dolomitised oolitic and crinoidal limestones) | 30 |
| Lower Dolomite (dolomitic limestones) | 122 |
| Lower Limestone Shale (crinoidal and oolitic limestones, shales) | 67 |

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vol. 4, pp. 229-236.

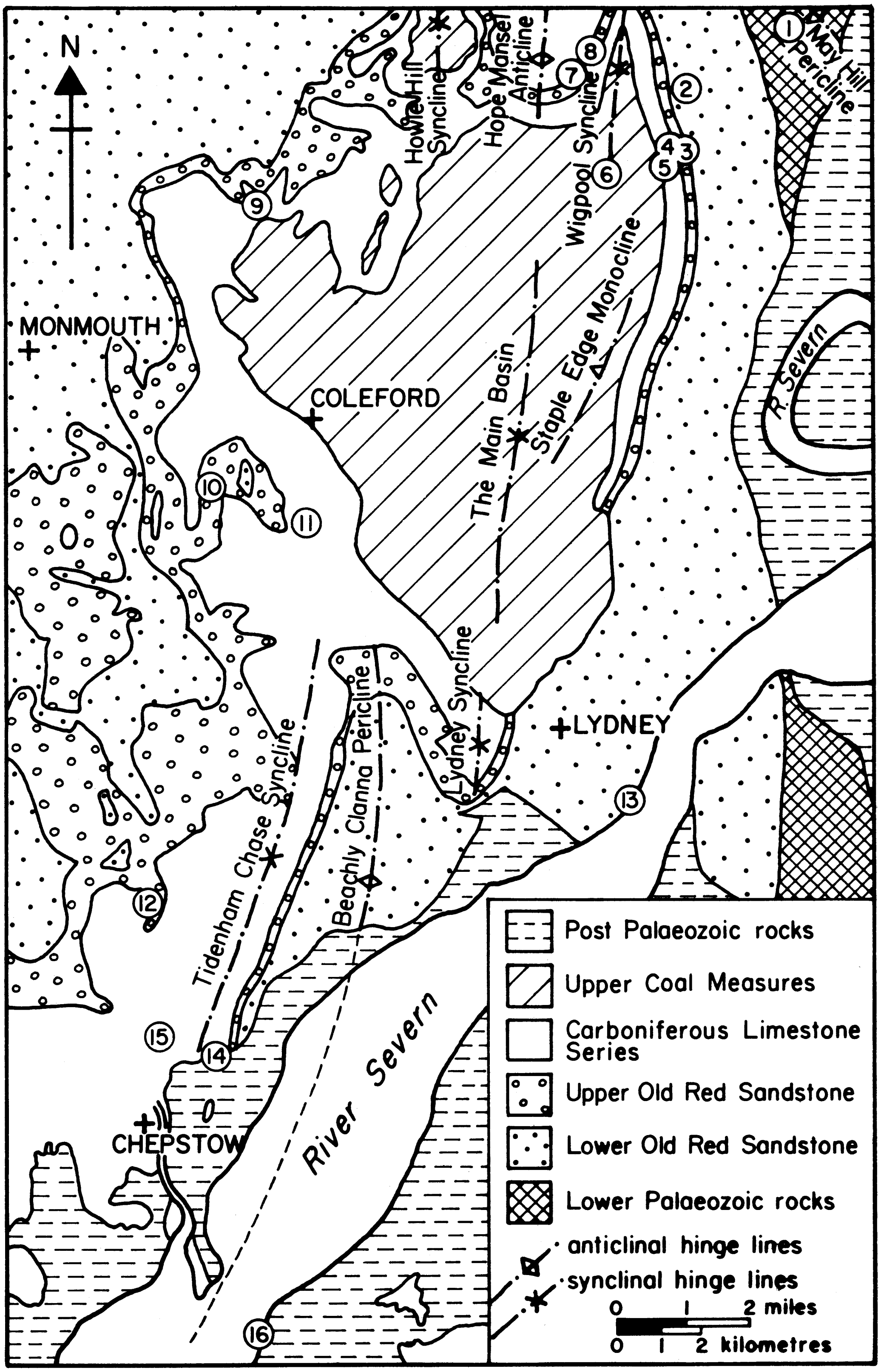
N
MONMOUTH
COLEFORD
LYDNEY
CHEPSTOW
Howle Hill Syncline
Hope Mansel Anticline
Wigpool Syncline
May Hill Pericline
Staple Edge Monocline
The Main Basin
R. Severn
Lydney Syncline
Beachly Clanna Pericline
Tidenham Chase Syncline
River Severn
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
⑫
⑬
⑭
⑮
⑯
Post Palaeozoic rocks
Upper Coal Measures
Carboniferous Limestone Series
Upper Old Red Sandstone
Lower Old Red Sandstone
Lower Palaeozoic rocks
anticlinal hinge lines
synclinal hinge lines
0 1 2 miles
0 1 2 kilometres

Figure 1

| | Maximum thickness in metres |
|---|---|
| DEVONIAN (OLD RED SANDSTONE) | |
| Upper Old Red Sandstone | |
| Tintern Sandstone Group (sandstones and siltstones) | 152 |
| Quartz Conglomerate (conglomerates and sandstones) | 30 |
| - - - - - - - - major unconformity - - - - - - - | |
| Lower Old Red Sandstone | |
| Brownstones (sandstones and conglomerates) | 838 |
| St. Maughan's Group (sandstones and siltstones) | 442 |
| Raglan Marl Group (siltstones and sandstones) | 518 |
| Downton Castle Sandstone (sandstones and siltstones) | 15 |
| SILURIAN | |
| Ludlow Series | |
| Upper Ludlow Beds (calcareous mudstones and thin limestones) | 91 |
| Aymestry Limestone (limestones and calcareous mudstones) | 30 |
| Lower Ludlow Beds (calcareous mudstones and thin limestones) | 152 |
| Wenlock Series | |
| Wenlock Limestone (limestones) | 107 |

Older beds are exposed in the core of the May Hill pericline but were not visited. Figure 1 shows the outline geology of the area and the approximate positions of the localities.

The dominant structures in the area are a series of approximately N - S trending folds (Fig. 1), developed during several phases of earth movements (Welch and Trotter, 1961). Major intra-Carboniferous movements caused the break between the Drybrook Sandstone and the Upper Coal Measures, and resulted in many of the present day westerly verging asymmetrical folds in the Carboniferous Limestone Series and the Old Red Sandstone. Gayer and Stead (1971) suggest that the folds were westerly facing, en-échelon monoclines prior to the folding of the overlying Coal Measures. Folds initiated during the intra-Carboniferous movements include the Hope Mansel anticline, the Wigpool syncline, the Lydney syncline, the Clanna-Beachley pericline and the Tidenham Chase syncline. The relatively open structure known as the Main Basin, which contains the principal outcrop of the Coal Measures, was formed during later Variscan movements which occurred before the Triassic and after the deposition of the Coal Measures. Most of the dips in the Main Basin are shallow except along the Staple Edge monocline where some beds are nearly vertical. Although the hinge lines of the intra-Carboniferous and the post-Coal Measures folds are approximately parallel, they are not necessarily coincident. For example, near Lydney the trough of the Main Basin is about 600 m east of the trough of the Lydney syncline. The resulting unconformity is clearly displayed on the map (Fig. 1). At the same time as the Coal Measures were being folded some of the intra Carboniferous folds were being accentuated. Post-Triassic movements were relatively minor and resulted in gentle dips. Triassic and Jurassic rocks are now preserved in basins elongated along NNE lines.

SATURDAY 5th June

About 25 members and friends assembled at 11.00 am in Huntley village. After a brief introductory talk from Dr. Hancock the party drove west to the first locality.

1. Hobbs Quarries, Longhope (SO 695195)

The Wenlock Limestone is exposed in a series of quarries on the western limb of the May Hill Pericline, and according to Lawson (1955) comprises three divisions:

|  |  |  |
|---|---|---|
| upper limestone | - | irregularly bedded, fragmental, ferruginous limestones; |
| nodular beds | - | thin-bedded, nodular limestones and calcareous shales; |
| lower limestone | - | thin-bedded limestones with ballstone structures. |

About 100 m south of where the lane from Dursley Cross to Longhope crosses the crest of a minor hogback ridge, the party examined the lower limestone division. The dip of the Wenlock Limestone is about 25° to the west, but in the quarry the uniformity of this dip is masked by the presence of several masses of reef limestone called ballstones by Lawson (1955). They are exposed in the lower part of the quarry face, while directly above them the bedded limestones are arched. Hobb's Quarries are famous for the abundance of fossils which they contain. Despite the overgrown state of the quarry some members made collections from the talus slopes; specimens of *Atrypa*, rhynchonellids, *Favosites*, *Calymene* and algae were found.

From Hobb's Quarries the party returned to the main A40 road and proceeded to Longhope for lunch.

2. Wilderness Quarry, Mitcheldean (SO 672185)

About 43 m of beds belonging to the Brownstones dip steeply to the west in this quarry on the eastern limb of the Wigpool syncline. The sequence comprises six completely exposed, and two partly exposed, fluviatile cyclothems which have been described by Allen *et al* (1968). Each cycle commences with an erosional surface which is overlain by sandstones which grade up into siltstones interbedded with thin, fine-grained sandstones. The fine-grained top of the cycle is terminated by the erosional base of the succeeding cyclothem. The easily accessible second cyclothem, the base of which is about 2 m above the top of the extensive green bedding surface forming the eastern quarry face, is described in detail by Allen (1964). Members examined this and other cyclothems, and noted excellent examples of red and green colouration, intraformational conglomerates, flat and cross-bedding, parting lineation, current ripple marks, bioturbation features, suncracks, pedogenic limestone concretions and erosional channels. In addition to the sedimentological features, the presence of a fish bed was also an incentive to visit the quarry. The fish bed is a fine-grained sandstone, 14 to 25 cm in thickness, within the fifth cyclothem. Abundant fragments of the pteraspid *Althaspis leachi* indicative of an Upper Dittonian age, have been found, and also some of the articulated thelodont *Turinia pagei* (Allen *et al*, 1968). Despite an exhaustive and sometimes hazardous search members were able to find only a few small fish scales.

3. Former Point Inn, Plump Hill, Mitcheldean (SO 663171)

Adjacent to the site of the former inn westerly dipping beds of Quartz Conglomerate are visible at the start of a path. The rocks are mainly pebbly sandstones containing well-rounded clasts of quartz. They are overlain by sediments of the Tintern Sandstone Group. The party were able to examine these green sandstones and siltstones in small exposures which were available as a consequence of the recent demolition of the inn. The party then walked about 150 m up the hill to a quarry just north of the road.

4. Quarry in Lower Dolomite, Plump Hill, Mitcheldean (SO 662172)

In this quarry members examined fine-grained dolomitic limestones belonging to the Lower Dolomite, and collected calcite crystals from veinlets. Dr. Hancock pointed out that many of the bedding surfaces are stylolitic, a specimen of one showed the stylolite to be filled by about 1 mm of red, hematite-rich material. The stylolitic form of many of the bedding surfaces may be responsible for obscuring the steep westerly dip; the more noticeable discontinuities being a set of easterly dipping strike-joints.

5. Edge Hills Sand Quarry, Mitcheldean (SO 661168)

The brightly-coloured sandstones and shales of the diachronous Drybrook Sandstone are exposed dipping moderately west about 300 m south-west of the previous quarry. The Drybrook Sandstone sediments in the quarry have been dated by Sullivan (1964), using miospores, as Lower Visean. They were being deposited at the same time as limestones were being laid down elsewhere in the South-West Province. The 43 m of strata comprise alternating sandstones and shales. A shaly coal is visible just west of a minor fault in the southern quarry face. The party examined the succession and detailed features such as rootlet beds, bioturbated sandstones, and ripple marks. There was some discussion about the significance and position of the Edge Hills Coal and accompanying strata of suggested Lower Westphalian age (Sullivan, 1964).

6. Quarry east of Nailbridge (SO 647163)

In this quarry, about 1.5 km west-south-west of the Edge Hills Quarry, subgreywackes of the Pennant Group dip gently south-south-east close to the core of the Wigpool syncline. The higher units are flat-bedded and generally show parting lineation while some of the lower units comprise cross-stratified channel fill. Some surfaces of the large smooth joints display plumose marks and, at right angles to them, concentric rib marks. Plumes indicate a rapid rate of crack formation and are orientated parallel to the direction of fracture propogation.

7. Euroclydon, Puddlebrook (SO 643187)

In the narrow road cutting members were able to see about 80 m of sandstones and siltstones of the Tintern Sandstone Group dipping moderately south-east on the western limb of the Wigpool syncline. The Lower Limestone Shale crops out at the extreme eastern end of the section. From the cutting the party descended the hill along the road for a further 300 m.

8. Bailey Gate, Puddlebrook (SO 643190)

At the roadside there are bluffs of easterly dipping conglomerates and sandstones of the Quartz Conglomerate which forms the steep escarpment. A level is reputed to have been driven from near here to work gold in the Conglomerate (Welch and Trotter, 1961).

9. Symonds Yat Rock (SO 563161)

This famous vantage point is a bluff of gently dipping Lower Dolomite high above an entrenched meander of the Wye. At the view point members observed the scenery and its relation to the underlying geology. From Symonds Yat the party dispersed, mainly to their hotel in Gloucester.

SUNDAY 6th June

10. Newland (SO 551092)

The party reassembled just below the village in the floor of an abandoned and entrenched meander of the Wye. It is thought that the early Wye flowed over a wide flood plain developed on a surface which is now at about 600 ft (183 m). During its subsequent history, it has been entrenched and several meanders abandoned, the one at Newland being at a maximum about 400 ft (127 m) above the present level of the Wye (Welch and Trotter, 1961). Although the length of the loop is about 8 km, the separation at its neck is only about 400 m. From where members were standing the steep valley sides cut in the Tintern Sandstone Group and the Lower Limestone Shale were visible looking south. The flat floor of the valley which is 200 m wide contains only a small stream.

### 11. Clearwell Scowles (SO 577081)

In the Scowles members collected specimens of hematite and iron-coated dolomite crystals from the Carboniferous Limestone. The ore is generally thought to have been derived during Permo-Triassic times by the weathering of iron bearing minerals in the former cover of Coal Measures. Downward percolating waters transported the iron in solution until it reached a favourable host rock, such as the relatively open-textured Crease Limestone, where mineral replacement occurred.

### 12. Road section south of Tintern Abbey (ST 535997 to 537993)

About 400 m south-east of the Abbey recent widening of the A466 road, has exposed a new section which displays the passage from the continental, red and green sandstones and siltstones of the Tintern Sandstone Group into the grey marine limestones of the Lower Limestone Shale. Members found at least one limestone, about 2 m in thickness, interbedded with red and green siltstones within the upper part of the Tintern Sandstone sequence. A similar Tintern Sandstone succession containing two limestone bands is described by Welch and Trotter (1961, p. 56) from a stream section about 1 km west of the road. In the cutting the rocks dip gently into the core of the Tidenham Chase syncline. After collecting specimens members returned to the Abbey for Lunch.

### 13. Lydney Harbour cliff section (SO 652015 to 654019)

About 140 m north of the entrance to the harbour a continuous river section in folded Lower Old Red Sandstone rocks commences. The first exposures, and most of those on the foreshore, are of red and green siltstones and fine-grained sandstones belonging to the Raglan Marl Group, which Allen (1971) interprets as a mainly intertidal sequence. Many of the siltstones contain pedogenic limestone concretions, which in some beds are sufficiently plentiful for the rock to be called a limestone. A concretionary bed first seen in the core of an asymmetric syncline about 90 m north of the start of the section is thought to be the equivalent of the ***Psammosteus*** Limestone which marks the top of the Raglan Marl Group (Welch and Trotter, 1961, p. 38). Dr. Hancock pointed out that although the concretions are irregular, many possess a long axis which is orientated approximately perpendicular to the bedding on the gently dipping limb of the fold, and, as a consequence of strain, at an acute angle to the bedding on the steep limb. The concretions were probably precipitated from carbonate-rich ground waters when there was exposure during the dry seasons of an arid or semi-arid climate.

From the outcrop of the concretionary limestone the party walked a further 250 m to the north, passing the core of a gentle anticline and a noticeable fault, to the start of a cliff section in a cyclothem near to the base of the overlying St. Maughan's Group. According to Allen (1964, p. 176) this fining upwards fluvial cycle, which is 8.8 m in thickness, can be divided into four members: interbedded sandstones and siltstones deposited in a tidal channel; cross-stratified, fluvial channel sandstones; interbedded backswamp siltstones and sandstones; and siltstones interbedded with minor sandstones also deposited in a backswamp which was sometimes exposed. At the base of the cycle is a scoured surface showing noticeable relief; a second scoured surface marks the base of the second member. The party examined the more accessible parts of the cyclothem and examples of internal structures such as cross-bedding, contorted foresets, ripple marks and burrows. Members also found specimens of fish spines and scales. ***Traquairaspis***, indicative of a Dittonian age, is recorded by Allen (1964, p.176) from some of the lower sandstones. Low angle thrust faults disturb the sequence at the north end of the section.

### 14. Tidenham Quarry (ST 554955)

The worked quarry is in the Lower Dolomite and Crease Limestone which dip steeply west towards the core of the Tidenham Chase syncline. Members were reminded that the dip of the other limb, as seen at Tintern, is gentle, thus demonstrating the asymmetry of the fold and its westerly vergence. As time was limited, the limestones were not examined in detail except to note the tectonic ripples visible in the northern face and the well-developed dip-joints. Excellent crystals of calcite from veins and cavities in the breccia of the unconformably overlying Dolomitic Conglomerate were collected from the south-western corner of the quarry.

15. Wintour's Leap, Woodcroft (ST 542963)

The spectacular 90 m high cliffs are cut mainly in the oolitic Drybrook Limestone, the Drybrook Sandstone cropping out near the base. The rocks dip about 10° to the east on the western limb of the Tidenham Chase syncline. The dip at Wintour's Leap is into the cliff, thus rendering it reasonably stable. At Wynd Cliff, on the opposite bank, the dip is in the same direction as the slope of the ground but it is less steep than the slope, and thus there has been landslipping. A remarkable crescent-shaped hook of alluvial land on the opposite bank is attributed to the combined effects of river flow and tidal scour.

From Wintour's Leap members made their way to Aust Cliff via Chepstow and the Severn Bridge. On the way it was possible to glimpse the small sharp anticline in the Whitehead Limestone adjacent to the road north of Chepstow (ST 534945), the gentle folds in the Drybrook Limestone near to the bridge over the Wye (ST 537944), and the Crease Limestone on which Chepstow Castle is sited (ST 534941).

16. Aust Cliff (ST 564890 to 565897)

This classic riverside section exposing the Rhaetic has been described by Reynolds (1946), Whittard (1949) and Welch and Trotter (1961). A summary of the succession is:

| | | Metres |
|---|---|---|
| JURASSIC | Lower Liassic | 1 |
| TRIASSIC | Rhaetic | 8 |
| | Keuper Tea Green Marl | 7 |
| | Keuper Red Marl | 30 |
| | ------ unconformity ------ | |
| CARBONIFEROUS | Lower Dolomite | |

The Keuper sediments are mainly red and green silty mudstones containing some carbonate material. Beneath the upper-most 15 m of Red Marl there are discontinuous beds and veins of granular and fibrous gypsum, some of them containing calcite and celestine. Both the Cotham and Westbury Beds of the Rhaetic are cyclic (Cowie *et al*, 1965), the principal rock types being black shales and fossiliferous grey limestones. The Bone Bed at the base of the Rhaetic is thin and lenticular, nevertheless some members obtained good specimens for comparison with material collected during the Society's investigation of the Rhaetic in the East Midlands.

South of the Severn Bridge the sequence is on the southern limb of a gentle E - W trending anticline. The rocks are displaced by several faults downthrowing south. The fault nearest the bridge is still well exposed and can be seen to be a normal fault dipping south at about 60°.

The main eastern pier of the bridge is founded in the strong Lower Dolomite which occurs beneath the Triassic unconformity which rises to about sea-level at Aust. Some pockets of Dolomitic Conglomerate rest on the unconformity and can be seen in a reef just to south of the eastern pier.

After members had finished inspecting the section, Dr. Taylor expressed the Society's thanks to Dr. Hancock, who would here like to take the opportunity of thanking Mr. R. Bradshaw and Dr. B.P.J. Williams for discussing the localities with him.

P.L.H.

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| | |
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# PERMO - TRIASSIC ROCKS OF THE NOTTINGHAM AREA

Leaders: F.M. Taylor & A.R.E. Houldsworth     Sunday, 2nd May 1971

In order that this excursion would differ somewhat from that of September 1964 (Taylor 1964) the opportunity was taken to demonstrate to Members of the Society, recent research work undertaken by the excursion leaders in the Trowell and Bramcote area and published in this issue of the journal, (Taylor and Houldsworth 1972 a, b). A full bus left Nottingham and travelled direct to Kimberley, where the lowest beds of the Permo - Triassic sequence are exposed. The excursion then visited localities in an ascending stratigraphical order up to the Mapperley Plains Skerry in the Keuper Marl. The route and the description of the localities, follow this ascending sequence.

The Kimberley Railway Cutting (SK 503453). Since the 1964 visit, an extensive landslip had taken place, exposing rocks on the north side of the cutting. The following sequence was seen:

| | |
|---|---|
| Magnesian Limestones | 2.8 metres |
| Dolomitic Siltstones | 5.0 metres |
| Basal Breccia | 0.8 to 2.0 metres |

- - - - - - unconformity - - - - - -

shales of the Coal Measures

Although the age of the Coal Measures rocks could not be proved, the shales immediately underneath the breccia are coloured red, green and grey. The breccia contained angular fragments of many Coal Measures rocks and good specimens were collected. The Dolomitic Siltstones were full of plant fragments, none of them well preserved, though their carbonaceous remains covered the bedding planes. These rocks pass upwards into the Magnesian Limestone. Water was seeping out of the base of the breccia and the waterlogged slip material gave ample evidence of the instability of the side of the cutting. The water collecting points, constructed by the Kimberley Brewery for their water supply, were seen further to the east along the cutting.

From Kimberley, Members travelled by bus to Bulwell.

Wilkinson's Quarry, Bulwell (SK 532455). This quarry is a few metres south of a quarry visited in 1964, which is now closed and filled with rubbish. The coarse dolomite, typical of the Bulwell Magnesian Limestone is well displayed. The beds of dolomite are separated by thin green clay seams. Cross-bedded layers can be seen on the weathered quarry walls. Two bivalve beds, only the moulds being preserved, were located, one close to the top of the quarry and a second, more persistent bed midway in the quarry face. Dolomite crystals, in geodes were found by some Members.

An attempt to see the mineralised top bed of the Magnesian Limestone and the overlying marls at Sankey's Pit (SK 433450) was thwarted by locked gates, irate property owners and large dogs.

Stonepit Plantation Quarry, Strelley (SK 513422). The quarry at this location is at the southern end of the Magnesian Limestone outcrop and exhibits the littoral facies of the formation. The dolomite is coarse grained and contains a large amount of sand and small quartz pebbles. Some of the layers resemble a shingle beach. The beds are cross-laminated. This quarry is larger, less overgrown and shows the littoral facies of the Magnesian Limestone, much better, than the quarry near Strelley Church, visited in 1964.

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vol. 4, pp. 237-239.

Swancar Quarry, Trowell (SK 491393). South of the Nottingham - Ilkeston road, there is a marked facies change and the Magnesian Limestone Formation is not recognised. Instead, the Mottled Sandstone Formation, normally seen above the Magnesian Limestone in the Bulwell area, now rests directly on Coal Measures. The unconformity, seen in Swancar Quarry is described in detail, elsewhere in this issue (p.165).

From the quarry, the party crossed the canal and walked along the tow-path for a short distance to the east. On the way, the position of the Nottingham City Water Department Pipe-Line (Derwent Abstraction Scheme) was pointed out and also the position of the Clifton Fault, as revised after the hard labour carried out by certain Members of the Society, excavating trial pits to prove its location. Crossing the railway bridge a short visit was paid to another old quarry (SK 493391), containing sandstones with both dolomite and barite cement. Cross-bedded units and ripple-marks can be seen here (Taylor and Houldsworth 1972 Plate 12 fig. 1). The leaders, then led the party up the west face of Stapleford Hill.

Stapleford Hill (SK 498387). A pause was made, close to the summit, to see the iron rich sandstones exposed a few metres below the trig. point. On the top, the well cemented pebbly sandstones contain both calcite and barite as cementing minerals and are extremely hard. The hill makes an excellent view point and details of the Coal Measures rocks to the west, Permian rocks to the north, in the area already visited, and Triassic rocks to the east and south were pointed out. Members of the excursion then walked down to the Hemlock Stone.

The Hemlock Stone (SK 499386). This isolated stack (cover of this issue) is made up of sandstones with an irregular barite cement. Weathering has removed the softer layers emphasising the cross-bedded characteristics. Flaggy sandstones, outside the fenced-off stack were seen to contain barite crystals. The name - Hemlock Stone - indicates one possible origin of the stack and also its use, but glacial, arid and marine erosion have been postulated for its origin. It is almost certainly an ancient quarry remnant, too hard for the equipment of the time, and left, accidentally or otherwise, for nature to erode. This was the opinion of Stukely (see Shipman 1884).

Bramcote Sand Quarry (SK 504387). This large quarry on the east side of Coventry Lane had already been seen from the top of Stapleford Hill. The sequence of Mottled Sandstones and Pebble Beds were to be examined in the quarry so the party had not been given much time to examine these lithologies so far on the excursion. Details of the quarry are given elsewhere in this issue (Taylor and Houldsworth 1972 a, b). Members examined the lithology, the junction of the formations, the occurrence of barite and the faulting. Those who were a bit sceptical about the occurrence of barite up to this point on the excursion, were impressed by the large specimens of barite cemented sandstones at the top of the quarry. Despite all offers, copper minerals either in this quarry or on Stapleford Hill remained illusive.

Nottingham Castle Rock (SK 569394). The stop below Nottingham Castle Museum was brief, merely to point out the buff coloured Pebble Beds, typical of much of the City of Nottingham, in contrast to the red sandstones seen at the previous locality, and to note the similarity of structures.

Colwick Road, Nottingham (SK 592397). At one time, a railway bridge spanned Colwick Road at this point and the original excavations were re-exposed when the bridge was demolished in 1965. The top bed of the Pebble Beds is exposed here, said to be the lowest bed in the cutting below a thick red marl, but this layer is followed by sandstones of similar grain size and with rounded pebbles. There is no obvious erosion surface, or a layer, well cemented with calcite, which would indicate the junction between the Pebble Beds below and the Keuper Basement Beds above. Starting at the floor of the cutting, there is a thick bed of typical Pebble Beds, followed by a layer of red marl. Another sandstone follows with smaller but well rounded pebbles. Above, a second marl layer occurs and then thin sandstones, still coarse but with much smaller and flattened pebbles. Thin marls separate these sandstones. Higher in the sequence, the sandstones become finer grained and greenish-yellow in colour. This type of sandstone then alternates with thin marl seams until the sandstones become micaceous, brown in colour and finer grained. These sandstones at the top of the cutting are at the base of the Waterstones Formation.

Colwick Wood (SK 601398). At this locality, the top of the Waterstones Formation forms a high cliff adjacent to the railway. The fine grained, brown, micaceous sandstones with interbedded marl were examined and a number of sedimentary structures, noted.

Gunthorpe Wier (SK 688735). A fine river cliff on the south bank of the River Trent exposes the Keuper Marls, with fibrous gypsum, above the Mapperley Plains Skerry, which is located at the foot of the cliff and in the river bed. The skerry was examined and its characteristic sedimentary structures eventually found. These include two types of ripple marks, salt pseudomorphs, and slump bedding. The coach returned to Nottingham.

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# EXCURSION TO NORTH LINCOLNSHIRE

Leader: P.E. Kent

Sunday, 17th October 1971

The party left Shakespeare Street a little late, and travelled via Radcliffe and the Fosse Road to Newark. From there the route ran north below the Rhaetic Scarp to Marton (with its Saxon church), where it turned east to cross the Lias outcrop via Stow to reach the Inferior Oolite at Ingham. The Lias hereabouts produces a very featureless landscape, but the piercing together of information from temporary exposures has provided fairly detailed knowledge of the sequence.

From Ingham the route followed "Lincoln Cliff", the edge of the Oolite scarp, northwards to Kirton Lindsay. The main quarry (SE 9401) in the Lincolnshire Limestone was visited by permission of the Associated Portland Cement Co.; it shows this formation in its northern, cementstone, facies - an alteration of grey calcilutite beds with shales (Kirton Cementstones), overlain by a thicker shale (Kirton Shale) with irregular coralliferous limestone masses; the latter yielded abundant bivalves including *Lopha*, *Parvirhynchia* and *Acanthothyris crossi*.

The party then continued north to Scunthorpe, where it was met by Mr. David Elford of The British Steel Corporation for visits to the extensive Frodingham ironstone quarries which currently produce five million tons of ore per year. Lunch was taken at the first stop, at the Crosby Warren Ironstone mine (SE 905125) before beginning examination of the Lias section with the excellently exposed Pecten Bed at the base of the davoei zone, a six foot ferrunginous limestone/calcareous ironstone with abundant large well preserved *Pseudopecten aequivalvis*. An oblique road provided access to the main bulk of Lias clays, the lower part of the 90 foot exposure providing a wealth of Echcoceratidae and striking large "Deroceras".

The party then moved north again to Thealby to a parallel section (SE 905187) which provided better collecting conditions in the Frodingham Ironstone beneath the clay sequence; here members collected a range of characteristic lamellibranchs and a few ammonites, including *Pararnioceras* from the upper beds.

The party returned to Nottingham, loaded with fossils, via Ermine Street, Lincoln, and Newark.

P.E. Kent

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vol. 4, p. 241.

# REVIEW

The Copper and Lead Mines of Ecton Hill, Staffordshire by John Robey and Lindsey Porter 92p. Obtainable from the authors or from Peak District Mines Historical Society (M.J. Luff, 14 Tredington Road, Glenfield, Leicester, at £1.25).

This book includes an account of the geology of Ecton Hill which suggests that the Old Man may not have found all there is to find. Itineraries for tours of the remains of the copper mines both on the surface and underground are included, but the main part of the book is a detailed history of mining. As this was one of the richest copper mines in Europe in its day, and was the site of several innovations in mining technology, the careful analysis of all the available historical documents carried out by the authors goes far beyond being just a local history. There is an extensive bibliography and numerous photographs.

T.D.F.

## Secretary's Report 1971-72

The eighth year of the Society commenced in the limbo of the postal strike and ended in the gloom of the coal strike. Nevertheless, yet another successful year of activities was added to its record.

It was not possible to send out a circular in January, and it was greatly to the credit of our Members that without a reminder they attended the Presidential Address in February in such force. The postal strike continued throughout February, and again a circular could not be sent out to give notice of the Annual General Meeting which had been arranged for March 13th. The meeting was held, however, and it was agreed that the geological films should be shown but that the business should be adjourned until May 8th. Mr. J.E. Metcalfe had undertaken to arrange the film show, and succeeded in presenting an excellent series of films in spite of being restricted to communication by telephone, of being obliged to arrange transport by rail, and at the last having to travel to London himself to collect the remainder of the reels in time for the meeting. Mr. Metcalfe is to be thanked for his efforts and congratulated on his efficiency.

In April Dr. A. Woodland had agreed to speak to the Society on the work of the Institute of Geological Sciences. However, at the time of the meeting he was engaged in a removal to London to take up duties as Deputy Director, and he asked if his lecture might be postponed until later in the year. At very short notice indeed, Mr. D.M. Taylor, research student, Nottingham University, was invited to take his place. We are exceedingly grateful to Mr. Taylor for accepting the invitation and for sharing with us the results of his research on Andesites.

The first field excursion of the season was led by the President and dealt with the area around Nottingham. The day was fine and sunny and the large party in high spirits to be in the field again. A contribution was made by Mr. A. Houldsworth who demonstrated a previously unrecorded exposure of the unconformity between Coal Measures and Lower Mottled Sandstone.

On May 8th the Annual General Meeting was held. An amendment was made to the Constitution whereby the annual subscription for Ordinary Members was increased to £2.00 for Joint Members to £2.25 beginning with the 1972 subscription. Five Council Members retired from office, and five new Members were elected in their place. The same Officers were re-elected to serve for a further year. The business was followed by a show of geological films again arranged by Mr. J.E. Metcalfe, but with something less of self sacrifice than before.

At one point during the postal strike it had seemed almost as if it would be impossible to plan a weekend meeting in June. Communication was virtually impossible and delay followed delay until at least the Treasurer succeeded in establishing personal contact with Dr. P.L. Hancock of Bristol University. Dr. Hancock at once agreed with enthusiasm to lead a party to the Wye Valley, Herefordshire. It was then found that all available accommodation in that area had been taken over by salmon fishermen, but at the eleventh hour a hotel was found in Gloucester where a provisional booking was accepted by telephone. The excursion began on Saturday morning and ended on Sunday evening. Dr. Hancock, who is an old friend of Nottingham Members and an early Member of the Society himself, met the party near Gloucester and spent the day in the Forest of Dean. On Sunday the party visited the Wye Valley and a locality on the Severn estuary, and the excursion finished with the spectacular climax of Aust Cliff. It was a splendid excursion geologically and socially.

The July excursion to Ashover was led by Mr. A.M. Honeyman of Nottingham University. A large party travelled by coach from Nottingham, and Members from other areas joined in at Ashover. The complete sequence of rocks was followed, the structure of the area described, and the day ended briskly with a scramble up the slope of the escarpment.

In September Dr. R. Neves of Sheffield University led a large party to the area North and West of Sheffield. The morning was dull and the coach travelled from Nottingham through thick patches of fog, but upon emerging to the level of the moors the sky was cloudless, the sun brilliant and the air warm. The peerless day which followed showed the sunlit purple moors at their best, and a highly appreciative party was conducted along narrow winding roads from one locality to another. The excursion, grossly over-running time, ended at the classic base locality of the British Westphalian in the grounds of the Sheffield water-works at Langsett.

Earlier in the year, Dr. T.D. Ford of Leicester University had agreed to lead a small party - it must, he said, of necessity be a small party - to see the underground drainage of the Castleton area. This was finally planned for October, and a limited party arranged. When 48 members were found to have assembled at Castleton, to the dismay of the Secretary and the displeasure of the leader, it had to be admitted that the Society displayed an unexpectedly keen interest in the underworld which would have to rebuked. It was greatly to the credit of Dr. Ford that he coped magnificently with twice the number he had expected, and that he provided a most memorable and exciting excursion, leaving out nothing that he had planned, and indeed including an extra cavern.

The following Sunday, Dr. P.E. Kent, Chief Geologist, B.P. Ltd., led an excursion to the Scunthorpe area. A coach ran from Nottingham and Dr. Kent described the geology as the party travelled. A convoy of cars joined in at Kirton-in-Lindsey, and at the first locality some 60 people were present. The afternoon was fine and breezy and the party were delighted with the wealth of fossils awaiting collection in the ironstone quarries.

There were in all six eminently successful excursions during 1971, attendance averaged 50 and indeed rose to 60 at the end. The Society is greatly indebted to the six leaders, Dr. F.M. Taylor, Dr. P.L. Hancock, Mr. A.M. Honeyman, Dr. R. Neves, Dr. T.D. Ford, and Dr. P.E. Kent who provided such a magnificent excursion season.

The first indoor meeting was held in the Dept. of Geology, Nottingham University, early in November when Dr. A.W. Woodland, Deputy Director of the Institute of Geological Sciences gave his deferred lecture on the work of the I.G.S. Members were surprised at the vast scope of the Institute and the wide range of its activities, and questioned Dr. Woodland closely at the end of his lecture.

In December, Dr. I.D. Sutton of the University of Nottingham Adult Education Dept. gave a lecture entitled 'Siluria". He first marked the centenary of Sir Roderick Murchison by describing his work among the Silurian rocks of Wales, and followed by a general survey of Silurian fauna, particularly of tabulate corals. He showed splendid slides and arranged an exhibition of Silurian fossils and microscope slides to be seen after his lecture.

The January meeting was held in Matlock jointly with the Matlock Field Club. On this occasion Dr. R.H. Johnson of Manchester University gave a most interesting lecture which described some of the glacial problems in the Southern Pennines. A large audience of about 100 were present.

The Society's Seventh Annual Dinner was also held in January, again in the Nottingham University Staff Club. Dr. and Mrs. W.A.S. Sarjeant were invited to be the Society's Guests of Honour. Dr. Sarjeant was shortly to leave Nottingham University to take up an appointment as Associate Professor at the University of Saskatchewan, Canada, and the Society wished to show appreciation of the great contribution he had made to the founding of the Society and of the "Mercian Geologist". After dinner, an illustrated book of minerals was presented to him by the President as a memento.

As on previous occasions Members provided slides illustrating some of the high spots of the year's excursions.

In February the Presidential Address marked the anniversary of the foundation of the Society. The President gave an account of some of his own researches and introduced some original and controversial suggestions which the meeting found very stimulating and thought provoking. The Presidential Address will be published in the "Mercian Geologist" in due course.

The indoor meetings were well attended and the Society is grateful to Dr. Woodland, Dr. Sutton, Dr. Johnson, Mr. Taylor and the President for such interesting and varied lectures.

Early in the year the Society was again invited by the South of England Building Society to arrange a display in their office window. Mr. R.J.A. Travis agreed to do this, and the exhibition he produced gave the Society very successful publicity. Mr. Travis is to be congratulated.

The Editor was this year unfortunate in having to contend with difficulties in the printing of the Journal, and it was not possible to publish Vol.4. No.1. before September 1971. Happily, circumstances improved and Vol. 4. No.2. was published in February 1972.

Eleven circulars were produced during 1971. During the year a service of "postmen" was initiated, who kindly deliver circulars by hand to Members who live nearby. By this means there is a considerable saving in postage, and gratitude is due to Miss E. Colthorpe, and Messrs. J.E. Sykes, W.S. Moffat, H.M. Hickling, A.E.G. Allsop, J.E. Metcalfe, J.S. Cargill, N. Leiter, D. Manning.

Membership of the Society has continued to increase steadily. During the year 33 Ordinary Members, 9 Joint Members, 10 Juniors and 4 Institutions have been elected. There have been a certain number of resignations and some lapsed memberships through non-payment of subscriptions, but there has been an overall gain of 37 Members, and the present state of membership is as follows:

| Honorary | Ordinary | Joint | Junior | Institutional | Total |
|---|---|---|---|---|---|
| 2 | 243 | 88 | 25 | 127 | 485 |

The Society continues to be grateful to Professor Lord Energlyn and the University of Nottingham for providing a comfortable home base, and for making available any facilities which may be required.

Finally, may I thank the many Members who have been helpful to me during the year, and particularly Dr. F.M. Taylor, our President, who is always ready with advice and support.

D.M. Morrow.

# THE MERCIAN GEOLOGIST

## Journal of the East Midlands Geological Society

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

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| Vol.1 | No.1 | December 1964 |
| Vol.1 | No.2 | June 1965 |
| Vol.1 | No.3 | January 1966 |
| Vol.1 | No.4 | September 1966 |
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