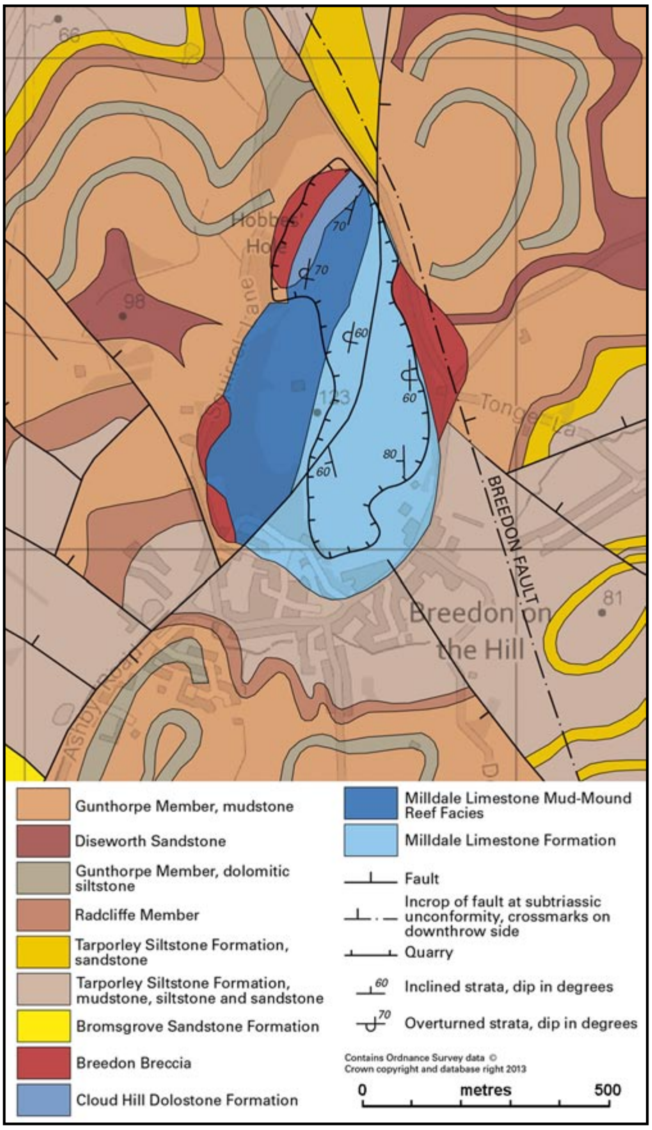
LANDMARK OF GEOLOGY IN THE EAST MIDLANDS

Breedon Hill

Breedon Hill forms one of the most prominent features in the landscape of north-west Leicestershire, standing up 50 m above the surrounding ground. That it has been a major landmark throughout recorded history is suggested by its name, which is derived from the Celtic 'bre' and the Anglo-Saxon 'dun', both words meaning 'hill'. Viewed from the east, the rugged vertical western quarry face is crowned by the church that looks very precarious; it stands about 70 m behind the quarry face, but looks much closer from a distance. To see the quarry and its geology at relatively close quarters, the viewing platform at the north end of the quarry should be visited. There is also a footpath that follows the quarry's eastern rim. Quarry visits are limited to organized groups, but a few small exposures are present along the footpath from Breedon village up the western slopes of the hill.



The geology of Breedon Hill (by British Geological Survey).

Breedon quarry seen from the viewing platform. The rocks in the right foreground are the massive mud-mound reef dolostones. On the left side of the quarry are well bedded, steeply dipping dolostones which, in the distance, show gentle folding. The cave with its red-brown Triassic fill can be seen to the left of the foreground tree in blossom.

Breedon Hill is one of six inliers of the Peak Limestone Group (informally known as the Carboniferous Limestone) in north west Leicestershire. The others are at Cloud Hill, Barrow Hill, Osgathorpe and Grace Dieu; all have been quarried in the past but the only other operating quarry is at Cloud Hill, just over a kilometre south of Breedon Hill. Cloud Hill is the larger quarry and is currently the only producer of aggregate. All these inliers are surrounded by rocks of Triassic age, with Precambrian Charnian rocks also abutting on the south side of the Grace Dieu inlier. Other inliers of these limestones occur 3-4 km to the west, around Ticknall, Calke Abbey and Dimminsdale in south Derbyshire.

The Breedon carbonates

The geology of Breedon Hill has been summarised in several publications, including Fox Strangways (1905), Parsons (1918), Mitchell and Stubblefield (1941), Ambrose and Carney (1997) and Carney *et al.* (2001, 2002). The Breedon story starts in the early Carboniferous, in Early Chadian times, when much of England was enveloped in a warm tropical sea close to the equator, where carbonates were deposited to form the Peak Limestone Group. Breedon Hill and Cloud Hill, lay on the Hathern Shelf, just south of the Widmerpool half-graben (or 'gulf'), a deep, fault-bounded Carboniferous basin. Its location and evidence from sediments in the quarry suggest that Breedon was just on the flanks of the half-graben, in deeper water than most of the shelf area, and in water slightly deeper than that at Cloud Hill. But deposition at both quarry sites followed the same general pattern. The earliest rocks are the Milldale Limestone Formation, which consists mostly of the well-bedded, generally fine-grained carbonates, now dolostones, deposited by storms, possibly with some turbidite development. In quiet periods, fine muds and silts settled out from suspension to form partings between the carbonates. These storm deposits in Breedon quarry generally yield

The northern end of the quarry with red-brown Triassic sediments lying unconformably over the steeply dipping Carboniferous carbonates. The red colour of the limestone on the left side of the upper bench is the result of groundwater re-depositing iron oxide carried down from the overlying Triassic rocks.

only a few crinoids and brachiopods, but the paucity of fossils may be due to the later dolomitisation process that has affected all the rocks in Breedon, and may have destroyed fossil remains. The thickness of the Milldale Limestone at Breedon is around 400 m.

The rock that indicates water depth occurs on the west face of the quarry, where a very fine-grained, massive dolostone has no internal bedding structures. It is also more fossiliferous than the storm carbonates,

The quarries of Breedon Hill and Cloud Hill, either side of the curving M42 motorway (from Google Earth).

additionally yielding corals, nautiloids, and ammonoids. This unbedded dolostone has been interpreted as a mud-mound reef, which formed by micro-organisms secreting a carbonate mud that built up into a mound (or reef). The reef at Breedon has been likened to those in Derbyshire, where all the Early Chadian reefs are of a Waulsortian reef facies, known to occur in water depths of 220-280 m (Bridges and Chapman, 1988). On the northern face of the quarry, similar well-bedded dolostones with the same fauna are interpreted as the reef flank, with debris cascading off the reef and building up in beds. Found in this part of the sequence, the ammonoid *Fascipericyclus fasciculatus* indicates an Early Chadian age. The only other age-diagnostic fossils found in Breedon quarry are the brachiopod *Levitusa humerosus* and a microfauna in layers of chert nodules within the storm carbonates. These nodules were unaffected by the dolomitisation and the microfauna has been preserved. Both indicate the same Early Chadian age. Cloud Hill quarry is the type locality for the brachiopod *Levitusa humerosus.* Other mud-mound reefs are seen in Cloud Hill quarry but these formed in shallower water of probably around 100 m depth, as fringing reefs on the Hathern Shelf.

Two important features occurs on the north face of Breedon quarry. An unconformity lies within the Peak Limestone, although the position of it is not precisely known. It represents a time gap of around 10 million years, separating the Early Chadian Milldale Limestone from the Holkerian-Asbian Cloud Hill Dolostone Formation. The latter is known from a fallen block that contained a coral of this age. A bedding plane crowded with the trace fossil *Thallasinoides*, which indicates a prolonged period of bioturbation, has provisionally been taken as the unconformity base in Breedon quarry. These younger beds and the unconformity are well exposed in Cloud Hill quarry, where a pronounced angular unconformity has been well exposed over time and has been named the ‘Main Breedon discontinuity’ (Carney *et al*., 2001). At the top of the north face of Breedon quarry, there is a major unconformity with the younger Triassic rocks exposed. This represents a time gap of around 100 million years.

Dolomitisation and mineralisation

The carbonate rocks at Breedon have been pervasively altered by the conversion of the original calcite to the magnesium-rich dolomite and the rocks are now referred to as dolostones. The timing of this process is not fully known, though an early, pene-contemporaneous stage and a later stage of Triassic age have been suggested (Parsons, 1918). Evidence from mapping the quarries showed that the dolomitisation occurred before the Triassic, as fragments of dolostone occur within caves and voids infilled with Triassic sediments. It is very likely that the dolomitisation occurred in the latest Carboniferous times, when the area was subjected to higher temperatures, pressures and mineralisation associated with the Variscan orogeny.

Mineralisation has occurred in two phases in these rocks. The earlier, in the Late Carboniferous (King, 1968, 1980, 1982, 1983), resulted in the deposition of calcite as a gangue mineral along with a variety of other minerals of which the most common is galena. Others found include wulfenite and cinnabar. The second phase occurred in the Triassic, associated with fluids moving along the unconformity. These left mainly copper minerals; none has been seen at Breedon because the unconformity is inaccessible, but they are common at Cloud Hill.

Cavity in the limestone infilled with dog-tooth spar calcite, indicating that the caves pre-date the late Carboniferous mineralisation.

Karst and cave development

Karst development in the form of caves and small voids is another feature of the rocks in Breedon quarry. Again, the timing of their formation is not known precisely but there are several clues. The 15% volume reduction of the rock resulting from the dolomitisation process may have played a significant part. Many of the smaller voids are lined with dog-tooth spar calcite associated with the end-Carboniferous mineralisation, so they formed probably quite soon after deposition of the carbonates and probably in response to circulating ground waters. Widening of some of the larger caves could have occurred throughout the Permian. Many were formed by Early Triassic times at the latest, as some are infilled with sediments of Mercia Mudstone Group age. Further cave enlargement may be attributed to groundwater flow during the Quaternary.

Perhaps the most striking karstic feature lies in the east face of Breedon quarry, where a large cave has been completely infilled with Triassic sediments. It is about 60 m wide and 10 m high, and the roof slopes into the quarry at around 40º. The sediments infilling the cave are dominantly massive red-brown siltstones, with some included clasts of finer and commonly laminated mudstones. These represent rapid deposition from water flowing into the cave. The uppermost deposit in the cave is a thin finely laminated, waterlain bed of sandstone-siltstone/mudstone couplets. The most likely timing for the infilling of the cave is during deposition of the Tarporley Siltstone Formation, the basal unit of the Mercia Mudstone Group. Laminated mudstone forming the cave deposit clasts commonly occurs in this formation, and the depositional environment is a flat alluvial plain washed by streams, so there was abundant water that could wash into the cave. Indeterminate bone fragments have been found in the cave fill (Fraser, 1994).

Development of the Breedon landscape

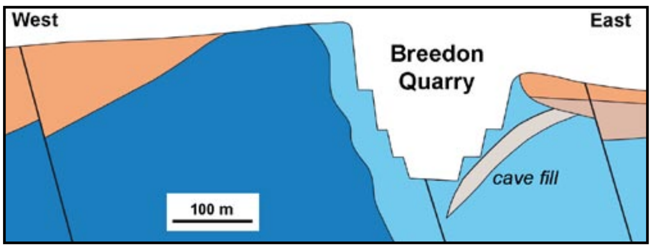
The landscape of Breedon Hill has its origins dating back some 300 million years to the late Carboniferous Variscan orogeny, when earth movements in the

The cave exposed in the quarry, before it was more overgrown, with its Triassic fill of red-brown siltstones of the Mercia Mudstone Group.

Midlands microcraton, pushed the Early Carboniferous limestones up into their near vertical aspect now exposed in Breedon and Cloud Hill quarries. The regional dip is to the west but the rocks are commonly overturned at Breedon and dip to the east. Erosion during the Permian removed younger Carboniferous rocks of the Millstone Grit and Pennine Coal Measures groups, leaving low hills of the Peak Limestone. Breedon Hill was probably somewhat higher than it is today. About 250 million years ago, in the Triassic, Breedon Hill was surrounded by the river system that deposited the Sherwood Sandstone Group, with the river flowing from northern France across much of England. This river had two courses, with a divergence somewhere in the English Midlands. It flowed north along the western side of England through the Staffordshire and Cheshire basins and into the East Irish Sea Basin, and also along the eastern side, through Nottinghamshire and Yorkshire and out into the North Sea, but it is unlikely that it occupied both courses at the same time.

About 10 million years later, the river ceased flowing, leaving a broad flat alluvial plane that was washed by river channels and contained many lakes; its deposits are the Tarporley Siltstone Formation at the base of the Mercia Mudstone Group. Following this, desert conditions set in. Much of England was a low-lying and flat landscape, with hills like Breedon and Mountsorrel standing up as inselbergs. Charnwood Forest formed a range of low, craggy hills that were probably mountains in the earliest Triassic. The desert was not a sandy desert like parts of the modern day Sahara, but a pelleted clay particles or 'dust' desert. Modern day analogues include the *parna* of southern Australia (Jefferson *et al.,* 2002). Clouds of dust blew across the flat plain and accretion occurred because of a high water table and frequently damp ground surface. This also resulted in the precipitation of gypsum close to the ground surface.

As the layers of sediment built up, Breedon Hill was gradually buried. The heavy rains that resulted in the deposition of the fine sandstones and siltstones on the desert plains had their impact on Breedon Hill. Screes that built up on the hillside were mobilised and flowed down the hill as debris flows. These survive in the quarry as fallen blocks of dolostone breccias. They are all matrix-supported, indicating deposition in debris flows, as opposed to clast-supported screes. The infilled cave now exposed in the quarry face had an opening on the surface of the hill. When the sediment accumulation on the plains reached its level, surface water washed sediment into the cave.



Profile through Breedon Hill; colour keys as on the map; vertical scale is double the horizontal scale.

A block of Breedon Breccia with matrix-supported clasts, which formed as debris flows on the side of the Triassic hill.

Eventually, towards the end of the Triassic, Breedon Hill, Cloud Hill, Mountsorrel and Charnwood Forest were completely buried. A prerequisite for this burial was continued regional subsidence (Carney, 2007) which favoured preservation of the soft desert muds. But this was not the end of sedimentation. Regional subsidence continued throughout the Jurassic and Cretaceous; Breedon Hill was under the sea and a great thickness of marine sediments accumulated on top of the Triassic strata. When the sea finally retreated at the end of the Cretaceous, the area was uplifted and tilted, and a long period of erosion ensued throughout the Palaeogene and Neogene. All of the Cretaceous and Jurassic rocks were stripped off, together with some of the Triassic, leaving behind the more resistant dolostones. Breedon Hill's Permo-Triassic expression as an inselberg is thus being revealed once again. What was left prior to the Quaternary glaciations is pure guess work, but the Breedon Hill of today was trimmed by the passage of glaciers particularly during the Anglian glaciations of around 440 000 years ago.

Quarrying at Breedon

Breedon quarry has been working since around the 1880s, and there is evidence of earlier quarrying going back hundreds of years. At the present time, quarrying activities are limited, with only a few thousand tons extracted each year, all for ornamental stone. In the past the limestone has been extensively used as roadstone, as is much of the current Cloud Hill output. The quarry has also produced agricultural lime, fluxing stone, rockery, walling and edging stone, flux for blast furnaces and foundries, tarred and bituminous aggregate, foundation stone and top-dressing for tennis courts. In the past, the variety of colours of the stone at Breedon and Cloud Hill quarries have been used for surfacing driveways and paths. Products have included the self-binding Breedon Golden Amber Gravel, which has been used for the garden pathways at Chatsworth House, in Derbyshire; this gravel is self-setting under treatment by water and roller. Much of the quarry overburden has been used around the village and to create the village green.

Planning permission has been granted for an eastward extension of the quarry into the neighbouring field, which will necessitate rerouting of the road from Breedon to Wilson. This should reveal more of the course of the cave that is infilled with Triassic sediments. There is a good possibility of finding animal bones on the cave floor as it is exposed, and these could even indicate what *Chirotherium* really looked like. This mysterious animal is, to date, only known from footprints, found mainly in the Sherwood Sandstone but also in the Mercia Mudstone Group, up until Late Triassic Carnian times.

Breedon Church

No visit to Breedon would be complete without a visit to the fine 12th century church of St. Mary and St. Hardulph, which crowns the hill, and constitutes another treasure trove of geological features. Surprisingly, it is built not of the local rock nor even of the Millstone Grit sandstones from the Melbourne area, but from Bromsgrove Sandstone, part of the Sherwood Sandstone Group. This crops out in many areas nearby but the precise source used is not known. A wide variety of rocks have been used for headstones in the graveyard, but most striking are the slates. Up to around the middle of the 19th century, the locally quarried Swithland Slate provided all the headstones, but improved transport links made the cheaper and better Welsh slate more accessible, and this led to the decline and eventual collapse of the Swithland industry. Apart from the dates on the graves, the two slates are readily distinguished; the Swithland Slate, because of its relatively poor cleavage, has a rough back surface, whereas the much better cleaved Welsh slates have smooth front and back surfaces.

Breedon Hill was home to an Anglo-Saxon monastery, founded in about AD 676. When this fell into disrepair, some of the carvings were rescued and placed in the church; they were carved in the Jurassic

Breedon church, with its gravestones of rough-backed Swithland Slate and smooth-backed Welsh Slate.

Tomb carved from local alabaster within Breedon church.

Lincolnshire Limestone, sourced from at least 40 km away to the east. Another geological gem inside the church is a tomb carved from local alabaster, a tough variety of gypsum, sourced locally, either from Fauld, Chellaston or Aston, and carved in Burton upon Trent where an alabaster industry was well established.

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