EXCURSION

Asbian and Brigantian evolution of the Central Derbyshire carbonate platform: Wye Valley

Leader: Peter Gutteridge, Cambridge Carbonates Ltd, 11 Newcastle Drive, The Park, Nottingham.

7th June, 1998

The aim of this trip was to demonstrate the sedimentary evolution of the central part of the Derbyshire carbonate platform during the Asbian and Brigantian, with emphasis on:

- The nature of carbonate sedimentation on a flat-topped carbonate shelf during the Asbian.
- The volcanic and sedimentary events associated with the development of an intrashelf basin within the Derbyshire carbonate platform.
- The depositional mechanisms of deep water carbonates in the intrashelf basin.
- The contrasting effects of sea level variations on sedimentation in the intrashelf basin and on carbonate platform sedimentation.

Asbian platform limestones were examined at Hartington Station Quarry. The main features of the evolution of the carbonate platform during the Asbian and Brigantian were illustrated by a traverse from Millers Dale to Monsal Head along the former railway line and the story was completed near Ashford. The general geology of the Derbyshire carbonate platform is described by Gutteridge (1987) and Aitkenhead *et al.* (1985).

1. Hartington Station Quarry (SK 151 613)

Hartington Station Quarry exposes the Bee Low Limestones of Asbian age. These were deposited in the shelf interior before the intrashelf basin was formed. The succession comprises thickly bedded limestones separated by prominent bedding planes. Each limestone bed contains evidence of progressive shallowing. The bases of some beds comprise a thin unit with large brachiopods in an argillaceous matrix deposited in relatively deep water. This passes upward into grainstone and packstone with abundant peloids, crinoids and other open marine bioclasts deposited in shallow water high-energy conditions. The tops of limestone beds often show features indicative of subaerial exposure such as calcrete and desiccation structures including fenestrae. Bedding planes represent a lithified palaeokarstic surface that has undergone dissolution during subaerial exposure. This took place either beneath a soil cover or on an exposed bedding plane. The palaeokarsts are overlain by former volcanic soils.

These limestones were deposited on a flat-topped carbonate platform in water depths ranging from tens of metres to emergent. The succession represents several repeated shallowing events culminating in subaerial exposure followed by flooding. This pattern of sedimentation is a common feature of shelf carbonates of this age in Britain and beyond and was probably caused by a combination of variations in subsidence rate and eustatic sea level variations induced by accretion and melting of polar ice caps (Horbury, 1989; Walkden, 1987).

2. Great Rocks Dale: Overview from lay-by on the A6 (SK 114 725)

The main features of the stratigraphy of the central part of the Derbyshire carbonate platform can be seen from this viewpoint. The Woo Dale Limestones of Holkerian age crop out in the Wye Valley to the west. These are the oldest exposed limestones on the Derbyshire carbonate platform and were deposited in shallow subtidal and peritidal environments (Schofield and Adams, 1985). The lower part of the Woo Dale Limestones has been replaced by dolomite. The dolomitisation was caused by the influx of Mg-rich pore fluids during Upper Carboniferous burial (Schofield and Adams, 1986). The lay-by is close to the boundary of the Woo Dale (Holkerian) and Bee Low Limestones (Asbian). The Bee Low Limestones are exposed in the old Greater Rocks Dale Quarry and in Tunstall Quarry to the north. They are equivalent to those exposed in Hartington Station Quarry and were deposited in similar enviroments. To the east, the former Buxton to Bakewell Railway follows the River Wye. The regional dip of the limestones is, with minor variations, to the east. Progressively younger limestones are therefore exposed to the east, providing an almost continuous record of the sedimentary evolution of the Derbyshire carbonate platform from the Holkerian to its final demise in the mid Brigantian.

3. Millers Dale Station Quarry (SK 137 732)

This locality demonstrates the stratigraphical relationships associated with the development of an intrashelf basin within the Derbyshire carbonate platform. The detailed stratigraphical relationships, sequence of events and sedimentology of the Station Quarry Beds has been described by Walkden (1977) and Gutteridge (1990).

The exposure behind the car park at the old Millers Dale Station comprises thickly bedded, pale limestones of Asbian age deposited in a platform interior setting. These are equivalent to the limestones exposed at Hartington Station Quarry. The top of the Asbian limestones is marked by a palaeokarst. This is overlain by more thinly bedded, darker limestones known as the Station Quarry Beds, which represent the first limestones of Brigantian age to be deposited on the Derbyshire carbonate platform. The sequence of events was:

1. Deposition of Asbian shelf limestones.
2. Subaerial exposure of the carbonate shelf at the Asbian/Brigantian boundary, producing a major palaeokarstic surface at the top of the Asbian

shelf carbonates.

3. Differential subsidence of the central part of the Derbyshire carbonate platform and the development of an intrashelf basin in which the Station Quarry Beds were deposited.

4. Litton Mills disused railway cutting (SK 156 729 to SK 162 728)

The west to east transect along the old railway cutting shows the relationship between basinal sedimentation, volcanism and a facies change from deep water basinal sedimentation to shallow water sedimentation over a structurally-controlled intrabasinal high.

The transect starts at the eastern margin of the Upper Millers Dale lava which was extruded into water. This formed a local area of shallow water over which bioclastic sediment grew. This was shed off the lava to form a wedge of bioclastic limestone containing corals and brachiopods draped over the front of the lava. The overlying Monsal Dale limestones are younger than the Station Quarry Beds. They were deposited in deep-water conditions within the intrashelf basin. The limestones exposed along the rest of the cutting to the east are at approximately the same stratigraphical level as the lava flow and show a progressive eastward change to deposition in more open marine and higher energy conditions. At the tunnel entrance at the eastern end of the cutting, the Asbian carbonate shelf limestones are seen at the base of the face. These are overlain by a palaeokarstic surface with a deep pit infilled by brownish clay. This palaeokarstic surface formed during the local uplift that produced the intrabasinal high. The Station Quarry Beds have been removed by erosion at this locality. The sequence of events recorded here is:

1. Localised uplift resulted in subaerial exposure of the Asbian limestones and removal of the Station Quarry Beds.
2. Extrusion of the Upper Millers Dale lava seen at the western end of the section. The distribution of the lava was controlled by this uplift.
3. Deposition of the Monsal Dale Limestones in an intrashelf basin setting. These show a transition from deep to shallow water deposition across this uplift.

5. Cressbrook Railway Cutting (SK 172 724)

This locality exposes the Monsal Dale limestones that were deposited in deep water in the intrashelf basin. The detailed sedimentology of limestones deposited in the intrashelf basin has been described by Gutteridge (1989).

The main limestone type comprises evenly bedded fine-grained carbonates with common tabular chert. These were deposited in low energy conditions with very low oxygen levels. They represent the background deposition of very fine-grained carbonate sediment reworked from the surrounding carbonate shelf. Several slump sheets are present which are composed of bioclast packstone and wackestone which was deposited in higher, more oxic conditions in shallow water. These are overlain erosively by bioclastic turbidites that probably represent repeated slope failure after slumping.

6. Monsal Dale viaduct cutting (SK 179 718 to SK 183 717)

This section commences at the Hobs House Coral Bed which can be traced throughout the basin. A total of three coral beds are present in the succession and are thought to represent transgressive events when sea level rose after a period of lowstand. The majority of the limestones in the Monsal Dale Viaduct Cutting are fine-grained bioclastic sediments with rare beds of coarse bioclastic sediment. They were deposited as carbonate turbidites derived from the surrounding carbonate shelf. A slump sheet is present part of the way along the section. Both the up dip extensional and down dip compressional parts of the slump sheet can be seen. In one example, a colonial coral appears to have surfed down slope on this slump sheet.

The ‘Rosewood Marble’ is present at the top of the succession. This is a finely laminated dolomitic unit. The laminations consist of alternating mm-scale carbonate mudstone and grainstone. The ‘Rosewood Marble’ is one of four similar units in the basinal succession that were deposited in a peritidal setting during a sea level lowstand when the intrashelf basin was almost completely drained. The ‘Rosewood Marble’ is slumped, showing that it is not in its initial depositional setting.

7. A6 By-Pass: Ashford Village (SK 195 695)

The highest finely laminated dolomitic unit present in the intrashelf basin succession is exposed here. This marks the boundary between the Monsal Dale and overlying Eyam Limestones (both Brigantian in age) in the intrashelf basin (Gutteridge, 1991).

This unit contains evidence of desiccation including fenestrae and desiccation curls. Other features indicative of deposition in shallow to emergent conditions, such as pseudomorphs of early-formed evaporites, plant fragments and calcrete textures are also present. This unit was deposited in a peritidal environment that developed in the intrashelf basin during sea level lowstands. The abundance of soft sediment deformation features in this laminite also shows that it is not in its original depositional setting. The details of the depositional environments of these dolomitised laminated units have been described by Gutteridge (1989). The laminated dolomitic unit is overlain erosively by a thin bed containing reworked spiriferid brachiopods. This was deposited during flooding of the intrashelf basin and is overlain by interbedded fine-grained carbonate turbidites and shale.

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EXCURSION

Cloud Hill Quarry

Leader: Keith Ambrose

Wednesday, 17th June, 1998

Twenty-three members met at this vast working quarry operated by Breedon Quarries plc. Access to the quarry is strictly controlled for safety reasons. These controls required the party to be conveyed between stops by Land Rovers supplied by quarry operators and the BGS. The quarry management also maintained a safety vigil throughout the duration of the trip.

The purpose of this excursion was to examine the Carboniferous Limestone exposed in the quarry. Two main facies are present, separated by an unconformity, the Main Breedon Discontinuity. Virtually the entire sequence is heavily dolomitised and as a result, precise environmental interpretation remains speculative. Undolomitised limestone is restricted to a small part of one face.

Cloud Hill [SK 41 21] is situated about 1km south of Breedon on the Hill and is one of 5 inliers of Carboniferous Limestone aligned NNW-SSE, lying between Shepshed and Melbourne. The quarry has a maximum depth of over 120m, the lowest part lying below sea level. It exploits the dolostone for roadstone and is excavated into the Milldale Limestone Formation (Aitkenhead and Chisholm, 1982) of Early Chadian age and the Cloud Hill Dolostone Formation, of ?Holkerian-Asbian age. The Milldale Limestone crops out in the eastern part of the quarry and in the lower levels in the western part; the Cloud Hill Dolostone crops out in the north and upper western faces. The major unconformity between the two formations is well exposed on these faces. The highest beds seen, in the south-west of the quarry, have been correlated with the Ticknall Limestone Formation. They have not been dated here, but are of Brigantian age at Ticknall. The rocks dip steeply (approximately 60 degrees) to the west, the dip magnitude decreasing westwards.

The inliers of Carboniferous Limestone in South Derbyshire have received little attention over the years. Table 1 shows the lithostratigraphy of the Carboniferous Limestone in Cloud Hill and Breedon quarries (Ambrose and Carney, 1997). The first detailed accounts were by Parsons (1918) and Mitchell and Stubblefield (1941), who both erected a stratigraphy for the beds. The quarries also received brief mention by Ford (1968). Monteleone (1973) produced the first detailed work on the Carboniferous Limestone of Leicestershire and South Derbyshire in an unpublished PhD thesis. King (1968, 1980, 1982, 1983) has published various papers relating to the mineralisation seen in the quarries. In 1993, the British Geological Survey commenced a full resurvey of the 1:50,000 sheet 141 (Loughborough) which includes all of the Carboniferous Limestone outcrops. The results of the mapping and detailed logging of the quarries have enabled stratigraphical revision, age determination and palaeoenvironmental interpretation. A summary of the stratigraphy is given in Table 1.

Throughout the Early Carboniferous, the area south of Breedon was submerged below a shallow shelf sea, the Hathern Shelf. This lapped onto the emergent Charnwood Forest to the south, with a fault-bounded deep-sea trough, the Widmerpool Half-Graben or Gulf, lying to the north. Here, a thick turbidite sequence accumulated as a result of fault-controlled subsidence. The Cloud Hill inlier formed in response to Late Carboniferous deformation. It stood out as an inselberg in the Permo-Triassic desert and gradually became buried by sediment deposited by fluvial and aeolian processes. The inselberg was probably completely buried in Mid to Late Triassic times. It may have remained buried until the Pleistocene, when it was exhumed by erosion associated with glacial advances and accompanying periglacial denudation.

At the **first locality**, on the eastern face of the old floor of the quarry, the oldest part of the sequence was examined. The beds here comprise thinly bedded dolostones with common, undulating, stylolite-enhanced clay or shaly mudstone partings. The beds appear moderately fossiliferous, with brachiopods and crinoids readily visible; the former

<table>
<tr><th colspan="2">LITHOSTRATIGRAPHY</th><th>AGE</th></tr>
<tr><td colspan="2">Mercia Mudstone Group</td><td>Early to Mid-Triassic</td></tr>
<tr><td colspan="3">Major unconformity</td></tr>
<tr><td colspan="2">Ticknall
Limstone
Formation</td><td>Early Carboniferous
(?Late Asbian-Brigantian)</td></tr>
<tr><td rowspan="2">Cloud Hill
Dolostone
Formation</td><td></td><td rowspan="2">Early Carboniferous
(?Holkerian-Asbian)</td></tr>
<tr><td>Cloud Wood Member</td></tr>
<tr><td colspan="3">Main Breedon Discontinuity</td></tr>
<tr><td rowspan="3">Milldale
Limstone
Formation</td><td></td><td rowspan="3">Early Carboniferous
(Early Chadian)</td></tr>
<tr><td>Holly Bush Member</td></tr>
<tr><td></td></tr>
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Table 1. Stratigraphy of the rocks exposed in Cloud Hill Quarry

includes *Levitusia (Productus) humerosus*, an Early Chadian form for which this quarry is the type area. Casts of this fossil were seen in fallen blocks on the quarry floor and coquinas (shell pavements) of these and other brachiopods are visible in the face. Other fossils noted in this part of the sequence include solitary and colonial corals, gastropods and the echinoid *Archaeocidaris*. Chert nodules occur in discrete layers or within beds of dolostone. They were formed prior to dolomitisation and have therefore preserved the original structure of the rock; they have yielded a microfauna that supports an Early Chadian age. Evidence of Lead mineralisation was seen in the form of small cubic crystals of galena lining a small cavity.

Moving westwards along the face, beds of sandy dolostone and dolomitic sandstone are interbedded with the dolostone. These beds have been grouped into the 61m thick Holly Bush Member. Its occurrence is extremely localised as it dies out rapidly to the north and is only about 6m thick on the uppermost level of the quarry. Some sandy beds contain well-rounded pebbles, though these were noted only in fallen blocks. The pebbles consist mostly of vein quartz, with some quartzite, intraformational clasts and a few other lithologies, including a porphyritic, glassy volcanic rock of probable dacitic composition which may be derived from the Charnian. Some of the dolostone beds show a fine, commonly undulating lamination defined by darker, muddy laminae, reminiscent of hummocky cross stratification. Impersistent, non-sutured stylolites can also be seen in some beds.

The **second locality**, on the next face up at the south end of the quarry, allowed examination of the Milldale Limestone in its original, undolomitised state. A sequence of about 25m of partially or undolomitised limestone can be seen, occurring above the Holly Bush Member. It is a grey, fine- to coarse-grained, thin to thickly bedded, oolitic and pelloidal, bioclastic grainstone. Normal and inverse graded cycles up to 0.2m thick can be seen. Some internal bedding is visible, including wavy laminae and draping. Undulating clay, silt or shaly mudstone partings are common.

The Milldale Limestones of Cloud Hill are thought to represent accumulations of carbonate sand (shell detritus, ooids, peloids) in a shelf sea. The absence of any emergent features suggests an outer shelf rather than an inner shelf environment. These can nevertheless be high-energy zones with depositional processes affected by storm events, oceanic waves and possibly tidal currents. The shell pavements are typical storm event features and the bedding undulations may, in part, reflect hummocky cross stratification, also formed during storm events. The interbedded mudstones and siltstones settled out from suspension in quieter periods between the storms. The beds are in a shallower, more proximal setting than their equivalents at Breedon Hill, indicated by the more abundant fauna and the local clastic component seen in the Holly Bush Member.

Between localities 2 and 3, fallen blocks of dolostone were examined, showing a variety of features. They included colonial corals; burrows which are visible on several dark grey mudstone-lined bedding planes; very irregular, rubbly weathering dolostones, interpreted as palaeosols; yellowish blocks of the Late Asbian ‘reef’ facies showing in-filled cavities and bright green malachite mineralisation; blocks of Triassic breccia, composed of angular dolostone clasts set in a red or green muddy sand matrix. The palaeosols occur in the youngest beds (Ticknall Limestone Formation) and represent emergence. The primary sedimentary fabric of these rocks has been destroyed by pedogenesis and their original depositional environment is not known. Where the formation is exposed around Ticknall, and in the Ticknall Borehole, the rocks are typical shallow water carbonates. The malachite mineralisation is associated with the Triassic unconformity and precipitated from mineral-charged water percolating down during the Triassic period.

A little to the north of the undolomitised sequence, the unconformity (Main Breedon Discontinuity) between the Milldale Limestone and the Cloud Hill Dolostone was examined at **locality 3**. Strata of Late Chadian and Arundian age are missing and Holkerian age strata, though tentatively inferred, have not been proved. Current geochronological time scales indicate the time gap represented by the Discontinuity is between 7 and 10 million years. The beds above the unconformity dip less steeply than those below. This indicates there was uplift and slight tilting of the rocks in the intervening period. No evidence has been observed for any karstic development along the unconformity.

Farther to the north on the same face, **locality 4** showed the contact of the Asbian 'reef' and bedded carbonate sequences. Here, the contact is interpreted as a fault, but earlier exposures on the higher level showed a passage from the reef into bedded carbonates, with inter-digitation of the two. The bedded dolostones are particularly crinoid-rich hereabouts, with a high porosity resulting from dissolution of the original organisms. The 'reef' itself is a massive, finely crystalline, fossiliferous dolostone, although many potential fossils were destroyed during dolomitisation. Fossils noted in the 'reef' include brachiopods, crinoids, corals including *Amplexus*, gastropods, nautiloids and ammonoids, including the genus *Goniatites*. The fauna indicates a Late Asbian age.

These rocks represent a mud-mound 'reef' ('Cracoean buildup' of Mundy, 1994), deposited on the margin of the Hathern Shelf, probably in water depths up to 100m. The Cloud Hill 'reef' is at least 80m thick. Other Asbian 'reefs' on the northern flanks of the Widmerpool Gulf are composed of carbonate mud produced by various organisms (microbialite). They contain a diverse fauna that includes sponges, bryozoans and corals as secondary constituents, together with brachiopods, molluscs and other taxa. Crinoids can be a very common component. The Cloud Hill Dolostone 'reefs' are assumed to be of similar composition, although coral debris is not commonly preserved.

The **fifth locality**, on a higher level at the north end of the quarry, showed exposures of the Cloud Wood Member of the Cloud Hill Dolostone Formation. At the time of the visit, exposures were rather poor. In the past the formation has been well exposed, showing a thinly bedded sequence of mudstones, dolomitic siltstones and dolostones. The unit overlies the Main Breedon Discontinuity and the basal mudstone was seen near the top of the face. This bed is highly sheared and tight folding has also been observed, suggesting penecontemporaneous slumping. The underlying Early Chadian rocks are also folded here. The 'reef' can also be seen in this face, apparently overlying the Cloud Wood Member conformably. No dateable macro- or micro fossils have been recovered from these beds, but spores indicate a ?Late Holkerian to Early Asbian age.

The **final locality** allowed examination of Triassic rocks, which can be seen on the topmost face in several places throughout the quarry. The exposed face showed over 2m of greyish green and grey, interbedded mudstone and sandstone, a typical 'skerry' of older terminology. These strata occupy a hollow in the original land surface. The Triassic 'skerries' generally formed in response to short-lived sheet floods and associated periods of standing water (playa lakes) on a continental playa mudflat or sabkha. The exposed bed here has yielded a diverse assemblage of miospores, acritarchs and algae, which indicate a Mid-Triassic age. The acritarchs and algae both indicate deposition in waters of marine origin, suggesting a connection with the sea at this time. Detailed mapping of the Triassic in the surrounding area suggests that a number of the component formations (Sneinton, Radcliffe and Gunthorpe) should crop out around the quarry rim, but access problems and complex faulting make identification of the individual formations very difficult. At locality 5, the Triassic rocks are overlain mostly by red-brown till with quartzite and other pebbles derived from the Triassic. This is correlated with the Thrussington Till of the Midlands, the earliest deposit of the Anglian glaciation. On the high ground to the south of Cloud Hill, the Thrussington Till is overlain by the chalk-rich Oadby Till.

On completion of the itinerary, the President thanked Keith Ambrose for a fascinating and expertly-led trip, and also Tim Colman of BGS for his contributions to the mineralisation 'story'. Keith, Tim and Breedon Quarries were also thanked for supplying and driving the Land Rovers, which proved to be invaluable on the day.

Acknowledgements

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Compiled by the Editor from contributions by Keith Ambrose and Alan Filmer

EXCURSION

Field excursion to Skipton Moor

Leader: Neil Aitkenhead

12th July, 1998

On a grey, wet and windy day, 23 members enjoyed a very interesting trip mainly to study the rocks of the Millstone Grit Group (Upper Carboniferous) south-east of Skipton. On the way the coach detoured to the top of Otley Chevin, where the Leeds Geological Association had been involved in producing a display panel, giving an excellent explanation of "The Geological Evolution of Otley Chevin and Lower Wharfdale". The rock underfoot here is a fluvial sandstone of equivalent age (Kinderscoutian Stage) to the Kinderscout Grit. Almscliff Crag, which could just be seen through the drizzle to the north-east at the other side of Wharfedale, is of equivalent age (Pendleian) to the much older Warley Wise Grit, which we would see later. On a clear day you can apparently see the White Horse on Sutton Bank, across the Vale of York at the western end of the North Yorkshire Moors!

Before we left the coach, Neil described the geological background to the day's excursion. Skipton Moor lies to the south-east of Skipton and is flanked by a steep escarpment overlooking the town, formed by the Pendle Grit Formation of Pendleian (E_1) age. This comprises the lowest sandstones of the Upper Carboniferous Millstone Grit Group, overlying the Bowland Shales, which in turn overlie the Lower Carboniferous limestones and shales of the largely drift-covered Craven lowlands to the north-west. The Millstone Grit Group is characterised by a succession of coarse feldspathic sandstones, deposited in the Central Pennine Basin from a large river system that drained a rising mountain range probably far to the north, near Greenland. At times, particularly during the Pendleian (E_1), Kinderscoutian (R_1) and Marsdenian (R_2) stages, huge influxes of sand and silt were carried to deeper water beyond the river delta to be deposited in suspension from turbidity currents. The Pendle Grit Formation represents the first such influx, reaching a thickness of about 400m in the Skipton Moor area. The delta prograded intermittently farther and farther south with time but it wasn't until Marsdenian times that it eventually reached the Derby and Stoke districts, where it deposited the Ashover/Roaches grit succession.

During the last (Devensian) glaciation to affect the area, a large ice stream flowed across the Craven lowlands from the north-west. The orientation of the long axes of drumlins around Skipton indicate that this ice stream was diverted and divided by the escarpment, so that one flow went east towards Wharfedale and the other south-east down Airedale towards Keighley.

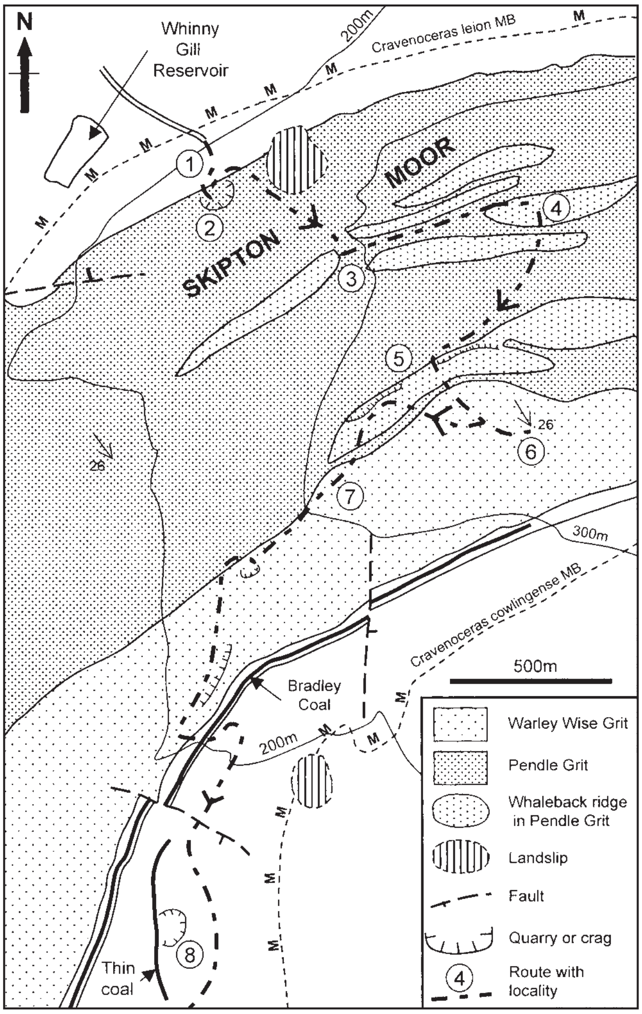
The planned itinerary included a visit to see an exposure of the *Cravenoceras leion* Marine Band in the southern corner of Whinney Gill Reservoir. This marks the base of both the Namurian and the Upper Bowland Shales. It was unfortunately under water, so had to be omitted. A section and list of fossils is given in the Bradford Memoir (Stephens *et al.*, 1953, pp.11-12).

Locality 1. Shale Plantation (SE 004 511)

The coach dropped us at the top of Short Bank Road on the south-east edge of Skipton. The track onto Skipton Moor took us up the scarp slope through Shale Plantation. The shaly mudstones here are in the upper part of the Upper Bowland Shales of Pendleian age. The *Cravenoceras malhamense* Marine Band should be present here but has not so far been detected. A few pale, thin sideritic ironstone bands are visible within the mudstone. The beds dip at 25-27 degrees to the SSE, into the hillside.

Locality 2. Jenny Gill Quarry (SE 0035 5097)

We followed the track up through the wood to Jenny Gill Quarry. This disused stone quarry exposes the lowest leaf of the Pendle Grit Formation, here comprising about 22m of medium- to coarse-grained sandstone. Proximal turbidites form individual massive beds 0.5-2.0m thick, each with a sharp base and shaly intercalations. Some show parallel laminations in their upper parts and are pebble free except for a few beds with mudstone flakes. The shallow dip of the beds into the hillside is displayed in the north wall of the quarry. Higher up the sequence in the back wall there is evidence of erosion surfaces at the base of a channel, filled with much thicker beds. There may have been an active growth fault at the time of deposition of the lowest beds; A. P. Simms (1988), who did his PhD in the area, suggested that these sandstones may be downfaulted to the same level as the previously seen Upper Bowland Shales. Thick vegetation precluded our fully checking the theory. At the base of the south face of the quarry, a thick lens-shaped sandstone bed probably represents a submarine channel fill. The sole of this bed shows well-displayed prod marks and flute casts revealed by the



Sketch map of the geology of the route.

partial removal of the underlying shaly mudstones. The prod marks give a good indication of turbidite flow, typically to the south. They are thought to be produced by woody plant stems being carried along in the current, abruptly digging into the muddy substrate, and then being slowly pulled out again as the current moved on.

Goniatites (or ammonoids in the latest parlance) had previously been collected from small exposures of mudstone in the steep grassy slope above the channel sandstone. These proved to be of late Dinantian (P_1) age, totally at variance with the Pendleian (E_1) age inferred for the quarry succession. Neil suggested that the mudstones were actually fragments in a localised cover of till or boulder clay, moved and deposited by ice from the Dinantian shale outcrop in the valley below to this elevated position high on the Pendle Grit escarpment.

Lunch was taken quickly in the rain before we continued our upwards climb following a path around the north side of the quarry. A planned stop at Cawder Gill (SE 0003 5020) was omitted due to the inclement weather. As we made our way up the hill there was evidence of post glacial landslips adjacent to the path.

Locality 3. (SE 0075 5073)

Here there was a small disused and largely grassed-over pit exposing about 1.8m of thinly interbedded siltstones and fine-grained sandstones showing well developed sole structures, which include some of those illustrated in Eager *et al.* (1985). These fine-grained turbidite beds constitute the 'background facies' into which the series of channels filled with coarse sandstone, to be seen later on, were emplaced.

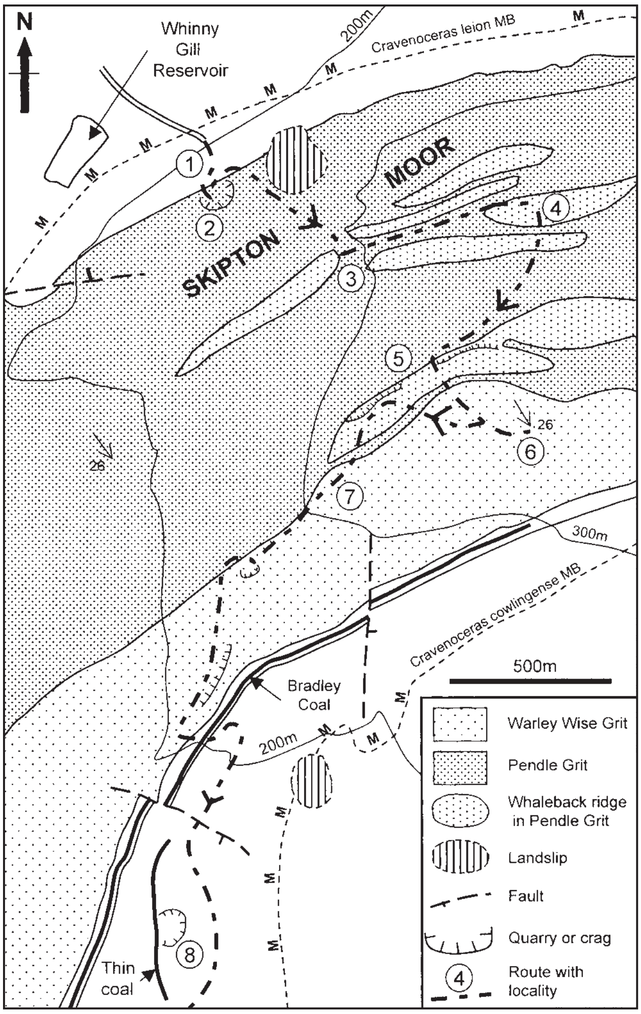
We were now high enough to appreciate the view to the north-west. Neil explained that we were looking at the deeply eroded Skipton Anticline, with the Pendle Grit of Skipton Moor dipping to the south-east forming the south-east limb and another escarpment of Pendle Grit, dipping to the north, forming the other limb. In the middle distance, the sharply featured and extensively quarried ridge in the core of the anticline consists of Lower Carboniferous limestone. The shales separating us from the limestones are mostly covered by Devensian glacial till, largely moulded into the form of drumlins.

Locality 4. (SE 0140 5093)

From here the group walked across the top of the moor towards the Trig Point at 373m on the summit of the highest whaleback ridge. Here we had a good view of the special feature of Skipton Moor, the en-echelon whaleback ridge topography. This is thought to represent high density mass flows eroding and infilling submarine channels. These have been cut into broad turbidite fans (the 'background facies') which underlies the slacks between the sandstone ridges. Alternative but rejected explanations are that the ridges may be fault controlled or even shaped by glacial erosion. The crags below the summit are the most elevated exposure of Pendle Grit. The rocks here are coarse-grained, unsorted pebbly sandstone, indicating very rapid deposition and showing ropey weathering.

Locality 5. Standard Crag and 'Standard' (SE 0110 5050 to 0081 5031)

From here the group cut back across a slack to a line of crags known as 'Standard Crag' and 'Standard'. Here the highest leaves of coarse pebbly sandstone in the Pendle Grit were exposed. This is a feldspathic sandstone with no cross bedding, showing ropey weathering. The uppermost thicker turbidite bed had scoured out the thinner bed beneath. The causes of faint laminations in these otherwise unlaminated (or massive) sandstones, and of 'ropey weathering', were discussed without any firm conclusions being reached. Grain flow was tentatively suggested to explain the former and post-glacial stress release, plus wind abrasion, the latter.



Sketch map of the geology of the route.

Locality 6. Millstone Hill (SE 0132 5022)

By now the rain had stopped and we were beginning to dry out. As we walked south to Millstone Hill, we were leaving the Pendle Grit and moving up the sequence onto the coarse-grained, cross-bedded sandstones of the Warley Wise Grit, which formed this outcrop.

Locality 7. (SE 0078 5017)

From here we turned west to reach an excellent exposure of weathered trough cross-bedded coarse-grained sandstones which are thought to be river or river mouth deposits. These comprise the lower part of the lowest leaf of the Warley Wise Grit. The change from massive turbidite to cross-bedded sandstones indicated a fundamental change in the palaeoenvironment from pro-delta slope to river-dominated delta top.

Leaving the moor on our way down to the coach at High Bradley we made a stop at a small flooded disused quarry (SE 004 499), where the rocks exposed are low in the sequence of Warley Wise Grit, with siderite and quartz pebbles, mica and also mud pellets. The low angle of cross bedding suggested probable fluvial or river mouth deposits.

The track now ran alongside a long line of crags trending NE-SW (SE 003 496). These consisted of coarse-grained, cross bedded sandstones from the upper leaf of the Warley Wise Grit. When viewed more closely they show cross-bedding, ropey weathering and sporadic quartz pebbles.

The field to the right of the road down to the village has the remains of bell pits where the Bradley Coal had been worked in the past.

Locality 8. Bradley Quarry (SE 0020 4885)

The final locality of the day enabled an examination of the Bradley Flags. About 14m of mainly fine-grained micaceous sandstone with a variety of bedforms are exposed, and are probably river mouth bar deposits. The quarry had been worked for curb stones, flagstones and building stones (Stephens, *et al.*, 1953).

By the time we returned to the coach we had dried out and our boots were well washed! We had followed the changes in deposition that had occurred in this area as the large river system from the north had prograded southwards across the Central Pennine Basin during early Namurian (Pendleian) times, from deep water marine shales to turbidites and then deltaic and fluvial sandstones. None of us will ever forget the difference between Pendle Grit and Warley Wise Grit! Many thanks to Neil for a splendid day.

Acknowledgements

I am grateful to Neil Aitkenhead for his help with this report and for providing the following references. Sketch map based on 1:10,560 geological maps SD94NE, SD95SE, SE04NW, SE05SW. Reproduced by permission of the Director, British Geological Survey.

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Judy Small

EXCURSION

Ticknall and Ibstock Brick Pit

Leaders: Keith Ambrose and Albert Horton

Sunday, 6th September, 1998

This excursion visited two sites of contrasting geology. The first stop, at Ticknall, examined two facies seen in exposures in the stratigraphically highest beds of the Carboniferous Limestone cropping out in South Derbyshire. The beds here dip gently, contrasting with the deformed, steeply dipping, older rocks of the Carboniferous Limestone seen at Breedon and Cloud Hill quarries. The afternoon stop, at Ibstock, allowed detailed examination of a range of depositional environments in the Mercia Mudstone Group, commencing in the Sneinton Formation and continuing up into the Gunthorpe Formation.

Locality 1. Ticknall Lime Quarries

The village of Ticknall, in South Derbyshire, is sited in an area of varied geology. The excursion visited some former lime quarries that worked the uppermost beds of the Carboniferous Limestone, the Ticknall Limestone Formation, of Brigantian age. These rocks, which dip gently to the north-east, are overlain by the Millstone Grit. The limited evidence available suggests the contact is unconformable, with probable Arnsbergian age strata resting on the Carboniferous Limestone; all of the Pendleian age strata are thought to be absent. Locally, the Carboniferous Limestone is unconformably overlain by the Permo-Triassic Moira Formation and the Early Triassic Polesworth Formation. The former is a predominantly mudstone sequence around Ticknall and has been worked for brick clay. Elsewhere in the area, it is mainly composed of breccia, formerly known as the Moira Breccia. The Polesworth Formation (formerly Bunter Pebble Beds) consists of conglomerates and sandstones and forms the basal unit of the Sherwood Sandstone Group. It is equivalent to the Nottingham Castle Sandstone Formation of south Nottinghamshire. The Thringstone Fault, one of the major syn-Carboniferous structures of this region, runs NW-SE through the village. Coal Measures crop out to the south-west of the fault in the North-west Leicestershire Coalfield. Glacial deposits (Till; Sand and Gravel) cap some of the hills around the village.

The lime quarries in the village have long since been abandoned. They probably closed around the middle of the 19th century; Hull (1860) referred to operations in the present tense suggesting they were still working at the time of his visit. Fox-Strangways (1905) describes the workings as long abandoned. Both of these writers give only brief mention of the Carboniferous Limestone at Ticknall and adjacent inliers. Parsons (1918) was the first to describe detailed sections from this locality, dividing the exposed sequence, then about 15m thick, into 5 units (Table 1). Mitchell and Stubblefield (1941) agreed with Parsons' findings. The only recent work in the area was an unpublished PhD thesis by Monteleone (1973). He examined the Ticknall sections in detail and proposed a two-fold subdivision, combining Parsons' units. He proposed the name Ticknall Limestone Formation for these strata.

Past workers have published faunal lists from the Ticknall quarries (Hull, 1860; Fox-Strangways, 1905, 1907; Parsons, 1918; Monteleone, 1973). The fauna is dominated by brachiopods, in particular *Gigantoproductus*. Other fossils noted include corals, foraminifera, ostracods, conodonts, gastropods, crinoids, echinoids and a trilobite. In addition, Wilson (1880) found 30 species of fish, mainly identified by teeth, in the mudstone beds of these quarries, and he lists several other species found by other workers at the same locality. In 1993, the British Gological Survey commenced a full resurvey of the 1:50,000 scale sheet 141 (Loughborough) which includes all of the Carboniferous Limestone outcrops. The results of the mapping and detailed logging of the quarries have enabled the stratigraphy to be revised, a more accurate assessment of the age of the rocks to be determined and environmental interpretations to be made. The strata are now all referred to the Ticknall Limestone Formation (Ambrose and Carney, 1997), following Monteleone (1973)

The **first stop** [SK3626 2370] showed the unconformity between the Millstone Grit and the Carboniferous Limestone. A 0.3m thick fine- to coarse-grained pebbly sandstone of the Millstone Grit can be seen at the top of the section. The 'pebbles', ranging from very coarse sand to small pebble in size, comprise mainly quartz and quartzite, together with minor red claystone and some intraformational sandstone clasts. The lowermost few centimetres are dolomitic and the contact is undulating and erosive. The underlying Ticknall

Parsons (1918)		Monteleone (1973)	
Grey and yellow dolostone Thinly bedded limestones	3.4m 3.4m	Thick bedded limestone and Dolostone member	7m
Sandy stratum Foraminiferal limestones and shales Crinoidal limestones	0.7m 4.1m 3.4m	Limestone and shale member	8m

Table 1. Comparison of the lithostratigraphy of the Ticknall Limestone of past workers, giving thicknesses.

Limestone consists of grey-buff, variably red and ochreous stained, finely crystalline dolostone with a few thin clayey partings. Some fossils are visible, mainly *Gigantoproductus*. The dolostones appear to be generally massive, with some lamination visible towards the base of the exposed section.

The massive dolostone occurs throughout the quarry complex and is 4-6m thick. Locally it is sandy, grading to a dolomitic sandstone.

The **second stop** [SK361 236] includes several exposures, with the massive dolostone seen at the first stop visible in the upper part of all sections. The underlying beds are also well exposed and accessible. They consist of grey, finely crystalline, muddy and coarser bioclastic limestones which are locally dolomitised, with common interbeds of fissile mudstone up to 0.2m thick. The limestone beds have undulating boundaries and are nodular where thin, due to the secondary (diagenetic) migration of lime. They commonly have sharp, irregular contacts with the mudstones. Fossils are common locally with shell beds of *Gigantoproductus*, together with crinoids, solitary and colonial corals. Two prominent limestone beds are visible in many of the exposures and were the main beds targeted for lime production. Only about 6m of section is now exposed, compared to over 9m noted by Parsons (1918). Also seen at this stop are a number of large, disturbed and steeply dipping blocks of limestone and dolostone isolated from the main faces. Examination of the nearby faces shows no sign of any tectonic disturbance, the blocks having assumed their present aspect as a result of roof falls from former underground workings of the limestone.

The Ticknall Limestone has been mineralised and was worked for lead at Dimminsdale, a little to the south of Ticknall. Minerals noted from the Ticknall inlier include galena, chalcopyrite, baryte and aurichalcite (King, 1968).

The generally massive uppermost beds of the Ticknall succession are almost completely dolomitised and their original composition is uncertain. They are interpreted as a proximal shallow water marine facies, based on the presence of the clastic (sand) component. The second facies, comprising the fine-grained muddy limestones and coarser bioclastic limestones interbedded with fossiliferous mudstone, is interpreted as distal, shallow water marine.

Locality 2. Ibstock Brick Pit [SK 412 110]

The Ibstock Brick Pit provides some excellent exposures in the lower part of the Triassic Mercia Mudstone Group and overlying Oadby Till. Three formations are present, the Sneinton, Radcliffe and Gunthorpe formations, which were defined and mapped in the Nottingham area (Elliott, 1961; Charsley *et al.*, 1989). No recent work has been carried out by BGS in the Ibstock area since the British Geological Survey revised the Coalville Sheet (Worssam and Old, 1988) and no detailed logs of the quarry are available. Boreholes in the area indicate a thickness of around 40m for the Mercia Mudstone Group, possibly with a thin development of the Moira Formation at the base. The Sherwood Sandstone Group is absent, the Triassic rocks resting unconformably on Coal Measures.

The **first stops** were at the bottom of the quarry where exposures of the Sneinton Formation were examined. This formation, formerly known as the 'Waterstones', is the lowermost unit of the Mercia Mudstone Group. Here, it consists predominantly of structureless red-brown, micaceous siltstones and silty mudstones, with local aeolian sand grains. These are interbedded with beds of sandstone and laminated mudstones, siltstones and sandstones. The presence of mica and fine- to medium-grained sandstone beds are the main distinguishing features of the formation. The structureless argillaceous rocks also tend to be darker in colour than those seen in the higher Gunthorpe Formation. The sandstones are generally cross-bedded or cross-laminated and ripple marks are common features. One sandstone bed seen near the bottom of the quarry is lenticular in form, with well-developed cross bedding indicating deposition in a minor fluvial channel, with currents flowing approximately to the north. The base of this bed contains numerous small cavities, which probably resulted from the dissolution of calcite. The top of the bed is noticeably coarse-grained, with small pebbles visible. They include intraformational clasts, quartzite and possible Charnian lithologies. One feature of note is the well-developed spheroidal weathering, seen on some exposed faces of the structureless siltstones and mudstones. Higher in the formation, several other sandstone beds could be seen in the quarry faces, some of which were continuous and others lenticular. The sequence here contains a greater proportion of structureless mudstone and much less sandstone and laminated mudstone/siltstone/sandstone compared to the type area around Nottingham.

The **second stops** allowed examination of the overlying Radcliffe Formation. This formation is marked by the incoming of very finely laminated red-brown mudstone and paler siltstone and sandstone. It includes some thicker beds of structureless mudstone and sandstone. One of the stops showed a number of sedimentary structures, which included soft sediment deformation features (loading, convolution, pillows), mud cracks, salt pseudomorphs and ripple marks. Horizontal burrows were also noted. Of particular note were the presence of a number of layers in the middle part of the formation which contained scattered pink gypsum nodules.

The **third stops** in the upper part of the quarry showed the Gunthorpe Formation. It consists mostly of brick-red, structureless silty mudstone with some thin beds of sandstone and siltstone. The base is marked by a c.2m bed of green siltstone and sandstone, overlying the well-laminated beds of the Radcliffe Formation.

The Mercia Mudstone Group sequence exposed in this quarry shows a progressive change in depositional environments within the generally arid climate of the Triassic. The Sneinton Formation was deposited on a broad alluvial plain, with sedimentation reflecting a complex association of environments and processes including ephemeral streams, bodies of standing water, periodic sheet floods and accumulation of wind-blown mud particles. The overlying strata of the Radcliffe Formation were deposited mainly in a lacustrine environment, with frequent drying out and desiccation, and the periodic accretion of wind-blown sediment. The overlying red mudstones and silty mudstones of the Gunthorpe Formation are accumulations of wind-blown sediments in an arid playa mudflat or sabkha environment. Short-lived sheet flood episodes associated with periods of standing water (playa lakes) led to the deposition of the intercalated beds of siltstone and fine-grained sandstone.

The **final stops** were made on the uppermost level at the northern end of the quarry. Here Oadby Till ('chalky boulder clay') is exposed, overlying the Gunthorpe Formation. The till consists of a dark grey, pebbly clay with a diverse suite of erratics including numerous flints and chalk pebbles, Jurassic mudstones, ironstone, various limestones (some Middle Jurassic oolite limestones were noted), fossils including belemnites and *Gryphaea*, and quartzites derived from the basal Triassic pebble beds ('Bunter pebbles'). A number of unidentified hard rock lithologies were also noted, which probably include rocks derived from the nearby Charnian outcrops. The Oadby Till was deposited during the Quaternary Anglian ice advance between 500,000 and 400,000 years ago.

Acknowledgements

The organisers of this excursion gratefully acknowledge the co-operation and assistance of the management and staff of Ibstock PLC. This account is published with the permission of the Director, British Geological Survey.

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Keith Ambrose

EXCURSION

Field visit to the Malverns Area

Leaders: Allan Brandon and Brian Moorlock, British Geological Survey

27th September, 1998

Over 50 members travelled down to the Malverns on a grey and wet day. The hired bus was full and a small number of other members, who travelled by car, joined the main group at Gullet Quarry (SO 762 381) — the first stop of the day. As we approached the Quarry good views of the solifluction terraces on the east side of the Malvern Hills could be seen. Underlain by two metres of stony clay head, these features were formed during successive periglacial episodes when warming caused slight melting and consequential sliding over the frozen sub-surface.

Upon arrival at Gullet Quarry, itself at the southern end of Swinyard Hill, the exposed junction between the Pre-Cambrian Malverns Complex and the overlying Silurian Wyche Formation of the May Hill Sandstone Group was seen. Debate as to whether this junction is an unconformity or a fault is now resolved in favour of the former. Brian Moorlock explained that some 680 million years ago, a south-east trending subduction zone resulted in the emplacement of igneous granite rocks ranging from basic to acidic in composition, which were then subject to regional metamorphism to garnet grade, followed by upthrust and shearing. The very high degree of shearing increases to the south end of the Malverns, and the once igneous gabbro has been weakened and weathered. Small pegmatite intrusions were seen to cut the Malverns Complex. Alternating sandstones, mudstones and silt bands of the overlying May Hill Sandstone Group are well exposed above the unconformity.

Returning to the bus for our waterproofs (the rain becoming increasingly heavy), the group then set out to climb up to the ridge to British Camp in the hope of getting good views of the landforms formed by the Quaternary deposits and processes, and the Lower

Palaeozoic and Mesozoic rocks. On the way, we stopped at Clutter's Cave (SO 7628 3953) which is formed in a range of metamorphosed oceanic basin volcanics. Allan Brandon pointed out the rather poorly defined pillow structures in these sodic basalts (Warren House Formation), indicative of extruded sub-aqueous activity some 566 million years ago.

Unfortunately, the weather was so bad that the anticipated views were not available to us, but Allan Brandon, with the help of a handout chart, explained that the Quaternary stratigraphy had to be set in the context of the relationship between deep sea isotope ratios and the British Quaternary stages. Prior to the Anglian glaciation of around 450,000 years ago, the major river of the area lay to the west of the Malvern Hills, not to the east as it is today. This so-called Mathon River laid down fluvial sands and gravels whose provenance lay to the north. Tributaries brought in Longmyndian rocks from the north-west and *Gryphaea arcuata* eroded from Jurassic rocks to the north-east. Interglacial deposits found beneath the river deposits near Colwall have yielded abundant beetle and macroplant remains and pollen. Some 5-600,000 years ago, the area was a boreal forest in which spruce, pine and larch flourished. This is the first and only record of larch in Britain — it was reintroduced by man in historical times. Allan produced a number of examples of amazingly well preserved Norwegian spruce cones and seeds, along with some pieces of partly burned wood that he had found in the interglacial deposits (Cromerian) indicating that forest fires occurred from time to time. The Mathon River drainage was entirely destroyed during the Anglian glaciation of the area, firstly by the valley being impounded at the south end of the Malverns by a glacier. The subsequent glaciolacustrine infill deposits were then over-ridden by the advancing glacier and till was deposited. The present day drainage was initiated at the end of the Anglian glaciation. A further interglacial deposit discovered at Colwall above the glacigenic deposits and below the Late Wolstonian (186 to 128 thousand years ago) head, has yielded late Anglian to early Hoxnian (339 to 303 thousand years ago) pollen. These discoveries have greatly helped to delimit the glaciation. During the stadials of the Middle and Upper Pliestocene, periglacial conditions gave rise to widespread gelifluction or head deposits on both flanks of the Malverns. These are manifest as dissected terraces which steepen up slope. They grade into the River Severn terrace deposits on the east side of the Malverns.

The walk continued over the well-preserved British Camp down to Wynd's Point and lunch at, or adjacent to (depending on preference), the Malvern Hills Hotel, just north of the Herefordshire Beacon.

The afternoon took the group to Eastnor Deer Park (SO 740 380) to view the landforms associated with the alternating limestone and shale sequences of the Silurian sediments. The Coalbrookdale Formation (Wenlock Shale) was seen very poorly exposed in the bottom of the valley where a number of fossils including brachiopods were found. Faulting in the Much Wenlock Limestone was also pointed out by Allan and Brian. We then moved on to see the Much Wenlock Limestone exposed at the very muddy Eastnor Castle Quarry (SO 7322 3629). Brachiopods, crinoids, and coral were found and collected along with trilobite fragments.

Continuing up the Silurian time column and into the Lower Old Red Sandstone, the group then visited a small roadside exposure at Stanley Hill, Bosbury (SO 6758 4394) to see the Bishop's Frome Limestone (previously known as the Psammosteus Limestone). This mature rubbly calcrete up to 8 metres thick is underlain by the Raglan Mudstone Formation, about 800 metres thick. This formation is comprised of silty mudstones, siltstones and interbedded sandstones representing cyclical deposition in a coastal alluvial flood plain environment. The hard calcrete at the top of the formation, Allan Brandon explained, represented the subaerial exposure of a stable surface for perhaps several thousand years. The calcrete has been quarried for the production of agricultural lime for many hundreds of years.

Finally, the group visited the old Linton Tile Works, near Bromyard (SO 668 538) to examine the early Devonian St. Maughan's Formation, which comprises around 750 metres of mudstones, siltstones with fluvial channelled sandstones, and intra-formational conglomerates. The flooded, disused quarry exposes about 24 metres of overbank floodplain mudstones with several immature calcrete profiles and channelled sandstones. The clearly defined basal sandstone has a bedding plane bearing the burrow trace fossil *Beaconites antarcticus*, first described from the Antarctic. They occur in non-marine Devonian and Carboniferous sediments and have been attributed to back-filled burrowing by a large arthropod. Fish fossils had also been found in the sandstone. After a search at the far end of the quarry, examples of *Beaconites antarcticus* were found. A good exposure of the 'cornstone conglomerate' was also seen along with evidence of pseudoanticlines.

After a long and rather wet but very enjoyable day, the coach arrived back in Nottingham just before 8.00pm. It must be added that our two leaders, Allan and Brian, handed out a very comprehensive set of excursion notes, diagrams and maps, from which much of this report has been culled!

Tony Morris