Revealing the geology of the Lickey Hills: the continuing importance of the amateur geologist

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Introduction

Generations of professional geologists, as well as academics and their students, have studied the geology of the United Kingdom. One might think that all the investigations that can be carried out with only a hammer and a hand lens have already been done. Is there any scope for the amateur geologist to make meaningful contributions to our body of knowledge?

When I retired in 2013 I thought the answer to this question was 'No', and I had no intention of carrying out any original research. However, fate took a hand when a petrographer friend of mine introduced me to the Lickey Hills Geo-Champions. This very active group of conservation volunteers is one of several such groups that belong to the Herefordshire & Worcestershire Earth Heritage Trust, based at Worcester University. As the Lickey Hills seemed to be nothing more than the surface expression of a big lump of quartzite, I did not imagine it would keep me interested for more than a year or so. However, things turned out rather differently.

Most of the sites lie within the Lickey Hills Country Park, close to Junction 4 of the M5. Although the park is divided between Birmingham and Worcestershire, it is wholly administered by Birmingham. The division between the two administrations has frustrated my attempts to get recognition for a number of important geological sites. Worcestershire has an excellent system for awarding Local Geological Site (LGS) status. It is administered by the Earth Heritage Trust, and each proposal is vetted by a panel of geologists with one or more representatives of the county planning department. By contrast, two of the sites for which I sought recognition lie within Birmingham, which does not use the LGS designation. Unfortunately, both were deemed to lie inside a Site of Interest for Nature Conservation for its heathland vegetation, and did not merit separate listings. 'SINC' seems an appropriate acronym as the online identities of these two highly significant geological exposures have been sunk without trace.

Lickey Hills Quartzite Formation

The Lickey Hills take the form of a NNW-trending ridge of rocks belonging to the Lickey Quartzite Formation (LQF). To the west, the horst block of this Ordovician inlier is bounded by the Leach Heath Fault, along which it abuts Upper Carboniferous rocks overlain by Permian breccias and Triassic conglomerates. The eastern margin of the block is delineated by the Rednal Fault, which separates it from Triassic sediments. The ridge marks the boundary between the Worcester Basin to the west, and the Knowle Basin to the east (Powell *et al.* 2000). To the south, the quartzite is down-faulted against the Lower Ordovician Barnt Green Volcanic Formation (Old *et al.* 1991). The northernmost outcrop of the LQF is at Holly Hill, beyond which it dives down beneath the cover of more recent rocks (Fig .1).

Many of the exposures of the Lickey Quartzite are abandoned quarries that produced aggregate chiefly for road construction. Most closed down in the 1920s, but one remained in use until the 1970s.

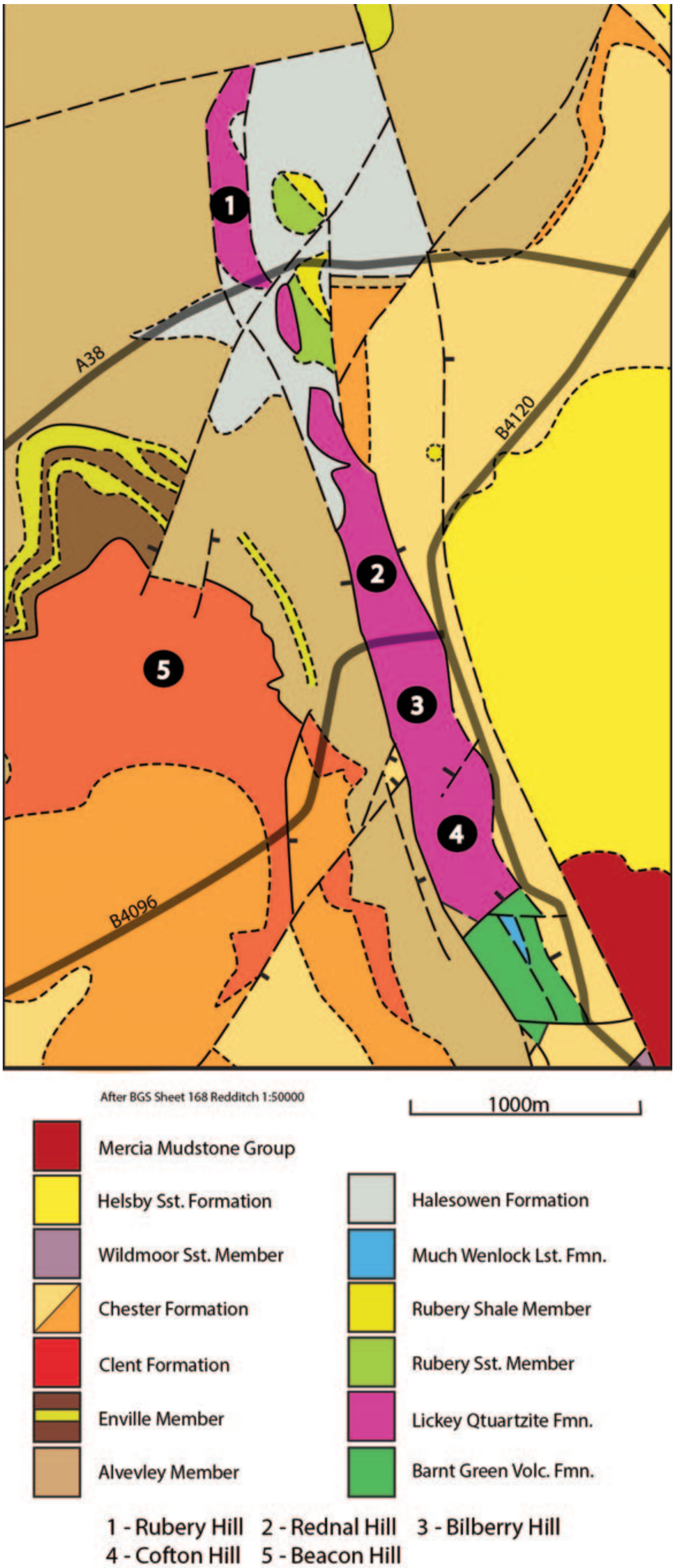


Figure 1 The geology of the Lickey Hills (based on the BG Survey map).

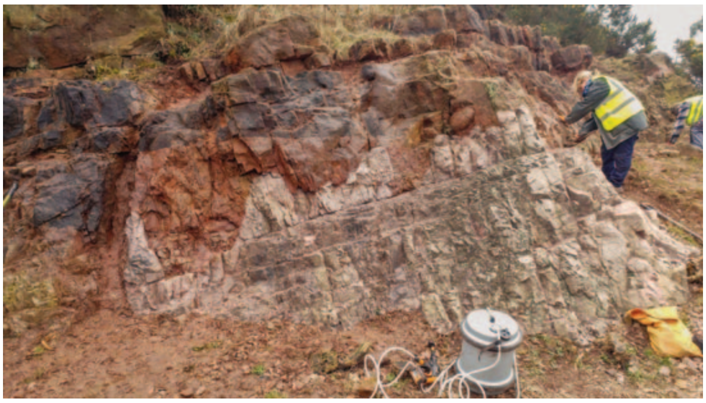
In his 1899 work, *Sketch of the Geology of the Birmingham District,* Professor Lapworth described the LQF as, "a thick mass of quartzite", and on the basis of perceived similarities with the Hartshill Quartzite, incorrectly assigned it to the Cambrian. He recognised the difficulty of interpreting the formation, "this Lickey Quartzite is much folded, jointed, and shattered. Neither the base nor the summit of the formation is exposed, and the disconnected sections do not afford a sufficiency of evidence to enable us to construct a complete ascending succession." (Lapworth 1899) The BGS *Redditch Memoir* offers the following description: "It is a hard, brittle, jointed and very shattered rock…" In terms of its age the BGS offers two insights, "at Rubery… the Lickey Quartzite is overlain unconformably by the [Llandovery] Rubery Sandstone or the [Upper Carboniferous] Halesowen Formation. Elsewhere, its stratigraphical relationships are unclear…". And later, "Tuffaceous material occurs most commonly in what are probably the oldest beds exposed, and there may be an upwards passage from the [Barnt Green Volcanic Formation 485–478 Ma]." (Old *et al.* 1991)

At Rubery, to the north of the country park, a cutting on the westbound off-ramp of the A38 exposes an impressive unconformity between the Ordovician Lickey Quartzite and the overlying Upper Llandovery (Silurian) Rubery Sandstone. Hollows in the irregular erosion surface harbour well-rounded pebbles and cobbles. Moving eastward up the slip road, the succession passes from sandstone into shale in the upward-fining sequence of a marine transgression (Ziegler *et al.* 1969). The exposure was logged in the 1920s by Wills, whose identification of fossils confirmed its age, and set a chronological limit for the top of the LQF (Wills *et al.* 1925). At the unconformity he identified a "joint in quartzite filled with Llandovery sandstone". However, recent cleaning of the exposure with a portable jet washer has revealed the fissure to be filled with fragments of lithified sandstone and the walls of the feature to display the sub-horizontal striations caused by a strike-slip fault movement, which post-dates the Rubery formation (Richardson 2023) (Figs 2 and 3).

The road cutting and the adjacent Leach Green Quarry constitute Birmingham's only Local Nature Reserve for geology. For a city that owes its wealth to the geology on which it was built, the state of this reserve points to a lamentable lack of understanding of Birmingham's geological foundations.The reserve is now entirely overgrown except for the roadside exposure of the unconformity, which is regularly cleared by the Geo-Champions. To make matters worse, a narrow access path to the main quarry face was fenced off, and houses were built in front. The neglect of the site has led to the householders utilising it as a disposal site for domestic rubbish, making access a hazardous enterprise. Risk notwithstanding, I recently entered the quarry in the company of Dr David Ray, who is collecting data for his current research on rates of sea-level change in the Silurian. Having cut down a considerable amount of vegetation, we revealed a striking pebble and cobble-filled channel in the erosion surface — a feature that has not been seen for decades (Figs 4 and 5, *opposite*).

Figure 3 After a thorough washing, the feature described by Hardie as a "joint in quartzite filled with Llandovery sandstone" can be seen to be a strike-slip fault.

Figure 2 The Rubery Road Cutting exposure. The benefits of using a pressure washer are clear. The irregular erosion surface on the Ordovician Lickey Quartzite has trapped pockets of well-rounded pebbles and cobbles at the base of the Upper Llandovery Rubery Formation.



Barnt Green Road Quarry

The base of the LQF is not exposed anywhere, so its stratigraphic relationships with older formations is less clear. At the southern end of the Lickey Ridge, the quartzite is down-faulted against the Barnt Green Volcanics. Originally assigned to the Pre-Cambrian,

Figure 4 In Leach Green Quarry the Rubery unconformity continues across the worked face.

these tuffs and tuffaceous sediments have now been dated to the Lower Ordovician (BGS 2024). In the nearby Barnt Green Road Quarry the Lickey Quartzite is less mature than at other sites and is interbedded with tuffaceous units including many sandy clay layers, which may be bentonites. A recumbent fold dominates the west face of the quarry: it has developed by flexural slip, facilitated by the ductile clay-rich layers between beds of competent quartzite. In the south-east corner of the quarry a fault can be seen to follow a clay-rich layer in the inverted upper limb of the fold, but it steps across the bedding in the lower limb immediately below the fold hinge. Movement has been accommodated along several bedding planes, each of which exhibits brecciation (Figs 6 and 7).

An initial interpretation of the fault suggested a reverse movement, but if the fault and fold were both the result of the same phase of deformation the 'Z' fold observed in the west face was at odds with a reverse movement on the fault. While there is no reason to link these two structures to a single episode of deformation, recent observation of very fine slickensides on the faulted surface of the footwall block suggest a normal movement. It is

Figure 5 In places the Leach Green Quarry exposes impressive features such as this pebble-filled channel, but all are rendered inaccessible by buildings, vegetation and domestic rubbish.

Figure 6 A general view across the main face of the Barnt Green Road Quarry, looking south-east, with the recumbent fold in the foreground.

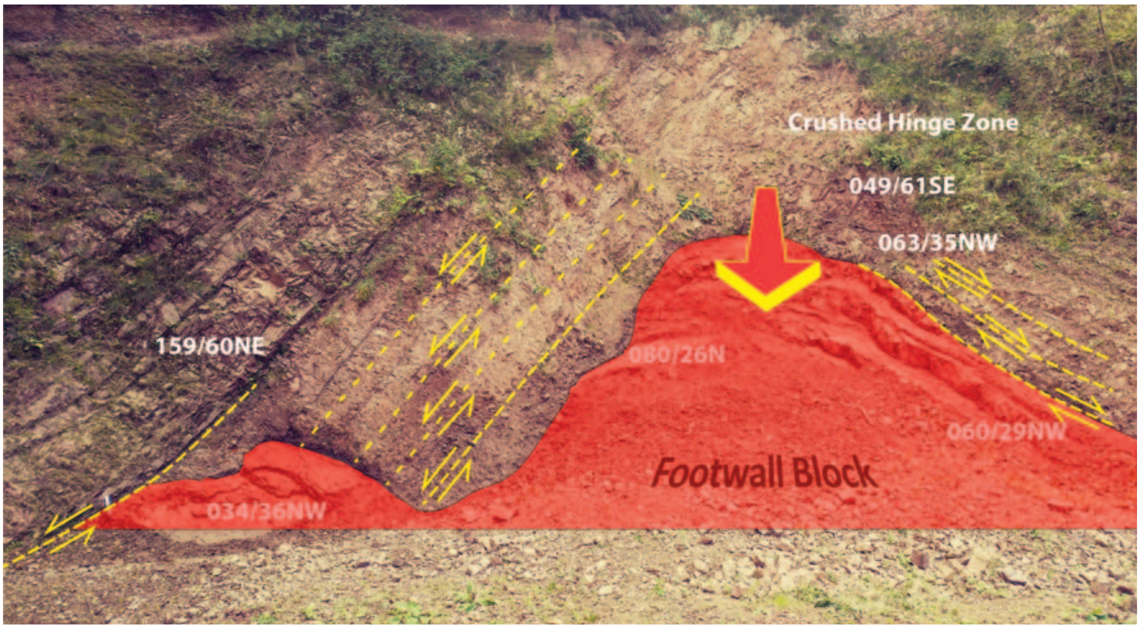


Figure 7 The south-east corner of the Barnt Green Road Quarry where the fault steps over the bedding in the footwall block, and movement has been accommodated along several planes of movement. There is some ambiguity in the evidence of the sense of movement, but adjacent features suggest a normal movement.

Figure 8 A panoramic view of Barnt Green Road Quarry showing the likely movement of the fault, and the 'Z' sense of the fold.

possible that this developed much later than the folding, and may have been associated with the development of the Rednal Fault only a few metres to the east (Fig. 8).

At Barnt Green Road Quarry, within the inverted upper limb in the hanging wall, the strike and dip of the bedding is 159/60NE. A short way to the south-west lies Kendal End Quarry. The bedding here exhibits large-scale ripples with a wavelength in excess of 1 m. However, the orientation of the bedding has been averaged at 161/46NE, close enough to that of the inverted limb of the BGRQ fold to suggest that this sequence may be the inverted limb of a much larger structure. Thus, the sedimentary structures initially identified as ripples are more likely to be the infilled troughs between the true ripples (Fig. 9).

I spotted a small exposure of quartzite on the east side of Eachway Lane. On examination, the exposed bedding plane revealed an abundance of 'dimples', where burrows were being preferentially eroded. With 'the eye of faith' these can be paired up, suggesting they might be diplocraterion, but I have not yet seen one in longitudinal section (Richardson). The obvious question has to be, 'In the whole Lickey Quartzite Formation, why is this the only bed that preserves these fossils?' The answer seems to lie in the overlying layer, which consists of sand with a high proportion of dark mineral grains in a clay matrix. I suspect it is a volcanic tuff that blanketed the sea floor, killing the occupants of the burrows and preventing mechanical reworking or bioturbation (Richardson 2023) (Figs 11 and 12, *opposite*).

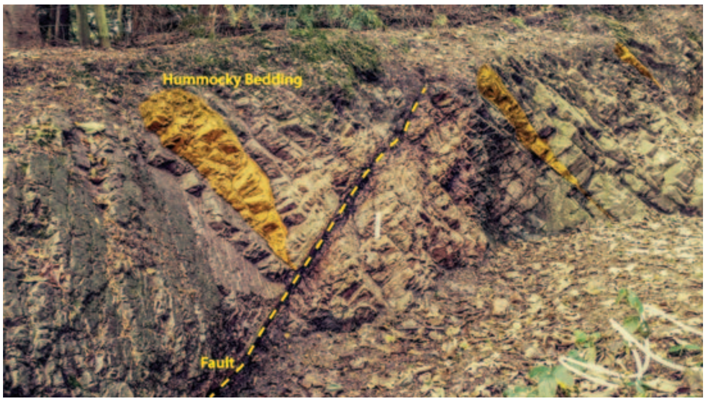


Figure 9 In Kendal End Quarry the strike and dip of the bedding is very close to that of the inverted limb of the recumbent fold in Barnt Green Road Quarry. It seems likely that the sequence in this image is also inverted, and the highlighted structures are not ripples, but the sediment fill in the troughs between inverted ripples.

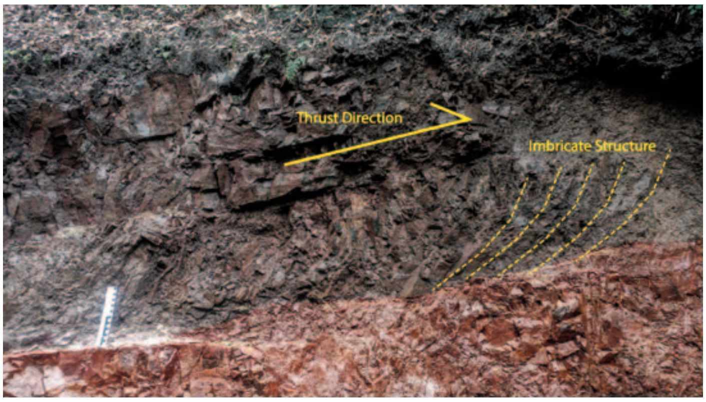


Figure 10 The lowest exposed thrust in Rose Hill Quarry. Like most planes of movement in the Lickey Quartzite Formation it follows a clay-rich layer of sediment. The footwall block has been coloured for clarity (the scale ruler sits on the thrust plain).

Lickey Hills gorge

Between Bilberry Hill and Rednal Hill the Lickey Ridge is transected by the Lickey Gorge. The north side of this valley is scarred by the three bays of the Rose Hill Quarry. In 1927 Professor Boulton published a sketch showing two thrusts near the base of the quarry. It is likely that these are now covered by quarry spoil, as nothing exactly matching the sketch has been found. Nevertheless, two thrusts have been identified; both follow clay-rich horizons, along which there is an abundance of brecciated quartzite fragments. Above the thrust planes imbricate structure indicates a northward movement of the hanging wall block (Fig. 10).

Eachway Lane

In 1899 Prof. Lapworth declared, "No fossils, except worm-burrows, have yet been detected in this Lickey Quartzite…" (Lapworth 1899). However, he did not do future generations the courtesy of recording the location of these trace fossils. On a reconnaissance walk with the Geo-Champions a few years ago,

Warren Lane Quarry

In its 1991 *Redditch Memoir* the BGS offers the following interpretation of the environment of deposition of the Lickey Quartzite: "The sorting, grain shape and sedimentary structures of the rock suggest deposition in a high-energy marine environment…" (Old *et al*. 1991). Supporting evidence is found in the Warren Lane Quarry opposite the Country Park Visitor Centre. The sediments here exhibit symmetric and asymmetric ripples, cross bedding, and more significantly, a recently discovered *Cruziana* trace fossil. As trilobites were exclusively marine, this evidence confirms the environment of deposition (Richardson 2023) (Fig. 13, *opposite*).

Warren Lane was where the story of the Lickey Hills got really interesting for me. In the north-west corner a First World War ammunition store was cut into the quarry face. Above its remains, a single layer of a red-stained pebbly sandstone offered clues that led to subsequent discoveries. The downward-tapering layer of sandstone contains angular fragments of Lickey Quartzite in a

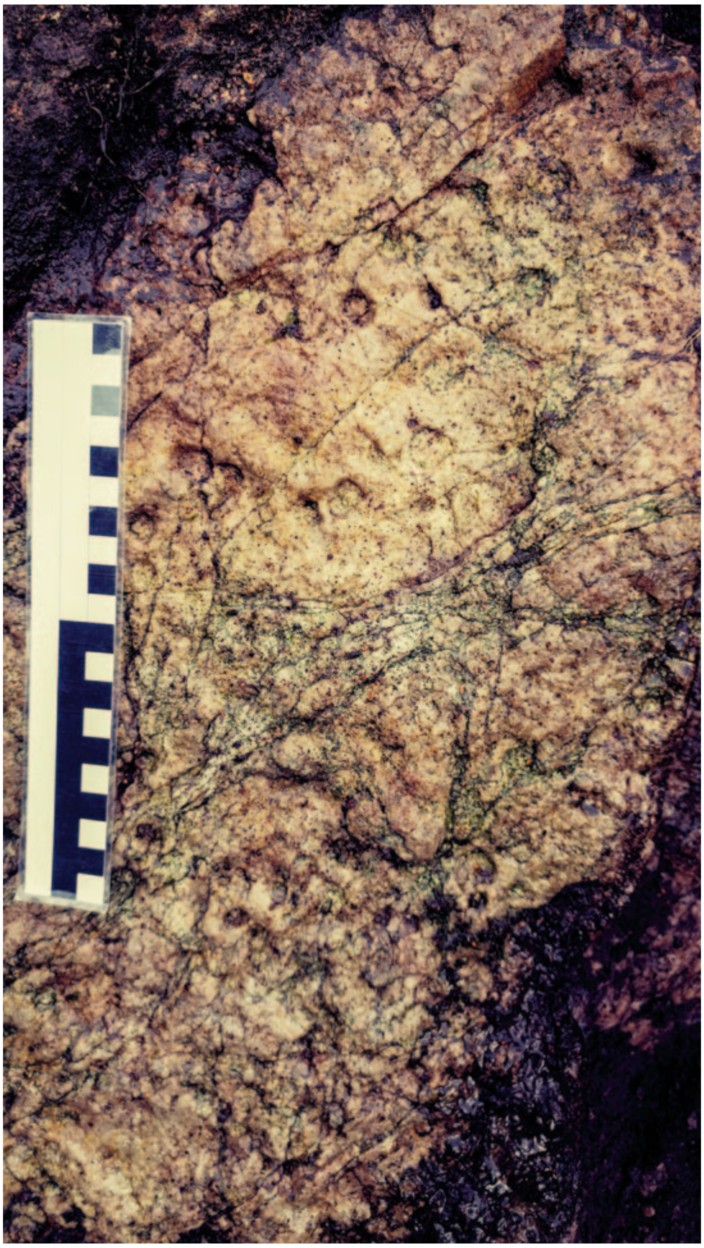


Figure 11 (left) Worm burrows exposed on a single bedding plane in Eachway Lane Quarry.

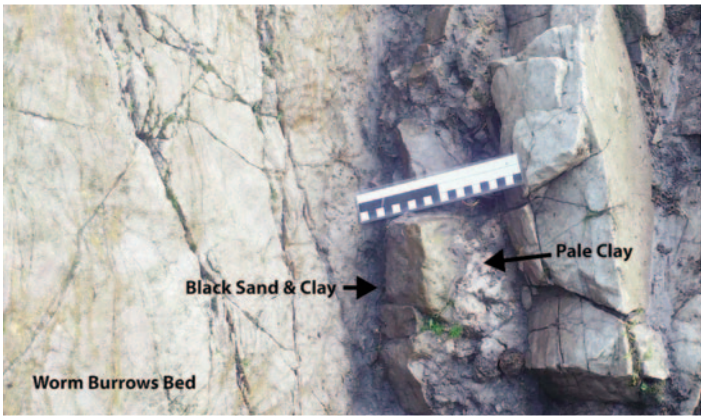


Figure 12 The layer immediately above the worm burrows is a black sand with a clay matrix, and may help to explain their preservation at this site.

Figure 13 The recently discovered Cruziana *trilobite feeding trace found in Warren Lane Quarry.*

sand matrix containing abundant well-rounded, frosted aeolian grains such as are found in Permian sandstones. In thin section, the Lickey Quartzite exhibits tightly sutured grain boundaries resulting from the pressures associated with deep burial. In contrast, the grains in the pebbly sandstone retain their original rounded outlines and a fine-grained matrix reflecting a much shallower depth of burial (Richardson). The presence of occasional rounded pebbles of vein quartz shows that this material was washed into an open fissure by flowing water (Richardson 2023). If this structure was open to the ground surface, it follows that it was part of an unconformity, and the obvious place to look for its continuation was upwards on Bilberry Hill (Figs 14, 15 and 16, *overleaf*).

The Bilberry Hill unconformity

In a geology guide for the area, Hardie noted "Some unusual examples of brecciated quartzite, which have been strongly cemented by quartz following brecciation (crushing) are of particular interest. These are strongly resistant to erosion, and form small but conspicuous masses standing about 1 m above the general level of the quartzite." (Hardie 1991). There had been much discussion about the nature of this cluster of rock masses protruding from the soil on the summit ridge of Bilberry Hill. There were two topics of contention: were they exposures or loose boulders; and were they structural or sedimentary breccias? I was in no doubt that they were *in situ* and sedimentary. I was now in a state of considerable excitement as I now approached my 'James Hutton Moment'! I asserted that if we were to dig down around these rocks, we would find an unconformity. We dug, I wielded the pressure washer, and there indeed was the unconformity, which shares some characteristics with a rather more famous one. Hutton's unconformity on Arran lies at the base of a Devonian 'cornstone' or calcrete, in which calcium carbonate has precipitated in the surface sediments through the evaporation of groundwater, soon after deposition. However, the addition of calcite extends into the top 300 mm (or so) of the underlying Dalradian phyllites, making them much more resistant to erosion. As a result many an unwary geologist has misplaced the unconformity to the level at which the exposure is undercut beneath the calcite-reinforced phyllites. On Bilberry Hill the sedimentary breccia and the uppermost 200 mm of quartzite are almost indistinguishable as the former is composed almost

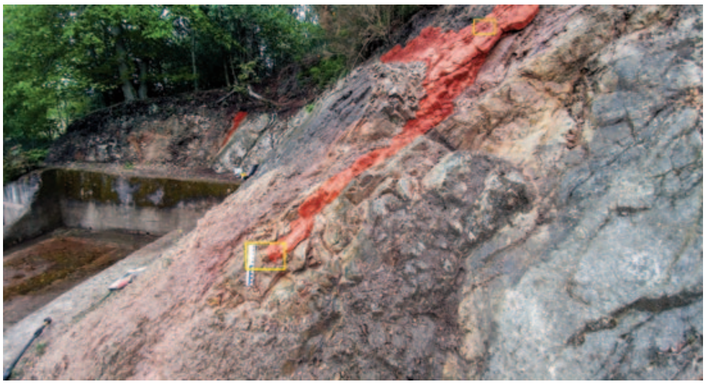


Figure 14 The view across the remains of the WW1 ammunition store in Warren Lane Quarry, with the two outcrops of the infilled fissure highlighted.

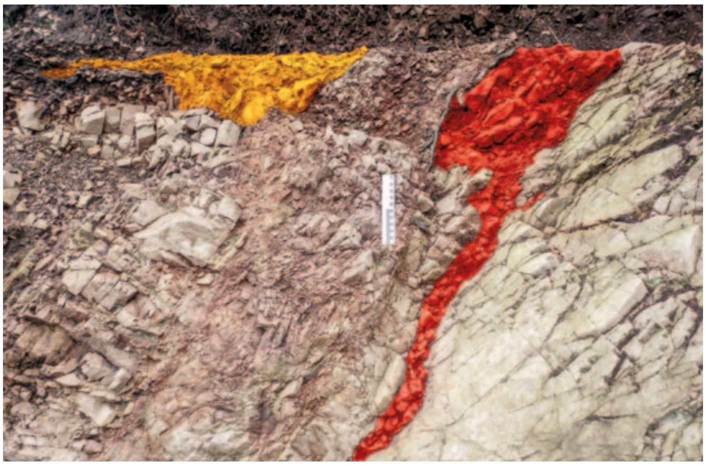


Figure 16 The highlighted tapering fissure contains fragments of Lickey Quartzite in a matrix dominated by aeolian sand grains. It is an extension of the Triassic unconformity on Bilberry Hill.

entirely of fragments of the latter. Both are particularly well cemented and are far more resistant to erosion than the heavily fractured quartzite beneath. This extremely hard layer is a silcrete, and like the calcrete on Arran, the unconformity lies within it (Richardson 2023) (Figs 17–24, *this page and opposite*)

Subsequently a 400cm^2 exposure of breccia was discovered on Rednal Hill by John and Julie Schroder of the Geo-Champions (Richardson 2023). Excavation and pressure-washing exposed the same silcrete and unconformity. While a thick soil layer and heavy vegetation covers any outcrop on Cofton Hill to the south, fallen blocks of silcrete are commonly found around its base, so it is reasonable to suggest it exists as a capping on all three of the southern hills in the Lickey Ridge (Figs 25 and 26, *page 14*).

Public works in the 1920s and 1930s revealed local deposits of Lickey Quartzite breccia interbedded with Lower Triassic rocks

Figure 15 The reddish sandy fissure infill lies between layers of grey Lickey Quartzite, a fragment of which has been incorporated into it.

Figure 17 The "unusual examples of brecciated quartzite" referred to by Hardie on the crest of Bilberry Hill.

Figure 18 After excavating around the breccia and scrubbing off the mosses, the exposure of breccia was pressure washed.

Figure 19 The breccia has been darkened to show the unconformity more clearly. The upper 200 mm of the Lickey Quartzite together with the breccia have been turned into a layer of silcrete by precipitation of silica from ground water at the ground surface.

Figure 20 Hutton's Unconformity on the Isle of Arran is similar to the Bilberry Hill Unconformity, but is a calcrete rather than a silcrete.

(Wills and Shotton 1938). The BGS has correlated this with the Hopwas Breccia (Old *et al.* 1991), which has been dated to the Lower Triassic by means of palaeomagnetic evidence, which records a latitude of 20ºN (Johnson 1995). This evidence confirms that the Lickey Hills were exposed during the Triassic, and the development of a silcrete is consistent with the climatic conditions at that time. The geological map of the area now needs updating to include the Triassic 'Bilberry Hill Breccia' (Fig. 27, *page 15*).

Lickey Hills horst

The faulting that generated the Lickey Hills horst occurred during the Late Permian extensional phase (Old *et al.* 1991). The sediment-filled fissure in Warren Lane Quarry would have opened at this time. Recently, comparable sediment-filled fissures have been found in Kendal End Quarry, Rose Hill Quarry and on the south side of the Lickey Gorge. All of these lie at the base of the hills and demonstrate the fact that the Lickey Hills in the Triassic were directly comparable to those we see now. Two of these sites

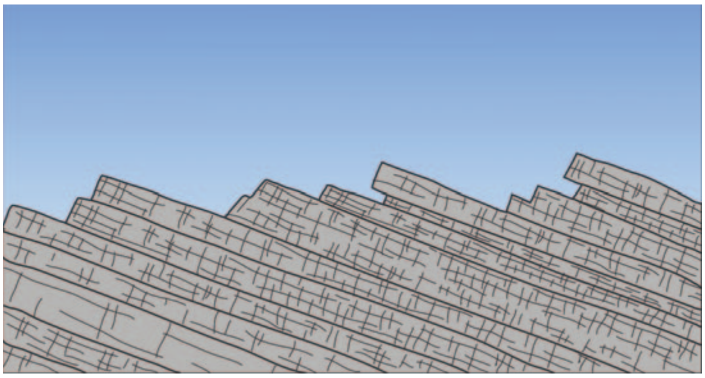


Figure 21 The newly-uplifted, and heavily-jointed, Lickey Quartzite was subjected to weathering, which created a layer of regolith.

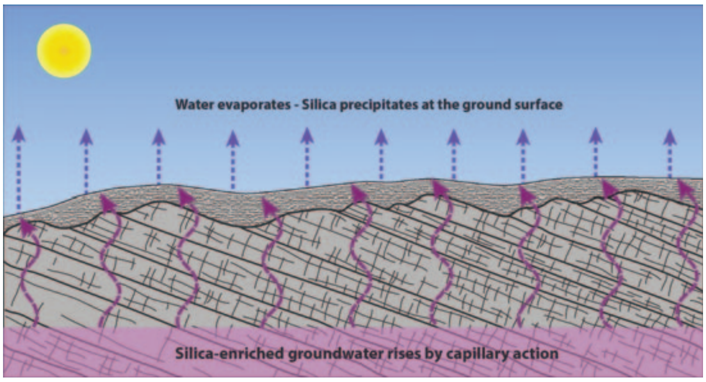


Figure 23 During prolonged periods of drought the silica-infused ground water rose by capillary action to the ground surface, where it evaporated leaving the silica as a precipitate in joints in the Lickey Quartzite, and in pores in the regolith.

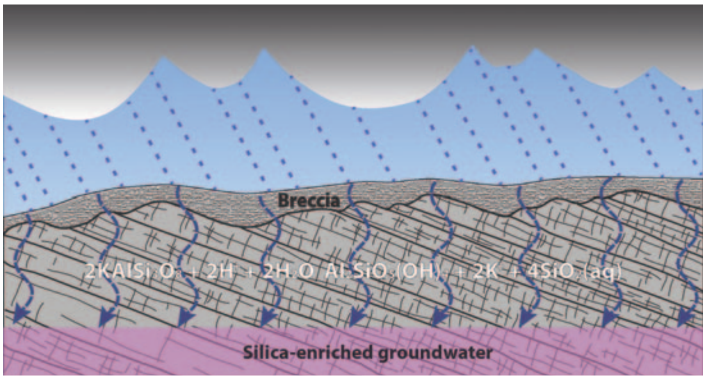


Figure 22 Infrequent heavy rainfall led to weathering of the feldspar grains in the Lickey Quartzite, resulting in the release of silica into solution.

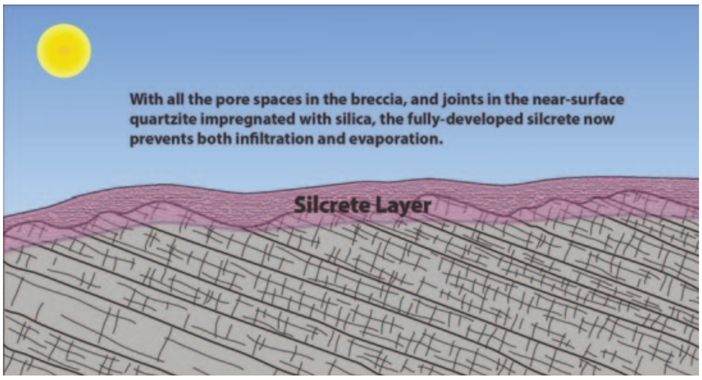


Figure 24 Ultimately, all upward routes for the groundwater were closed by silica cement and the silcrete was left as a highly resistant impermeable layer, which greatly slowed the rate of erosion. Consequently the Lickey Ridge survived the Triassic and was later buried under softer sediments.

Figure 25 Excavation of a tiny exposure on Rednal Hill uncovered the same unconformity in a layer of silcrete.

Figure 26 While no exposure of silcrete has yet been found on Cofton Hill, boulders of it, such as this, are found around its base.

lie within the Lickey Gorge. Previously it had been suggested that this was a glacial overflow channel from an ice-dammed lake. However, no drift deposits corresponding to an alluvial fan on the outflow side are recorded on the BGS map. The fissure infills, which contain derived aeolian sand, offer strong evidence for the gorge being a Triassic landscape feature analogous to the channel structure in the New Cliffe Hill Quarry in Leicestershire (Figs 28 and 29, *opposite*).

Conclusions

There is still considerable scope for continued research in the Lickey Hills, but a number of misconceptions about their geology have been resolved. The structure of the LQF is not a simple anticline, and the southern part may be the inverted limb of a large-scale recumbent fold. The silcrete on the southern three hills has acted as a resistant cap-rock, preventing deep erosion and resulting in their preservation under more recent sediments, which were subsequently eroded to reveal an exhumed Triassic landscape (Fig. 30, *opposite*).

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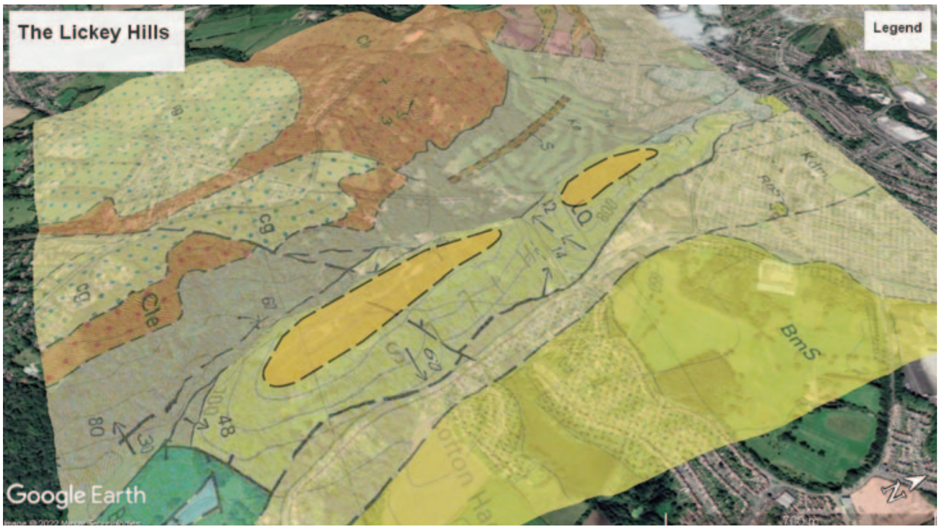

Figure 27 The geological map of the area needs to be revised to record the Triassic breccia, and may eventually look something like this (BGS Geology map draped over an oblique Google Earth image; vertical exaggeration ×3) (contains British Geological Survey materials © UKRI [2024]).

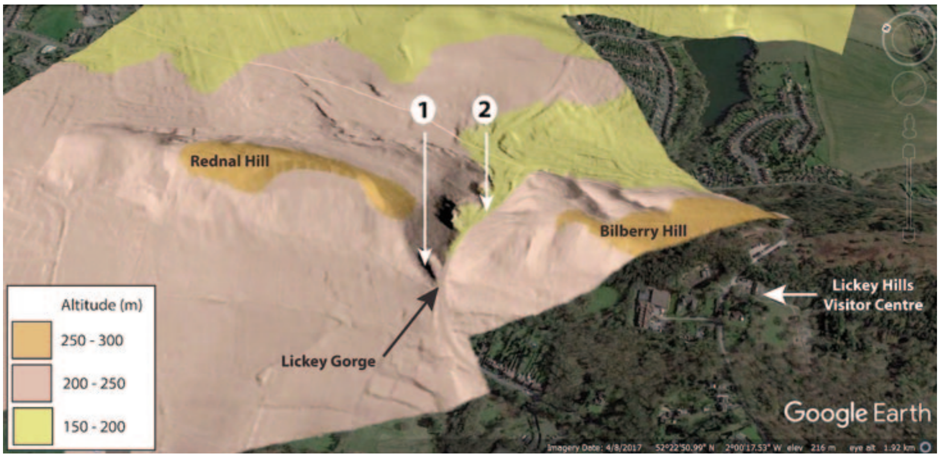

Figure 28 Partial LIDAR coverage draped over a Google Earth landscape shows the Lickey Gorge, with the locations of two sediment-filled fissures indicated: #1 Rose Hill Quarry (West Bay); #2 South Side of Lickey Gorge (LIDAR image © Environment Agency copyright and/or database right 2022. All rights reserved).

Figure 29 New Cliffe Hill Quarry in Leicestershire. A palaeovalley in Pre-Cambrian igneous rock was preserved by being infilled with sediments of the Triassic Mercian Mudstone Group. The Lickey Gorge appears to be a similar Triassic landform (BGS image P667862 © UKRI 2008).

Figure 30 A LIDAR image draped over a Google Earth landscape (vertical exaggeration ×1.5) reveals the exhumed Triassic landscape of the Lickey Hills. (LIDAR image © Environment Agency copyright and/or database right 2022. All rights reserved).