LGA

Leeds Geological Association

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Field Visit Reports
Summer 2019

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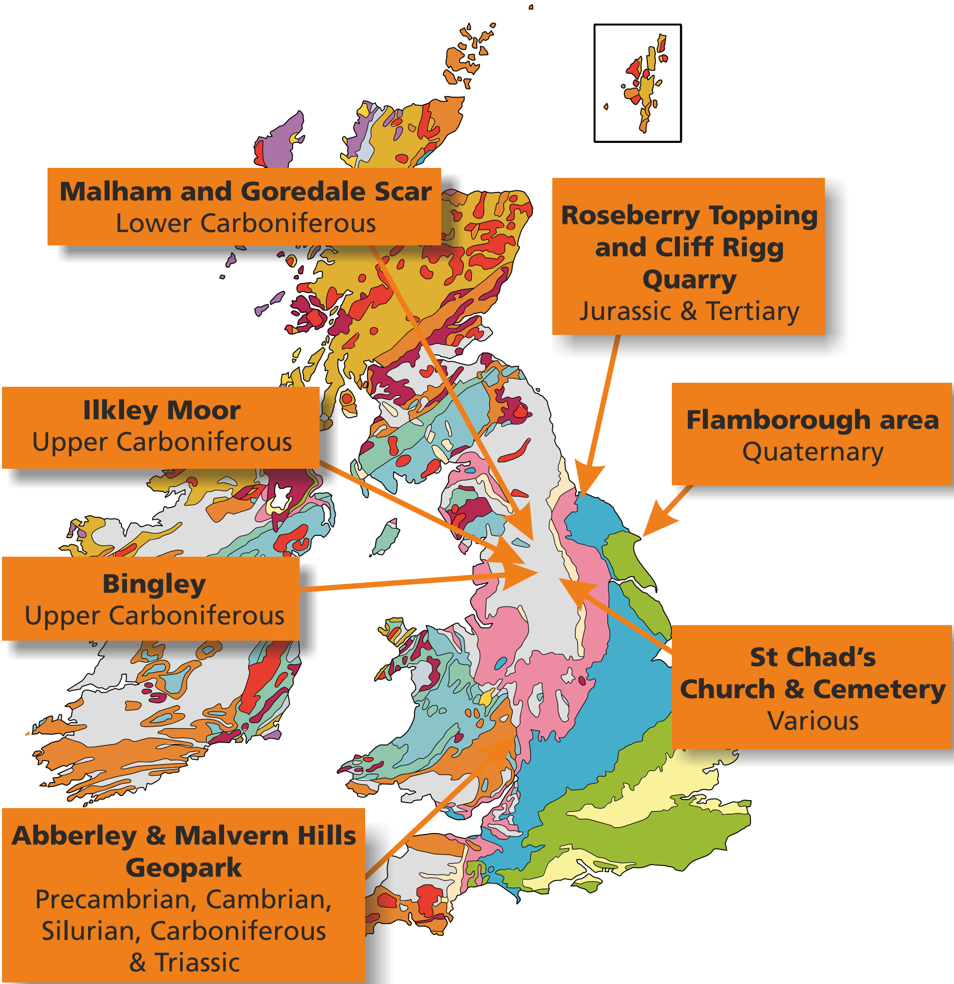
LGARocks

19 Where did we go?



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Thanks are due to the Field Visits Group for arranging the programme, to the leaders who gave up their time to take us, to Mike Bowles, Robert Chandler, Judith Dawson, Bill Fraser, Gareth Martin, Phil Robinson and David Taylor as authors of reports and to those who contributed photographs.

Cover Picture: The Calf Rock, Ilkley Moor. A block of Addingham Edge Grit

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Ilkley Moor
Saturday 11th May

Leaders: Gareth Martin, West Yorkshire Geology Trust & LGA and David Leather, LGA
Present: 24 members and 9 visitors

It was encouraging to see such a good attendance on this, the first field visit of the season. Two weeks earlier a wildfire had ravaged a large section of the Moor and while its affects were very evident it had fortunately just missed the area we were to cover. After a brief introduction to the day from Gareth and David the party headed up towards the Cow and Calf.

The first stop was at a large gritstone boulder which contained a good example of a fossilised plant stem preserved in 3D. David explained that this was an example of ***Knorria*** which is the imprint of the inner, 'pithy' layers of the giant club moss ***Lepidodendron*** and resulted from the outer woody layers having been stripped off as the stem was swept along by powerful, sediment-laden currents of a river before being buried.

The Calf (see photo on front cover) is a huge block of Addingham Edge Grit, 8 m high, which is estimated to weigh approximately 1000 tonnes and is believed to have become detached from the main outcrop, the Cow, during late Devensian times. Since then it has moved downslope by 25 m and rotated through 140° so it is now lying almost 'on its back'. Given the steepness of the slope below it is suggested that it may have originally been supported by the edge of the glacier that used to occupy the Wharfe Valley.

Moving into the Cow and Calf Quarry the massively bedded Addingham Edge Grit could be examined in situ. This was seen to be a coarse grained, poorly sorted feldspathic sandstone which in places showed graded bedding and other examples of ***Knorria***. On the floor of the quarry, in a much finer grained sandstone, some very well-preserved symmetrical ripples were exposed. David explained that these were part of a unit composed of beds of thin layers of fine sandstone separated by very thin layers of mudstone, which were recognised by the late Dr Neil Aitkenhead (BGS & LGA Ex-President), who mapped this area, as being deposited under tidal conditions and known as tidal laminites. These contrasting facies occurring so close together led to discussion on the nature of the sedimentary record.

A short walk took the party to the top of the quarry where the amazing variety of carved graffiti was examined as well as the view across Wharfedale. The valley probably owes its existence and orientation here to a fault that runs along its axis. This line of weakness has been exploited by weathering and erosion, first by rivers then by ice, to become the feature seen today. The contrast in slopes on either side is due to the regional dip of the Millstone Grit

Rocky Valley. Formed in a rotational shear slide.

Group which is to the south. The gently sloping northern slopes are developed on the dip slope whereas the steeper and more rugged southern slopes are carved into the upturned edges of the beds. Differential erosion of the weak mudrocks and hard sandstones has produced the step and bench topography which could be clearly seen looking west. The wide flat floor of the valley is carpeted in thick layers of glacial till and fluvio-glacial sands and gravels.

Moving on to Hangingstones Quarry the contrast in bedding with the Addingham Edge Grit in the Cow and Calf Quarry was noted. Here the beds are thinner and more evenly bedded which made it an ideal building stone. The rapid deposition of these coarse sandstones was indicated by the presence of sand volcanoes: dewatering structures formed as air and water was forced out of unconsolidated sands when new material was dumped on top. On glacially smoothed surfaces we were able to see the first of many enigmatic Bronze Age 'cup and ring' carvings that we would see during the day. Also well exposed were some prominent glacial striations clearly recording the direction of ice movement down the valley. Other striations were also seen on highly polished vertical faces, these being slickensides; scratches made along fault planes as opposing sides ground against each other. The slickensides appeared to run parallel to the direction of Backstone Beck Gill indicating that it too was fault controlled.

The final stop before lunch was in the feature known as Rocky Valley (see photo previous page). This boulder strewn valley contains no watercourse, runs parallel to the hillside and is overlooked on its south side by high, rocky scars of the Addingham Edge Grit. The valley was formed as a result of a landslip, one of many along the south side of Wharfedale. They formed in late glacial times where the over steepened hillsides cut in weak shale are capped by thick layers of hard gritstone. In periglacial conditions the shale became saturated, further weakened and unable to support the overlying sandstone causing it to fracture along curved surfaces and for large masses to slide down as rotational blocks. The backward rotation is indicated by the dip of the sandstones on the slipped block, which is southerly, into the hillside.

Lunch was taken in Rocky Valley just as one of the torrential showers that we had seen moving across the countryside all morning caught us. The sun was soon shining again though as we continued our onward and upward journey. A brief stop was made to view the site of the reconstructed Late Iron Age settlement which, from dates obtained from charcoal found on site, is believed to have been built on a site occupied since Late Neolithic times. This led to discussion as to the likely climate and vegetation at the times of these original settlers.

Continuing uphill we came to a low (2-3m), wide (up to 40m) ridge that follows a slightly sinuous E-W course for around 600m. This is Lanshaw Delves and is a lateral moraine of the ice stream that occupied the Wharfe Valley during the Devensian. Its height on the hillside, around 360m OD, shows the thickness of this ice mass. As well as forming a physical feature the moraine is marked as a strip of much greener vegetation running through the darker heather (see photo below). This is because the moraine contains a high proportion of limestone which has led to the development of more alkaline soils. The central portion of the moraine has largely been excavated as a series of shallow pits (delves) to be burnt for lime for agricultural purposes. Every 20-30 m along the ridge are grassy mounds which are the sites of small field kilns where this operation took place. In the exposed ground around these and in adjacent pits, fragments of limestone and coal were found along with chert and sandstone. Whether the coal came from the moraine or if it was imported instead of or to supplement more readily available, but less efficient, peat or wood is not known.

From here our journey was now downhill back to the car park. On the way a brief stop was made to examine the Long Ridge Sandstone which lies above the Addingham Edge Grit seen previously. Close to this another cup and ring carving was observed. This is the Idol Stone which consists of 25 cups laid out in lines. Discussion took place as to the purpose of such stones; the truth is - nobody knows!

At a loose gritstone block that contained some heavily weathered and eroded plant fossils Gareth and David were thanked for providing such an excellent day and handout before a dash was made for the cars to miss the approaching rainstorm.

(The handout for this visit is available on the LGA website)

Lanshaw Delves. A lateral moraine of the Wharfedale Glacier

Prince of Wales Park, Bingley
Thursday evening 23rd May

Leader: Bill Fraser, LGA
11 members and 22 visitors

This event was our second field meeting of the year and held as part of the Yorkshire Geology Month programme so it was very pleasing to see so many visitors. Bill met us at the south entrance to the Park on a warm and sunny evening from where he led us to the former drinking fountain, presented by the Total Abstainers of Bingley in 1866. Here, he gave us a brief history of the Park from its creation in 1863 following the closure of Brown Hill Quarry and an overview of the geological history of the region in Carboniferous times. At that time Bingley was on the equator and covered by a shallow sea into which vast river systems, flowing from a Himalayan sized mountain range to the north, were depositing huge amounts of mud and sand as a large delta system that prograded southwards. In the Park we were at the very top of the Namurian in the Rossendale Formation, which consists of dark mudstones overlain by two different sandstones: the Rough Rock Flags and above them the Rough Rock. The mudstones, being soft, are not exposed but the two very different sandstones are.

We climbed to what had been the main quarry - a large flat expanse now known as the 'Arena' and used for events. Here was a 5m or so high rock face of massively bedded, hard, coarse-grained sandstone with large numbers of angular feldspars, poorly sorted but with graded bedding (fining upwards) visible in places. Large scale trough cross-bedding could be seen. Bill explained that these features were characteristic of a sediment which had not travelled far, and which had been deposited rapidly in subaqueous dunes in braided streams by fast flowing currents which had been suddenly checked as they flowed across the delta top. This was the Rough Rock and, being hard and massively bedded, was a good dimensional stone, suitable for building. However, occasional brown patches could be seen in the face where iron cement had caused small areas of the face to be weathered out. These patches were known as 'mares' to the quarrymen.

At the western end of the quarry, beyond a retaining wall of dressed mixed stone, could be seen a very different rock. This was a thinly bedded, fine-grained micaceous sandstone - the Rough Rock Flags - which are interpreted as having been deposited as sandbars at the mouths of distributary channels. The abrupt change in the rocks was evidence of a fault as the Rough Rock Flags, being older than the Rough Rock, should lie below it (see photo opposite).

Fault boundary between Rough Rock and Rough Rock Flags

Climbing some steps to the right of the main face we examined a higher face within the Rough Rock to look at smaller scale trough cross-bedding as well as planar cross-bedding. Such changes in a very short distance are not unusual given the braided nature of the river channels and changing rates of flow.

Climbing higher we came across some shallow workings within a coarse-grained feldspathic sandstone - the Rough Rock again. The shallowness of the workings suggested that we were close to the base of the Rough Rock with the Rough Rock Flags not far below. Bill said that these were probably trial workings to ascertain the depth of the workable dimensional stone.

Turning downhill we walked along the so-called Promenade which runs parallel with, but some way below, the Arena. The retaining wall had been made up of discarded rocks, many of which had impressions of plant stems - largely ***Calamites*** but with the occasional ***Lepidodendron*** (see photo overleaf). These impressions were of plants which had grown on the delta tops and which had been carried downstream during flooding.

Returning to the arena, Bill drew to our attention that close to the retaining wall and the western entrance was an almost complete cast of a ***Calamites*** - perhaps ½ metre high and wide - which the party had completely missed on its earlier visit! Finally, on our way down towards the entrance we visited the 'Cascade' which is one of several springs in the Park. These springs indicate the existence of the mudstone at the base of the sandstone portion of the Rossendale Formation. In the decorative wall to the right of the Cascade could be seen the cast of a twinned ***Calamites***. Here, the group thanked Bill for a really excellent evening and went their various ways home.

Plant fossils lining paths

St Chad's Church and Cemetery, Far Headingley
Thursday 4th June

Leader: Dr John Varker, LGA
Present 13 members and 3 visitors

Torrential rain and rapidly failing light were to render the tour of the cemetery impractical, turning this evening field visit into an indoor meeting only. Inside the church John started by outlining the history of this fine Victorian church built in the gothic revivalist style, and pointed out one of its oddities: instead of the normal east-west alignment of churches this lies approximately north-south, to provide 'a good aspect from the Otley Road'. This unusual alignment also applies to the graves, very few of which are east – west, but certainly does not mean they were not Christian burials. The church, which took 12 years to complete (1856-68), is built from a pebbly, coarse grained, feldspathic sandstone. This is the Rough Rock, which belongs to the Rossendale Formation of the Millstone Grit Group. This horizon crops out extensively across north Leeds and from the distinctive chevron pattern of masons' tool marks identifies it from quarries in Meanwood. The blocks used on the original part of the building are fairly uniform in size, shape and thickness of industrial revolution soot deposit. However, those used in the later extension (1909-11) are more variable and show varying composition and surface blackness. Many have tool marks cut in a diagonal pattern which identifies them as coming from a company or quarry in Harehills. These differences suggest that the extension was built, at least partly, from recycled stone from other demolished buildings.

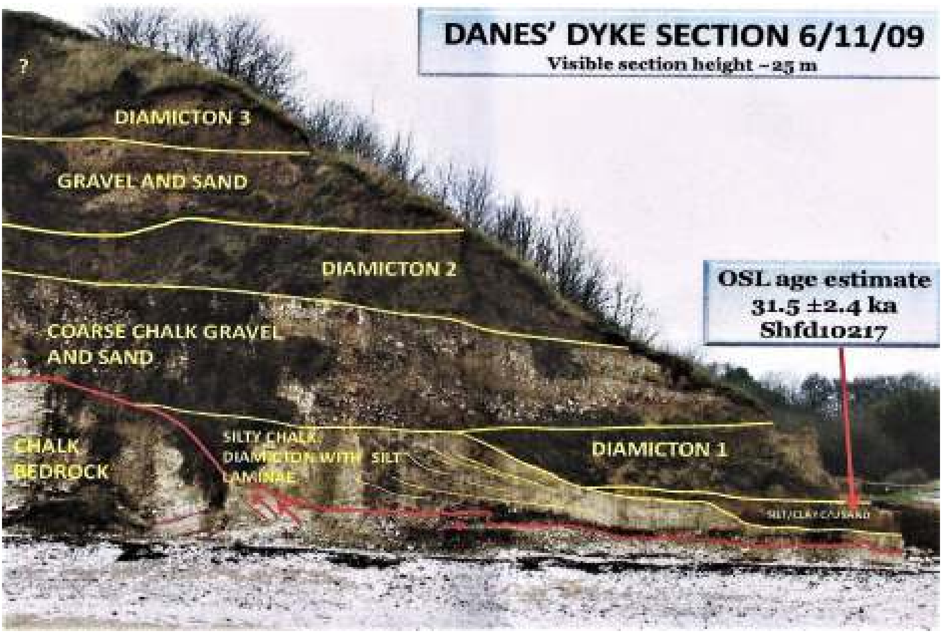
Different stones have also been used for the church interior. While the coarse grained Rough Rock has been used for the pillars and general structure, a much finer grained sandstone had to be used where detailed carving was required (see photo below). This can be seen in the capitals, the font and small inserts into the interior walls. This is the Coal Measure Group, Thornhill Sandstone which comes from the Huddersfield area and also makes up the recently laid floor. A very large (4m x 3m x 0.15m) slab of Coal Measure Group

Differences between Rough Rock and Thornhill Rock

Elland Flags sandstone which forms the top of the entrance steps, must have taken some handling. Faint parallel lines running across the top surface are traces of ripple marks indicating its shallow water origin. While the type area of the Elland Flags is Huddersfield, where few of the quarries still remain, this rock also occurs, and was quarried extensively, in north Leeds. The only 'foreign' stone used in the building is a brightly coloured rock that forms a strip on the floor inside the crèche screen and is a brecciated, slightly metamorphosed, fossiliferous limestone. The grey limestone fragments contain some faint outlines of fossils and are set in a matrix stained with iron oxide. The origin of this rock is possibly from the Alpine region of Europe.

At this point one of the visitors, Professor Mark Seaward, gave us a short talk on the lichens that he had hoped we would see on our tour of the graveyard and how they can be used for dating and measuring environmental change. St Chad's churchyard was evidently free of lichens in the 1960's but now hosts 35 different species. The reason for this was the various clean air acts introduced following the killing 'smogs' of the 50's which had until then inhibited their growth. The cleaner air since has allowed them to flourish which proves the point that 'the solution to pollution is dilution'.

John was thanked for making the most out of our curtailed visit and for the excellent Geological Trail guide he provided, which will allow us to complete the visit ourselves in better weather, before we departed into the darkness and rain.



Danes Dyke stratigraphy

Flamborough area: 'In the footsteps of Phillips, Lamplugh, Catt and Heppenstall'.
Saturday 22nd June

Leader: Dr Rodger Connell, University of Hull and Hull Geological Society
11 members

The party met at Danes Dyke car park for the day's visit to learn about the latest findings in the geological research of the Quaternary of the Holderness Coast, which follows up that of earlier workers. The earliest of these was John Phillips, who published his findings in his book of 1829 'Illustrations of the Geology of Yorkshire'. Further studies were made by George Lamplugh and published in his paper of 1891. John Catt worked on the area in 1963 and then Ian Heppenstall began work with a Hull University night school class and members of the Hull Geological Society in 2002. Work has continued to interpret glacial and periglacial sediment since then and has been aided by dating of sediments by Professor Mark Bateman of Sheffield University using Optically Stimulated Luminescence (OSL).

The first location was the palaeo-valley at Danes Dyke beach, the sides of which are ice shattered limestone but could be seen to be filled with different sediments, (see photo opposite), some of which contain Jurassic microflora. These were deposited in a glacial lake and while the ice flow is considered to have been NE-SW at this time, sand layers have indicators of a N-S flow direction with some upward grading. The valley itself is of uncertain age but is thought to have been controlled by N-S trending faults in conjunction with other faults located offshore and therefore unseen. The OSL date for the glacial lake sand is 31.5 +/- 2.4 Ka, which is older than expected. The overlying coarse chalk gravel and sand (see photo overleaf) was probably deposited after the lake sand but has not been dated. This evidence currently leads to the interpretation that there was an ice dam in nearby Bridlington Bay which allowed a lake to form. Around 31.5 Ka this was filled with sand derived from local Jurassic rocks, together with some limestone. Then there was more deposition of glacial sediments which are of unknown origin and date. The concept of an ice dam and lake has provided a new model for ice flow and sediment deposition on a local scale.

Moving on to South Landing both the bay and the palaeo-valley within it were seen to be wider than at Danes Dyke. The east cliff contained a thick chalk gravel deposit, dated by OSL at 67.4Ka which is equivalent to the marine isotope 4 cold period. Based on evidence from Scotland there is some debate over this date (and perhaps the samples used were contaminated) but it can be taken as a relative date.

In the west cliff at central South Landing the deposit has reverse bedding indicative of a debris flow. The limited erratic content is around 5%, consisting of sandstone, igneous rocks and flint. The source of these erratics is thought to be from north of Flamborough Head in the modern offshore area. The deposit is interpreted as a subglacial outwash fan proximal to the ice margin with material from nearby chalk. This has been dated at 67Ka. by OSL which is the oldest preserved deposit in the section. Thirty metres to the west of the outwash deposit there is a large calcreted limestone block containing 40% erratics with a reliable OSL date of 36.9Ka. The location has two chalk gravels in one face with different dates. The younger gravel cuts into the older gravel showing that it was possibly filling a hole in the older one. The deposit also has limestone that was shattered by frost after deposition.

To the south side of the lifeboat station and above the chalk bedrock there is a dense, poorly bedded chalk gravel with pebble to boulder size clasts and 45% erratic content dated by OSL at 36.5 Ka. Imbrication of the pebbles indicates that water flowed in different directions at the bottom and top of the deposit and Rodger interprets this as a braided river system. The top of the deposit is cryoturbated and is dated at 36Ka by OSL.

Detail of base of Paleo-valley fill at Danes Dyke

Lacustrine deposits overlying glacial till at Skipsea Withow Gap

Comparing these dates with those at Danes Dyke gives a picture of ice approaching from the north and meltwater flowing to the south into Bridlington Bay, which was open at 36Ka but closed at 31.5Ka. To the west of the gravel, in a southward draining valley, are more of the same lacustrine deposits as those seen earlier at Danes Dyke. These have been dated by OSL at 20.3Ka. At the top of the cliff is 3 metres of till also dated at 20.3Ka. This shows that there was a rapid build-up of deposits as the ice sheet built up and eventually advanced south as far as North Norfolk.

After lunch the group drove south to Skipsea Beach and parked at Mr. Moo's Ice Cream Café. On the walk towards the sea, Skipsea Withow Gap appears as a flat feature between raised land on each side. Here, in the lower part of the cliff, is the Skipsea Till with organic and inorganic sediments above (see photo above). These sediments were deposited close to the margins of a palaeo-mere, a fossil lake, that had formed on top of the glacial till as temperatures increased into the present interglacial. Material dated at 11 Ka has been found to contain elk skulls and antlers. The higher lacustrine deposit contains abundant oak and alder dated at 4.5Ka. This is covered by peat, and all is covered by slope wash. Pollen analysis done in 1933 shows the input of cereal crops at this time. John Philips reported that the mere was a quarter of a mile wide but now it is much smaller due to the continued erosion of the land by the sea.

At this point Rodger was thanked for an interesting and informative day and we departed for our journeys home.

Malham Cove and Goredale Scar
Sunday 14th July

Leader: Doug Holliday, BGS (retired) and LGA
Present: 10 members and 1 visitor

We assembled in Malham, where Doug gave us an introduction to the geology of the area. The Malham District is a classic area in British geology due to the dramatic changes in sequence, lithology, and thickness of the Carboniferous rocks, and the close juxtaposition of two contrasting successions of similar age. This geology has been much studied over more than two centuries, but despite all the attention there are still uncertainties, and debate continues over some aspects. The purpose of the visit was to give an overview of the complex geology of this area, particularly how the nature and location of the varied rock types impact on the current landscape.

Malham village and the area to the south lie in the Craven Basin, which consists largely of relatively thick strata of limestone and shale, giving rise to a generally green and rounded topography. The lithology, particularly in the rocks of Visean age, is predominantly of deep-water facies since sedimentation coming from further north was unable to keep pace with the sinking of the basin. To the north of Malham there is an abrupt change into the shallow marine limestones of the granite-cored Askrigg Block, also mainly Visean in age, giving a topography of pale grey cliffs and scars renowned for their karstic features of caves, potholes, dry valleys and limestone pavements.

The transition between these two areas is marked by the Middle Craven Fault (MCF), part of the Craven Fault system that was formed during the Carboniferous in a series of pulses, but which continued moving afterwards, even up to the present day. There was extensive erosion of the scarp of the MCF during the late Visean, and it continued to influence the deposition of Millstone Grit during the early Namurian. Along the southern edge of the fault lies a series of rounded limestone 'reef knolls' of the Cracoe Limestone Formation, and crags of turbiditic and fluvial grits.

From Malham we walked across to Malham Cove (see photo opposite), a very impressive limestone cliff in the Malham Formation. It is thought to be the site of a former waterfall formed during a period of glacial melting, but now it is very rare for water to come over the top and the drainage emerges from the bottom of the cove as Malham Beck. Water draining into a sink hole at the top of the cove normally emerges lower down the valley, but in times of flood will also flow into Malham Beck, an indication of the very complex

Malham Cove

Jointing in Goredale Scar Limestone on top of Malham Cove

hydrogeological pattern of underground drainage, with many interconnecting channels.

Most of Malham Cove is formed of the Cove Limestone Member, which appears to be a massive, poorly bedded grey limestone although on closer examination some bedding planes could be picked out as erosive surfaces. The upper ~10 metres of the cliff are of the Gordale Limestone Member, showing well-developed and often laterally continuous horizontal bedding planes with thin mudstone partings.

While at the cove we were fortunate to have the opportunity to look at the resident peregrines perched on the cliff, thanks to the RSPB viewpoint set up with telescopes. We then took the path up the western side of the cove, from where the characteristics of the two Members and the erosive contact between them could be more clearly seen.

At the top of Malham Cove we walked across the very well-developed limestone pavement within the Gordale Limestone Member (see photo opposite). Bedding planes and joints are important lines of water penetration, and current opinion is that the more prominent bedding planes could be palaeokarstic surfaces formed by water dissolution during periods of subaerial exposure, particularly during the Asbian, brought about by rising and falling sea levels associated with glacial episodes in the southern continents. Later post glacial erosion and dissolution has greatly added to the pavement formation.

The views from the top of Malham Cove were spectacular and Pendle Hill was clearly visible on the far side of the Craven Basin.

From the top of the cove, heading in a northerly direction, another typical karstic feature could be seen. This was the dry valley of Watlowes, which is thought to have formerly carried drainage from Malham Tarn, and the step-like topography and continuous bedding surfaces were clearly visible.

As we walked from the top of Malham Cove towards Gordale Scar there were extensive views east, along the line of the MCF, clearly showing the division between the limestone scenery to the north, and the Bowland Shale and drift covered topography of the Craven Basin to the south (see photo overleaf). Along the southern edge of the fault could be seen the rounded outcrops of the 'reef' limestone, including that of Cawden, just to the southeast of Malham Cove. The latest theory is that this 'reef' limestone formed an almost continuous ridge running parallel to and just to the south of the MCF, and has since undergone considerable erosion to leave the isolated knolls. Although the depositional conditions would have been very similar to those of today's coral reefs, its construction was based largely on microbes and algae which

Looking East along the Mid Craven Fault

acted as the cement binding the limestone.

Gordale Beck is thought to be a subglacial meltwater channel cut into the limestone on the southern margin of the Askrigg Block. It has formed the spectacular gorge of Gordale Scar with waterfalls and a tufa screen, and our attention was diverted to some very impressive climbing being undertaken on the vertical, and in places overhanging, walls of the gorge. The lower third of the gorge is formed of the Cove Limestone Member, and the upper two thirds of the Gordale Limestone Member. It was noticed that jointing was closer and more well-developed than we had seen elsewhere, running in a nearly N – S direction, this is possibly due to its close proximity to the MCF.

From Gordale Scar we followed Gordale Beck southwards, crossing the MCF, and then stopping at Janet's Foss. This is a waterfall formed by the beds of the Gordale Limestone Member dipping at ~20° ENE towards the MCF. As we continued downstream the limestone became more massive and less well-bedded, so probably moving into the Cracoe Limestone Formation of the 'reef' complex, or possibly into the Cove Limestone Member and then into the 'reef' complex, although it was difficult to see where the actual junctions occurred due to the abundant vegetation. Approaching Malham Village the limestone no longer crops out, and we entered the more open topography of the Bowland Shales.

Goniatites in limestone block

Although the limestones of the Malham Formation are known to be fossiliferous the fossils can be very difficult to find, and no macrofossils were seen on the day. However, examples of goniatites (see photo above) were seen in a block in a dry-stone wall, although their exact provenance could not be ascertained.

The final stop was near Mires Barn, where there was an excellent view looking northwards towards the MCF from the Craven Basin, and here Doug was warmly thanked for a very instructive, interesting, and enjoyable day.

Roseberry Topping and Cliff Rigg Quarry
Saturday 7th September

Leaders: Alan Simkins and Chris Hill. Tees Valley RIGS Group
Present: 16 members and 4 visitors.

We met our guides, Alan Simkins and Chris Hill from Tees Valley RIGS, on a bright and breezy day at the foot of Roseberry Topping (see photo below) where Alan gave an introductory talk describing the geology we'd encounter along the way. He noted that the hill was an erosional outlier of Lower and Middle Jurassic sandstones and mudstones sculpted by recent glacial action and was sitting on two distinct benches, with the Staithes Sandstone Formation forming the lower bench and the Cleveland Ironstone Formation forming the upper bench.

Ascending towards the peak through beautiful oak woodland, we stopped at several small exposures of the Lower Jurassic Staithes Sandstone Formation. We were informed it was probably deposited as a storm deposit in a low energy marine shelf environment, further evidence of this being the clear examples of bivalve and trace fossils. Several of the exposures were tilted, indicating the effect of recent land slipping.

Roseberry Topping from the car park

Plant Fossils below summit of Roseberry Topping

We emerged from the woodland onto the upper bench of the top of the Cleveland Ironstone Formation. Adjacent to an elegant stone folly lying directly beneath Roseberry Topping, Alan noted that the distinctive shape of the hill was caused by a landslide in 1912, likely linked to mining of the Cleveland Ironstone Formation's Main Seam. This formation lay above the Staithes Sandstone Formation in the lithological sequence. The ironstone was very economically important to the area and there are six ironstone seams (comprising 30% of the formation), separated by mudstones. Starting from the base these seams are the Osmotherley, Avicula, Raisdale, 2 Foot, Pecten and Main Seam. The iron content of the seams is around 28% and they are around 0.1-1.5m thick, although the Main Seam is thicker at 1.5-4.5m thick. The formation of the oolitic ironstones is still debated but it is generally accepted that they were formed in marine embayments with no terrigenous sediment input, into which iron rich waters flowed from a heavily vegetated land surface.

Adit in Cleveland Dyke

We ascended the hill towards the summit, which is comprised of Middle Jurassic fluvio-deltaic sandstones of the Saltwick Formation. After taking in the spectacular views, jostling with the crowds and being buffeted by the wind, we descended the hill to examine the plant beds located within the lowest deposits of the Saltwick Formation. These provided excellent examples of the plants which lived around the time and we were shown some exquisitely detailed fossils (see page 23). Following this we descended towards an old jet mine. Jet was mined extensively around the hill from the Jet Rock (within the Whitby Mudstone Formation) for Victorian era jewellery. Jet is fossilised wood, mostly from the Araucaria (Monkey Puzzle) tree, although it was highlighted that other woods contribute to its formation.

During lunch, taken amongst the spoil of the jet workings, some samples of jet were passed round the group before we walked to Cliff Rigg Quarry to observe exposures of the Cleveland Dyke. It was explained that this basaltic-andesite dyke originated from the Palaeocene Period (around 65-56 million years ago) Mull Intrusive Complex and was likely intruded the ~430km length (between Mull and the north east coast) at a rate of between 1-5m/s (!!), with this location being emplaced in a single pulse in an en-echelon form. Our first stop was in an offshoot of the dyke which lay in a shallow linear gorge where the dyke had been quarried out. Here the contact between the dyke and the contact-metamorphosed country rock (Staithes Sandstone Formation) was exposed. The dyke itself was extensively quarried by Leeds Corporation in the 19th century to supply the expanding city of Leeds with setts and road aggregate. At the end of the gorge we were presented with an impressive face of the dyke pierced by one of the adits by which the rock was mined from depth (see photo opposite). We were also shown excellent examples of a pepperite. This is an explosion breccia which was weakly cemented and was likely formed from the Mulgrave Shale Member of the Staithes Sandstone Formation when the intruding magma of the dyke interacted explosively with groundwaters.

We then ventured uphill towards Cliff Rigg Quarry to be presented with an awe-inspiring section of the Cleveland Dyke and the Cleveland Ironstone Formation (see photo overleaf). This section clearly displayed the six ironstone bands adjacent to part of the vertical dyke which was retained during quarrying of the dyke (called a “scab”) to prevent collapse of the surrounding country rock. There were also excellent views to the west with the surface expression of the dyke, called Langbaurgh Ridge, clearly visible. The party thanked our guides for a fantastic day's geology and headed back home.


Cleveland Ironstone Formation and dolerite ‘scab’ in Cliff Rigg Quarry

Abberley and Malvern Hills Geopark Residential
Date: 4th to the 6th October

Present: 14 members and 3 associate members

The location for this year's residential promised rocks from a wide range of geological time and didn't disappoint. We were to visit a number of sites in the Abberley and Malvern Hills which lie in the middle section of the Geopark Way, a 109-mile walking trail of rocks, landscape and heritage that runs between Bridgnorth and Gloucester. This was devised by the Herefordshire and Worcestershire Earth Heritage Trust and it was members of this and the Teme Valley Geological Society who were to be our guides for the weekend.

The party assembled on Friday at the Malvern Hills GeoCentre and Geopark Way Visitor Centre in the heart of the Malvern Hills for lunch and then an introduction to the geology from one of our leaders, Moira Jenkins. With the help of a box of rock specimens she briefly outlined the geology we would be seeing that would range from the Precambrian to the Triassic with almost everything in between. Following this we moved on to Ledbury where Howard had found what was to prove an excellent base for the weekend, the Talbot Hotel.

Saturday: 5th October
Leaders: Moira Jenkins & Dr John Payne, Herefordshire and Worcestershire Earth Heritage Trust
The Malvern Hills are composed of rocks of Precambrian age, formed around 677 Ma. They consist of igneous and metamorphic rocks and are known as the Malvern Complex. The most common rocks are dark coloured, speckled diorite and pink granite and were probably formed in a subduction zone of a destructive plate margin. Later episodes of plate tectonic activity led to further bodies of magma forming which intruded these as sills and dykes or were extruded as lava flows. Many of the rocks have been altered by metamorphism and metasomatism to form schists, gneisses and other 'exotics'.

The Malvern Hills were uplifted by Variscan events which reactivated the north-south East Malvern Fault, which has been the site of movements since Precambrian times. Deep crustal rocks were forced to the surface along thrust faults, disrupting the younger rocks to the west where there was folding of Lower Palaeozoic strata forming a series of ridges and valleys as erosion picked out the weaker beds. As compression relaxed in Permian and Triassic times, crustal extension resulted in a downthrow to the east of about 2.5kms that allowed deposition in the Worcester Graben of thick Permo-Triassic sandstones.

The first location was Gullet Quarry which lies at the southern end of the Malvern Hills. This was an impressive feature, but unfortunately public access is only possible by obtaining a key from the Malvern Hills Trust. It mainly worked the hard gneiss, schists and pegmatites of the Malvern Complex but finally closed in 1977 after having last supplied road stone for the motorway building programme. Following a path up Gullet Pass, we were able to view faint traces of a Precambrian, pink granite dyke intruding darker rocks adjacent to which were Cambrian age sandstones, the Malvern Quartzites. The nature of the boundary between these was uncertain and could either be an unconformity or fault bounded. A short distance further up the path a small quarry, Gullet Pass Pit, exposed these quartzites much better. They contained several conglomeratic lenses with the clasts being a mixture of quartz and fragments of Malvern Complex rocks. They dipped steeply to the NW and some surfaces showed faint marks of what could be trace fossils. These sandstones represent a transgressive event when shallow seas flooded an eroded land surface of Precambrian rocks. Higher up, in Gullet Top Quarry, steeply dipping beds of Silurian, Llandovery age rocks were exposed. These were siltstones and fine sandstones, some with rippled surfaces, and contained brachiopod and crinoid debris showing they had been deposited in shallow seas. The unconformable nature of these beds with the underlying Precambrian was beautifully exposed, being marked here by the 'Miss Phillips's Conglomerate' (see photo opposite - top), named after the sister to the Victorian geologist, John Phillips. Large, rounded Precambrian, Malvern Complex clasts in the conglomerate show the high energy environment that existed as the Silurian seas engulfed the upstanding land area.

We climbed up the side of Gullet Pass, a deep, steep sided narrow valley, one of the few that cuts west-east through the Malvern Hills. As the stream is small, there was speculation that this deep valley is cut along rock weakened by an E-W fault, possibly by melt water during the Pleistocene. From the ridge of the southern Malvern Hills, with its frost shattered surface, we saw the contrasting topography provided by the differing geology to east and west. To the west are ridges of Silurian limestone separated by clay valleys. To the east, in the Severn Valley, is the Worcester Graben infilled with Triassic sandstones and mudstones.

Walking north, we could see the rounded profiles of the volcanic, Warren House Formation on the east side of Malvern Ridge and to the north, the Iron Age hillfort, British Camp (see photo back cover). Also pointed out was an offset of the main ridge line between northern and southern hills with the southern hills displaced to the west by about 1km along a fault. Crossing the col of 'Silurian Pass' where small outcrops of Silurian age rocks could be seen in the path, we arrived at Clutter's Cave, a man-made feature of unknown purpose or date. Of geological interest were the dark, fine grained, vesicular rocks which are pillow lavas (see photo opposite - bottom) of the Late

The ‘Miss Phillip’s Conglomerate’, Gullet Top Quarry

Pillow lava at Clutter’s Cave

Precambrian, Warren House Formation dated at 566 Ma. The pillows were less distinct than others in Britain but were clear enough to prove their submarine origin and the probability that the area was part of a subduction zone at the time.

Lunch was taken in the refectory of Elim Conference Centre at West Malvern.
The afternoon session was largely devoted to examining the rocks of the Precambrian, Malvern Complex as seen in three large quarries at the northern end of the Malvern Hills viz: The Tank, North and Dingle quarries, which had mainly been worked for road stone. The rocks observed resembled those seen earlier in Gullet Quarry and comprised mostly a suite of highly altered and deformed dioritic rocks and granites (possibly tonalites) locally cut by dolerite and pegmatite dykes. Alteration of the diorite is commonly characterised by blotches, streaks and small veins of pink albite, together with minor epidote along fracture surfaces. Minor veins of barite occur locally which indicate hydrothermal activity. The massive dioritic rock also contains a spaced cleavage on which slickensided surfaces are generally noticeable. The complex has clearly seen a long history of folding and both reverse and normal faulting. A schistose rock, locally seen as a loose block in North Quarry, possibly formed within a ductile shear zone. Such rocks, which may represent meta-sediments, are apparently more commonly developed in the southern and possibly deeper part of the Malvern plutonic complex.

Between Tank and North Quarries stands the imposing North Malvern Clock Tower. This was built to dispense water from two large water tanks below and behind it, filled from one of the many springs that surround the Malvern Hills. The water is stored in and flows through, the joints and fractures in the rock resulting in many springs which rapidly respond to rainfall patterns.

At the entrance to North Quarry an exposure of fault breccia along the Malvern Fault was examined. This consisted of a steeply inclined layer of clasts of Precambrian Malvern Complex and Triassic rocks. Slickensides could be seen in both the adjacent Malvern Complex and within the breccia itself. There are various interpretations as to how the breccia formed but whichever is correct it does illustrate the large-scale movement that occurred along the Malvern Fault Zone.

Below Dingle Quarry on the western side of the Malverns is the site where Ann Phillips discovered the unconformity seen earlier at Gullet Top Quarry where Precambrian, Malvern Complex clasts occur within a Silurian basal conglomerate thus disproving Murchison's idea that the Malvern Complex was post-Silurian in age. Dingle Quarry provides another example of the complexity of the Malvern Complex rocks with the main rock type being diorite but intruded by a dolerite sill and pegmatite dykes (see photo opposite).

From here the party returned to Ledbury where our guides for the day joined us for our evening meal.

Sunday: 6th October
Leader: Ian Pennell. Teme Valley Geological Society

The heavy overnight rain had cleared before we left Ledbury for the drive to our locations for the day which were to be in and around the village of Martley. Here we assembled in the village hall for coffee and biscuits and an introduction from David Cropp, Chair of the Teme Valley Geological Society, and to meet our guide for the day, Ian Pennell. David gave a short but fascinating account of the work done in investigating and promoting the varied and complex geology of this area before we left for the short walk to the first location, Martley Rock. The site was originally a small roadstone quarry and was already disused when Murchison visited it sometime during the 1830's during his extensive travels in the Welsh Borders and other parts of the UK as he established his Silurian System. Since then the site experienced episodes of small scale working and infilling and was visited by various geologists who all recognised its significance, but by the late 1980's it had been backfilled and planted with trees. A chance meeting between TVGS current President, Dr Paul Olver and the site owner, in 2004, resulted in an initial examination then a programme, of trenching in 2010 across the infilled quarry and a neighbouring field in an attempt to understand the full nature

Dingle Quarry

Precambrian, Malvern Complex rocks at Martley Rock

of this complex site. This raised local awareness in geology and led to the formation of the Teme Valley Geology Society, the securing of European funding for the project and the village becoming a 'Geo-village' (one of only Five globally) – a remarkable story!

So why all the interest – what's here that is so special? Martley Rock lies adjacent to the East Malvern Fault and comprises of rocks of late Precambrian, early Cambrian, late Silurian, late Carboniferous and Triassic age, separated by unconformities and complex, thrust-faulted boundaries. While a total of twelve trenches were dug around the site between 2010-2014 only two remain open for viewing. The main trench exposes the backwall of the former quarry and at its central point Precambrian Malvern Complex rocks are exposed. (see photo above) These have been affected by metamorphism and metasomatism in addition to shearing and weathering which makes their original nature difficult to determine, especially in hand specimen, but they are thought to have been granites and diorites. The trench to the west of these exposes pale yellow, hard, splintery fine grained quartzites of Early Cambrian age thrust over the Malvern Complex rocks. Lying below these, separated by a low angle thrust are inter-bedded muddy sandstones and mudstones which vary in colour from orange, grey-green, through pale and dark greys to almost black. (see photo opposite). These belong to the Halesowen Formation and are of Late Carboniferous age. At

Cambrian, Malvern Quartzite thrust over Upper Carboniferous, Halesowen Formation at Martley Rock

the western end of the trench these lie unconformably on red-brown mudrocks of the Late Silurian, Moor Cliffs Formation.

The eastern half of the main trench exposes greenish grey muds of the Late Carboniferous, Halesowen Formation faulted against the Precambrian Malvern Complex rocks. Further east and above these, separated by a low angle thrust, are dark brown mudstones of the Late Silurian, Moor Cliffs Formation. At the eastern end bright red, Triassic age, Helsby Sandstone appears. The junction between these last two is the East Malvern Fault, the major feature that marks the eastern boundary of the Worcester Graben. To its west are Precambrian and Palaeozoic rocks, to the east are Mesozoic.

Moving on from this site Ian pointed out the geological features of the extensive views in all directions as we followed the geology trail back towards the village. Martley is overlooked on its northern side by a prominent escarpment known as the Nubbins. It is composed of brick red sandstone of the Triassic age Helsby Formation and was extensively quarried in the past for local building stone. The quarry faces showed low angle cross bedding in thick beds of well sorted and rounded sandstone. (see photo, inside back cover - top) The nature of the cross-bedding and thin bands of pebbles indicate that these sediments, while they may well have spent time being blown around by the wind, were deposited in water from flash floods in a desert environment. Some bedding planes were picked out by small solution cavities, some with a distinctive cubic shape, which probably formed as a result of solution of evaporite minerals that had developed in temporary bodies of standing water. Lunch was taken in the sunshine in the beautiful garden of our guide Ian, part of which was an old quarry, surrounded on two sides by 4-5m high, red sandstone cliffs of the Helsby Formation.

A short drive took us to our final destination of the weekend, Penny Hill Quarry, to see Silurian, Wenlock Limestone. The quarry had been opened into the south end of a prominent ridge and originally worked for roadstone but then, in the 1970's, was filled with domestic waste. This created enough methane to generate electricity for over 20 years but has dwindled to a point where the gas is now only periodically flared. Lying close to the Malvern Fault the well bedded limestones were folded during the compressive phase of the Variscan Orogeny. On either side of the quarry entrance the beds dip to the east at approximately 35°. However, corals that would have been attached to the sea floor, face downwards (see photo opposite - bottom) on the eastern side showing that these beds have been inverted and that these are in fact the limbs of an overturned anticline, facing west. The well bedded, nodular limestone is grey in colour, crystalline and with thin muddy partings. A short time was spent collecting fossils of brachiopods, bryozoans, sponges, corals and crinoids before we continued through woods on the western flank of the ridge, past several overgrown limestone quarries to reach a deep, narrow cutting, the entrance to an old quarry, appropriately known as The Canyon. This exposed, on both sides, the well bedded, nodular Wenlock Limestone dipping steeply to the east. The rocks had clearly been disturbed by faulting as well as folding as there were good examples of slickensides on some surfaces parallel to the bedding. A layer of clay material, 15-30 cm thick, which was originally considered as fault gouge developed along slip surfaces of a fault zone, has now been identified as bentonite, a weathered volcanic ash which could also have been the site of slippage.

Returning via field paths to the cars Ian pointed out more of the landscape features. The parallel ridge to the west being formed of the Silurian, Aymestry Limestone with the intervening vale eroded along the line of the soft, Lower Ludlow Shales that separates this from the (older) Wenlock Limestone.

At the cars Ian and the TVGS were thanked for providing such an interesting day and hospitality. Howard was also thanked for choosing the location and the excellent accommodation, arranging our guides, and providing the weather.

Low angle cross-bedding in Triassic sandstones, the Nubbins

Solitary coral in Wenlock Limestone. Penny Hill Quarry


Walking North along the Malvern Ridge