LGA

Leeds Geological Association

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Field Visit Reports Summer 2022

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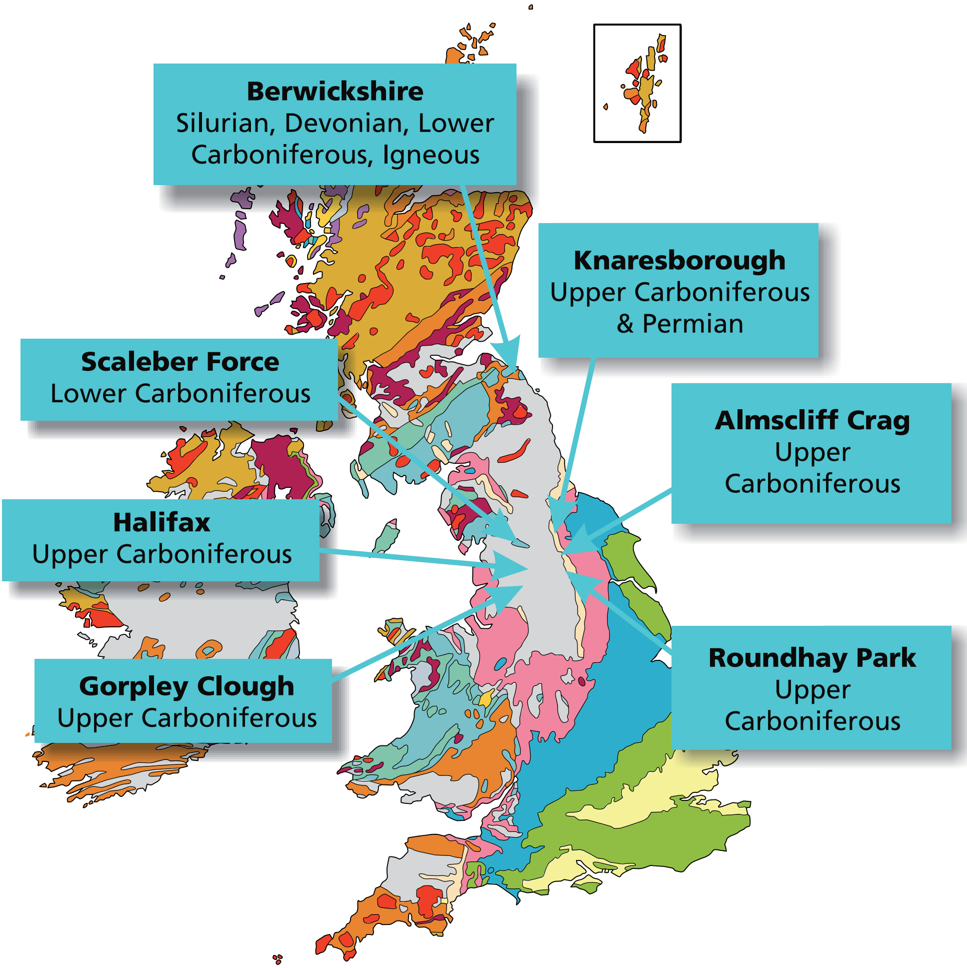
LGARocks

22 Where did we go?



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2022 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.

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Carboniferous and Permian Rocks of Knaresborough
Saturday 30th April

Leader: Bill Fraser, LGA
Present: 12 members, 3 visitors

The aim of the field visit was to examine the rocks exposed in the Nidd Gorge at Knaresborough by looking at their composition and sedimentary structures to determine their depositional environment and what they tell us about the Carboniferous - Permian succession, and how glaciation during the Quaternary Period influenced the formation of the gorge.

Rocks exposed in the Nidd Gorge were deposited during two geological periods and were laid down in very contrasting environments. The older of the two are Carboniferous in age and were formed during the Namurian stage, around 322 Ma when the area was part of the subsiding Pennine Basin which allowed for the accumulation of over 1000 m of alternating layers of gritstone, sandstone, siltstones, and mudstones, all part of the Millstone Grit Group.

At the end of the Carboniferous Period the sediments in the Pennine Basin were compressed against a rigid unit to the north, resulting in regional uplift and a long period of erosion that here removed all of the Coal Measures rocks as well as the upper parts of the Millstone Grit. Locally, this uplift formed the Harrogate Anticline, an asymmetrical, periclinal structure that, at Knaresborough, dips steeply to the NE.

The younger of the rocks were formed during the Upper Permian Period by which time the area was one of undulating relief on the western margin of a vast lowland basin. Breaching of the northern margin of this basin, which stretched all the way to Poland, resulted in the creation of the almost landlocked Zechstein Sea. As the area now lay in a hot, arid climate, the shallow sea evaporated. Fluctuations in its level resulted in the deposition of carbonates during times of higher levels but gypsum and calcareous muds when they fell. The carbonate was originally deposited as calcite, but much was quickly converted to dolomite resulting in the loss of most of the original textures making them difficult to interpret today. The oldest limestones lie with a marked unconformity on the eroded Carboniferous rocks. These are the Cadeby Formation which is divided into the Wetherby (lower) and Sprotborough (upper) Members. Above these are the Edlington Formation composed of gypsum and calcareous mudstones, followed by another limestone, the Brotherton Formation and finally the mud dominated Roxby Formation.

The most recent major effect on the geomorphology of the area was the fluctuation in climate during the Quaternary Period, resulting in the formation of ice sheets that ebbed and flowed across the region. The River

Nidd originally ran to the north of Knaresborough but, during the Devensian, outwash gravels and then the ice front moving down the Vale of York, blocked the route, creating a lake in the Nidd valley. This overflowed and exploited the lower, softest rocks between the ice margin and higher land to the west to form the Nidd Gorge.

After assembling at Conyngham Hall car park, we walked downstream along Waterside and Abbey Road on the north side of the river. The first stop was to examine the well-known and much photographed railway viaduct, opened in 1851. It is built of large blocks of pebbly sandstone, many showing cross and graded bedding with angular, poorly sorted grains of quartz and feldspar typical of the Upper Plompton Grit. Although there are quarries in this grit further along the road, the rock there is noticeably red in colour, which is not visible in the viaduct blocks, so it is unclear from where these blocks were sourced.

From there we climbed the steps and paths to the castle. On the way up, by the shelter, buff coloured dolomite of the Cadeby Formation could be seen, showing large scale cross-bedding dipping to the north. The rock is oolitic in places, with thin lenses of sandy material derived from Millstone Grit sandstones indicating the proximity of a shoreline. Further up, at the terrace, thinly bedded, weathered dolomite was exposed, but with cross-bedding now dipping towards the south.

We examined the castle walls, which are constructed of buff-coloured, locally quarried dolomite, mostly fine-grained but some being oolitic. Traces of shell debris were visible, and many blocks contained vugs, some of which were infilled. From the castle viewpoint there was an excellent overview of the glacial diversion channel. (see photo overleaf top)

Descending back to Waterside we examined the impressive vertical cliff section below the castle, which clearly shows the unconformity at the base of the Cadeby Formation. (see photo overleaf bottom) At road level 2-3 m of Addlethorpe Grit are exposed, a coarse-grained sandstone with pebbles and large-scale cross-bedding in which the heavily weathered remains of a fossilised tree could just be recognised. Immediately above this the unconformity was marked by blocks and fragments of eroded Addlethorpe Grit, held together by a dolomite cement, and dipping ~15° to the south. This was overlain by 6-7 m of reddish-buff sandy dolomite which in turn is overlain by ~17 m of dolomite showing large-scale cross-bedding, representing subaqueous dunes of the Cadeby Formation.

Progressing from Waterside into Abbey Road we stopped at Bunkers Hill Quarry, now a caravan park. The quarry entrance showed massive cross-bedded oolites of the Cadeby Formation, while inside the quarry the large scale of the structures could be clearly seen. A little further along the road at the 'House in the Rock' and the 'Chapel of our Lady of the Crag' the same features could be seen, and represent large, sub-aqueous, oolite sand waves of the upper, Sprotbrough Member of the Cadeby Formation.

The Nidd Gorge glacial diversion channel and viaduct. Knaresborough.

Unconformity between Carboniferous age Addlethorpe Grit and Permian age Cadeby Formation limestone. Waterside.

Further along Abbey Road, above Amtree House and Frogs Hollow, the unconformity was again clearly visible. The underlying Upper Plompton Grit is in the form of a rounded, buried hill with an exposed relief 8 m high and 32 m wide, covered by thin beds of the Cadeby Formation showing large-scale cross-bedding of 1-10 m on its flanks. The unconformity then dips down out of sight into a buried valley.

A short distance along the road is a quarry where the unconformity reappears, exposing 3.6 m of Upper Plompton Grit overlain by 13.5 m of Cadeby Formation. The sandstone is very coarse - to granule-grained, feldspathic with quartz pebbles, in cross-bedded units, and very reddened by weathering. Between this and the overlying limestone could be seen a thin, impersistent bed (0-0.1 m) of yellow, very coarse-grained sandstone with a dolomitic cement. It is unclear as to whether this is part of the Carboniferous sandstone re-cemented with dolomite, or a very sandy bed at the base of the Permian.

A second quarry shows the same unconformity, but higher up the cliff, with an exposure of 10.5 m of mainly massively bedded Upper Plompton Grit, a reddened, coarse-grained, angular, and poorly sorted sandstone, overlain by 4 m of dolomite. (see photo overleaf top)

The last locality visited on Abbey Road was St. Robert's Cave, the alleged home of a hermit in the late 12th century renowned for his charity to the poor and destitute. Cross-bedded oolitic dolomite beds are exposed, showing a channel structure to the south of the cave. Sparse fossils have been found that show this is probably the lower, Wetherby Member of the Cadeby Formation, although it must wedge out rapidly to the south as it is not present at Grimbald Crag, 300 m to the south on the opposite side of the river.

Crossing over the River Nidd at Grimbald Bridge we took the path back towards Knaresborough on the south side of the river. At the northern end of the caravan park, we took lunch in the sun on outcrops of a coarse, pebbly sandstone exposed in the river bed showing trough cross-bedding. This is the Lower Plompton Grit, which was again seen in the path that climbs over Grimbald Crag where dolomitic limestones of the Sprotbrough Member were visible above, indicating that the unconformity must be close by.

Running ~ENE-WSW across the loop in the river is the Grimbald Crag Fault, down-throwing to the south, and further along the path, exposures of Permian rocks close to river level, were evidence of this. These were horizontal, thinly bedded, fine-grained limestones of the Brotherton Formation, in which have been found fossils such as the bivalve ***Schidozus*** and threads of the algae ***Calcinema***.

A short distance further along the path a prominent spring marked the point where the Grimbald Crag Fault crosses the river. Here the Brotherton Formation limestones lie alongside those of the Cadeby Formation.

Massive, reddened Plompton Grit. Abbey Road.

Calcutt cricket ground is the site of an old quarry, excavated into the limestones of the Sprotbrough Member of the Cadeby Formation. Close examination of the limestones was not possible due to a cricket match taking place but from a distance they could be seen to be cross-bedded and have many solution hollows. Here on the west side of the river the top of the Cadeby Formation lies at 53 m O.D, where it is overlain by the Edlington Formation. On the east side of the river, however, the top of the Cadeby Formation is at 75 m O.D. Since the Lower Plompton Grit occurs in the riverbed on both sides of the gorge, and the Permian beds are dipping gently to the east, this difference in thickness shows how the Permian strata thin to the west.

Recrossing the river at Low Bridge we continued upstream past our starting point, before climbing up a steep overgrown slope underlain by weathered Carboniferous siltstones, to an outcrop below the boundary wall of Conyngham Hall that exposed 1 m of Cadeby Formation limestone overlain by ~2m of red-brown mudstones and siltstone of the Edlington Formation. (see photo opposite) The very thin Cadeby Formation again illustrates how the Permian rocks thin to the west. 50 m further along the riverside path, the weathered Carboniferous siltstones were seen in the riverbank, dipping east. Above them the Cadeby Formation was now ~2 m thick.

The next location was the bank and bed of the river where, near Conyngham

Hall, it is spanned by a footbridge. On the east side and dipping east at ~30° were two thick (~2 m) beds of coarse-grained sandstones separated by ~0.5 m of mud and siltstone. Scour marks appear on the base of the upper bed. This is the Upper Follifoot Grit which crosses the river, forming the foundations of the bridge, with more outcrops on the west side in the riverbed and bank. These outcrops also showed two beds of massive sandstone with bark impressions on their upper surfaces, separated by silts and a clay. These outcrops lie on the 'nose' of the Harrogate Anticline and would have formed a low rise in the landscape before being submerged by the marine transgression which deposited the basal Permian beds.

The final exposure, in a heavily overgrown quarry in Foolish Wood, showed coarse-grained sandstone of the Upper Follifoot Grit dipping at around 30° but now to the south-east indicating a position on the southern limb of the Harrogate Anticline. At the back of the quarry the sandstone was overlain by dolomitic limestone of the Cadeby Formation with patches of a basal conglomerate of locally derived sandstone fragments.

We finally arrived back at our starting point and those who had completed the full circuit thanked Bill for an informative day around what is such an accessible site.

Cadeby Formation limestone overlain by Edlington Formation mudstones. Conyngham Hall.

Gorpley Clough (nr Todmorden)
Saturday 28th May

Leader: Dr Gareth Martin, LGA and WYGT
Present: 4 members

Situated right on the Yorkshire / Lancashire border the clough is a steep sided, wooded valley featuring a succession of waterfalls with, tucked under the steep hillsides running down from the Pennine watershed, Gorpley Reservoir at its head. The site lies immediately to the west of the axis of the Pennine Anticline, so dips are at low angles to the southwest. In the past the valley has seen industrial development and remains of a water powered cotton mill and coal mining are still visible. It is one of West Yorkshire Geology Trust's Local Geological Sites and on a warm sunny day it was a very attractive place to be.

The clough exposes an almost continuous succession through Millstone Grit Group rocks of Upper Carboniferous Marsdenian and Yeadonian age during which the area was part of a vast delta system that was prograding into a shallow sea. Periodically the delta was inundated by rapid sea level rises only for the delta to rebuild resulting in a cyclic pattern of sedimentation.

On leaving the small car park the first rocks encountered were seen through the trees, exposed high up in the steep slopes above the path. Due to the steep gradient of the valley floor, we were soon able to access these at path level where they formed the first of a series of waterfalls. They consisted of a thick succession of mudstones and siltstones, overlain by thickly-bedded, fine to medium grained, micaceous sandstones with well-developed cross-bedding that created the waterfall. These rocks form the lower part of the Marsden Formation, and the sandstone is the Fletcher Bank Grit, which here is approximately 20 m thick. The mud and siltstones represent deposition in a low energy environment in offshore areas in front of a delta, the siltstones possibly being due to higher energy conditions during flood events. Although the contact between the sandstone and mudstone was sharp, no evidence of scouring could be found suggesting that the sands had prograded over them rather than having been formed in a river channel (when the contact would more likely be scoured) and that they were possibly the product of delta mouth sand bars.

Continuing up the clough we came to a second waterfall created where another sandstone overlays mudstones. (see photo opposite top) The sandstone here, the Guiseley Grit, was coarser than the Fletcher Bank Grit and its contact with the underlying mudstones irregular, with prominent scour marks. Within the sandstone large scale cross-bedding was clearly seen along with washout structures. These features, along with the coarse grain size, show that this sandstone was deposited within a braided distributary channel

Waterfall created by the Guiseley Grit. Gorpley Clough.

Iron staining caused by water seeping out at base of Huddersfield White Rock. Gorpley Clough.

of a delta which had cut into the previously deposited muds. An interesting feature of this waterfall is the existence of a tufa screen, a feature normally seen in rivers that have flowed over limestone, posing the question as to what the source of the carbonate is?

A short distance further up the clough it widened due to the existence of more easily eroded, thick mudstones above the Guiseley Grit. At a point where these were visible on the opposite bank, the mudstones were stained bright orange due to iron rich water that was flowing out of a sandstone layer that lay above them. (see photo overleaf bottom) This marked the base of the Huddersfield White Rock, the youngest sandstone of the Marsden Formation exposed in the clough.

Climbing out of the clough and admiring the masonry of the spillway of Gorpley Reservoir we walked up alongside it to reach one of the deep gullies cut by streams feeding it. On the way Gareth pointed out the likely position in the reservoir bank of the marine band that marks the boundary between the Marsden Formation and the overlying Rossendale Formation which we would see next.

The first rocks encountered were black mudstones, several metres thick, indicating deposition in a low energy environment. Above these the sediment became siltier, brown-grey in colour and contained ironstone nodules. These were the Lower Haslingden Flags and represent deposition in better oxygenated, shallower water conditions, possibly at the front of a delta distributary channel. Above the flagstones was another bed of black mudstone showing a return to deeper water, anoxic conditions before another band of flagstone, the Upper Haslingden Flags marked a return to shallower water conditions. These flagstones, like those below them, are more siltstone than sandstone but also contained a high proportion of ironstone nodules. Viewed from above the gully, the two bands of flagstone could be seen to form obvious features on the hillside which is at odds with the current BGS map for the area which only shows the lower unit at this locality. The Haslingden Flags were extensively quarried and split for paving stones in places where they were sandier and harder, but here they are too soft and easily weathered. Another notable feature of the flagstones and the underlying mudstones was the presence of a fairly dense system of vertical, mud filled vein structures running through them. (see photo opposite top) The origin of these is uncertain but they are possibly dewatering structures.

The variations in these lower beds of the Rossendale Formation led to discussion as to the causes. From other localities in the area, but which we did not visit, evidence shows that palaeocurrents here flowed from a westerly direction unlike deposits of similar age further east. A possibility is that these in Gorpley Clough were deposited in a birds foot type of delta with switches in channel directions leading to variation in sedimentary environments.

Concretions and mudstone veins in Haslingden Flags. Gorpley Clough.

Lower Meltham Coal. Gorpley Clough.

Walking back to the car park via a path along the valley side rather than its floor, we passed the entrances of three mines driven into the hillside. A recently fallen tree as well as work to widen the path exposed their purpose, a thin coal seam. This is believed to be the Lower Meltham Coal which lies between the Guiseley Grit and the Huddersfield White Rock. The coal was around 30 cm thick and overlain by a thin clay topped by siltstones and flaggy sandstone (see photo overleaf bottom) and show that parts of the Millstone Grit delta were emergent and stable enough to support vegetation for some time. The age and extent of these workings is unknown.

Arriving back at the cars, Gareth was thanked for an interesting day in an area that was new to all members of the party.

Almscliff Crag
Tuesday 21st June (evening)

Leader: Dr Crispin Little, SEE Leeds University
Present: 17 members, 7 visitors and one dog

We met at 6 pm on a beautiful sunny, warm evening with light winds and good visibility that enabled many local landmarks to be identified, including the North Yorkshire Moors, the Yorkshire Wolds and York Minster. Cris explained that the purpose of the visit was to look at the lithology and structure of the Crag and its setting in the wider local area.

Almscliff Crag (see photo below) is formed of Carboniferous, Namurian age Almscliff Grit, part of the Millstone Grit Group. Now re-named Warley Wise Grit, this belongs to the Pendleian sub-stage and is probably the oldest Millstone Grit in the area having been formed 329-328 Ma when Britain, as part of the Laurasian continent, lay on the equator. There was a large icecap at the south pole and fluctuations of this caused sea levels to vary. This resulted in cyclic deposition with non-marine conditions predominating as deltas advanced into shallow seas when the level dropped, depositing mainly sands, only for them to be inundated when levels rose and for marine muds to dominate.

Almscliff Crag.

Cris explaining cross-bedding at Almscliff Crag.

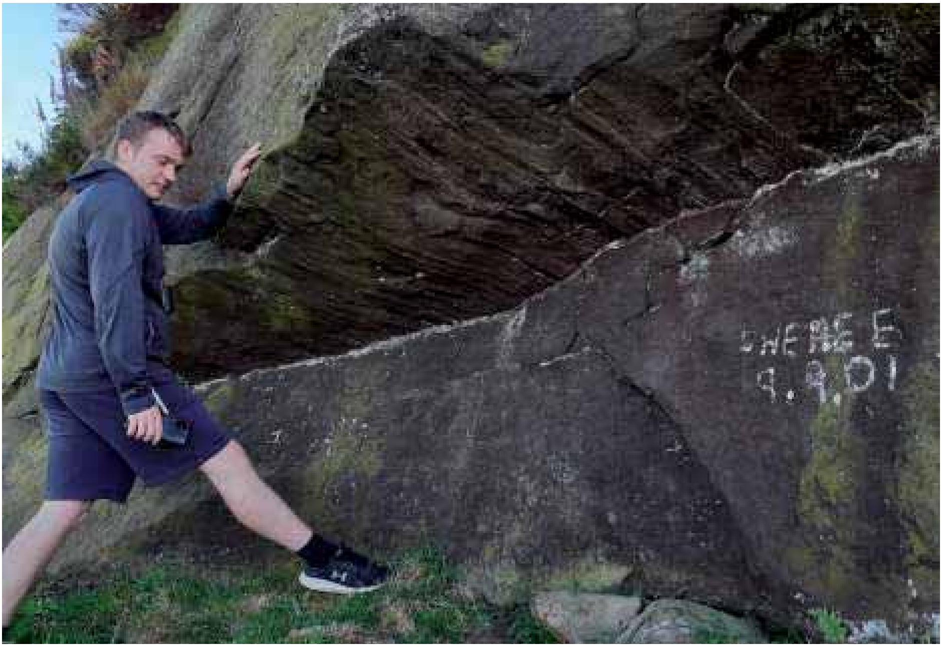
The sediment was deposited within a braided river that was part of a vast delta system and, as detail of the cross- bedding shows, the river flowed from the NE. (see photo above) The rock is very coarse-grained with some large quartz clasts. Grains are mostly quartz but with some orthoclase feldspar which indicates that the parent rock was granitic. Some of the material can be traced back to Scotland (or further) where the Caledonian Mountains, formed during the creation of Laurasia, were present. In some places patches of the grit were seen to be riddled with irregular shaped holes. These mark places where mudstone flakes, ripped up and included in the sediment at the time of deposition, have been weathered out. As well as transporting sediment, the river had also transported tree debris and several fossils of this were seen, one showing the distinctive diamond-shaped bark of ***Lepidodendron.*** Another showed a large diameter 'log', possibly from the 'Giant Horsetail', ***Calamites.***

The grit is about 100 m thick, much more than the same grit adjacent which is 65-75 m and the thickening is below the 'standard' base. Beds are several metres thick showing good examples of cross-bedding. Particularly well shown was 'trough cross-bedding' formed as subaqueous, crescent shaped dunes, several metres tall, moved downstream on the bed of a powerful river system.

The Crag is situated on the southern side of the SW to NE trending Harrogate Anticline and looking NE from the summit of the Crag, we could see the long crescent of the anticline picked out by the grits as, being harder than the surrounding mudstones, they form prominent ridges. (see photo below). Being on the southern side of the anticline the regional dip in the area is 15°-20° to the SE however, the bedding on parts of the Crag was seen to be dipping to the NE. An explanation for this anomaly, and thickness, has been provided by Chisholm (1981) who suggested that a low angle, southerly dipping fault seen on the north side of the crag was a 'growth fault'. (see photo overleaf top) A growth fault is one that was active at the time of deposition and resulted in gravity induced movement of a coherent mass of sediment along a curved surface. As the slipped mass moved down the fault it tilted backwards (explaining the contrary dip direction) allowing the build-up of a greater thickness of material on the down-throw side than in the adjacent area, which explains the local thickening. The crag is therefore seen as a 'tilted block' similar to a rotational landslip but of origin contemporary with deposition. The standard SE anticline dip was seen on a separate small exposure to the east of the crag. This is a younger part of the Warley Wise Grit sequence and suggests that the effect of the growth fault was not long-lasting.

While standing on the top of the Crag, Cris outlined how the local landscape

Looking along the southern limb of the Harrogate Anticline.



Growth fault. Almscliff Crag.

features had come into being. Looking east The Vale of York had been formed by ice eroding soft Triassic sandstones. Although the whole area would have been overridden by ice during earlier glaciations, during the last, the Devensian, the Howardian Hills and North York Moors stood above it. Cris explained that the Dales valleys would have been pre-existing rivers which were occupied and deepened by eastward flowing glaciers. To the south, Wharfedale has a steep scarp slope on its southern side composed of south dipping grits which form an east-west ridge that makes up Otley Chevin and Ilkley Moor. At its maximum the valley was filled with ice to a level high on Ilkley Moor marked by Lanshaw Delves, a lateral moraine. Between Ilkley Moor and Otley Chevin, Menston Gap was cut by ice spilling south into Airedale. The lowest point reached by the Wharfedale Glacier is marked by the Arthington Moraine behind which a lake once stood before being breached at its northern edge by the River Wharfe. The fact that Almscliff Crag stands up as an isolated tor is probably due to a combination of the hardness of the grit, its local thickening and faulting.

Amongst the growing crowd taking advantage of the perfect evening to celebrate the summer solstice Cris was thanked for his time and explanations of this prominent local feature.

Roundhay Park Geology Trail
Date: Sunday 17th July (am & pm)

Leader: Bill Fraser & Howard Dunnill, LGA
Present: 8 members 17 visitors

2022 was the 150th anniversary of the opening of Roundhay Park as a public park following the purchase by the City of Leeds of the estate of the Nicholson family. The LGA were asked by the Friends of Roundhay Park if we would like to contribute to the programme of celebrations they were planning for a week in July. An evening talk during the week on the geology of the Park followed by two guided walks around the geology trail (that was established in 2006 in partnership with FoRP) on the following Sunday were offered and gratefully accepted.

The talk, given by Bill Fraser, was held in the Ann Maguire Education Centre at the Mansion House in Roundhay Park and was well received by an audience of around 20 people which included some LGA members. The walks had to be pre-booked and were each limited to 15 participants and pleasingly were both almost full, again with a mixture of members and non-members. Two factors did arise however before they took place that did create some concerns. The first was that, on a recce during the preceding week, it was discovered that mountain bikers had constructed two sizeable 'jumps' off the top of the rock faces at the locality known as Scouts Quarry. A request to the Parks Department workforce resulted in one of these being removed but the second one would require the use of machinery. The second factor was the increasing dire weather warnings; not of heavy rains (which is what we might expect in a British summer) but of extreme heat! As most of the trail is in a heavily wooded area it was felt that this would reduce the temperature so, while warning participants to come prepared, it was decided to proceed.

On the day both walks ran smoothly with Bill and Howard accompanying each group (see photo overleaf) around the ten localities. Bill always encourages participants with suitable prompts to 'look for themselves' before expanding on these by giving further details and explanations of what they mean. As well as making full use of what can be seen at each locality, he also provides hand specimens of all the rocks and fossils. As the trail has been described in previous editions of this booklet and many members will have walked it before and have the trail guide, it is not proposed to describe it in detail here but to give a simple summary.

The rocks exposed in the Park provide the detail of the final phase of the formation of the Namurian, Millstone Grit delta. The oldest rocks are dark grey mudstones and shales deposited in both marine and non-marine low energy environments. These are succeeded by medium grained, well bedded sandstones (Rough Rock Flags) marking the advance of a delta front. These in turn are overlain by coarse grained, feldspathic sandstones (Rough Rock) which, along with the strong cross-bedding they display, show that they were deposited in fast flowing, braided river channels on a delta top.

Once the delta had become established its surface was covered by thick forest which, due to periodic inundation, and slow subsidence, resulted in the formation of the Coal Measures Group of which two small exposures occur on the downthrow (south) side of the Roundhay Park Fault that runs E-W through the Park. Other structures seen on the trail are a narrow zone of tightly folded shale (which probably includes a fault) and a textbook example of a normal fault. The only exception to the Carboniferous story is the material used in construction of 'The Folly' which is built mainly of rounded cobbles of Addingham Edge Grit which were dug from the Anglian till that mantles the area.

Participants in Roundhay Park walk.

Geology and Industrial history of Halifax – Shibden area
Date: Saturday 13th August

Leader: Michael Wood, LGA
Present: 10 members

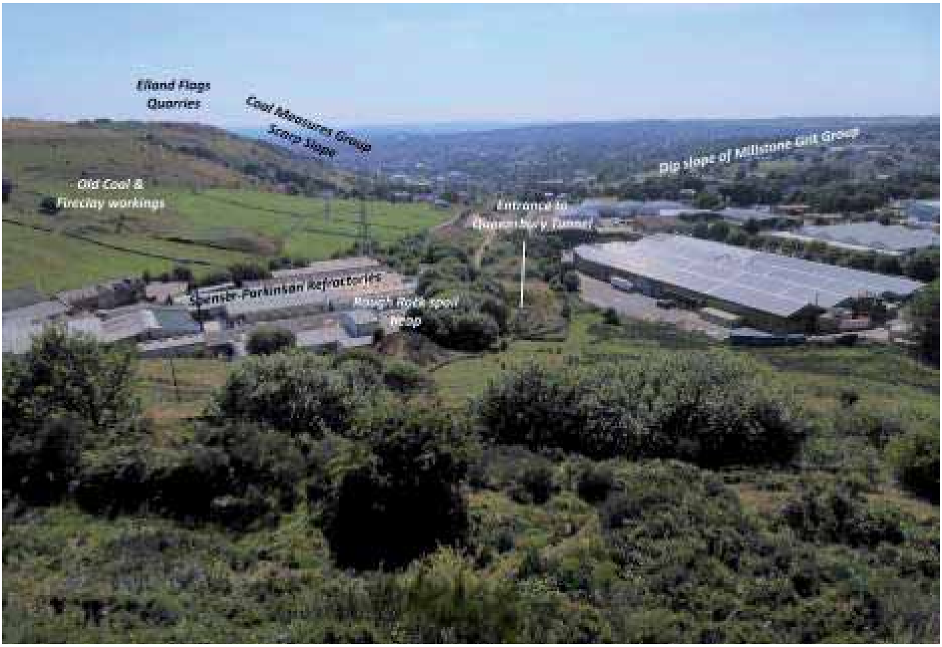
Located on the eastern slope of the Pennine Anticline, Halifax is situated at the interface of the Millstone Grit and Coal Measures Groups, the upper surface of the Millstone Grit dipping to the east from a height of 300m, and the scarp face of the Coal Measures rising to 300m as Pule Hill to the east of the town. (see photo overleaf) Six coal seams are found in the Coal Measures sequence, namely the 'Soft', 'Middle', 'Hard-bed', '36 Yard', '48 Yard' and '80 Yard,' with the 'Hard-bed' and 'Soft' being the most workable. To the south is the valley of the River Calder running west to east with drainage to the valley at Halifax from the gritstone to the north-west via cloughs (deep, steep sided valleys) and especially Hebble Clough.

Halifax grew as a town built almost exclusively of stone by extensive quarrying of both gritstones and Coal Measures sandstones; buildings, roads and pavements show the wide range of applications of stone from different sources: high quality 'Ashlar' lintels (often carved), mullions for doors and windows, cut and dressed stones for walls, and thinner, cleaved Elland flags for paving and roofing tiles.

Weaving of woollen cloth started as a cottage industry in medieval times with locally sourced fleeces prepared by cleaning in the soft water of the Hebble. Dwellings were designed to include a loom within the living space, wool was delivered to the door and 30-yard pieces of cloth produced for sale. In the 1500s Halifax was one of the three main centres of woollen fabric production in the country, using pack horses as the main form of transport. Business grew and eventually led to construction of the neo-classical Piece Hall, completed in 1779 as a trading centre, a great statement of wealth, pride and ambition – and remains today as a unique example of Georgian architecture.

The industrial revolution led to large scale production of cloth from factories built alongside the course of the Hebble, increasing the working population and demand not only for housing but also for coal. Great effort was required to extract coal from local seams by both shafts and adits and also to deliver it to factories and homes by pack horse.

Extraction of fireclay associated with the coal seams for production of refractory products started originally using pick and shovel, but with modern extraction methods became a long standing and important local industry,



Looking SW from Strines showing relationship between rocks and landscape.

and the most noted Halifax Hard Bed fireclay from the Shibden Valley has been in demand for over 200 years.

The railway arrived in the town in the mid nineteenth century but with great difficulty as local topography required the track bed to climb over 30 metres on the approaches to the town to reach a suitable location for the station, the line continuing east to Bradford. Later, from 1874 to 1878 a major project constructed the Queensbury rail line up the dip slope from Halifax and then east to Queensbury and Bradford with a branch to Keighley, a main feature of which was the 2.3 km long Queensbury Tunnel. This greatly helped the transport problems of Halifax. This very large investment at the time had twin tracks throughout, a complex triangular junction west of Queensbury, and many bridges and viaducts to cross difficult terrane. The lines were eventually closed in 1955. (Current efforts to reopen the tunnel as part of an amenity for public use are currently being frustrated by engineering complications and rising cost).

Despite this innovation, difficulty in meeting demand for, and delivering, coal, and difficult communications Halifax could not compete with more modern transport and better terrane with convenient access to coal in Bradford and Leeds which led to a decline in the weaving industry in Halifax.

On an extremely hot day of unbroken sunshine, we visited six sites to examine evidence of the geology and geomorphology involved in the evolution of the town and its industries.

At Claremont, exposures in the upper part of Godley Cutting (cut originally to allow transport of coal, sandstone and fireclay downhill to Halifax from Shibden but now the main road to Bradford) show ~ 10m of horizontal beds of mudstones, thin sandstones and bands of ironstone belonging to the Coal Measures. The abutments of the bridge carrying Lister Road across the cutting showed the use of local sandstones, typical of the area. (see photo overleaf top) In this case they were large blocks of coarse-grained Rough Rock (Millstone Grit Group) and smaller ones of a medium-grained, Coal Measures sandstone, both of which would have been quarried nearby. Further to the south at the entrance to the Aquaspersions factory car park in the face of an old fireclay quarry, we were able to access similar beds lower in the sequence. These were mostly shales with ironstone nodules but also exposed was a thin, poor quality coal seam.

We ascended Pule Hill on the Coal Measures scarp to visit Springfield Quarry, (see photo overleaf bottom) a family business working the Elland Flags. Stone quality varied through the quarry; thickly-bedded, well cemented, medium to fine-grained sandstone that provided good quality dimension stone was being worked at the lowest level above which, close to a small fault complex that runs through the quarry, thinly-bedded sandstone was being worked and cut for paving stones. There were also horizons consisting of soft, ripple marked sandstone and dark, extremely micaceous mudstones that were cast aside as waste. Included in this were sandstone blocks and slabs with the fossils of ***Calamites.***

Following lunch at the hostelry appropriately named The Shears Inn in the steep-sided, lower reaches of Hebble Clough we could see the difficulties presented to early workers in the wool trade and the benefits of transport by pack horses. It was however a useful location for creating energy from the Hebble by water driven wheels, made viable by the steady flow through the seasons as water drains all year round from the gritstone aquifers above. This avoided generating power from the main river in the valley which was prone to the risk of periodic floods. Also at this location was a very good exposure of the Rough Rock, the youngest of the coarse-grained sandstones of the Millstone Grit Group which underlie the Coal Measures, showing a variety of cross-bedding features. This was also another good location for looking at how different rock types had been used in construction of the buildings.

On the edge of the Coal Measures scarp face at Holmfield is an old shaft that was probably dug to provide ventilation to adits driven into underlying Coal

Use of local stone. Halifax.

Elland Flags being worked in Springfield Quarry.

Measures to extract coal and fire clays for the brick, tile and ceramics industry, some of which still operate today (albeit with material imported from elsewhere).

At Strines, another location on the Coal Measures scarp (see photo page 22), we passed an overgrown spoil heap created during the construction of Queensbury Tunnel. Although heavily overgrown this could be seen to consist of shales and mudstones reflecting the nature of the underlying rock. Some members made the steep descent to the valley floor past some old workings that revealed heavily weathered shale and fireclays to where the (now flooded) entrance to Queensbury Tunnel, which had been cut in the Rough Rock, was viewed. On the ascent, another spoil heap created during the tunnel construction was seen to consist entirely of blocks of Rough Rock and, at a higher level, burnt brickwork and furnace slag which suggested that iron smelting had been performed here at some time.

Finally, we reached the top of Soil Hill where the 48 Yard Rock, a Coal Measure sandstone, was once quarried. In the middle of a field adjacent to a derelict farm we examined 'Soil Henge' (see photo overleaf) which consisted of 1m wide sandstone slabs set into the ground in a 15m diameter circle around a dip in the ground. Another use of stone but for what purpose? Turns out it is a dew pond with a cleverly arranged gap in the slabs at one point to allow only one animal to drink at once and avoid fouling the water! (They thought of everything). The top of the infilled sandstone quarries, at a height of 400 m, provided an excellent vantage point. To the south the Millstone Grit dip slope meeting the Coal Measures scarp and the locations we had visited earlier could be seen, along with landmarks on the Pennine Anticline to the south and west. Nearer to the west was Ovenden Moor, the catchment area on gritstone for the Hebble, feeding into Ogden Reservoir before descending through the town, finally into Hebble Clough. Looking east we could see across Bradford, Leeds and beyond.

We thanked Michael for his extensive preparation for the visit and his energetic leadership on the day and noted that there is much more of interest for us to consider for a future visit to the area.

'Soil Henge', built of flagstones. Soil Hill.

Scaleber Force
Sunday 11th September

Leader: Bill Fraser, LGA
Present: 9 members

Parking three miles east of Settle on the road to Airton we were able to cover seven different locations without venturing more than a mile from our cars. However, the morning did test our stamina and knees with two significant descents to Scaleber Beck and back up again.

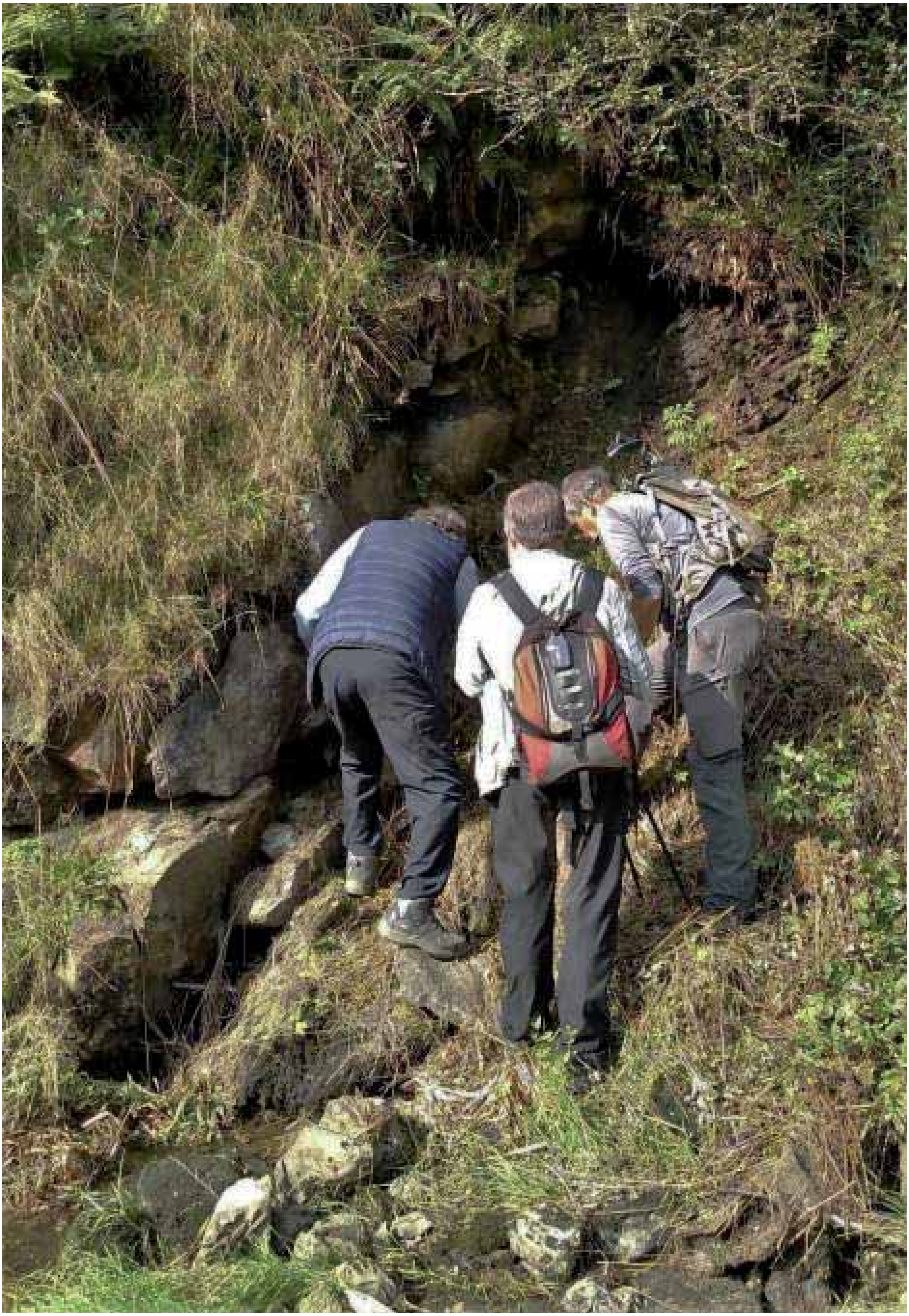
Bill provided excellent groundwork for the day, distributing a comprehensive handout with photos, tables and maps. He also gave an introduction, offering a geological history of the region before explaining in more detail the specifics of the locations we were about to inspect.

Scaleber Force lies on the boundary between the Askrigg Block and the Craven Basin, two structural units that were fundamental in controlling sedimentation during the Lower Carboniferous Period. A relatively thin sequence of mainly carbonate sediments were deposited on the block while at the same time thick mudstones were deposited in the basin. The boundary between the units is marked by the Craven Fault System comprising the North, Mid and South Craven Faults which were active throughout the Carboniferous and at various times since. Scaleber Force lies between the Mid and South Craven Faults in a transition zone, known as the 'Reef Belt', sharing characteristics of both units as well as having some unique features of its own.

The total displacement of the Craven Fault System is variable but is up to 1.8 km in places. It is believed that up to around 4 km of sediment accumulated in the Craven Basin in the Carboniferous Period as the land subsided and that a substantial proportion of these deposits of mudstones, limestones and sandstones were transported into the basin from the north thus crossing the transition zone on their way.

The morning session was spent south of the road.

The first location visited was Scaleber Force to view the Scaleber Force Limestone (Arundian), a 22 m thick sequence of limestone interbedded with mudstone. (see photo on front cover) The beds lay sub-horizontally and the limestones have formed undercut ledges due to the differential erosion of the softer mudstones. Both limestones and mudstones are relatively dark in colour, and both are fossiliferous containing crinoids, brachiopods, corals and trace fossils. This was the oldest sequence of rocks that we encountered, dating to 345-350 Ma, and were some of the first deposits on the block and indicating that a shallow marine environment existed here at that time.



Examining the South Craven Fault in Scaleber Beck.

Our next stop, a short distance downstream, involved another steep descent, the long, dry grass allowing a form of sledging to speed up the process and to avoid knee pain. Three weeks earlier Bill had been to this site to clear vegetation so we could enjoy a decent view of the South Craven Fault. (see photo opposite) On the south side (footwall) of the fault an almost horizontal, massive sandstone has a clean break but next to it were soft, dark grey, northward dipping mudstones. Close to the fault plane the mudstones were seen to dip in the opposite direction, having been deformed as the land to the south dropped. The sandstone is part of the Pendle Grit Formation (Pendleian) which were the youngest rocks seen on this trip but are here downthrown to lie adjacent to the Upper Bowland Shale (Brigantian).

After lunch we walked north and upstream along Scaleber Beck. First stop was the Scaleber Quarry where we spent some time examining features of the Scaleber Quarry Limestone (Arundian-Holkerian). Here the well-bedded limestone dips at 10-15° to the northwest. This limestone is paler than the underlying Scaleber Force Limestone. The main interests were the crinoid debris, the in-situ ***Lithostrotion*** colonial corals (again indicating a shallow marine environment), chert bands, and the brown (iron staining) colouration associated with dolomitisation.

Leaving the quarry and walking north we spent the rest of the afternoon looking at the Upper Bowland Shale and the remarkable Limestone Conglomerate (Asbian-Brigantian) in Scaleber Beck. My previous understanding of the word conglomerate was of rounded pebbles in a matrix. The Limestone Conglomerate here is made up of blocks and boulders of limestone, many strewn around randomly, and lying unconformably on top of the well-bedded Scaleber Quarry Limestone. The blocks and boulders consisted of both reef and bedded limestone and indicate a period of uplift and erosion of the southern margin of the Askrigg Block.

One of the features of this part of the walk was that rock outcrops appeared to be dolomitised in no obvious pattern, so we saw patches of brown, dolomitised limestone next to patches of grey. In Scaleber Quarry there had been evidence that the dolomitisation process was associated with joints but here in the beck it was not apparent. One dolomitised exposure showed another fine example of the coral ***Lithostrotion*** which, unlike those seen in the quarry which were in-situ, appeared to have been Inverted. (see photo overleaf top)

In the beck we had another opportunity to inspect the Upper Bowland Shale that we had seen at the fault site earlier in the day. It is exposed across the transition zone resting on rocks of various ages and here was unconformable on the Scaleber Quarry Limestone and Limestone Conglomerates, probably filling a hollow eroded during a phase of emergence. It was deposited during a period when, due to movement along the Craven Faults, deeper water encroached northwards, bringing conditions of the basin onto the block, causing the limestones to be buried in this dark grey mud.

Inverted *Lithostrotion* in dolomitised Scaleber Quarry Limestone. Scaleber Beck.

Our final stop involved a slightly longer walk southeast to Black Gill Beck a tributary of Scaleber Beck. Here, embedded in 20 m of black shale of the Upper Bowland Shale, is another thick patch of Limestone Conglomerate. (see photo below) These are younger than those seen earlier and the fossils in the boulders, brachiopods and crinoids, identify them as having been derived from Yoredale Group deposits. They can only have arrived here by some form of mass movement event, having been dislodged from their original positions somewhere to the north, possibly from a scarp face created by movement along the Mid-Craven Fault.

Limestone conglomerate embedded in Bowland Shale. Black Gill Beck.

From there we returned to our cars for the return home. A perfect day. Lots of well explained geology (fossils, sediments, minerals and chert, plus all the larger scale structural and stratigraphical observations), good conversations and perfect weather (dry with Goldilocks temperatures).

Residential visit to Berwickshire
Friday 7th - Sunday 9th October

Leader: Alison Tymon, Edinburgh Geological Society
Present: 15 members

Geological setting:
Throughout Lower Palaeozoic times the area to be visited lay near the north-west margin of the Iapetus Ocean when thick deposits of Ordovician and Silurian age sediments accumulated in an ocean trench formed as the ocean floor was subducted beneath the Laurentian continent. The sediments, which consist of turbidites interbedded with black shales, are interpreted as either belonging to a fore-arc accretionary prism that developed above the subduction zone along the trench slope or in a back-arc basin. Whatever their origin an imbricate structure which developed during and after deposition, resulted in a series of fault bounded slices of thick greywackes overlying black shales all tightly folded and dipping steeply to the north-west with successive slices becoming younger to the south-east.

By the end of the Lower Palaeozoic this part of the Iapetus Ocean had closed, and marine sedimentation was replaced by a phase of extensive volcanism. This involved large volumes of pyroclastic material being ejected, extensive basic lava flows, dyke intrusion as well as larger, more acid, bodies. In early Devonian times volcaniclastic deposits formed from subaerial erosion of these rocks. Further tectonic activity folded and faulted the rocks into broad structures with a NE-SW trend. In Upper Devonian times the area formed part of a land mass of hills surrounded by plains and was subjected to subaerial erosion in a tropical climate which resulted in the spread of fluvial deposits across the lowland parts.

By Lower Carboniferous times the lowland area had subsided and was covered by shallow lakes and coastal lagoons which were subject to partial evaporation resulting in the deposition of calcareous mudstones and fluvial sandstones. Another episode of volcanic activity, during which basaltic lavas and tuffs were erupted, preceded the advance from the north of a large delta system that spread sands and muds across the district. Later the delta became subjected to frequent and long-lasting invasions by the sea in which cyclic deposits that included limestones were formed. Apart from some late Carboniferous basic intrusions and Variscan folding, these are the last direct evidence of deposition in the area.

During the Quaternary the Southern Uplands were a centre of ice accumulation from which glaciers spread across Berwickshire in an easterly direction. As these retreated coastal districts were over-ridden by ice from the North Sea, much of which had originated in Scandinavia.

Friday: Preston Bridge
Meeting with our guides Alison and Barry Tymon just after lunch in a car park next to Preston Bridge which spans the Whiteadder River near Duns in Berwickshire, we were informed that the afternoon would be spent examining a wide variety of rocks spanning the Devonian and Lower Carboniferous boundary. However, it was emphasized that without any unconformity and the fact that little geochronology has been carried out on the igneous rocks to confirm their ages, these dates were largely inferred, and the term Old Red Sandstone could be applied to rocks of both periods.

Our first walk was to be upstream, along a riverside path for about half a mile. A dark grey basalt was the first solid geology encountered almost directly under the bridge. This displayed phenocrysts of pale feldspar, occasional quartz-filled amygdales, and well-developed vertical joints in-filled with quartz. Small to medium irregular quartz veins cut the rock in places that may indicate faulting. The basalt is believed to form part of the basaltic Kelso Volcanic Formation which includes widely distributed lava flows, doleritic plugs and sills across the whole Border region. It has been inferred that the Kelso volcanics were probably associated with a series of small volcanoes sited along, and structurally-controlled by, extensional faulting related to the initiation of the Tweed, Solway and Northumberland basins.

Further upstream we came across a partly submerged outcrop some 2 metres thick of fine-grained, red sandstone. One prominent bedding plane within the rock was seen to have symmetrical ripple marks. The rock, which also displayed yellow reduction spots and was interbedded with red mudstones, probably belongs to the Upper Devonian, Stratheden Group although distinguishing between rocks of this and Lower Carboniferous age in this area is difficult owing to their similarity and lack of fossils.

The next exposure was found on a shingle beach where a +12 m thick sequence of pyroclastic rocks dipped northwards at a moderate angle. Fine and coarse ash (lapilli tuff) intercalated with finely-bedded, fine-grained green and brown sandstones containing thin layers of water-lain volcanic ash (see photo opposite) suggested that the sandstones and pyroclastics were deposited pene-contemporaneously.

The penultimate stop on this section of the river was a prominent rocky outcrop jutting out into the river, known as Rocky Corner. The outcrop consisted of a jumbled mixture of 10 cm blocks of ash/tuff and blocks of basalt some 1.5 m across. These complicated, very coarse-grained rocks were most likely formed either proximal to a volcanic vent or within the vent itself as a vent agglomerate.

The final stop had the intriguing name of "Anger my Heart". Although very

Interbedded volcanic tuff and siltstones. Preston Bridge.

close to the Rocky Corner outcrop it lacked the presence of pyroclastic/agglomeratic rocks but comprises black, basaltic rock only. The basalt differed compositionally from the basalt previously seen at Preston Bridge in that it contained phenocrysts of black augite, yellow-weathered olivine and translucent plagioclase. Vertical, columnar jointing was however a common feature of the two basalts. The common olivine in the rock is typical of alkaline basalts which enhances the likelihood of its association with the Kelso Volcanic Formation.

Returning to Preston Bridge we then proceeded downstream to a point opposite a large 15-20 m high outcrop on the south bank of the river. Known as Crumble Edge this impressive exposure represents a section through the Lower Carboniferous, Ballagan Formation. (see photo on back cover) Dipping about 30° downstream the varied sedimentary rocks within this sequence comprised a thick bed of sandstone/siltstone at the top of the cliff, a number of thin pale beds of argillaceous ferroan dolostone (a type of limestone) and intercalated dark grey mudstones, and are part of what were historically referred to as the Cementstone Group. Red glacial sand, mud and boulders (glacial till) covered the top of the cliff.

The Tournaisian, Ballagan Formation of Northern Britain is one of only two successions worldwide to yield evidence of the earliest known tetrapods with terrestrial capability following the end-Devonian mass extinction event. The Ballagan Formation is a rare example in the geological record of a tropical, seasonal, coastal wetland containing abundant small-scale evaporite deposits. In terms of sedimentary facies, thin beds of micritic ferroan dolostone interbedded with planar, laminated grey siltstone are the defining characteristic of the Ballagan Formation. Siltstone occurs in both the saline and hypersaline facies and is likely to represent floodplain lake deposits. The diverse sedimentary environments and palaeosol types indicate a network of different terrestrial and aquatic habitats in which the tetrapods lived. While this exposure has good potential for yielding tetrapod specimens, the height and instability of the rock face make investigation dangerous.

In terms of regional setting and stratigraphy, during early Carboniferous times interconnected strike-slip, fault-controlled sedimentary basins opened up across northern Britain as a result of the break-up of the equatorial, southern part of the Laurussian (ORS) continental margin. The northern basins include those in the Midland Valley, Tweed and Northumberland-Solway regions. The early sedimentary fill to the basins comprises the Ballagan Formation which was preceded by the Upper Devonian Kinnesswood Formation and succeeded in part by the Lyne and Fell Sandstone formations.

Saturday: Around Duns

On a sunny but breezy morning the group met at the gates of Borthwick Quarry just west of Duns which, for much of the last century, had been worked for dolerite for roadstone and aggregate. Extraction stopped a few years ago and the large hole is now used for disposal of inert building waste and storage of construction materials. Specimens of rock collected around the quarry showed it to be very dark grey in colour with crystal sizes varying between 1-2 mm. Some specimens contained dark green phenocrysts of pyroxenes and a few were vesicular. In several places the rock was cut by vertical or near vertical alteration zones formed by hot fluids that had passed upwards in the later stages of cooling. These were up to 3 m wide and identifiable by the loss of columnar structure and thin veins of quartz and calcite. (see photo below) The igneous body is referred to as a sill and, although no dating has been done, thought to be of early Carboniferous age and, like the basalts seen at Preston Bridge, is part of the Kelso Volcanic Formation. While crystal sizes and the vertical columnar jointing supported the interpretation as a sill, two features were problematic. One was that many of the columns were inclined at angles varying from vertical to horizontal and in places, missing. Second was the nature of the contact. Any lower contact was buried by infill and access to the upper contact, which was visible in one corner, impossible due to the 20 m vertical height of the walls. Viewed from the quarry floor this contact, which dipped southwards, showed the structure had an irregular top and was covered by up to 3 m of horizontally bedded, red and white rock believed to belong to the Upper Old Red Sandstone. Fallen blocks of this showed it to be a medium grained sandstone, but there was no sign of any metamorphism that would be expected if this was the rock the dolerite had intruded.

After lunch the party reassembled about 5 km further west to walk over Harden Hill to view rocks in Hell's Cleugh, a deep narrow gorge. Climbing Harden Hill provided a vantage point from which Alison was able to point out the geology of the skyline to the south which ranged from Carboniferous sandstone crags in the east, Devonian lavas and granites of the Cheviot Hills,

Borthwick Quarry, a dolerite intrusion showing alteration zones, mineral veins and variations in columnar jointing. Duns.

Great Conglomerate. Hell's Cleugh.

Carboniferous volcanic plugs and sills forming the Eildon Hills to the greywacke hills of the Southern Uplands in the west. Dropping down the hill we were able to look down into Hell's Cleugh which exposed 70-80 m of red coloured rock. A careful descent led us to the bottom where it was possible to access them where they proved to be a poorly sorted, matrix supported conglomerate consisting of sub-rounded clasts, mainly of greywacke but also some igneous of granitic composition, up to 40 cm in diameter. This is known as the Great Conglomerate Formation and showed little structure except for some thin, horizontal beds of red sandstone. (see photo above) The rock was deposited at the foot of steep slopes with the material having been produced by weathering on the upper slopes of the eroding Caledonian Mountains and then washed down by powerful rivers at a time when the area was part of Laurasia and lay 20-30° south of the equator.

The final stop of the day was a small overgrown quarry in the village of Longformacus. The rock worked here had been greywacke and while access to the rock faces was restricted due to vegetation, we had been able to see good examples of these in the clasts at the previous locations. The obvious features of this quarry were the very steeply dipping bedding planes and the thick nature of the beds. These greywackes belonged to the Etterick Group of Silurian age and were formed from repeated turbidity flows into a fore-arc basin of sediments eroded from the Caledonian Mountains that lay to the north. The steeply dipping bedding planes were created as the ocean floor was subducted and overlying sediments were scraped off as a series of accretionary prisms.

Sunday: Cocklawburn Beach. Northumberland

Another sunny morning saw the group meeting Alison at Cocklawburn Beach south of Berwick where we were to examine features on the shore at Middle Skerrs which, due to the low spring tide, were well exposed. Walking down the gently seaward dipping bedding planes on the top of one of the 'posts' of the Sandbanks Limestone, its smooth surface was soon found to be sculptured into pronounced symmetrically shaped, regularly spaced grooves aligned at 90° to the sea. (see photo below) Alison explained that similar ones occurred at other locations nearby, and as no descriptions or explanations had ever been made of them, she and Barry had set out to investigate. They found that at this location the grooves had a mean width of 69 cm, mean depth of 13 cm and mean slope angle of 42° and that these values decreased towards high and low water marks, beyond which they died out. Very similar figures were recorded at the other local sites which suggested they were not random features and must somehow be related to wave action when water, armed with sediment, will erode rock.

Grooves in Sandbanks Limestone cut by Edge Waves. Middle Skerrs.

***Eione moniliforme*, a trace fossil. Far Skerrs.**

Alison recounted how discussions with mathematicians had revealed that when waves break, their energy is not just dissipated by their waters moving up and down the shore as the swash and backwash, but that they also propagate standing waves at right angles to their direction of travel. These are known as 'edge waves' and there is a mathematical relationship between them and the wave period. Wave buoys around the coast of Britain record wave period and one happens to be sited in Berwick Bay. When wave period data from this was put into the formula it showed that the groove widths were consistent with those of the edge waves generated along this stretch of coast. Alison went on to explain other factors that had to exist before grooves would form which were: strong, homogenous rocks, beds >30 cm thick, bedding planes dipping towards the sea at < 5°.

Having had our minds stretched we walked further down the beach to look at more 'traditional' geology. An exposure in a low cliff at Far Skerrs, beneath an old lime kiln, showed a section through part of a cyclothem showing sandstone grading into siltstone, seat earth and coal. The siltstones contained fine sedimentary structures and trace fossils, especially of the beaded trails of ***Eione moniliforme*** (see photo above).

At Cheswick Black Rocks unusual patterns on boulders of limestones and pink sandstones were examined. A very regular honeycombed pattern is interpreted either as due to varying amounts of calcite cement or the growth of salt crystals within the rock. In-situ sandstones showed large numbers of concretions; as individuals ranging from a few centimetres to over a metre in diameter to large, closely packed masses. What caused strong debate though was that some of these are claimed to be, cup and ring markings. (see photo below)

At this point Alison (and Barry in his absence) was thanked for providing us, once again, with a varied programme, for delivering it in a manner that was accessible to all and with such enthusiasm.

Concretions or Cup and Ring carvings? Cheswick Black Rocks.

Crumble Edge. Ballagan Formation. Preston Bridge