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Field Visit Reports Summer 2023

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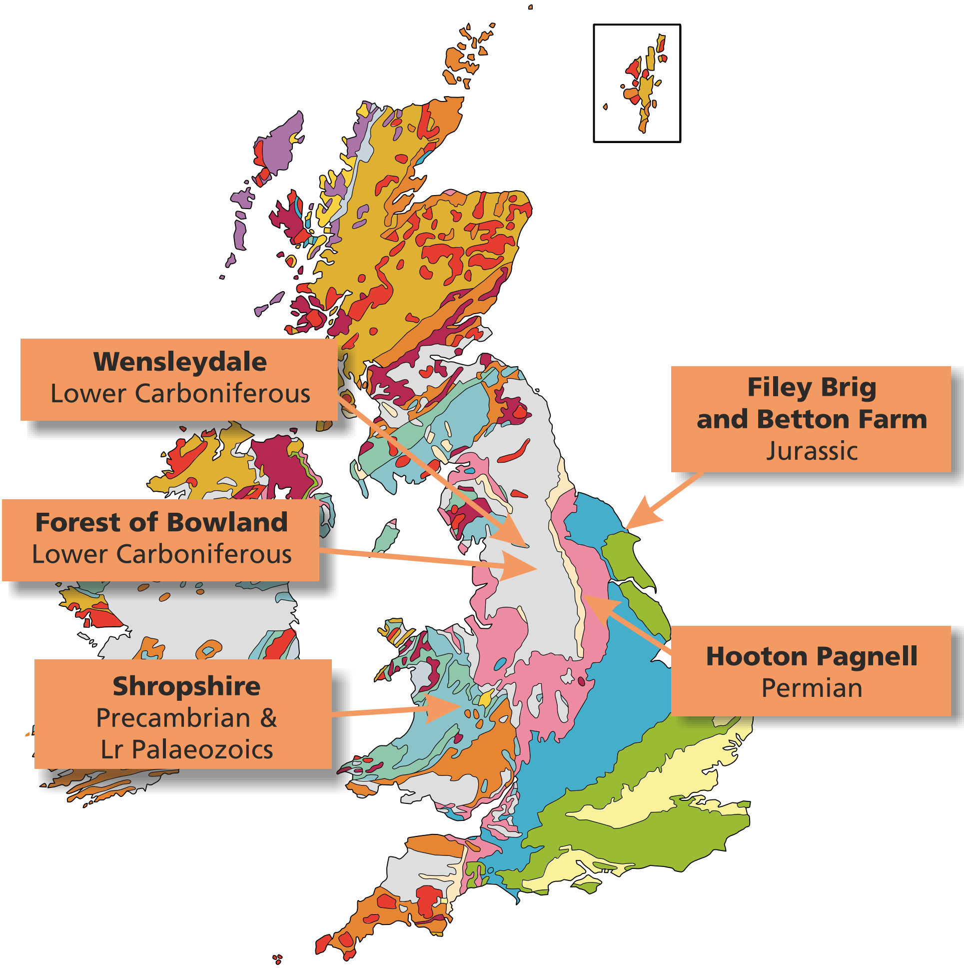
LGARocks

23 Where did we go?



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2023 Field Visit Locations

Thanks are due to the leaders who gave up their time to take us, to the authors of reports, and to those who contributed photographs.

Cover Picture: Mill Gill Force. Askrigg

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Mill Gill and Wet Grooves Lead Mines, Wensleydale. Sunday April 23rd

Leader: Lesley Collins
Present: 5 members, 4 visitors

We met Lesley outside the church in Askrigg but, being St George's Day, the bells were being rung with such vigour that we were forced to move to a quieter location before she could outline the day's visit. Once there she was able to explain that the morning would be spent in Mill Gill looking at rocks that make up the Yoredale Group cyclothems and the afternoon a few miles further down Wensleydale where, in addition to more Yoredale Group rocks, we would examine the remains of a former lead mining area at Wet Grooves.

After a brief outline from Lesley of the geological setting of Mill Gill, including the fact that this was a key location used by John Phillips in 1825 when he established the Yoredale Group, we made our way across a field path to the now derelict West Mill where the river flowed through a narrow gorge with vertical rock sides. The thick bedding, vertical jointing and pavement features developed on bedding surfaces showed that this was limestone. This was the Gayle Limestone and marked the base of one of the lower cyclothems of the Yoredale Group when offshore conditions prevailed. Upstream the valley widened and deepened, but with no right of way along the stream, it was impossible to examine the nature of the rocks lying above the limestone. However, a footpath followed the rim of the valley and where it began to drop down to the stream again it became possible to see what these were. As the path descended, dark, horizontal, laminated beds could be seen in the stream bed. These were shales in which the stream had carved a pronounced undercut in the almost vertical sides of the gorge. The shale graded upwards into thinly-bedded siltstones above which were increasingly thicker-bedded, medium-grained sandstones, some showing cross-bedding. This coarsening upward sequence represents the advance of a delta into a shallow sea. Above the path, the contact between the sandstones and overlying beds was clearly visible and marked by a spring. Fallen blocks showed that the overlying rock was a dark grey, fossiliferous limestone. This was the Hardraw Scar Limestone, marking the time when sea levels rose rapidly, returning the area to offshore conditions, and the beginning of the next cycle. A short distance further on, the full sequence from mudstone to limestone was seen exposed in the face and sides of Mill Gill Force where the Hardraw Scar Limestone forms the lip of the waterfall. (See photo on Front cover).

After returning to Askrigg where lunch was taken, we drove a short distance down Wensleydale to Ballowfields, parking at a nature reserve at the foot of Haw Bank. Here the top of the Hardraw Scar Limestone, dipping to the NE, was exposed in some overgrown quarries adjacent to the road, and mounds of mining spoil lay on the flat area alongside Eller Beck. This had come from an adit, still just visible, that had been driven into the base of Haw Bank to drain workings (for lead and fluorspar) in the beds above. After following a path alongside the beck, a strong flow of water was seen coming from another adit. This was the Disher Force Level, driven into the Simonstone Limestone, the next in the Yoredale Group above the Hardraw Scar Limestone. Continuing our ascent of Haw Bank, the path steepened alongside Disher Force, formed where Eller Beck tumbled down the next limestone, the Middle Limestone, which displayed large, closely packed brachiopods (***Gigantoproductus***), corals and crinoids. (see photo below) We continued to follow the stream, first across a shelf formed on top of the Middle Limestone, then, as the slope steepened, past the site of a breached dam that had originally provided water to the nearby ore dressing floors. Above the dam we came to a series of waterfalls formed by layers of sandstone that dipped NE, into the hillside at 15°, which belonged to the Five Yard Limestone Cyclothem. Inter-bedded with the lower sandstone layers were beds of bioturbated silt and mudstone one of which was very carbonaceous indicating that they were deposited in a very shallow water/swamp environment.

***Gigantoproductus* in Middle Limestone. Disher Force.**

Surface workings alongside Eller Beck.

Ivy Scar with scars of lead mining in foreground.

Above the waterfalls the ground was covered by mine waste and by climbing higher we came into some of the workings. These lay on the Disher Force Vein and had been worked from the surface leaving deep scars where material had been extracted. In the side of one of these a mineral vein was still visible. The existence of another breached dam above these workings led to a discussion on the mechanisms of 'hushing' that are frequently referred to in accounts of mineral workings. Descending the hillside past more surface workings that followed minor veins, (see photo opposite top) we returned to the shelf formed by the Middle Limestone from where we then walked SE below Ivy Scar, a prominent feature formed by the Underset Limestone (see photo opposite bottom) to an area of extensive spoil heaps of dressing mills that have stood on this site at various times since at least the C16th.

A short time was spent picking through the waste heaps that proved very productive and good specimens of galena, sphalerite, traces of some copper ore as well as fluorspar, barytes and calcite were quickly found. Further on, covered by a sheet of corrugated iron, was the entrance to Wet Grooves Mine, from which some mud-covered mine researchers had just emerged. Lesley explained the general layout of the mine as it is today and that it is a place mineral collectors still visit for high quality specimens. The main mineralisation is in the Three-Yard and Five-Yard Limestones and the sandstone we had seen earlier in Eller Beck but also extends downwards, through the Middle and into the Simonstone Limestone. The Wet Grooves mining area lies within the Carperby Basin, a small, triangular shaped, structural basin defined by faults, and it is these, along with offshoots from them, that are mineralised. An unusual feature of the basin is a large mass of structureless limestone known as the Knot. This is considered to be a land-slipped mass of the Underset Limestone and has been heavily mineralised by fracture filling and mineral replacement and is itself honeycombed with workings. (see photo overleaf) The last record of active mining around Wet Grooves was 1889 but between 1959 until the early 1970's the waste heaps were worked for fluorspar, producing ~1000 tons for use in the production of high-grade steel.

Returning to the path across the shelf of the Middle Limestone and looking up at Ivy Scar we were able to pick out numerous shallow surface workings and adits that had been driven into the cliff face following mineralised veins. At this point, after a brief rain shower, we retraced our route back to Ballowfields where Lesley was thanked for providing us with such an interesting and varied day.

The Knot. A slumped and mineralised mass of the Underset Limestone.

Forest of Bowland
Saturday 20th May

Leader: Nigel Price, Craven & Pendle Geological Society
Present: 8 members, 4 visitors.

We met our leader at a roadside parking area in the Trough of Bowland on probably the best weather day of the year so far. Before setting out on the short walk to the first outcrop, Nigel gave us a very comprehensive introduction to the geological setting of the area.

The day was to be spent looking at various rock types, structures and fossils that lay within the Craven Basin which developed at the beginning of the Carboniferous Period as crustal extension in a back-arc basin caused the then crust of Lower Palaeozoic rocks to fracture. Sections with granite intrusions were buoyant and formed upstanding 'blocks' but those without subsided along fault lines to form 'basins'. The Craven Basin is a large, E-W trending graben, bounded to the north-west by the Lake District High, to the north by the Askrigg Block and to the south by the Central Lancashire High. Within it are a number of smaller, sub-basins and the area we were visiting in the first part of the day was the Bowland Sub-basin. This is a complex half-graben, controlled along its northern margin with the Askrigg Block by the Craven Fault System, and along its southern boundary with the Bowland High by the

Steeply dipping Hetton Beck Limestone. West Sykes Quarry

Pendle Fault and Pendle Monocline.

Seas had quickly flooded the subsiding basin in early Carboniferous times but their depth varied due to changes in the rate of subsidence, the rate of infilling by sediment and by glacial eustacy caused by fluctuations in the ice cap that covered those parts of Gondwanaland that lay across the south polar regions at this time. What was to eventually become the British Isles lay across equatorial regions so the climate would have been warm.

Walking north along the narrow road from our meeting point our attention was drawn to an outcrop of limestone in the valley side which was seen to be dipping to the south-west at around 30°. About 800 m further along the road we came to West Sykes Quarry which exposed a section approximately 30 m high of steeply dipping, well-bedded limestones. (see photo previous page) These were the same limestones seen previously but as they were now dipping to the north-east they showed that we had crossed the axis of an anticline and were now on its northern limb. This was the Sykes Anticline and is one of a series of similar ENE- WSW trending structures in the Craven Basin that together form the Ribblesdale Fold Belt. They were formed during the later stages of the Variscan Orogeny as the thick sequence of basin sediments were squeezed against the rigid Askrigg Block to the north.

The limestone was dark grey in colour and composed mostly of fine- to coarse-grained packstone in beds that varied from 0.1 – 0.4 m thick. The irregular nature of the bedding planes and the fact that some beds were separated by bands of laminated muddy and silty sediment showed that scouring had taken place during their deposition. Fossils were present throughout but more abundant in some layers than others. Disarticulated crinoids were very common along with brachiopods and solitary corals but the most obvious, due to them having been replaced by chert, were specimens of ***Syringopora***, a colonial, tabulate coral. (see photo opposite top) These were scattered in random positions showing they were not in their position of growth and this, along with the scoured surfaces and disarticulated crinoids, showed that these limestones were deposited as turbidites. Originally, they would have been deposited as carbonate muds in shallow waters on the sloping margins of the neighbouring Askrigg Block but then, either triggered by an earthquake or simply because they became unstable, they avalanched down the slope, out into the basin where they settled out of suspension to form the beds seen today. In the upper part of the main quarry face, and even better in a small quarry higher up the hillside, excellent examples of soft sediment deformation were seen where layers of limestone had both slid down-slope and been folded prior to becoming lithified (see photo opposite bottom).

Specimens of galena, sphalerite and fluorspar were collected from the scree at the foot of the quarry face and at the highest point, the entrances to four adits could be seen. Whilst the principal vein was not visible there were many thin calcite veins cutting vertically through the strata parallel to the fold axis.

Syringopora in Hetton Beck Limestone. West Sykes Quarry.

Soft sediment deformation in Hetton Beck Limestone. West Sykes Quarry.

Mineralisation is common throughout the Ribblesdale Fold Belt and was caused by hot fluids being squeezed out of the thick mudstones of the Craven Basin and cooling down within fractures in the limestones or reacting with and replacing them. Mining for galena occurred from at least 1768 when lead ore from here is recorded as having been smelted at Grassington.

Following lunch in the quarry we moved across the road to East Sykes Quarry. This showed the same limestones dipping steeply to the NNW but shallowing slightly at their southern end suggesting proximity to the fold axis. The limestone here was more thickly bedded and not so fossiliferous as in West Sykes Quarry although one bedding surface did expose a section of crinoid stem 15-20 cm long. Also, another example of soft sediment deformation was seen in an overgrown corner. The limestone in both quarries was the Hetton Beck Limestone, part of the Hodder Mudstone Formation of the Visean age Craven Group.

Leaving East Sykes Quarry, we walked about 800 m along the road, climbing steeply to some small roadside outcrops at Trough Scar where we were able to examine exposures of the rocks that lay above the Hetton Beck Limestone. The first of these was a small exposure of dark grey, almost black, extremely fissile shales that dipped NNW. The finding of a poorly preserved goniatite showed that these were marine sediments. The shale belongs to the Bowland Shale Formation and indicated a period of time when the Bowland Basin was an anoxic environment starved of sediment, either due to it deepening (and that these are distal deposits), or a lack of sediment from neighbouring highs. Above these, at the next outcrop, dipping at 30° to the NNW, 2 m of interbedded mudstones and sandstones were exposed. (see photo opposite top) The sandstones were fine- to medium-grained, poorly sorted, muddy, dark in colour and micaceous, and occurred in beds 20-30 cm thick and had sharp, irregular contact with the thinner mudstones below them. This was the Hind Sandstone, still part of the Bowland Shale Formation but close to the top and was clearly deposited in a higher energy environment than the underlying shales. The unsorted nature of the sands and their sharp contacts with the underlying mudstones suggested these were another turbidite deposit formed by sediment avalanching off a neighbouring shelf out into deeper water.

The final outcrop, at the head of the Trough of Bowland, was heavily degraded but loose blocks of rock showed that it was a medium-grained, buff coloured sandstone. It belongs to the lower part of the Pendle Grit of the Namurian age, Millstone Grit Group and represents the beginnings of deposition in deltaic conditions. It is interpreted as having been formed within submarine channels at the front edge of the delta.

From here we then drove to the final location for the day, Salthill Quarry in Clitheroe. In 1980, having stood empty since limestone extraction ceased in 1959, an industrial estate was built in the quarry and a geological trail set up using the old faces. These had recently been cleared of encroaching

Interbedded sand and mudstones of the Hind Sandstone. Trough of Bowland.

Waulsortian Mud-Mound. Salthill Quarry

vegetation, so exposure was good. In the centre of the quarry face (approximately 50 m x 7 m) adjacent to the car park, a dome of light-grey, massive, micritic limestone with an irregular upper surface was seen. This was overlain by a thin layer of rubbly limestone which in turn was overlain by dark, well-bedded limestones. (see photo overleaf bottom). This exposure is a cross-section through a Waulsortian Mud-Mound, a rare feature in the geological record, that formed under unusual marine conditions. The mud-mound is thought to have been formed during late Tournasian times as calcareous mud became bound together by microbial activity in the deep waters of a basin, building a mound of mud that could grow to heights of over 200 m above the sea floor. A fall in sea level resulted in the upper surface of the mound being eroded and the deposition of the thin rubbly layers. A rise in sea level at the start of the Visean resulted in the deposition of the bedded limestones which are draped over the eroded dome.

Due to its deposition in deep water the micritic limestone in the core of the mound is devoid of fossils but the bedded limestones are packed with them showing its formation in a shallow marine environment. The most abundant fossils are crinoids, and a short time was spent at another location on the mound, where the bedded limestones were exposed and weathered, sifting through gravel sized material and small blocks entirely composed of individual ossicles and short sections of stems. (see photo below) Returning to the car park a brief stop was made to observe, on eroded surfaces of the mound, long sections of articulated crinoid stems and glacial striations that are remarkably well preserved.

At the car park Nigel was thanked for providing us with such a wealth of information on an interesting area that was new to most of the party and for stepping into the leadership role at such short notice.

Crinoid debris on the floor of Salthill Quarry.

Filey Brigg and Betton Farm Quarry
Date: Sunday 18th June

Leader: Professor Cris Little, Leeds University
Present: 14 Members and 4 Visitors

We met up at the cliff top car park where Cris, who had provided us with handouts, outlined what we would be looking at in this location. We then made our way down the steep road to the beach and walked the short distance to the Brigg.

As we approached this point, we had clear views of the boundary where the thick, poorly sorted Quaternary glacial till deposits overlaid the underlying rocks. This till was deposited during the Last Glacial Maximum of the Devensian Glaciation, between 25,000 -18,000 years ago, by the North Sea Ice Lobe. Some consolidated areas within the till indicate that they may have been the result of more than one glacial event.

Immediately below the till we saw a band of rounded limestone pebbles, about two metres thick, with internal folds and contortions which Cris explained was of periglacial origin. (see photo below) This geomorphic process resulted in local rocks being fragmented by seasonal freezing and

Hambleton Oolite deformed by solifluction with glacial till above. Filey Brigg.

thawing during a cold arid period before the LGM. The folded structures were formed by solifluction, which is the process where material creeps down a slope.The next visually different band below this was several metres thick and contained, in descending order, layers of shelly limestones underlain by a layer of calcareous sandstone, then another layer of shelly limestone which now formed the wave cut platform. These rocks were the lower part of the Upper Jurassic, Coralline Oolite Formation. We were encouraged to look closely for fossils and found fragments of bivalves, including oysters, Gryphaea, scallops (***Radulopecten***), serpulid worm tubes and a few gastropods. Cris told us that these were shells which had been broken up by wave action in a shallow water setting.

The wave cut platform had a nodular appearance and as we followed it around to the Brigg we saw that it contained additional fossils. Parts of these massive limestone blocks had broken away and some were inverted on the foreshore. These blocks were at least one metre thick and on what would have been the underside (if they had not been turned upside down) were spectacular three-dimensional examples of trace fossils. These were mainly ***Thalassinoides*** burrows with their typical T- or Y-shaped endings. (see photo opposite) They are thought to have been made by shrimp like crustaceans, but the occupants of these cylindrical tube structures are largely absent from the fossil record. In between these burrows (which were approximately 35 mm in diameter) many smaller burrows were evident which had possibly been created by worms.

We made our way along the Brigg observing the rocks for fossils and Cris spotted a crinoid stem in a small boulder. He drew our attention to the small 1 mm white specks which covered the surface of the rock which he told us were ooliths and that the rock was probably from the Hambleton Oolite Member (Lower Leaf).

Sitting in the sunshine on the Brigg we ate lunch before making our way back to the cars and driving about nine miles inland to Betton Farm Quarry, near Scarborough where we parked in the farm carpark before walking the short distance to the quarry. As we were about to enter, Cris showed us, with the aid of diagrams from his handout, how far inland the Corallian Group that we had seen on the Brigg extended and how it surrounded the Vale of Pickering. He informed us that it, along with Lower and Upper Calcareous Grit, formed the Tabular Hills to our north. The Coralline Oolite Formation had been deposited during the Lower and Middle Oxfordian stages of the Upper Jurassic. Most of the sediments were carbonates, such as ooidal limestones, and were laid down in shallow water settings and this, along with weak palaeotopographic control, resulted in considerable lateral facies variation, so that the stratigraphy in the inland quarries differs from that at Filey Brigg.

Thalassinoides burrows. Filey Brigg

Boundary between patch reef and bedded limestone. Betton Farm Quarry.

Inside the quarry we examined the exposed faces and immediately found many different kinds of fossils including bivalves, echinoid spines, gastropods and an ammonite. This rock, known locally as the Betton Rag, seemed very soft and crumbly leading to speculation as to why such material would be dug out and what it would have been used for.

In one of the quarry faces Cris pointed out a rare Jurassic coral patch reef, which had formed at this time when the Cleveland Basin was roughly at the same latitude that modern day South of France now occupies. In this rock face were a series of well-bedded, fossiliferous limestones abutting more massive limestone layers with a fault-like boundary sloping at 45°, between them. The massive limestone was formed mainly of recrystallized coral, which was proven when Cris pointed out, on a detached piece, some patches of well-preserved ***Thamnasteria*** corallites. Within this were also some small borings produced by the bivalve ***Lithophaga inclusa*** that had burrowed into the coral while it was still growing, a palaeoecological relationship that can be seen on modern coral reefs. The sloping boundary between the massive coral and the bedded limestone (see photo above) was not in fact a fault but where the coral reef had grown over the surrounding layers of shell-rich sediments. Later, during compaction, the massive coral was pushed into the surrounding sediments, deflecting the beds downwards at the margin of the coral reef.

Leaving the quarry and after thanking Professor Little for leading the trip, we made our way home.

Watchley Crags and Hooton Pagnell, South Yorkshire.
Date: Sunday 10th September 2023

Leader: Dr Gareth Martin, LGA & WYGT
Present: 5 members

After meeting at the end of Watchley Lane we had a pleasant walk along the path which led to the Crags. The path ran along a low ridge formed of Permian limestones and projected west from the main outcrop. Looking back along the ridge, through a gap in the trees, the noticeable break in slope at its foot was most likely the position of the Permo-Carboniferous unconformity. To the south, across some fields, Gareth pointed out a wooded area that had similar exposures to the ones we were going to see, and which is designated an SSSI, but that he felt the exposures we would see at Watchley Crags were much better.

At our first stop on Watchley Crags, the rock face clearly showed the Yellow Sand Formation, of which approximately 0.8 m was visible, overlain by 2 m of Cadeby Formation, dolomitic limestone. (see photo below) We were informed that the Yellow Sand was approximately 3 m thick in this location,

Yellow Sands overlain by dolomitic limestone of Cadeby Formation. Watchley Crags.

(compared with sixty-nine metres in the Durham area) and sat on top of the Permo-Carboniferous unconformity, which must have been below where we were standing. As their name suggests, the sands when exposed, are a strong yellow colour but appear grey when fresh. They were found to be horizontal, thinly-bedded, fine-grained, and weakly-cemented, which was why they occurred in a prominent undercut below the overlying limestone. The contact between the sand and limestone was seen to be sharp. The Yellow Sands were originally deposited in a desert environment but had subsequently been reworked after being rapidly submerged by the shallow Zechstein Sea, around 255 Ma. (The following five million years saw transgressions and regressions, as sea levels rose and fell and the floor of the Zechstein basin gradually subsided.)

The fine-grained, thin-bedded dolomitic limestone above the Yellow Sands belonged to the Wetherby Member of the Cadeby Formation. This was thought to have been deposited as a calcareous mud as the sea began to evaporate but some fallen blocks were found to be formed almost entirely from broken shells, a form of limestone known as "Coquina". (see photo below) At this location, another layer of Yellow Sands had formed over the limestone, having possibly been washed into the shallow sea by a flood event. (see photo opposite) The undulating nature of the junction between the Wetherby Member and the Yellow Sands, was pointed out and it was speculated that this may have been the result of storm events.

'Coquina' - a shelly limestone. Watchley Crags.

Interbedded Yellow Sands and dolomitic limestone. Watchley Crags.

We walked a short distance along the exposure and examined a rock face where just the Wetherby Member was exposed, the Yellow Sands being below ground. Here we found a variety of features including small areas of cross-bedding, small teepee-like structures, (possibly the result of algal colonization) and a thin layer which contained many fragments of shells, (a Coquina). These features suggested a dynamic environment which reflected the various phases of the Zechstein Sea, with its varying sea levels and salinity, dictating which animal life could exist there.

As we walked back through the woods, towards the east, the finer-grained deposits seen in the outcrops may have indicated that they were laid down in slightly deeper (or lower energy) waters. We discussed whether rock faces that we'd looked at occurred naturally or were the result of quarrying. Some features of the immediate areas, such as possible spoil heaps, seemed to point towards it being worked at some time. On a slope below an exposure of limestones, we noticed that the recent heavy rains had partially exposed a sandy face. We cleaned up the surface and found a thick layer of friable sand. In the past, many workings had dug this material out to use as moulding sand. Making our way back to the cars lunch was taken before we walked the short distance into the attractive village of Hooton Pagnell which is almost entirely built of, and stands on, Cadeby Formation, dolomitic limestones. Looking at the stone with which the walls and buildings were constructed, we noticed

Algal patch reefs. Hooton Pagnell

many of the same features we had seen at the crags showing that they had most likely been quarried locally.

Exposures of the bedrock which formed the foundations of many of the walls and buildings showed a variety of textures and structures. Some were dome-like in shape with irregular tops and were made of fine-grained dolomite, some showing fine lamination, and are interpreted as stromatolite patch reefs. (see photo above) Other exposures were clearly bedded, some horizontal, others lying at shallow angles, with layers ranging from 1- 10 cm thick and showing variation in grain sizes ranging from clasts several centimetres across to sand-sized, with some clearly oolitic. (see photo opposite) The dome-shaped bodies were originally reef mounds that grew in shallow water while the bedded deposits formed on their flanks or in channels between them as material was eroded from the mounds by wave or tidal action.

Back at the cars Gareth was thanked for providing such a wealth of information on such a small area and we departed just as the threatened thunderstorms arrived.

Bedded limestone on reef flank. Hooton Pagnell

Residential visit to Shropshire
Date: Friday 29 September – Sunday 1st October

Leader: David Smith, Shropshire Geological Society
Present: 10 members

Geological Setting

Shropshire probably has the most varied geology of any UK county with only rocks of Cretaceous, Palaeogene and Neogene age not represented. Its oldest rocks are of late Precambrian age and consist of a mixture of sedimentary, igneous and metamorphic types formed by a variety of different processes and environments at a time when, what was to become Shropshire, lay around 60° S of the equator. During, and subsequent to their formation, these rocks were subjected to an episode of folding and faulting, largely controlled by movements associated with the Welsh Borderland Fault System that is largely comprised of two major, NW-SE trending faults, the Church Stretton and Pontesford-Linley Faults, that run across the region.

During the Lower Palaeozoic the region moved steadily north, reaching 25° S by the end of the Silurian. For most of this time, while some of the Precambrian rocks stood as islands, shallow seas covered the eastern part of the county with deeper waters in the west. Sea levels and coastlines however were constantly changing, and this is reflected in the sediments that were deposited and the life that inhabited them. Late Silurian and Devonian times saw the whole area rise above the sea with the products of the resulting erosion being deposited in lakes and lagoons that bordered a shallow sea to the south.

By Carboniferous times the area lay across the equator and was covered by tropical rain forests and swamps. Sometime during this period, hot fluids invaded patches of Lower Palaeozoic rocks to the west of the Long Mynd forming an area rich in metalliferous ores. The northward drift continued and by Permo-Triassic times the area lay 25° N of the equator and was once more a landmass, and being situated in the interior of a continent, was a hot, dry desert.

The youngest rocks represented are of early Jurassic age, formed when shallow seas flooded the desert. Rocks younger than these probably did exist but have been removed by erosion since the general uplift around 70 Ma that resulted in the formation of the British Isles. It was during this time that the landscape seen today developed as various agents exploited the differing resistances of the rocks and structures. The area was covered by ice on more than one occasion during the Quaternary but, being largely a lowland area, Shropshire did not suffer major erosion. Its effects were mainly the deposition of drift deposits, frost shattering of areas that stood above the ice sheets, and diversion of rivers.

With rocks spanning over 500 million years of geological time but with only 3 days in which to visit them we were not aiming to see them all! From our base in a comfortable pub in Much Wenlock our visit organiser Doug Pollock, had asked our guide to provide things that were 'different'.

Friday: The Shropshire Lead Mines and the Stiperstones
We met our leader in the visitor centre at 'The Bog', the site of an old lead mine on the western side of the Stiperstones, a long, narrow ridge of hills that are part of the Shropshire Hills Area of Outstanding Natural Beauty, south-west of Shrewsbury. A short drive took us to Snailbeach where one of the largest of the many mines that operated in this small area, has been preserved.

The ores of Shropshire were known to and extracted by the Romans but then largely abandoned until the mid-18th century when mining restarted. The 1870's were the most productive years after which prices fell and, combined with shrinking reserves, mines closed. While the last galena was mined here in 1911 small scale extraction of barytes continued until 1955.

The mine was situated on the side of a deep, narrow, wooded valley and had shafts and adits, extensive mine buildings, its own narrow gauge railway system, aerial ropeway and smelt works. (see photo overleaf) Naturally for such an operation there were large amounts of spoil and after a walk round the preserved buildings it was on the remains of the tips that we spent most time. The main tip was largely composed of the host rock, a hard, dark-grey, flaggy siltstone with some greywacke, belonging to the Ordovician (Arenig), Mytton Flag Formation. In addition, some pieces of pale-grey, extremely finely-crystalline rock were found which were probably rhyolite. Amongst the host rocks were plenty of good specimens of sphalerite (ZnS) and some galena (PbS), which was the principal ore worked. In addition to these were large amounts of barytes ($BaSO_4$), calcite ($CaCO_3$) and quartz ($Si0_2$). The minerals occurred in NW-SE trending veins and fragments of these, cutting through their host rock, were seen in the spoil. They were emplaced from hydrothermal fluids and have been radiometrically dated as early Carboniferous in age.

Adjacent to this tip another area was covered in fragments of calcite and quartz marking the position of what had been known as the 'White Tip'. This was the waste from the mineral separation processes and was worked for pebble dash in the 1960's-80's but removed in the early 90's due to concerns about airborne dust containing high levels of lead and heavy metals polluting water courses.

Leaving Snailbeach we drove west to a car park near the summit ridge of the Stiperstones. A short walk took us to the first of several tors that give the ridge its distinctive 'spikey' profile. The rock was found to be a very pale grey, almost white, quartzite. It was mostly medium-grained but loose blocks showing coarse- to pebble-sized grains were also found. The rock occurred in beds 60-70 cm thick that dipped ~60-70° to the west and which were extremely hard. Some showed traces of cross-bedding and large (50 cm

Snailbeach Mine.

wavelength) symmetrical ripples were noted on some surfaces. Vertical and horizontal burrows were evident along with other structures that may have been formed by dewatering. The rock was well jointed in two directions at right angles to each other and to the bedding planes. These were the Ordovician (Arenig), Stiperstones Quartzite and lie below the Mytton Flags that formed the host rock for the mineral veins seen earlier at Snailbeach and are interpreted as a shallow water, beach deposit. Their toughness, combined with their pattern of jointing and bedding, resulted in intense frost shattering when exposed to periglacial conditions during the last glaciation and leading to the formation of the tors and extensive screes. (see photo below)

Returning to the car park we were able to examine a small, heavily weathered outcrop of grey, thinly- bedded Shineton Shale Formation mudstone which is of the earliest Ordovician (Tremadoc) age and lies below the Stiperstone Quartzite. Its fine-grain size suggests deposition in a low energy, deeper water environment that must have existed here before it shallowed, and the overlying quartzite deposited.

The evening sunshine provided ideal conditions for viewing the general features of the landscape and how these were controlled by geology, and to enjoy the drive over the Long Mynd and on to our base at Much Wenlock.

Saturday Morning: Wenlock Edge
The group gathered at 10 am in the hotel car park, before driving about two miles south-west to Stretton Westwood Nature Reserve, a former limestone quarry now managed by the National Trust, on the dip slope of Wenlock Edge. Walking into the site we immediately saw the quarry face that stood approximately 10-15 m high and extended for over 150 m.

The group examined the massive piles of loose material which had been tipped in the quarry, looking for fossils. This material had been excavated during the construction of two large ponds on the outskirts of Much Wenlock

Tors of Cambrian quartzite. The Stiperstones.

***Heliolites* and an articulated crinoid stem in Wenlock Limestone. Westwood Quarry**

as part of a flood alleviation scheme. The excess material which could not be reused in the landscaping work around these ponds, was from the same geological strata and contained similar characteristics to the rock which had previously been taken from Westwood quarry.

Searching through the mounds of boulders and smaller fragments of Silurian age, Wenlock Limestone Formation, we found many good specimens of various colonial and solitary corals, bryozoans, brachiopods, gastropods and crinoids, including one with a nice articulated stem (see photo above). One of the colonial corals was identified as ***Halysites*** which, when seen in cross-section, resembled the links of a chain, giving it the common name the 'Chain Coral'. Other colonial corals identified were ***Syringopora*** and ***Heliolites***. All these fossils had once been part of the multitude of marine life which had lived here approximately 425 Ma where the place where we now stood had been a warm shallow sea, just south of the equator.

Deeper into the quarry, tucked away behind a clump of trees, were the remains of two lime kilns. The most modern one, approximately 12 metres high, was a circular, brick-built chimney surrounded by a metal casing stood next to an older one built of stone. (see photo opposite top) The remains of a bridge was still in place connecting the banking to the top of the more modern kiln. This was used to load limestone, layered with coal or coke, into the kiln before it was ignited. As it burnt through, lime was extracted from the bottom of the kiln, through the draw hole with further layers of stone and fuel being added from the top. The resulting calcium oxide (quicklime)

Limekilns in Westwood Quarry

could be used to improve acid soil or have water added, “slaked”, to be used as mortar. At the nearby Knowle Quarry the disused lime kilns have been restored using lime mortar produced this way from a kiln specially built on site. This kiln is fired up a few times per year and produces about 50% of the lime mortar that the National Trust uses each year.

Walking back towards the car park, we examined the quarry face. While much of the rock was well-bedded and dipped gently to the east, several large, non-bedded, 'mounds' surrounded by bedded limestone were seen which were identified as patch reefs. (see photo overleaf) These flat-bottomed lenticular masses, 5-10 m wide at the base but tapering upwards consisted of a framework of coral, sponge, bryozoans, and crinoids and were referred to by quarrymen as 'Ballstones'. The patch reefs grew individually on the seabed in very shallow clear water, probably less than 10 m deep. Small patches of coarsely-crystalline calcite in the mounds had probably been cavities within the reef that had been infilled. The bedded limestones which surrounded and enclosed the reefs consisted largely of the skeletons of reef-forming organisms, particularly corals and stromatoporoids shed from the reefs, along with material deposited directly on the sea floor.

Saturday Afternoon: Cardingmill Valley, Church Stretton
Cardingmill Valley, owned by the National Trust, lies one mile west of Church Stretton and is a very popular site, offering a variety of outdoor pursuits in the valley of the Ashbrooke river and the impressive hills and fine scenery of the

Patch reef surrounded by bedded limestone. Westwood Quarry.

Long Mynd. The purpose of the visit was to examine part of Shropshire's largest Precambrian rock inliers that form the Long Mynd massif.

From the tourist facilities in the eastern and lower part of the valley the group made its way upstream stopping at a number of points to examine the rocks mainly in or adjacent to the bed of the river. The rocks examined form part of the clastic sedimentary sequence of the Longmyndian Supergroup which represents one of the thickest continuous successions (at least 6,500 m) of latest Precambrian rocks in southern Britain. Its strata are mainly disposed in the Longmynd Syncline, a major eastward-facing isoclinal fold within the Welsh Borderland Fault System strike-slip fault zone. The rocks under examination in the stretch of valley all lay within the Stretton Group, or more precisely extend stratigraphically from the basal Stretton Shale Formation to the Synalds Formation. The first outcrop examined showed a series of progradational turbidites and subaqueous deltaic mudstones and siltstones (see photo opposite top) forming the upper part of the Burway Formation. The top of the Burway Formation is characterised by fluvial environments represented by the Cardingmill Grit. This succession represents a major coarsening up regressive sequence within the Stretton Group. The more argillaceous lithologies within the sequence display a penetrative, slatey cleavage that strikes NE-NNE transecting the associated NNE-N fold axes – a fold/cleavage geometry considered to have developed during transpressional deformation associated with the sinistral displacements along the Welsh Borderland Fault System.

Precambrian turbidites in Cardingmill Valley

Trace fossils in Precambrian, Synalds Group mudstones. Cardingmill Valley

The final stop was in a small tributary valley to, and east of, the Cardingmill Valley. Here we clambered up a tricky slope to view a rock face, protected by a cage, displaying enigmatic impressions/trace fossils in the Synalds Formation. One of the two structural types seen comprises small patches of small (2-5 mm) circular impressions or pits. (see photo overleaf bottom). These have been interpreted as either rain prints or some form of obscure organic feature. The other trace fossil here consists of a series of fine, parallel ridges or rills which are thought to represent water channels.

To finish off the day the building stones of St Laurence's Church in Church Stretton were examined. These showed a variety of roughly dressed local stones laid, in the older parts of the building, in a very random manner. A particularly striking rock displayed colour banding and was, we were told, an Ordovician sandstone. (see photo below)

Sunday Morning: Ercall Quarries. Nr Telford.
By the time we arrived at the busy carparks at the foot of the Wrekin the showery rain forecast had become continuous, and this was to continue for the remainder of the day. The purpose of the morning was to examine some of the oldest Precambrian rocks of the district and their relationship with the younger Cambrian ones. Ercall quarries closed in the mid 1980's having been worked for over a century, their final role being to supply material for the construction of the nearby M54 motorway. The five quarries were made safe and became a SSSI with a geological trail laid out although nature, despite

Building stone in St Laurence's Church

the efforts of the Shropshire Wildlife Trust, has made some of the features it displayed originally almost invisible.

Quarry 1 exposed a rock face around 10 m high of a hard, pale brown, finely-crystalline, almost glassy in places, rhyolite some of which displayed flow banding. This contrasted with an outcrop at the other end of the quarry that was of a dark, finely-crystalline but quite weathered basalt which is mapped as a dyke. Both rocks belonged to the Uriconian Volcanics, a suite of igneous rocks erupted and emplaced in late Precambrian times 570-560 Ma. In Quarry 2 the scale of workings cut into the hillside could be better appreciated, with the top of the north face standing over 70 m above the quarry floor. Above the two benches made of spoil, a vertical rock face 25 m high x 50 m wide was exposed. The central portion was composed of a pink coloured rock but at the eastern end this was overlain by thick beds of grey rock that dipped steeply to the east. The pink rock was the Ercall Granophyre, an intrusive body belonging to the Uriconian Volcanic Series, while the bedded rock was the Wrekin Quartzite of Cambrian age. (see photo on back cover) At the western end of the face, but not so obvious as it was partially obscured by trees, more quartzite was observed, also dipping to the east.

On our way to examine the upper quarry face we passed an 8 m high face on the south side of Quarry 2 which exposed some fine examples of slickensides and crush breccias in the Wrekin Quartzite. The E-W trending slickensides presented as highly polished surfaces dipping steeply to the N and indicated movement in a transverse direction.

Reaching the first bench we were able to examine the bedding planes of the Wrekin Quartzite at the western end of the quarry. Dipping at 45° to the SW these were covered in beautifully preserved ripple marks with consistent wavelengths of 15-20 cm. (see photo overleaf) Climbing up to the second bench a shattered band of granophyre was seen to separate the granophyre and quartzite at the western end of the quarry suggesting the contact here was faulted. The contact at the eastern end of the quarry was accessed via a steep path to where both rocks were accessible. (see photo top of page 35) The granophyre was a well jointed, pink, fine- to medium-grained rock composed of quartz and feldspar. The upper surface was weathered and overlain by approximately 7 m of coarse, clast-supported, breccio-conglomerates of the Wrekin Quartzite arranged in beds 0.5 m thick beds separated by thinner (0.05 m) ones of finer-grained conglomerate with a soft, muddy matrix. Surprisingly, very few of the clasts in the conglomerate appeared to be of the underlying granophyre, most resembling the rhyolites seen earlier. However, their large sizes (up to 10 cm), subangular and angular shapes, show they were very likely to have been derived locally and deposited in a high energy, environment. This junction is clearly an unconformity and marks a significant time gap between the Precambrian, Uriconian Volcanics and the Cambrian sedimentary rocks. That the unconformity is dipping so steeply is the result of subsequent earth movements. Above the conglomerates the beds became thinner and grain size reduced to fine to medium marking the base of the main Wrekin Quartzite.

In Quarry 3 the top of the conglomerates and base of the Wrekin Quartzite were examined. Here, more beds dipping steeply SE at 45° were seen on surfaces 10-15 m tall and stretching for many metres. Slickenside surfaces and zones of crushed rock showed that the beds are cut by minor faults. Bedding planes in the thinner, finer-grained quartzite displayed ripple marks running in two different directions, one in which ripple axes ran NE-SW being overlain by a bed with ripple axes running NW-SE. Trace fossils in the form of grazing trails were seen on some surfaces (see photo opposite bottom) and these, along with the grain size and ripple marks support the shallow water, marine origin of these rocks.

Leaving the quarry, we made a brief stop at a very overgrown and weathered outcrop of brown, fine-grained micaceous sandstone. This we were told was of the Lower Comley Sandstone, also of Cambrian age, showing a change to a lower energy environment than the Wrekin Quartzite that it overlies.

Arriving back at our cars it was decided that, in view of the weather, it wasn't worth continuing to another site so, before we departed for home, David was thanked for his time and wealth of local knowledge and for whetting our appetites for a return visit to see more of what this extremely variable part of the country has to offer.

Ripple marks in Cambrian Wrekin Quartzite. Ercall Quarry

Unconformity between pink, Precambrian granophyre and steeply dipping Cambrian conglomerate. Ercall Quarry

Grazing trails in ripple marked Wrekin Quartzite. Ercall Quarry

Pink, Precambrian granophyre overlain unconformably by grey Wrekin Quartzite. Ercall Quarry