LGA

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Field Visit Reports Summer 2021

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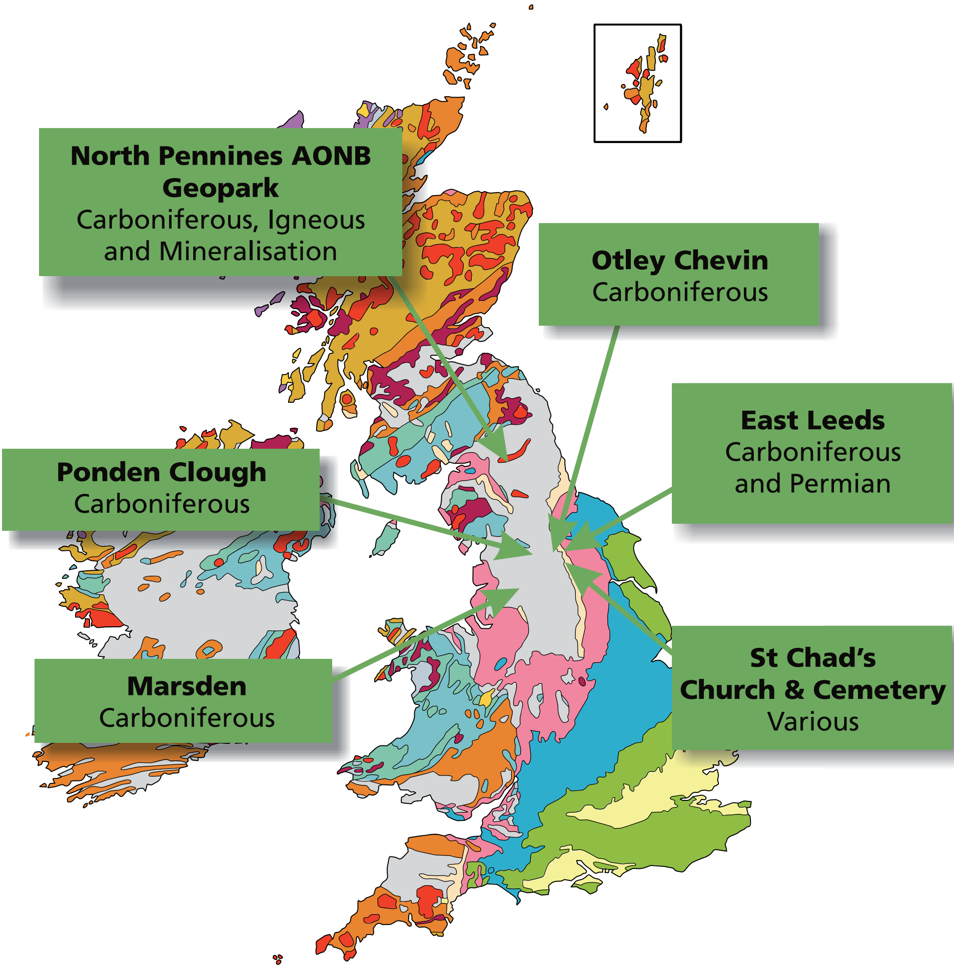
21 Where did we go?



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2021 Field Visit Locations

Following cancellation of all field visits in 2020 due to the Coronavirus Pandemic and the uncertainty that still existed during the early part of 2021, this years programme was, with the exception of the residential, intentionally restricted to local sites using local leaders.

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: Ready to go underground, Carr's Level, Nenthead Mine.

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The Chevin Forest Geology Trail.
Thursday 1st July

Leaders: Bill Fraser LGA & David Leather LGA
Present 8 members and 20 visitors

A pleasant evening for this visit which had been offered as part of the annual Otley Walking Festival and was intended as much as a publicity event for the Association than a detailed field visit. As it was one of the first events to take place following lifting of some of the government pandemic restrictions, a good turnout had been expected. With such a large party, the restricted access to some sites, and the desire to maintain as much 'social distancing' as possible, the party was split into two and, with everyone provided with copies of the trail guide, set off with Bill leading one group and David following a short distance behind with the other.

Stop 1. The Tidal Laminations sequence
An excellent example of the power of science. An exposure of laminated sandstones, in an unremarkable location, but a portal into an exotic past when fully understood. David set out all the necessary facts: shoreline/delta location, laminations: thick to thin and back again over a 28-day cycle; and a Moon, closer and with a tidal power much greater than anything today. This created the tidal depositional sequence, waxing and waning with the moon's phases.

Stop 2. Lithology and structures in the Addingham Edge Grit.
An excellent example of the coarse-grained, poorly sorted nature of the Addingham Edge Grit and iron-stained weathering. (see photo opposite) This locality also illustrates the massive nature of some of the cross-bedding in these gritstones. The Addingham Edge Grits were laid down in a huge Carboniferous delta and aspects of this depositional environment were discussed.

Stop 3. The Great Dib Land Slip.
David explained rotational slides and the physics was debated: periglacial conditions, dry-wet, freeze-thaw, slope failure, spring melts and permafrost. The precipitous and dangerous nature of the slip was relevant to David's explanation of the Otley Shell Bed which occurs below the Long Ridge Sandstone that outcrops here. This was formed during one of the brief marine transgressions across the Carboniferous delta. While we all love to collect fossils, the dangers of exploring this precipitous, overgrown location meant that discretion be the better part of valour in this case.

Lithology of Addingham Edge Grit, Otley Chevin

Stop 4. Tree fossils.
A large block of Doubler Stones Sandstone has become detached from the outcrop and rotated through 90°, exposing the under surface which carries the impressions of the trunks and/or branches of some large plants. These had probably become stranded on a sand bank after a flood before being buried in coarse sand by a subsequent one and preserved.

Stop 5. Cross-bedding in the Doubler Stones Sandstone.
The perfect teaching aid - the cross-bedding is beautifully revealed in this example. (see top photo overleaf) The sequences promoted discussion on migrating meanders, and the termination of one depositional regime and the onset of new conditions. Also discussed was a possible scenario that resulted in the movement of large blocks downslope, in which tundra-like conditions with cold desiccating winds, oscillating with slightly warmer and wetter ameliorating interludes was the climatic regime. Erosional mechanisms would attack and under-cut the softer mudstones below the harder grits exposed on the over steepened valley sides, leading to their collapse. The Victorian quarrymen employed the same process - undercut first, then use gravity to break out a section.

Cross-bedding in Doubler Stones Sandstone, Otley Chevin

Morton Banks Coal and seatearth, Otley Chevin

Stop 6. The Morton Banks Coal.
David pointed out the now rather badly eroded, fossilised tree roots on the top of the southerly dipping Doubler Stones Sandstone, and the seat earth with the thin Morton Banks Coal, preserved in the overlying deposits (see bottom photo opposite) and explained the conditions under which these had been formed and preserved.

Stop 7. Yorkgate Quarry.
A good location for discussion of the Pennine anticline and the Variscan Orogeny. David used this 4m face which dips 24 degrees to the south, to illustrate how rocks can be moved, fractured and folded given deep time and geological power.

Stop 8. Interpretation panel at Surprise View.
Emerging back onto the top of the scarp we walked along to the interpretation panel, which is still in good condition, and the salient features it illustrates were pointed out.

One of the enjoyable things about a geology field trip with non-geologists is when the light comes on, that moment when the penny drops, and the innocent suddenly acquire X-ray vision and time travel. We looked at the outlier of Almscliff Crag and discussed how it was a more resistant remnant holding the same sands and fossils as the Chevin. So, what happened to all the stuff in between? And when? And how? Wow!

Returning to the car park thanks were expressed to the leaders by many of those who had attended. Just after the last people departed, a fire engine arrived with lights and sirens going making us worry that we hadn't accounted for all and that an accident had occurred. We were relieved to discover that they were in fact responding to reports of smoke being seen rising from the trees. We had seen some people setting up a barbeque at one of the picnic tables a short distance up the path, so two firemen, armed with beaters and a back-pack water container set off to investigate – no doubt to put a damp end to affairs!

Rocks and landscapes to the east of Leeds
Saturday 10th July

Leader: Bill Fraser LGA
Present: 11 members

The purpose of this visit was to look at the contrasting environments of deposition in which rocks on this side of the city were deposited and how they have influenced the landscape.

William Parkin Way. Our party assembled in the car park of The Springs retail park at Thorpe Park, adjacent to the M1 at its intersection with the A63, to view an exposure of Carboniferous age, Pennine Lower Coal Measures. Construction of the William Parkin Way, a new section of the East Leeds Orbital Road opened in 2018, made a cutting through an east-west trending ridge, creating an exposure about 80m long with a maximum height of about 10m. (see photo below)

The exposure shows sequences of sandstones, siltstones and mudstones typical of deposition in Coal Measures times that was dominated by river channel, swamp and estuarial environments. The beds are dipping in a southerly direction at about 10 degrees. When the cutting was first excavated

Crevasse splay deposits, William Parkin Way

a thin coal seam was visible at the base but is now obscured. From the base is about 3m of buff-coloured, medium to fine-grained sandstone with prominent cross-bedding in some beds. This is overlaid by about 4m of thinner beds of grey coloured sandstones, rich in plant debris, interbedded with increasingly thicker units of thinly bedded siltstones and about 3m of grey mudstone. Capping this, after a sharp contact, was the lower portion of another thick sequence of buff-coloured sandstone. The fining upward sequence seen here is the reverse of the usual cyclothem coarsening upward sequence, suggesting that this is a crevasse splay deposit, formed when a river channel confined between levees rose above the surrounding area, and levee failure released a flood of sediment across the surrounding vegetated area, creating a temporary lake environment, with sediment settling into a fining upward sequence. The thick sandstones, which are more resistant to erosion than the surrounding mudstones, coupled with the southerly dip created the pronounced ridge that had to be cut through for this new road.

During the rest of the day we visited a series of exposures in the Permian, Cadeby Formation progressing from east of Garforth north to Aberford.

Roach Hill. This location is an SSSI of magnesian limestone grassland at the top of the west-facing Permian scarp slope; the high Permian upstand exists as a result of the limestone being more resistant to erosion than the undulating eroded surface of the softer Carboniferous mudstones that it overlies. Upstanding to the southwest are two hills, which are outliers capped by Permian limestone, showing that before erosion the Permian deposits extended further to the west. We descended to the base of the scarp where a change of gradient indicated the position of the Permo-Carboniferous unconformity; crops masked the boundary but we were informed that when the fields are ploughed a change of soil 'colour' from yellow to dark brown can be seen at the junction. At this boundary, in the 19th century, adits were driven into the scarp face to extract sand from the Yellow Sands Formation at the base of the Permian which was primarily used in glassmaking and as moulding sand. When the adits became too long for safe working, shafts were sunk from the top of the hill to extract the sand by bell pits, the spoil from which forms the hummocky grassland of the SSSI. The Yellow Sand Formation consists generally of weakly consolidated bright yellow sand, medium to fine grain size, well-sorted and rounded, occurring as sheets or lenses 2 to 3m thick and, in places, strongly cross-bedded. In some parts they include breccias and sandstone fragments. They are thought to be aeolian in origin but in some places appear to have been re-worked by water, possibly by the transgression of the Zechstein Sea.

The quarry on this site is one of many along the Permian outcrop extracting limestone for use in lime burning for agriculture, aggregates and construction during the 19th century. The rock is dolomitic limestone, the original calcite having been modified soon after deposition by replacement of calcium atoms by magnesium, considered to be from infiltration of hypersaline solutions, converting calcium carbonate ($CaCO_3$) to dolomite, $CaMg(CO_3)_2$. The smaller size of the magnesium atom results in loss of volume which creates small cavities (vugs), a characteristic of dolomitic rocks. The quarry here is in the lower member of the Cadeby Formation, the Wetherby Member, and rests directly on the Yellow Sands Formation. We were able to approach a small section of the overgrown face to see horizontal, cream-coloured limestone in beds about 0.3m thick. There is some evidence of ooids and fossil debris, the latter showing that some hardy marine life could exist in this very saline environment. Bill showed us specimens of the bivalve ***Schizodus***, collected from a field below this location, after it was ploughed. (see photo above).

Schizodus (bivalve), Roach Hills

Vandicourt Quarry, Micklefield. We travelled 2 miles to the east to another SSSI at Vandicourt Quarry, where a rock face about 80m long and up to 10m high is the remaining exposure of an extensive quarrying operation, the lower quarry face having been back filled. Following its appointment as an SSSI the environment is much improved and well-kept with an information board.

The quarry worked the Cadeby Formation, both the Wetherby (lower) and the Sprotborough (upper) Members, between which are located the Hampole Beds, a significant marker in the Cadeby Formation of Yorkshire, Derbyshire and Nottinghamshire.

The Wetherby Member (as seen at Roach Hills) consists of planar bedded dolomite with oolitic and grainstone fabrics that were deposited in shallow waters. The strength of the stone is shown by passages cut for air-raid shelters in WWI still being in good condition.

The overlying Hampole Beds are a distinctive group of mudstones and dolomites overlying a minor discontinuity, about 0.8m thick, containing two partings of pale green claystones separated by a 5cm bed of finely laminated dolomite. (see photo opposite top) Their formation is thought to have accumulated partly by intermittent deposition on an extensive inter-tidal coastal flat during a period when sea levels fell.

The Hampole Beds, Vandicourt Quarry

Sedimentary structures in Cadeby Formation, Pinfold Quarry

The overlying Sprotborough Member consists of well-bedded dolomites that show cross-bedding on a large and small scale. These were deposited in a high energy environment as large ripples and dunes in shallow water, following a rapid sea level rise.

The whole face has so many detailed features that we resolved to return to this exposure in the future with a specialist to interpret the features for us.

Pinfold Quarry, Aberford. Moving 2 miles north to Aberford we examined exposures in Pinfold Quarry, located adjacent to the track of the old rail line used to transport coal from Garforth pits to the Great North Road at Aberford. The faces exposed a total length of about 40m, about 8m high, still in the Cadeby Formation but with no certainty as to which member. Beds are horizontal with thicknesses ranging from laminae up to 40cm thick and showing structures varying from planar to hummocky cross-stratification. (see photo overleaf bottom) Some horizons have many cavities (vugs), some containing crystals, some empty. In one face, dome-shaped structures are stromatolite reefs. The variation in texture up the face points to the sequence having been deposited in a shallow water environment with fluctuating energy levels. In a small exposure in another adjacent overgrown quarry was a particularly good dome structure in well-bedded dolomite with many vugs lined with crystals, one showing well-formed dolomite crystals.

Algal mats, Aberford

Cattle Lane, Aberford. Finally, Bill led us to an exposure of a stromatolite bed in a roadside cutting clearly showing the sequential deposition of algal mats that here form a series of domes. (see photo above)

We thanked Bill for a very informative and enjoyable day, and for his excellent detailed handout covering the locations and their geological background.

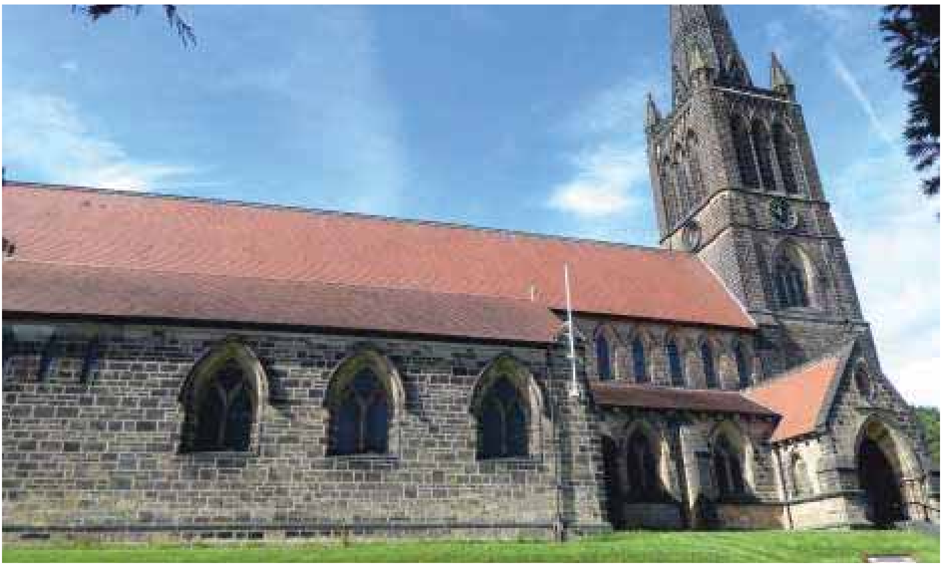
St Chad's Church, Far Headingley.
Thursday August 4th (evening)

Leader: Dr John Varker LGA
Present: 9 Members 2 visitors

This visit was to complete that started in 2019 when torrential rain had confined us to an extended tour and discussion of the church interior, and so made it the longest field excursion the LGA has ever undertaken. Details of the history of the church and its building materials can be found in the Field Visit Reports booklet of that year.

We began by revisiting the examples of Millstone Grit, Rough Rock that make up the pillars flanking the doors, and the large slab of Coal Measure Group, Elland Flags that forms the top of the steps that we had briefly viewed on our last visit. The coarse and quite deeply weathered nature of some patches of the Rough Rock contrasted strongly with the medium-grained, almost polished appearance of the Elland Flags.

Looking at the east side of the building the different phases of construction were recognised by differences in the colour and arrangement of the stonework. The oldest parts of the building were built of regular sized and shaped Rough Rock blocks, all discoloured by the same amount and laid in regular courses. In comparison the Lady Chapel blocks varied in the types of sandstone, their size, shape and degree of discolouration, and are laid in irregular courses. This shows that these stones were recycled from previous, presumably local, buildings. (see photo below) This was confirmed by the



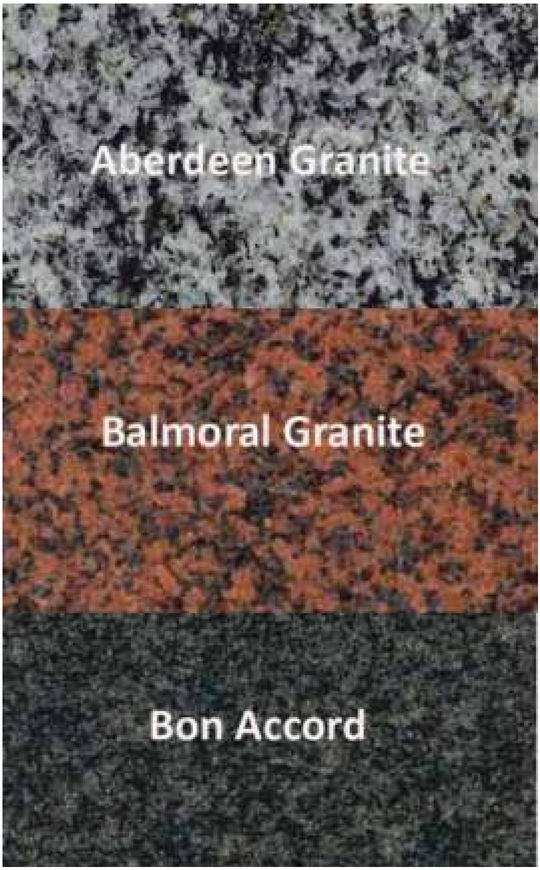
Contrasts in stonework, St Chad's Church

varied types of masons' marks in these stones showing that these came from different sources whereas those in the original building all came from the same source in Meanwood. At the height of quarrying in Leeds there were 216 known quarries working Rough Rock. Walking round the building, where recent repairs had been carried out, the rock was a much brighter orange than the buff-coloured Rough Rock. This is because the closest match to Rough Rock obtainable today is from Blackhill Quarry in Bramhope which exploits the older, Midgley Grit, which has a higher iron content.

The headstones in the graveyard date from 1868 and illustrate a wide range of rock types from many different places. This was possible because by this date, growth of the railway network made the transport of bulky raw materials over long distances much easier and cheaper. From the multitude available for study John drew our attention to a limited number from the three main rock groups, and explained their significance:

Aberdeen Granite. (see opposite) This is a fairly dark grey rock composed of evenly sized crystals of quartz, feldspar and biotite (black) mica, probably from the Rubislaw Quarry. Being crystalline it polishes well and being impermeable resists weathering, making it long lasting. Examples were seen of this in the polished and unpolished state.

Balmoral Red. (see opposite middle) Despite its Scottish name this strong red, igneous rock comes from Finland. It is a granite and it is the feldspars that give the red colour to the rock, which is best seen when polished. The raw stone was imported to Aberdeen where it was worked in the many stone yards using the skills developed over their long history of working 'native' granites, and then sold under this 'trade name'. The reason for importing it when they had plenty of local supplies would have been to give more variety



Different igneous rocks found in St Chad's graveyard

to their catalogue as many of the local granites were different shades of grey. The high proportion of silica in granites shows that they are most likely to have originated by melting of crustal rocks, usually in the 'roots' of mountain ranges, before being intruded at higher levels.

Bon Accord. (see opposite bottom) Another igneous rock but, as another of its trade names suggest, one that is very dark in colour, some being black. Two examples of this rock were compared. One that was dark grey and could be seen to be made of visible crystals of a black mineral (pyroxene) along with grey and almost white feldspars (plagioclase). The other was made almost entirely of pyroxene which gave the very dark colour. The minerals, and the fact they form crystals visible to the naked eye, show that this is a gabbro and formed from a magma that originated within the mantle and cooled slowly, deep underground. These gabbros were also imported into Aberdeen, the paler one from Norway and the dark one from South Africa. The name 'Bon Accord', the motto of Aberdeen, like Balmoral Red, gives the stone a Scottish theme, popular in Victorian times, and so was a marketing ploy. The darker variety from South Africa was also marketed under the name Ebony Black, possibly to disguise its South African origins following the Boer Wars.

Carrara Marble. This pure white marble, formed by metamorphism of pure limestones, has been a long-time favourite for statues and monuments, and comes from quarries around the city of the same name in Tuscany. The purest limestones gave pure white marbles, those with impurities resulted in marbles with coloured streaks. The disadvantage of using marble outside is that it slowly dissolves in rainwater, but this has the advantage that the surface doesn't become covered in dirt. One quite unusual headstone (see photo right) which appeared to be made of random lumps of white, unpolished marble held together by a white cement, prompted discussion regarding its structure and its poignant inscription which reads: Alf Cook. Born July 4 1842, died March 23 1902. 'Useful in his day and generation'.

An unusual Carrara Marble headstone, St Chad's graveyard

Carboniferous, Crinoidal Limestone, St Chad's graveyard

Carboniferous Limestone. This pale grey rock had been used to form a Celtic cross. While today it was rough to the touch, when new it would most likely have been polished, the change indicating by how much it had weathered. Looking closely, it could be seen to contain crinoid fragments and solitary corals. On the reverse side there was a particularly good example of a section through a length of crinoid stem. (see photo above) The fossils indicate this rock to be a Carboniferous limestone and ones like this have been worked in Yorkshire and Derbyshire.

With the light beginning to fade and rain beginning to fall we thanked John for taking the trouble to complete this tour. John's excellent guide to St Chad's Church and its graveyard can be downloaded from our website (https://leedsga.org.uk/local-geology/local-sites/) and is well worth following.

The Geology of Ponden Clough
Saturday 14th August 2021

Leader: Gareth Martin, LGA & WYGT
Present: 4 members

We assembled at Ponden Reservoir, where Gareth gave us an overview of the geology to be encountered on the day. The Ponden Clough area lies predominantly in the Millstone Grit Group of the Upper Carboniferous, and the rocks visited date from the Bashkirian Stage, formed between 319 and 315 Ma. At that time the area lay on the edge of Pangea, in a NW – SE trending graben between the South Craven Fault to the north and the Denholme Clough Fault to the south.

The Pennine Basin was actively subsiding and filling with sediment brought down by three fluvial systems. At Ponden Clough rivers flowed into the basin from the north, bringing garnet-rich, monazitic heavy minerals from high grade metasediments and granites that occurred in upland areas covering what is now Greenland and Scandinavia.

From the reservoir we followed the steep path up the hillside to Site 1 at Crow Hill Delph. As we gained height the views became extensive to the north and east, and the ridge line that follows the Keighley Bluestone sediments could be clearly seen to the north of the reservoir. This had been extensively mined for roadstone but there are no known exposures of the rock at these sites.

Crow Hill Delph is an excellent exposure, showing the Woodhouse Flags overlain by the Midgley Grit, with a thin mudstone between the two sandstones. (see photo overleaf top)

The Woodhouse Flags (previously known as the Scotland Flags) lie in the Millstone Grit Group and are fine to very fine-grained micaceous sandstones which can be up to 30m thick. Ripple bedding was seen in the roof of the exposure, and loose boulders showed trace fossils of resting bivalves (see photo overleaf bottom) and also symmetrical ripples. These indicate a very low energy depositional environment, and it is thought that these sandstones were deposited at a fluvial mouth bar. Historically these flags were mined, and an adit has been identified at this site but was not visible.

Overlying the Woodhouse Flags is the Midgley Grit, a coarse-grained sandstone that can be up to 25m thick but is around 4 metres at Crow Hill Delph. The base of the exposure showed a slightly rounded, erosive surface,

Woodhouse Flags and Midgely Grit, Crow Hill Delph, Ponden Clough

Trace fossils formed by resting bivalves in Woodhouse Flags, Ponden Clough

and root fossils of ***Lepidodendron*** or ***Sigillaria*** were visible in a fallen block. The depositional environment is thought to be on the margin of a laterally extensive braided river system, probably several tens of kilometres wide, and possibly indicates infilling of an incised valley which developed when water levels in the Pennine Basin fell.

Between the two sandstones a thin grey and orange weathered mudstone was visible. Here it is only 0.2 – 0.4m thick but further south can be up to 15m thick and contains a band of the brachiopod ***Lingula***. This indicates a marine incursion, probably due to global sea level rise, and the erosive base of the Midgley Grit could explain why the marine band is largely missing in this area.

We retraced our path down the hill then followed the hillside round to Ponden Clough.

At Site 2 at Lower Ponden Clough the valley is steep-sided and well-vegetated, so exposures are very scanty and quite difficult to access. However, it is an important section as there is a marine band (***Bilinguites gracilis*** Marine Band) which marks the junction of the base of the Marsdenian regional stage and the top of the Kinderscoutian regional stage.

At this site the marine band rests on top of the Doubler Stones Sandstone (here a leaf of the Upper Kinderscout Grit) but this sandstone cannot be

Keighley Bluestone, Ponden Clough

distinguished from the overlying High Moor Sandstone (also a leaf of the Upper Kinderscout Grit) so is labelled as undifferentiated. This is possibly because the two thin mudstones (Morton Banks Coal and Butterly Marine Band) that separate the two sandstones to the south have been removed by erosion, or possibly because of the lack of exposure due to extensive vegetation. As with the Midgley Grit, it is thought that these sandstones were laid down in a braided river system.

Although we weren't able to visit any exposures here, looking down the valley side a step in the topography could be traced for a considerable distance along the hillside and quite possibly marked the level of the Marine Band.

We walked further up the clough to Site 3, where Ponden Clough makes a right-angled turn and is joined by Middle Moor Clough. This part of the clough also lies in the Millstone Grit Group, which can be 50 – 60m thick in this area, but further up the clough it is overlain by the Midgley Grit sandstone again. Looking down into the stream bed could be seen an exposure of the Keighley Bluestone, (see photo overleaf bottom) which is very unusual if not unique in West Yorkshire, and at this site separates the Upper Kinderscout Grit from the Woodhouse Flags. As it would have been a quite slippery and precipitous climb down to the stream bed we were grateful that Gareth had brought along a hand specimen of the Bluestone. It is indeed very blue, very fine-grained, with sharp edges and no obvious bedding. It has been described as "a hard, compact, dark bluish-grey siliceous siltstone, chert, and claystone with abundant spines, composed of cryptocrystalline chert of chalcedony, of the sponge ***Hyalostelia smithi***". At this site it is 0.5 – 1m thick but can be up to 7m thick. ***Zoophycos*** trace fossils have been found on the bed surface at this site, and the depositional environment is thought to be a marginal marine environment, quite possibly a lagoon.

Above this sequence there are at least 3 coarsening upwards cycles of mudstone, siltstone, and sandstone with rippled and burrowed upper surfaces, and looking further up the clough, in the Millstone Grit Group, visible steps in the watercourse could be seen which probably relate to these sequences. These are thought to be minor deltas prograding into a lagoon. A fallen boulder, likely of the Woodhouse Flags, was found with excellent trace fossils of ***Olivellites plummeri*** burrows, (see photo opposite) which are thought to be indicative of deposition in a mouth bar environment.

Looking back down the clough there was evidence of a possible landslip on the south side, where the stream seemed to have cut down an excessive amount and there was no evidence of stepping on the valley side, which there is on the north side.

***Olivellites plummeri* burrows, Woodhouse Flags, Ponden Clough**

We took the path up the side of Middle Moor Clough, before crossing over the stream and taking the path back down the south side of Ponden Clough. We passed two intakes on Ponden Clough which take water directly to Watersheddles Reservoir, which is upstream of Ponden Reservoir, and both of these were in rather poor state of repair.

Ponden Reservoir was built in 1876 to act as a compensation reservoir to provide flow down the valley to the River Worth after Watersheddles Reservoir was built, and can store up to 865,000 m^3 of water.

As we descended the clough we paused at Site 4, Ponden Kirk. Here there is an exposure of the Woodhouse Flags overlain by the Midgley Grit, as at Site 1, Crow Hill Delph, but the lithologies are difficult to view close up. The thin mudstone seen at Site 1 is considerably thicker here, at ~1.2 – 1.8m, and a thin coal seam has also been identified which would indicate a fairly stable environment, but neither is currently visible due to the vegetation cover.

Continuing our descent we arrived back at Ponden Reservoir, where Gareth was warmly thanked for a very interesting field visit, it was fascinating to see how much information can be gleaned by thorough examination of what at first sight appear to be fairly 'ordinary' exposures.

Butterly Cutting and Pule Hill
Saturday 11 September

Leader Dr Gareth Martin. LGA & WYGT
4 members and 1 visitor present

The object of this excursion was to examine the various lithologies of the Namurian, Millstone Grit Group of the area around Marsden.

The group met at Butterly Reservoir, the lowest of 4 reservoirs in the Wessenden Valley constructed by Hudddersfield Corporation Water Works. The earth dam was constructed between 1891 – 1906, the lengthy period of construction being partly due to an outbreak of smallpox amongst the workforce in 1893, the "severe and prolonged frost and snowstorms" in 1895, but principally because, in September 1901, as the reservoir was being filled, problems were identified with the underlying rock strata which caused the main embankment to leak. By March 1903, it was reported that the construction costs had spiralled to £304,000 — more than double the original estimate — and that around a further £90,000 would be needed to remedy the leaks. The work was eventually completed in the summer of 1906 and the reservoir filled to capacity by the end of the year.

Adjacent to the track on the west side of the reservoir is a rock face, created during construction, that is around 5m high at the north end but becomes higher to the south, first as a shear face, then as a number of steps, created by the working of former quarries. The rocks belong to the Hebden Formation of Namurian, Kinderscoutian substage age and dip gently to the north, which enables the full sequence to be accessed. Starting at the southern end the oldest rocks were seen to be thinly bedded siltstones with some slightly thicker, micaceous sandstones. All showed ripple marks and bioturbation indicating a shallow water origin and form the upper parts of the Lower Kinderscout Grit. Moving north (up the sequence) these were replaced by black shales and mudstones in which, at a point where a recently fallen tree had created a clean face, fossils of the brachiopod ***Lingula*** were found. (see photo opposite) This identified the horizon as the Butterly Marine Band and marked a time when sea level rose and flooded the area. As this horizon can be found throughout the Pennine Basin and beyond, this event must have been eustatic and linked to fluctuations in the ice cap that at that time covered the south polar region.

Above the mudrocks but separated by a sharp, erosive boundary was the beginning of a thick sequence of coarse-grained sandstones. In the lowest, most accessible sections, these were seen to comprise of three distinct units; a

Lingula **(brachiopod) in the Butterly Marine Band, Butterly Cutting**

massive, planar bedded, basal unit 3m thick, a massive cross-bedded unit 1m thick and another massive, planar bedded unit 2- 3m thick, each unit being separated by scoured surfaces. (see photo overleaf top) These sandstones are part of the Upper Kinderscout Grits, which can reach up to 40m thick, and represent the refilling of the Pennine Basin as deltas advanced from the north. The sheet-like layers developed in association with turbidite-fronted deltas on submarine slopes, the cross bedded units in river channels.

A short drive took us to the next site at the foot of the southern end of Pule Hill, unofficially referred to as 'Goniatite Gully'. As the name suggests this is a series of deep, steep sided gullies that have been cut into the country rock of dark mudstones and shales by small streams draining from the adjacent hill. These rocks are younger than those seen in Butterly Cutting and belong to the Marsden Formation of Namurian, Marsdenian age. Working up the gullies, picking through loose debris, a zone around 2m thick was identified first by the appearance of bivalves, then by masses of goniatites. These ranged from a few millimetres in diameter to over 3cm and, even to the inexperienced eye, could be seen to represent several different genera. (see photo overleaf bottom) This concentration of marine fauna marks the position of another marine band, this time the ***Bilinguites bilinguis*** Marine Band (named after the goniatite ***Bilinguites bilinguis***) and, as it too can be traced over a wide area, marks the onset of another eustatic rise in sea level.

Upper Kinderscout Grit, Butterly Cutting

Goniatites from 'Goniatite Gully', Pule Hill

Large scale cross-bedding and cavities in Midgely Grit, Pule Hill Quarry

'Mares Balls', Little End Nab Quarry

The abundance of fossils made it quite easy to trace the marine band exposed in the sides of the gullies.

Lunch was taken in a layby on the busy A62 below Pule Hill adjacent to one of the air shafts of Standedge Tunnel. Walking up an inclined plane we reached Pule Hill Quarries that, until the 1930s, provided building stone, setts and paving to the Marsden area. Today they are also the location of one of the poet Simon Armitage's 'Stanza Stones' poems. The quarries, with faces 20m high, extend for over 100m along the western edge of the hill. The rock consists mostly of coarse to very coarse-grained sandstones, rich in feldspar although thin, impersistent beds of mudstone occur between some of the them. The sandstones display cross bedding on scales ranging from several metres to a few centimetres thick with many units separated by scoured surfaces. These sandstones are part of the Midgley Grit of the Marsden Formation, the same sandstone that is being worked today at Mones, Black Hill Quarry at Bramhope. While the general trend of cross bedding showed direction of deposition to be from a northerly direction there was a lot of variation, which supports the understanding that these sediments were deposited along the course of a deep, wide, braided river system. (see photo overleaf top) Impressions of individual, and jumbled masses, of tree fossils were evident on surfaces of fallen blocks as well as in situ. A distinctive feature in these quarries are large (up to 3m across) cavities, some of which are filled with soft, extremely coarse grained sandstone which is weathering bright orange, indicating a high iron content. Some of these were found to contain abundant plant debris which led to speculation as to their origin.

Descending part way down the hillside we then walked north for approx. 800m to reach another set of abandoned quarries at Little End Nab. These are also in the Midgley Grit and, not surprisingly, show many similarities in rock type and structures to those at Pule Hill. However, one striking difference seen here was that instead of the rock containing cavities, it displays concretions which range in size from 0.3m to 2m in diameter. These are mostly spherical and can be seen protruding from rock faces as well as scattered across the quarry floor. (see photo overleaf bottom) Quarry men referred to these as 'Mares Balls'. Broken ones did not show the same degree of weathering as those at Pule Hill and in none of them were any form of nuclei apparent. Time was spent considering the processes by which these structures may have formed and why they appeared to be so localised. Returning to the cars Gareth was thanked for providing such a rewarding day, which illustrated again the variety of rock types, structures and fossils that can be found in the Millstone Grit.

Residential Visit: North Pennine AONB Geopark
Friday October 1st – Sunday October 3rd

Attendance: 10 members 1 visitor

This visit should have taken place in September 2020 but was postponed due to government restrictions imposed to combat the Coronavirus Pandemic that restricted the size of groups allowed to meet, as well as the working conditions of those who had agreed to lead us. Thanks are due to these people for agreeing again to lead us and to Lowbyer Manor Country House for keeping our booking and putting up with the fluctuating group numbers and membership.

The LGA has visited sites in the North Pennines on day trips in the past, but a weekend based in Alston gave us the opportunity to visit a number of different locations without the long journey times. The North Pennines AONB has been a Geopark since 2003 and became part of the UNESCO Global Geopark programme in 2015. This means that it is an area where 'outstanding geological heritage is used to support sustainable development through conservation, education, interpretation and nature tourism', and our visit 'ticked all these boxes'. We were there for its geological heritage, in this case its mining history, which of course is controlled by the geology. We visited a site where conservation was very much the order of the day, were certainly educated and encouraged to interpret what we saw, and by residing there, were part of nature tourism.

Geological setting:
The North Pennines consist of a fault-bounded 'block' that has, as its foundation, rocks of Lower Palaeozoic age that were folded and subjected to low grade metamorphism as part of the Caledonian Orogeny, which resulted in the area becoming part of a mountain chain. Early in Devonian times the roots of the mountains were intruded by granite magmas which, due to erosion, were exposed at the surface by the beginning of the Carboniferous. Tensional forces, part of the Variscan Orogeny at the beginning of the Carboniferous, caused the crust to fracture along fault planes that probably followed older, Caledonian fractures in the basement rocks. The section on which the North Pennines sits today, being partly made up of low-density granite, remained buoyant forming a 'block', while surrounding sections, with no granite, subsided to form 'basins'.
During Carboniferous times the continually subsiding basins accumulated thick deposits of mainly muddy and sandy sediments, while the block, which only subsided slowly, received a relatively thin covering of cyclic sediments, caused by repeated deepening and shallowing of seas as a south polar ice cap

expanded and contracted in response to changes in the earth's orbit and tilt (Milankovitch Cycles). A typical cycle began with limestone, followed by shale, silt sandstone and, sometimes seat earths and a coal seam, which reflects an initial flooding and deepening of the sea before it shallowed and was filled by sediments washed in by rivers flowing from the north. There are 22 cycles on the Alston Block which vary in thickness from a few tens of metres to over 60 m, but not all are complete. The limestones, being recognisable and consistent across wide areas, were named by early miners on their characteristic features. Where there is a limestone at its base the cyclothem is named after it.

Late in Carboniferous times important events occurred that were to shape the future geological heritage and the landscape of the Alston Block. These were: tectonic activity that created a series of faults in the Carboniferous cover, a series of magma intrusions, collectively known as the Whin Sill, into the Carboniferous rocks over an area which extends to nearly 8000 km^2, and the invasion, also into the Carboniferous rocks, of hot, mineral-bearing brines, that cooled in the earlier formed faults to form mineral veins or reacted with limestones to form deposits known as mineral flats.

No evidence survives of any rocks that may have been deposited on the Block since Carboniferous times, and` if they ever were, they have been removed by erosion following major uplift of the Pennines during the Alpine Orogeny. What there is though is plenty of evidence of the work of ice. Valleys have been deepened and straightened by glaciers and deposits of glacial till left smeared across the surface as these retreated. The vast amounts of water released as ice melted carved a number of pronounced channels either below the ice, or at its margins, many of which are now dry.

Friday: Nenthead Mine at Nenthead
Leaders: Peter Jackson, Karl, Rosemary & Joyce. Nenthead Mines Conservation Society

We met our guides for the afternoon at Nenthead Mine on a day of sunshine and heavy showers. The Mine and surrounding land is a scheduled ancient monument and contains a geological SSSI. The site has been managed for the past 9 years by volunteer members of the Nenthead Mines Conservation Society of which our guides for the afternoon were all members. The site contains remains of mines, hushes, spoil heaps, mineral processing and smelting operations as well as associated buildings and transport. The site has been worked from at least the C12th, initially for galena but later for sphalerite, until final closure in 1921.

After a brief description of the site, its history and current management in the Barracks (originally a lodging house for miners) we went out for a surface tour of part of the site. Walking past the remains of ore processing and smelting buildings and machinery, we were told that as a scheduled ancient monument their work was restricted to conservation and not restoration. In the steep bank of the stream that runs through the site, shales with overlying sandstone could be seen beneath thick overlying till. Recent heavy rain meant the stream level was too high to allow access for the party, but Peter crossed to point these out and bring back samples for inspection. These are believed to belong to the Four-Fathom Cyclothem. Further up the valley, protruding out from its spoil-covered sides, we were able to access the boundary between the Iron Post and overlying Great Limestone Cyclothems which showed as a sharp contact between a brown, micaceous sandstone (Tuft Sandstone) containing traces of roots, and the overlying dark grey, Great Limestone. A distinctive feature of the base of this limestone, which was well exposed here is the Chaetetes Band, (see photo below) composed of layers of the sponge ***Chaetetes*** and other fossils, which in this outcrop was the colonial coral ***Diphyphyllum***.

Moving further upstream the valley narrowed to a rock-walled gorge with a waterfall at its head, formed where the stream plunged over the Great Limestone. The viewing platform enabled the limestone to be examined safely and it was seen to be dark brown colour, caused by the development of ankerite (an iron carbonate) with a scattering of galena crystals which

***Chaetetes* Band, Nenthead Mine**

A demonstration of mining, Carr's Level, Nenthead Mine

indicate that here it has been chemically altered by hydrothermal fluids. At this point Peter produced a large block 'he had found earlier' containing sphalerite and pyrite.

Returning to the Barracks, while being plied with hot drinks and choices of cakes and biscuits, we had an opportunity to study the displays of geological specimens, mining artifacts, maps, photographs and literature available for purchase. Suitably refreshed we donned helmets and made our way to Carr's Level, an entrance to part of the extensive network of tunnels and workings that underly the area around Nenthead. (see photo front cover) The level was driven in 1815 through interbedded shales and sandstones below the Great Limestone as a prospective level. While our guides described miners' working practices and conditions, members were given the opportunity of 'swinging a pick' themselves (see photo above). Approximately 200m into the mine we crossed a fault plane and entered the Great Limestone. The fault plane, filled with gouge but with no mineralisation, was clearly visible in the tunnel wall and it could be seen how shales, which had been horizontal, dipped into it.

After walking along a stope that had been worked along a mineralised vein, we entered a chamber that was an example of a mineral flat, formed when hydrothermal fluids reacted with the limestone, replacing it with ore deposits and gangues. The mine was originally worked for galena, which here contained silver, making it more valuable. Although sphalerite was encountered as well, initially this was considered waste as the market for zinc was poor. It was only in the later 1800s, when the market and refining techniques improved, that it was exploited. Our guides demonstrated the techniques used to hand drill holes and blast and it wasn't difficult to imagine the working conditions, especially when the lights were turned off!

After walking along another stope and being shown more modern drilling equipment, powered by compressed air, we climbed 2 sets of ladders to reach a higher chamber excavated in a flat deposit. With the lights extinguished we were treated to a spectacular display of the fluorescent properties of the various minerals (see photo overleaf top) before we passed through a door, back into the open air at the head of the gorge we had visited on our surface tour. Returning to the Barracks we thanked our guides for such an excellent afternoon. Throughout the surface and underground tours they had fed us a stream of information covering, as well as geology, the history, mining practices and operation, processing techniques, mining society and social welfare.

Saturday: Ashgill Force, Garrigill
Leaders:Naomi Foster. North Pennine AONB Geology Project Officer, James Dill-Russell. Geology Projects Trainee
We met Naomi and James in Garrigill on a wet and windy morning, where Naomi gave us a brief outline of the local geology and the plan for the day, which was to walk to Ashgill Force to study components of cyclothems and their effect on the landscape.

Looking over the bridge in Garrigill, despite the high level of water in the South Tyne, we were still able make out the horizontal beds of limestone that make up the Tynebottom Limestone and some of its overlying shales which meant we were near the base of the Tynebottom Cyclothem. Climbing the valley side, an outcrop at the side of the path showed loose rock fragments embedded in a silt/sand matrix. A brief examination showed that the fragments were mainly of sandstone with a few of limestone, but one was found that could have been a piece of Lower Palaeozoic basement rock. The deposit is identified as glacial till and there followed a discussion about the origin of these and the possibility of it also being a head deposit. Traversing the hillside into the wind and rain, the next outcrop was a low scar with a stream issuing from its base. This proved to be a dark limestone which contained the colonial rugose coral ***Siphonodendron***, as well as solitary corals and crinoid debris. This was the Scar Limestone and marked the base of the cyclothem above the Tynebottom. Despite the rain the cloud base was high enough to be able to see the typical stepped nature of the hillsides that

Fluorescence, Nenthead Mine

Ashgill Force, Garrigill

develop on these Carboniferous cyclothems.

After dropping down the hillside into the more sheltered valley of Ash Gill we began to ascend the stream which tumbled down the deep valley in a series of waterfalls formed by the harder limestones and sandstones within the Tynebottom Cyclothem. In order of ascent these were (possibly) the Single Post Limestone (aptly named as it consists of one bed ~0.5m thick), an un-named sandstone and the Cockleshell Limestone (named due to the abundance of ***Gigantoproductus***, a large brachiopod, of which examples were seen in loose block). Crossing the footbridge above this waterfall we were presented with the dramatic site of Ashgill Force, spanned by a fine, stone, arched bridge, formed by the Scar Limestone. (see photo opposite bottom) Before approaching the waterfall Naomi pointed out the 'Bouseteems', (a series of stone-built alcoves) of Ashgill Field Mine where partnerships of miners stored their 'bouse' (unprocessed ore). These examples are unusual in that the back wall of each compartment is curved. (see photo below)

Climbing up to the waterfall we passed the mine entrance cut into shales and sandstones below the Scar Limestone. The level was driven south to intersect mineralised veins that run parallel to the valley to the south. Close to the waterfall it was possible to get access to the alternating, thin beds of

Bouseteems, Ashgill Field Mine

sandstones, siltstones and shales. Root marks were observed in one layer of sandstone and the shales were very black suggesting a high carbon content. These beds represented the upper parts of a cyclothem, when the delta top was emergent, and swamp conditions had developed.

The junction with the overlying Scar Limestone, of which approximately 10m are exposed in the waterfall, was very sharp but no obvious erosion marks could be seen. The limestone was a blue grey colour and comprised of horizontal, planar beds, each of approximately 30cm thick. Erosion of the underlying shales and sandstones has created an overhang (see photo back cover) below the limestone meaning it was possible to walk behind the curtain of falling water which, with the river in flood, was spectacular.

Retracing our path to the main valley it was decided that it was not worth extending the walk further in such wet conditions, so a path back was taken alongside the South Tyne, which here has cut into its bedrock forming a rock-lined gorge, which we followed back to Garrigill where Naomi and James were thanked before we all departed to get warm and dry.

Sunday: Cowshill and St John's Chapel, Weardale.
Leaders: Karl Egeland-Eriksen and Brenda Turnbull. Natural History Society of Northumberland

Fortunately, the torrential rain that was falling as we left Alston had cleared to be replaced by a day of sunshine and light showers by the time we met Karl and Brenda at Cowshill. After a brief introduction to the plan for the day and the geological background, we set off. Our first stop, on Burtreeford Bridge, was to observe the waterfall in the Killhope Burn, formed by the Four-Fathom Limestone which here was dipping very gently to the west. Walking upstream it was seen that the beds that lie above the Four-Fathom Limestone were now dipping in the opposite direction, i.e., to the east, and that their dip was increasing. At a point 300m above the bridge, where the dip had increased to ~45°, a brown weathering, unbedded rock appeared in the stream bed and banks. This was the top contact of the Whin Sill, the dolerite intrusion that underlies much of the North Pennines. Fresh samples of the rock showed it to be almost black in colour and composed of medium sized crystals of plagioclase feldspar and pyroxene. We were informed that on an earlier visit a small amount of mineralisation had been detected along the contact between the Sill and the overlying, hornfelsed shales.

Adjacent to the stream we were able to look into the waterfilled, Copt Hill Quarry, an abandoned working in the Whin Sill, and see its relationships with its surrounding sedimentary rocks. At the south end of the quarry the contact, which was only a few metres above the water level, and overlying bedded rocks, were both dipping steeply in an easterly direction. Northwards the

Dolerite Phaccolith, Copt Hill Quarry, Cowsgill

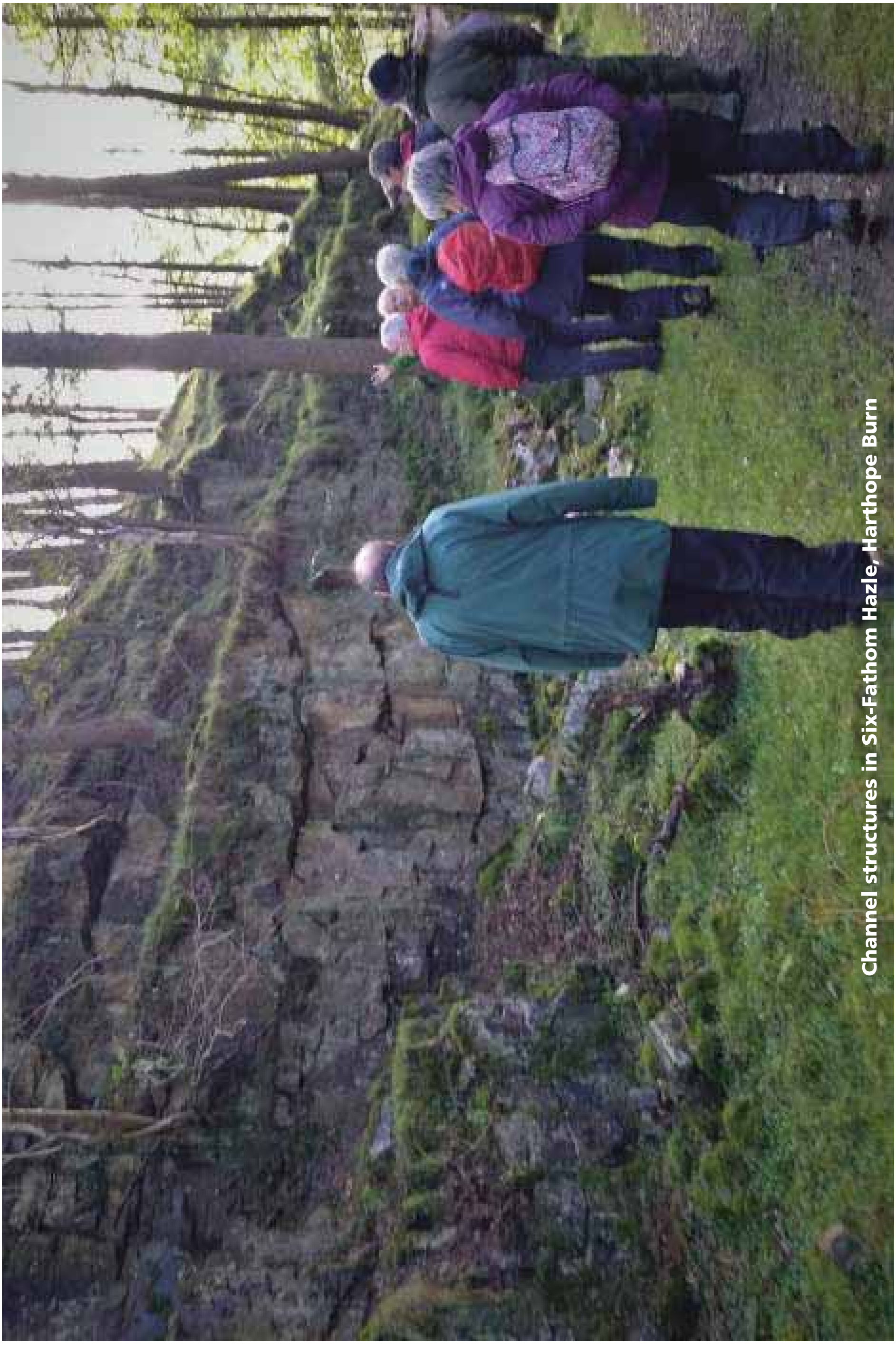
contact rose to a height of around 25m and it and the overlying, sedimentary rocks were horizontal, before both started dipping to the west. Throughout the outcrop the jointing in the Whin Sill remained vertical showing that the intrusion here has an arched roof and is therefore, because the base (although now invisible due to the lake) also curves upwards, is a phaccolith. (see photo above) The reason for this is that it is intruded into the core of the Burtreeford Disturbance, an important N-S structural feature that runs through the Alston Block. In places, such as here, the structure takes the form of an east-facing monocline, in others it is a fault. Displacement across the structure is approximately 150 m and it is possible that it may follow the same trend as older faults in the underlying, Lower Palaeozoic basement rocks. That we had walked from horizontally bedded rocks, through steeply dipping ones and back onto horizontal showed that the zone of disturbance is only a few hundred metres wide. Discussion took place on the origin of the magma, its mode of intrusion and cooling processes, both here and across the wider region.

Returning to the cars we drove further down Weardale to St John's Chapel, where lunch was taken before heading out up Harthope Burn, along what was once a tramway. The stream cut through more of the cyclothems where small waterfalls formed on the horizontal limestones and sandstones, similar

Zoophycos in Five-yard Limestone, Harthope Burn

to those seen in Ashgill the previous day. In this case these were the Five-Yard and Three-Yard Limestones which lie above the Scar Limestone that formed Ashgill Force. Bedding surfaces of the muddy, Five-Yard Limestone exposed in the stream bed showed an array of trace fossils, crinoid debris and occasional solitary corals. Particularly good examples were seen of ***Zoophycos***, the feeding burrow of a type of worm. (see photo above)

The tramway ended in a disused quarry, cut into the hillside and stretching for over 100m with faces up to 5m high. This was Harthope Quarry and was worked for sandstone which, in hand specimen was buff coloured, composed of quartz and extremely hard. Although bedding was generally horizontal there were good examples of cross-bedding and many channel structures. (see photo opposite) This is the Six-Fathom Hazle (hazle being the name miners used for sandstone beds in the N. Pennines) and is classed as a quartz-arenite as >90% of its grains are quartz, and in this case, are also cemented by quartz. These sandstones are extremely mature, having experienced much reworking before final deposition, probably in shallow marine conditions at the mouth of a distributary channel. Another feature shown in some beds were stylolites, irregular wavy lines caused by pressure solution of original grains, that occurs under high pressure conditions. The rock was worked by the Weardale Ganister Company for its high silica content and used to make firebricks for blast furnaces.



Channel structures in Six-Fathom Hazle, Harthope Burn

Climbing out of the valley up a flight of steps we crossed open moorland before continuing uphill to reach some old quarries. These had worked the Great Limestone which, as across much of its outcrop, formed a prominent bench on the hillside. Walking down a track that had been surfaced with mine and quarry spoil, specimens of purple fluorspar were collected, along with crinoids and corals and what were probably some pieces of Borrowdale Volcanics that may have come from glacial till. Reaching the Greenlaw Hush where the Greenlaw West Vein, which had proved rather unproductive compared to the neighbouring Greenlaw East Vein, had been exploited, a discussion took place over the technique of hushing (the practice of releasing water from a dam to assist in the excavation/exploration of mineral veins) and other mining methods. Descending into Daddryshield Burn, which had also been enlarged by hushing (see photo below), time was spent collecting samples of purple fluorspar and galena from the stream bed. Fluorspar was not originally exploited here, nor were the spoil heaps ever reworked when uses for it were found, which explained its abundance in the stream sediments. (see photo opposite)

Returning to the cars Karl and Brenda were thanked for a fascinating day. Like our other leaders for the weekend, their knowledge and enthusiasm was much appreciated and made a fitting end to our weekend.

Daddryshield Burn Hush

Fluorspar from Daddryshield Burn

Undercutting below Scar Limestone, Ashgill Force