EXCURSION

Excursion to Breedon on the Hill Quarry

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The purpose of this excursion was to examine the Carboniferous Limestone exposed in the quarry at Breedon on the Hill, South Derbyshire [SK 40 23]. Three main limestone types or 'facies' are present, the base of the upper one being defined by an unconformity. The entire sequence is heavily dolomitised and as a result, precise environmental interpretation remains speculative. Mineralisation was also examined together with several caves with a variety of fills, including one choked with sediments of Triassic age.

Breedon Hill forms the most northerly of 5 inliers of Carboniferous Limestone aligned NNW-SSE, lying between Grace Dieu (west of Shepshed) and Melbourne. The quarry has a maximum depth of about 90m and exploits the limestone for roadstone. It is excavated almost entirely into the Milldale Limestone Formation (Aitkenhead and Chisholm, 1982) of Early Chadian age. The younger Cloud Hill Dolostone Formation, of ?Holkerian-Asbian age, is exposed only in the upper part of the north-west face. A major fault crosses the quarry, trending approximately north-south.

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 Breedon and the neighbouring Cloud Hill quarry, situated about 1km to the south (based on 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(1973) produced the first detailed work on the Carboniferous Limestone of Leicestershire and South Derbyshire in an unpublished PhD thesis.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. The caves at Breedon Hill have been described by Ford and King (1966) and Simms (1990).

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 the stratigraphy to be revised, a more accurate assessment of the age of the rocks to be determined and environmental interpretations to be made.

Throughout the early Carboniferous, the area south of Breedon (the Hathern Shelf) was submerged below a shallow shelf sea, lapping onto the emergent Charnwood block. To the north lay a fault-bounded deep sea trough, the Widmerpool Half Graben or Gulf, in which a thick turbidite sequence accumulated as a result of fault-controlled subsidence. The Breedon inlier formed as a result of intense 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. The cave system at Breedon probably formed in response to a number of processes, attaining much of its visible extent by Early Triassic times. The inselberg may have remained buried until at least the Palaeogene, and was doubtless further exhumed by the various ice advances and accompanying periglacial erosion during the Pleistocene.

LITHOSTRAT.	AGE
Mercia Mudstone Group	Mid-Triassic
Major unconformity	
Cloud Hill Dolostone Formation	Early Carboniferous (Asbian-Holkerian)
Main Breedon Discontinuity	
Milldale Limestone Formation	Early Carboniferous (early Chadian)

Table 1. Stratigraphy of the rocks exposed in Breedon on the Hill Quarry.

The Milldale Limestone is about 400m thick at Breedon and was examined at the **first locality** along the entrance roadway at the south end of the quarry. These are the oldest strata in the quarry. They comprise at least 170m of grey to buff, locally red, purple or ochreous-stained, thin to thickly bedded, fine to coarsely crystalline dolostone. The individual beds of dolostone are generally massive, although some show evidence of internal lamination. The beds are commonly separated by thin, undulating, grey or red shaly mudstone or silty mudstone partings, some of which have been emphasised by stylolitisation, a process of rock dissolution by pressure solution. These strata are very poorly fossiliferous, with only crinoids noted in both the limestones and the shaly partings. Chert nodules occur at some levels in this part of the sequence and were seen in fallen blocks. The cherts formed penecontemporaneously with deposition and were unaffected by dolomitisation. They usually contain well-preserved foraminifera, which may provide one of the very few indications of age in these heavily dolomitised rocks, though no foraminiferal analyses of the cherts from Breedon Quarry have been carried out. At the bottom of the roadway, the dolostones are thinly bedded and dark grey patches are visible on the rock face, caused by increased carbonaceous debris and bitumen staining. Bitumen spots also occur along some of the bedding and joint surfaces. Finely comminuted crinoid debris is locally common. These bedded dolostones are thought to represent distal storm deposits, gravity flows and turbidites, deposited on the ramp between the Hathern Shelf to the south and Widmerpool Half Graben (Gulf) to the north. The muds and silts settled out from suspension during quieter periods.

The major fault running north-south through the quarry is most clearly observed on the western face, where it produces a broad shatter zone. Neither the direction nor the amount of throw of this fault can be determined, but it can be traced away from the quarry in the overlying Triassic rocks where it downthrows to the east. The Carboniferous Limestone beds on either side of the fault are steeply dipping, locally folded and overturned in places.

The **second locality** was at a large cave which is completely filled with sediments of Triassic age. The present exposure on the quarry floor is about 60m wide with a vertical face of about 11m. Both the cave roof and the infilling sediments dip at about 40°, giving a true thickness of at least 9m. The infill deposits comprise red and green breccias, massive siltstones and mudstones. A laminated bed is visible near the top of the sequence and was examined from fallen blocks. It consists of clay-silt/sand couplets and clay/silt couplets, the latter locally showing microfaulting and slumping. The breccias are matrix supported and contain a very high proportion of intraformational sandstone, siltstone and mudstone clasts, some showing very thin lamination. There are also a few Carboniferous Limestone clasts, which occur mainly near the margin of the cave deposits and are more common at the northern end. The breccias probably represent debris flows, and the massive silts were probably deposited rapidly from sediment-laden water. In contrast, the laminated bed suggests more quiescent deposition from suspension; the couplets may represent seasonal variations in sediment discharge. The projected topographical level of the cave, where it intersects the outer edge of the inlier, occurs close to the boundary of the Sneinton, Radcliffe and Gunthorpe formations, suggesting a latest infill of early Middle Triassic (Anisian-Ladinian) age. Alternatively, Simms (1990) suggested a Late Triassic (Late Carnian) age for the formation of the Breedon Hill caves.

Other caves and voids were observed at various points in the quarry. They are mainly open, but at least two types of partial infill were observed: dolostone debris which has probably collapsed from the cave walls and roof; and large dog-tooth spar calcite crystals lining the walls. Many of these calcite linings are stained by iron oxides and other minerals; some copper minerals were noted, including malachite and chalcopyrite.

The **third locality**, at the northern end of the lower level of the quarry, showed the second main facies type present in the quarry and provided an opportunity for fossil hunting. The beds here are assumed to overlie the bedded dolostones seen at the first stop and comprise at least 100m of massive, unbedded, pale grey to buff, generally fine to very finely crystalline dolostone. These strata are richly fossiliferous and contain a diverse fauna of brachiopods, crinoids, corals (including the solitary coral *Amplexus coraloides*), nautiloids and ammonoids (goniatites). The structureless dolostone is thought to represent a deep-water, mud-mound 'reef', an accretion of calcite mud produced by micro-organisms. The dolostone contains many small cavities, which usually show a distinct alignment. These are thought to be primary cavities that formed just below the sediment surface during accretion of the mound. Other cavities represent the casts of bioclasts. Some contain concentric fills.

The Breedon mud mound is assumed to be of the same composition as the Chadian 'reefs' of Derbyshire. These 'reefs' are skeletal mounds (Waulsortian reefs), composed of fenestrate bryozoa and sponge spicules, with common crinoids (e.g. Bridges and Chapman, 1988; Bridges *et al.*, 1995). Such Waulsortian mounds were deposited in water of between 200-300m depth, deeper than the underlying ramp carbonates seen at the first stop. The massive dolostone beds form the core of the mound; overlying bedded dolostones, visible in the north-west face of the quarry, probably represent accumulation of debris on the flanks of the mound.

The **final locality** was on the upper level at the northern end of the quarry. The face exposes a near

vertical dipping, strike section of pale grey to buff, bedded mud-mound dolostones which have yielded the Early Chadian goniatite *Fascipericyclus fasiculatus*. At one point, quarrying and rock falls have revealed the unconformity (the Main Breedon Discontinuity of Figure 1) at the base of the overlying Cloud Hill Dolostone Formation. The unconformity consists of a red-stained bedding plane with common *Thalassinoides* burrows. Also seen in a fallen block was the colonial coral *Lithostrotion*, of Viséan, ?Holkerian age.

The basal Triassic unconformity occurs about 5m higher up the face and is overlain by a bed of coarse, matrix-supported breccia infilling a shallow wadi-like structure with an irregular, undulating base. A bed of sandstone overlies the breccia and can be seen to overlap it and rest on the Carboniferous Limestone at either end of the face. Fallen blocks of the breccia and overlying sandstone were examined on the quarry floor. The breccia is composed exclusively of angular clasts of Carboniferous Limestone set in a matrix of sand, silt and clay. Many of the coarser sand grains are well rounded and wind-etched, suggesting an aeolian origin. The matrix-support fabric of the breccia indicates deposition as a debris flow, but the limestone clasts may originally have formed a scree on the flanks of the inlier. The overlying sandstone is predominantly red-brown, with pale red, greenish grey and ochreous mottling, and is fine-grained with some coarser, well-rounded aeolian grains. Some laminae are coarser, with reworked grains of granular dolomite derived from the Carboniferous Limestone. It is well laminated and there is evidence of disruption and soft sediment deformation.

The excursion ended with a visit to the Church at Breedon on the Hill. The party was given an account of the history of the church, which is built of sandstone originating from both the Triassic and the Millstone Grit, with later repair work using Lincolnshire Limestone. The latter was also used for the Saxon carvings displayed in the church, which also contains some superbly preserved alabaster monuments.

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