LGA

Leeds Geological Association

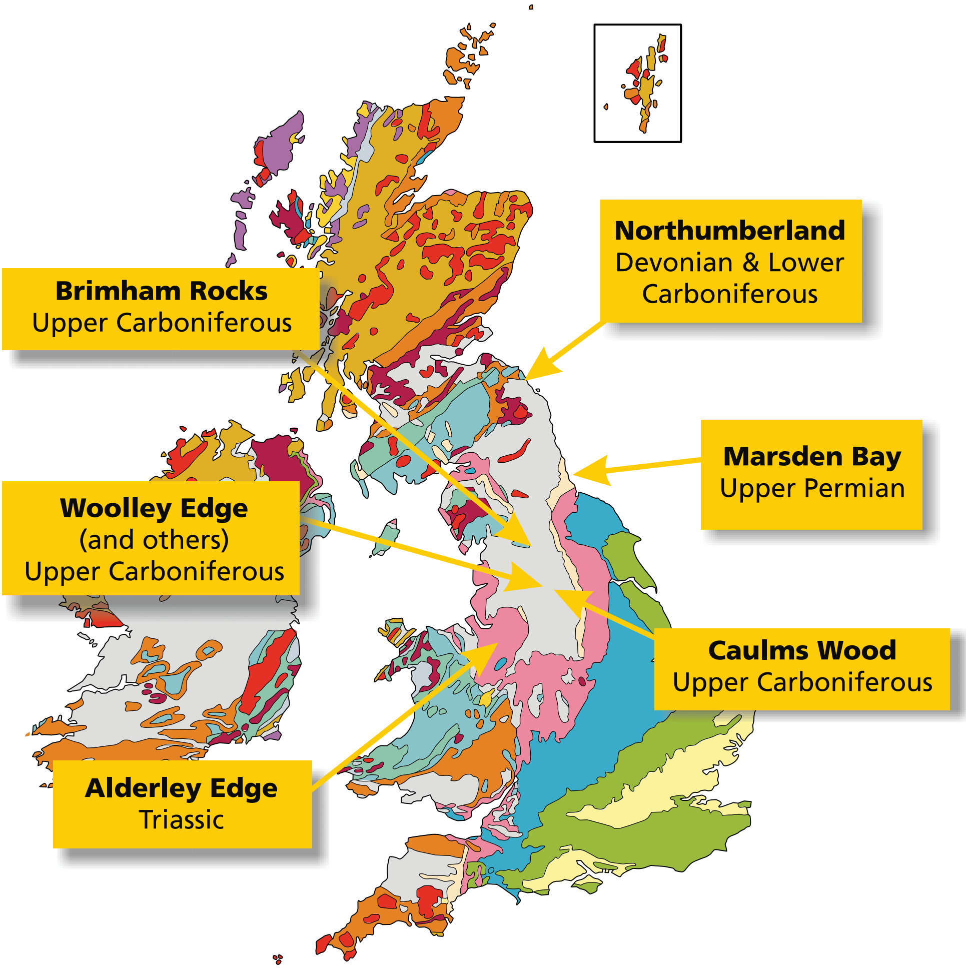
Founded 1874

Registered Charity
No. 1016696

Field Visit Reports Summer 2016

www.leedsga.org.uk

16 Where did we go?



Contents

2016 Field Visit Locations

Thanks are due to the Field Visits Secretary, David Holmes, for arranging the programme, to the leaders who gave up their time to take us and to the authors of the reports and photographs.

Cover Picture: Inside Wood Mine, Alderley Edge

Booklet designed and printed by Trendsetter Marketing Limited ☎ 01274 611222
www.trendsettermarketing.co.uk

Mineralisation at Alderley Edge and Wood Mine
Saturday 2nd April 2016

8 members
Leader: Anton Petho, Leicester University

The party met Anton at the National Trust car park at Alderley Edge in persistent rain. As the forecast was for the rain to ease later it was decided to visit the mine in the morning and the exposures on Alderley Edge in the afternoon.

Alderley Edge consists of a series of sedimentary rocks laid down in the mid-Triassic Anisian Stage and forms part of the southward-dipping limb of the Wilmslow Anticline. It is bounded by two faults running N-S about 3 km apart; the Alderley Fault in the west and the Kirkleyditch Fault to the east. The faulting produced a horst block which, uplifted by several hundred metres, forms one of the few high points on the Cheshire Plain. Superimposed on this is a series of later normal throw faults running WNW-ESE giving the Edge its distinctive scarp slope.

The rocks outcropping here are part of the Sherwood Sandstone Group. The lower part of the Edge is formed of Wilmslow Sandstone Formation: 300m of mixed aeolian and fluvial sediments, predominantly sandstones with some siltstones and conglomerates. These are directly overlain by the 120m thick Helsby Sandstone Formation, a series of channel fill and over-bank deposits laid down as fluvial sediments from a braided river system flowing from the south. This Formation has been split into a series of Members, each represented by a number of fining-upwards cycles. Again these are mainly sandstones with sporadic conglomerates and some siltstones.

We entered Wood Mine along an adit (see photo on front cover) driven through the Wood Mine Conglomerate, a Member of the Helsby Sandstone Formation. This Member contains 10 fining upwards cycles, of which only the top 3 show mineralisation. Anton explained the complex mineralisation within the rocks of the Cheshire Basin which contain an unusual assemblage of copper, cobalt, and nickel sulphides, sulphur-arsenides and also, at Alderley Edge, lead sulphide. The metal ions were derived from the basement Carboniferous Coal Measures, the transport system being diagenetic fluids from red-bed clastics and saline fluids from evaporites, driven down basin-bounding faults and heated by thermal gradients due to deep burial. These ions then reacted with reduced sulphur ions in the form of hydrocarbons (also derived from the underlying Coal Measures) resulting in deposition of large quantities of barite and, followed later, by copper, lead, zinc, cobalt and nickel-bearing compounds. This primary mineralisation occurred along faults and in the host rocks in close proximity to the faults, infilling pore spaces in the conglomerate and sandstone.

When the rocks were uplifted by the Alderley and Kirkleyditch Faults the water table fell, allowing water to percolate down through the rocks due to the diffusion gradients. This allowed metal ions to go back into solution, which were then redeposited in the surrounding host rocks, resulting in extensive secondary mineralisation. This mineralisation shows clear zonation away from the faults, with lead closest, then copper, and finally cobalt and manganese. The minerals tend to be concentrated between bands of mudstone (which acted as caps) although at lower concentrations and extending further than in the primary mineralisation.

Evidence of mining at Alderley Edge goes back to the Bronze Age, with some Roman activity as well, extracting copper, lead, and cobalt. Further mining occurred during the 17th Century, mainly for copper from the primary mineralisation but the main mining period was by the Alderley Edge Mining Co. between 1857 and 1878, focussing on the secondary, lower grade copper minerals but also some lead. Although the average ore grade of copper was <1.5% it was still profitable due to a pioneering extraction process that required no furnace but used HCl to extract copper in solution as the chloride. This was then pumped into tanks containing scrap iron from the tin plate industry to produce copper metal at 75% purity.

The mine is excellently maintained by the Derbyshire Caving Club since being reopened in 1970. There are 2.4 km of tunnels, mostly 19th Century, going down to a depth of 30m and we were able to visit several chambers interlinked by passages that were quite low in some places!

In the mine the bedrock was predominantly red due to oxidised iron but there were patches of white rock where mineralising fluids had reduced the iron. These were used by the miners as an indication of where to look for the ores which were removed by blasting with black powder. There was very little gangue material so nearly all the rock had to be extracted and processed. We were able to see evidence of primary mineralisation along fault planes, predominantly barite with some native galena and copper minerals. In several chambers the secondary mineralisation was still clearly visible as extensive bands of predominantly copper minerals, often highlighted by the widespread cross-stratification seen in the sandstones.

Other features seen in the mine were fault planes with rip-up clasts and slickensides, desiccation cracks, a small lake coloured blue by copper minerals, and in Stump Chamber evidence of back-walling, with a replica post in the middle of the chamber which was used as a warning of potential roof collapse

Tertiary mineralisation with azurite and malachite

– it would start to creak and groan when under excessive pressure. In one chamber the presence of manganese was shown by inhibition of the growth of white micro-organisms on the walls. There was also evidence of relatively recent tertiary mineralisation (formed since the tunnels were dug), by mineral-rich water running down passage walls and oxidising out as spectacular sheets of bright blue azurite and green malachite (see photo above).

Fortunately, after lunch the rain had stopped and we visited exposures along Alderley Edge. The first stop was at Church Quarry which is in the Wood Mine Conglomerate of the Helsby Sandstone Formation (as seen in Wood Mine earlier). This exposure showed a conglomerate overlying better grade sandstone which had been quarried out for building material. There was an erosional surface between the two beds, but no visible siltstone.

We then walked to the top of Alderley Edge where there was a good view over the half graben of the Cheshire Plain. Just below the top we visited Castle Rocks, which clearly shows the contact between the Wilmslow Sandstone Formation and the Engine Vein Conglomerate, the first Member of the Helsby Sandstone Formation (see photo opposite).

Continuing on, we passed over the Cobalt Fault which, contrary to the trend, runs N-S. It was worked for its cobalt ore for use in the pottery industry, although there is now more manganese present than cobalt. There was also evidence of perched water tables along the Edge due to the layers of siltstone between the sandstones and conglomerates. Passing the now disused Old Alderley Quarry where sandstone was quarried for building use, a small fault was clearly visible in the quarried face.

The next exposure visited was at Stormy Point in the Engine Vein Conglomerate where another fault was observed. There is more galena here than copper minerals so it had not been extensively mined but we saw remains of Bronze Age workings as well as triangular shot holes used in the 19th Century. Rare fossils of fresh-water ostracods have been found here showing that water must have been lying for sufficient time to allow for colonisation.

The final exposure was at Engine Vein Fault, a bifurcating fault downthrown by about 3.5m to the north. Mineral rich fluids flowed down the dip and were redeposited in the porous sandstones and conglomerates. Bronze Age workings were again visible and it was also worked in the 16th Century.

Returning to the car park Anton was warmly thanked for a fascinating and very informative tour covering the sedimentology and complex mineralisation of Alderley Edge as well as the industrial aspects of the mining.

Contact between the Wilmslow Sandstone and Engine Vein Conglomerate

A geological walk around Caulms Wood Quarry in Festival Park, Dewsbury
Sunday 29th May 2016

Leader: Dr Gareth Martin, Leeds Geological Association and West Yorkshire Geology Trust
Present: 8 members, 2 visitors

This was a Yorkshire Geology Month event intended for members of the public and it was pleasing to have enthusiastic visitors from the local area join us in Festival Park which was created on the made-ground of the spoil from the very extensive quarrying of the sandstones and coal found on the valley side.

Gareth first led us to a view point on the northern end of Crakenedge looking over the valley of the River Calder and Dewsbury to set the geological scene. In the distance we could see the Millstone Grits of the Pennines with the steep scarp edge and gentle hollow of the Meltham Syncline on the horizon. Discussion took place about the sedimentary deposition of the area: we were standing on the site of a coastal plain with swamps and lagoons fed by huge braided river systems situated on the Equator and liable to the effects of seasonal monsoonal rainfalls on a very high mountain range (not unlike the Himalayas today) to the east and north. We then made our way down to the extensive exposure of the Thornhill Rock which was generally a fine grained and very thickly bedded sandstone. It is now designated as an LGS (Local Geological Site) for its features but was originally mined for building stone, aggregate and coal. We started at a point where there was an exposure of the Jane Coal, a fairly poor coal in two leaves with mudstone and associated seat-earth under a sharp base to the Thornhill Rock (see photo opposite top). As we moved along the face the number of coal seams went up to four (see photo opposite bottom) then back down to one as it gradually pinched out to the west. The Thornhill Rock, thought to have been transported from the west, is mica poor with heavy minerals containing monazite and variable chrome spinel and was derived from Devonian and Lower Palaeozoic age rocks. It is thought to have been deposited between 313.4Ma – 311.7Ma (Middle Carboniferous Coal Measures). Below the coal an unnamed sandstone is mica rich and contains garnet rich monazitic heavy minerals from high grade meta-sediments and granites and was derived from the north.

Moving back to the mid-point of the exposure the cliff face must show almost the total 40m thickness of the Thornhill Rock. Descending the slope to its base the number of dewatering structures increased, presumably formed because

The Jane Coal below Thornhill Rock

The Jane Coal split into 4 leaves

of the large volume of wet sandstone that had been deposited in the one major event. There was also an increase in the number and size of iron-rich concretions, some of which showed signs of having being mined for their iron content. (see photo below). In the centre of the exposure there were a host of sedimentary features shown in the rock face which provided evidence as to its depositional history. For those adventurous souls a climb up the rock face provided some good examples of ripples exposed on a bedding plane (see photo opposite) while both trough and tabular cross-bedding abounded in the face itself for those not wishing to emulate mountain goats! One feature which was the subject of much debate were the beds composed of finer sandstones and siltstones which are present between the bedding planes in certain areas. These were commonly shaped like elongate lenses, with some having internal features. After much discussion it was suggested that these were likely to be areas of ponded water or abandoned channels in the river system. It was noted that these types of bedding are common in the Thornhill Rock and other Carboniferous Coal Measures Sandstones in West Yorkshire.

The group reached the end of the face which concluded the visit. After a descent through the pleasant woodland of the park the group convened to thank Gareth before parting ways to leave for home.

Remains of an Iron concretion in the Thornhill Rock

Ripple marks in the Thornhill Rock

Interpreting complex fluvial channel and barform architecture at Brimham Rocks
Saturday 18th June

19 members
Leader: Roman Soltan, Fluvial Research Group, Leeds University

This visit was a follow up to the talk given to the Association in March by Dr Nigel Mountney and in marked contrast to the last LGA visit to Brimham in 2013 when the rain was torrential and we were the only visitors, took place on a warm dry day with the site busy with visitors. Our purpose was to examine sedimentary facies in an attempt to understand the complex nature of their depositional environment. The beauty of Brimham as a study area is that the sedimentary structures can be examined in 3 dimensions and so flow directions can be accurately deduced.

The Lower Brimham Grit is a fluvio-deltaic sandstone of Bashkirian (Namurian - Kinderscoutian) age and forms part of the Millstone Grit Group and was deposited along the north-eastern margin of the Craven Basin and adjacent regions. The source of sediment was predominantly from eroded remnants of Scottish and Norwegian Caledonian Mountains to the north and

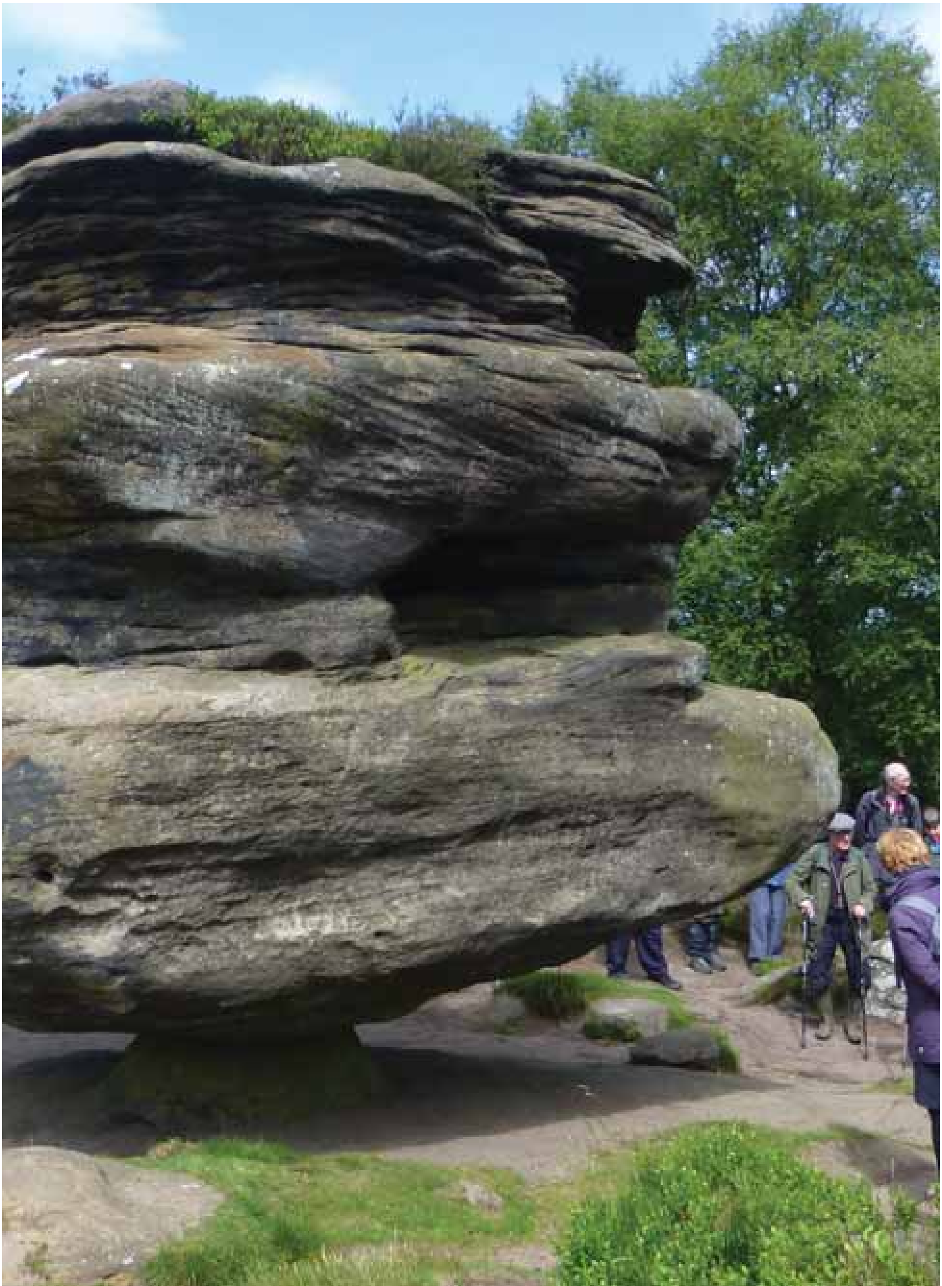
Joints widened by ice wedging and cambering.

northeast and varies from fine to granular sandstones, some with quite a high pebble content. The poor sorting and angular nature of the grains along with the high feldspar content indicates that the sediment experienced a relatively brief history of transport and erosion before being deposited. The sediments represent the preserved remains of part of an upper-delta plain system across which a network of braided channels was flowing. Following deposition these thick sandstones were buried, compacted and lithified.

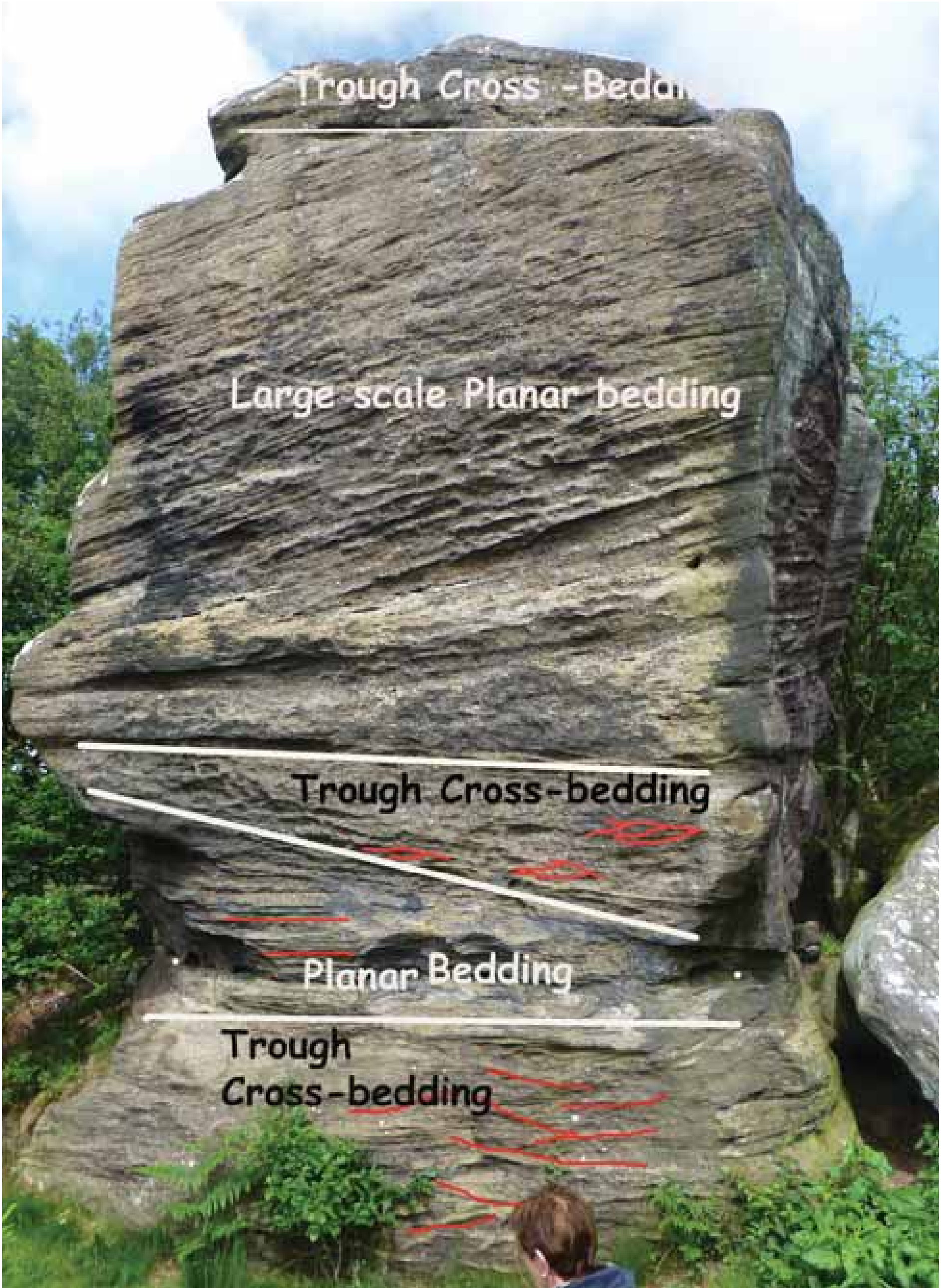
Uplift and removal of great thicknesses of overlying rock resulted in the formation of horizontal and vertical joints as compressive strain was reduced. This then allowed groundwater to exploit the jointing allowing water to penetrate and to decompose rock adjacent to the joints. Further erosion, especially by ice during the past 2.5 m.yrs resulted in the rock becoming exposed and the weathered material to be removed leaving the unaltered rock standing as a series of gritstone tors and associated corestones. Although Brimham was not covered by ice during the last stages of the Devensian it was affected by periglacial conditions. Ice wedging has widened vertical joints by forcing blocks apart and cambering, where weak, underlying, less competent rocks have been unable to support the competent gritstone, is common. (see photo opposite)

The first locations of the day were visited to illustrate the possible origins of the exotic landscape features for which Brimham is famous. Cold dry winds blowing loose sand were responsible for much abrasion, further widening joints and bedding planes and the subsequent temperate climate, with regular precipitation to assist weathering processes, have created the tors seen today. The most obvious effects occur where variation in the competencies of facies has resulted in marked differential erosion and probably the best example of this is the feature known as “The Idol” where a huge mass of largely coarse sandstone is supported by a tiny pedestal of finer sandstone (see photo overleaf left) - not a place to linger too long?

Attention now turned to the nature and orientation of the sedimentary structures and time was spent at the next exposure (see photo overleaf right) which displayed a good variety. The lowest section was a medium grained sand with trough cross-bedding indicating flow in a southerly direction which graded up into planar bedded, slightly finer sand. The trough cross bedding indicates the formation of a sand bar in the bed of a channel and the grain size shows a fairly low current and sediment supply; probably as the river level fell. As the sand bar built up the water shallowed and so its velocity increased across the top resulting in the formation of planar bedding. The planar beds are abruptly cut by an easterly dipping erosion surface above which the sand becomes coarse and is arranged in a series of trough cross-bedded units representing a channel in which flow was now in a westerly direction. Above is approximately 3m of very coarse sand that displays large scale planar bedding before the outcrop is capped by approx 1.5m of trough cross-bedded



“The Idol” - an example of differential erosion. Brimham



Different types of cross-bedding.

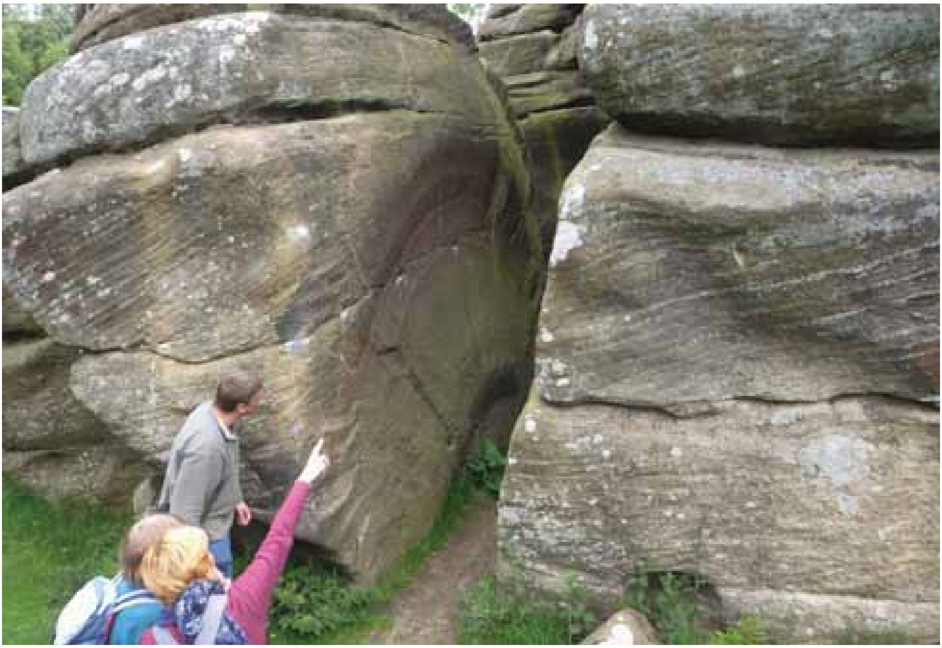
sediment with a marked erosional base. These structures are interpreted as being associated, in part, with a chute channel and subsequent alternate bar that was accreting laterally and downstream and would have been covered by at least 6m of water during their formation in a large flood event.

The variation in current direction between southerly and a more westerly direction was seen repeated in other outcrops. Generally the smaller scale structures showed southerly directions with the larger ones being more westerly. The reasons for this are not clear but one possibility suggested is that during times of flood a channel confluence may have deflected flow direction to the more westerly one represented by many of the larger structures.

Roman continued to lead us on a winding route through the maze of outcrops to point out other features of interest, the main ones being: (i) Deformation structures formed where saturated unstable planar cross-bedding had been distorted by the rapid deposition of sediment on top. While this feature can also be formed by tectonic activity this is discounted at Brimham by the fact that the feature is not widespread and appears to have been moving in a similar direction to the overlying deposit. (ii) Bands of large, angular quartz pebbles at the base of several beds known as lag deposits. These represent the residue left behind after finer particles have been transported away, due to the inability of the transporting medium to move the coarser particles. (iii) Several large example of trough cross-bedding, one of which (see photo opposite top) must have originally been a 4-5m high subaqueous dune. (iv) Successive co-sets of cross-bedding showing that current direction had changed by 180° (v) Three examples of a very distinctive circular pattern exposed on joint planes. The best (and largest) of these (see photo opposite bottom) displayed its mirror image on the opposite joint surface and each was decorated by a faint radial pattern that cut across the bedding planes. Roman was not sure about their origin - and neither was anyone else that he had showed them to! Lengthy discussion took place as to what this might be and the general consensus was that they were some sort of fracture pattern (akin to conchoidal fracture) formed during pressure release as the Brimham Grits were exhumed.

At this point Roman was thanked for such an enlightening tour of this well known beauty spot which left participants under no illusions as to the complex nature of the story that Brimham has to tell (but much better informed than Rooke who, in 1786, put its origin down to 'a violent convulsion of nature') and for the production of such a detailed handout.

Roman demonstrating the scale of trough-bedding.



Unusual structures at Brimham

Upper Permian Carbonates Trow Point to Marsden Bay, [South Shields]
Saturday 9th July

8 members 1 visitor
Leader: Dr Michael Mawson, Durham University

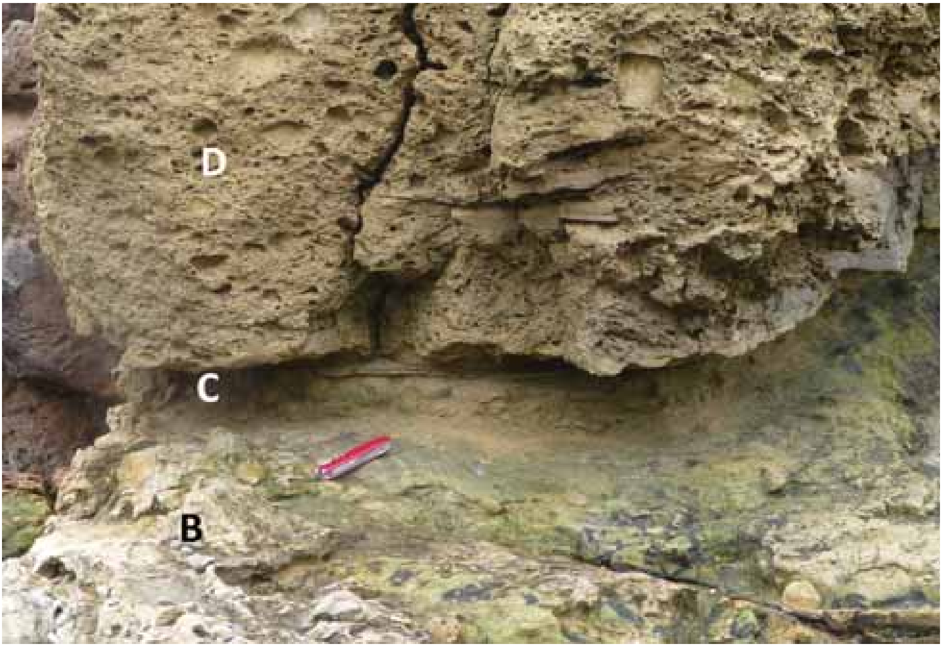
The purpose of this visit was to look at more features of the Upper Permian carbonates that we had seen last year when Michael had taken us to Blackhall Rocks, 20km to the south. We met Michael and members of the Tees Valley RIGS Group (with whom this was a joint visit) in the car park at Marsden Grotto where the sight of a man running past carrying a fridge on his back was a perhaps a prelude to some of the unusual rocks that we were to see during the day.

To reach the first location we walked north to Trow Point where, down on the beach, Michael gave us a brief resume of the conditions under which the rocks we were to see had been formed. Around 270 million years ago the area had been part of a large basin in the interior of Pangea and, being located 20 - 25 N of the equator, was subject to a hot, dry climate. This resulted in the deposition of continental deposits of the Rotliegend Group, the erosion products of uplifted Carboniferous and older rocks. Here they are represented by the Yellow Sands; aeolian deposits that formed extensive sand dunes built by the prevailing north-easterly winds. A little less than 260 million years ago, possibly due to a rise in global sea level, sea water poured into the basin from the Boreal Ocean to the north and created the landlocked Zechstein Sea. The inundation would have been very rapid as the basin, which stretched from eastern England to Poland, lay well below sea level. Marine carbonates and evaporites of the Zechstein Group were deposited right across it with the 1.0 - 1.5m organic-rich, finely laminated Marl Slate representing the deposits of the initial transgression. The sea, while oxygenated in its upper levels, must have been anoxic at depth as the Marl Slate is well known for the perfectly preserved fossil fish it contains. For the rest of Zechstein times, the Sea was subject to periodic desiccation as its connection to the open sea was either restricted or severed. As a result of the hot, arid climate of the time this resulted in the formation of thick evaporite deposits. Five cycles (Z1 - Z5) of evaporation can be recognised in the succession which in northeast England is ~ 300m thick. Each cycle begins with carbonates, which represent an episode of transgression (connection to open sea).These are followed by evaporites, formed as a result of regression when the sea water evaporated away (connection to open sea restricted/severed).

Trow Point

The northeast of England was located on the margins of the basin where the sea was shallow and the deposits consist largely of carbonates whereas those formed at the same time further east, towards the centre of the basin, consist largely of evaporites, including very thick halites. The fieldtrip was to look in detail at rocks from the first two cycles (Z1 and Z2).

At Trow Point, (see photo above) four distinctive units (A, B, C & D) were clearly displayed in a cliff ~ 10m high. At the base (A) were well bedded, bioturbated carbonate mudstones of the Raisby Formation (equivalent to the Yorkshire Province Wetherby Member) whose fine grain size and sparse bioclastic content indicate that they were deposited in a low-energy, well-oxygenated marine environment. Above this (B) are ~ 4m of similar carbonate mudstones in which the bedding was badly contorted and dipped steeply in a southerly direction. This is known as the Downhill Slide and is believed to represent a drop in the relative sea level which caused gravitational collapse of the basinward margin of the Raisby carbonate platform. The Yorkshire



The rocks above the Downhill Slide

Stromatolites in the Trow Point Bed

Province equivalent of the Downhill Slide are the Hampole Beds which also contain evidence for sudden shallowing showing that this was not a local event but a basin wide one.

The rocks above the Downhill Slide were examined at a more accessible location just above the level of the beach (see photo opposite top). Immediately above the slide (C) was a ~15 cm layer composed of pisoids which contained small stromatolites (see photo opposite bottom). This is the Trow Point Bed which, Michael informed us, can be traced throughout the Zechstein Basin and is so thin due to very low rates of sedimentation in the basin centre. Overlying this is a 2-3cm thick layer of clay which is the dissolution residue of the ~ 100m Hartlepool Anhydrite. The anhydrite formed as the Zechstein Sea suffered desiccation following a major regression and marks the end the first Zechstein cycle. The fact that anhydrite has been removed by dissolution is demonstrated by the nature of the overlying beds (D) which have been collapse-brecciated. The breccia comprises poorly sorted angular clasts of yellow dolomite and are set in a grey calcite matrix (thought to be either rock flour generated by the collapse and/or cement) The collapse breccias here have a broadly stratiform geometry and are up to 18m thick. They belong to the Roker Formation representing the beginning of the second Zechstein cycle (Z2) and were deposited following a marine transgression and became brecciated as a result of uplift-related dissolution of the Hartlepool Anhydrite by meteoric ground water. The timing of the dissolution is uncertain; while it is conventionally thought to be Tertiary in age it could be much older as in parts of the North Sea, where similar collapse-breccias are found, there is evidence that dissolution may have occurred in the Jurassic. The difference in chemical composition between the clasts and matrix could be attributed to de-dolomitization of the fine grained matrix by the large volumes of calcium rich fluids that were generated by the dissolution of the Hartlepool Anhydrite; the clasts, being more lithified (and therefore less permeable) may have been more resistant to this alteration.

After lunch (eaten under an overhanging! cliff that provided shelter from a brief rain shower) the party walked south towards Marsden Bay. At Graham's Sand a bedding plane within the Raisby Formation was seen to be extensively burrowed and the Downhill Slide to be much thinner than at Trow Point. A brief stop was made to look into Frenchman's Bay where Michael told us that the Rotliegend Group, Yellow Sands, here forming an antiformal feature (relict dune topography), and the overlying Marl Slate used to be exposed until recently but are now sadly covered by a cliff fall.

Returning to beach level, on the north side of Marsden Bay the slight south-

Breccia 'pipes' in The Roker Formation

easterly regional dip had brought rocks higher in the Roker Formation into view. The top of the collapse breccias seen at Trow Point here form the lower half of the cliff while above the succession comprises of less altered dolomitic rocks in which the degree of brecciation decreases upwards and displays vertical breccia pipes (see photo above). Without being able to see a 3D view of the features it was not possible to say whether the pipes were circular or linear in shape. The exposures caused plenty of discussion as to the nature and controls of collapse and it was concluded that: it was clearly a polyphase event, that the collapse pipes had grown upwards and that faulting and jointing must have had a significant control by acting as conduits for the fluids dissolving the Hartlepool Anhydrite.

Further south along the cliffs near Lot's Wife (the sea stack in the centre of Marsden Bay) in relatively unbrecciated exposures of the Roker Formation two stratigraphic units were recognisable; a lower yellow dolomitic one and an upper grey (limestone) one. These both consisted of interbedded carbonate turbidites and laminated, organic rich carbonate muds ('background' sediments). Slump folds, (see photo opposite) lack of shallow water grains and the relatively high organic content suggest deposition of these beds occurred on the lower part of the Roker carbonate platform slope. Closer to Marsden Grotto a fault, down-throwing to the south, brought the upper part of the Roker platform slope to beach level. These rocks were more thickly and irregularly bedded than those of the lower slope and contained more shallow-water grains, such as ooids and shell debris, derived from the platform top. They displayed channels through which sediment had been transported and many syn-sedimentary slide planes, all related to gravitation collapse caused by the steeper gradient of the upper slope compared to the lower slope.

At Marsden Grotto we thanked Michael for another detailed insight into these fascinating rocks before climbing the many steps back up to the car park.

Slump folds in the Roker Formation

Sandstones of the Middle Coal Measures at Wooley Edge and other locations in West Yorkshire
Saturday August 6th

13 members
Leader: Dr Gareth Martin. Leeds Goelocial Association & West Yorkshire Geology Trust

Thirteen members met Gareth at the Woolley Edge viewpoint on a clear, sunny morning. To start Gareth drew the party's attention to the Pennine hills visible in the far West and explained that these were formed from the Millstone Grit Group of the Lower Carboniferous, but the rocks we would be seeing during the day would be from the Middle Coal Measures deposited some 313 to 311 Ma ago. Gareth informed us that the four exposures of rocks to be seen would not be visited in chronological order, but all had been deposited in river systems of the braided or meandering type. Geological overview complete, we were led through the woods to the quarry face exposure of the Woolley Edge Rock. Here Gareth pointed out features such as bedding planes, cross-stratification and infilled abandoned channels, all of which indicated different directions of flow. Between some of the sandstone beds were siltstone lenses some of which appeared to contain wormcast like trace fossils. It was explained to us that the Woolley Edge Rock was deposited in a braided river system and, based on the deposition features and geochemistry, the general flow direction was from the east. The quarry face was about 250 metres long and at the North end of the quarry was a high point from which, looking due east, the Permian ridge and the topography of Cretaceous rocks underlying East Yorkshire could be seen.

Our next exposure was of the Thornhill Rock in Coxley Quarry, Horbury. Again Gareth led us to a high point above the quarry and pointed out across the Calder Valley the two exposures of Horbury Rock at Storrs Hill and Horbury Quarry we would be seeing later during the day. Coxley Quarry has a large exposed face, the rocks of which were laid down in a complex depositional environment. Massive sandstones, lenticular sandbodies (some with pebbles at the base) and beds separated by silty layers were all visible (see photo opposite top). Gareth's interpretation was that these were flood plain deposits cut into by channel sandstones from a meandering river system. Moving north-east through the quarry we came across thicker sandstone units and crevasse splays with fossilised plant matter between the deposited layers (see photo opposite bottom). A recent rock fall (care is needed in this quarry as the face is unstable in parts) had deposited a slab of sandstone showing an excellent example of flow-ripples.

Lenticular sand bodies separated by silts Coxley Quarry

Plant debris in Coxley Quarry

Erosion surfaces. Storrs Hill Quarry

After lunch in Coxley Quarry we drove across the Calder Valley to Storrs Hill and followed a narrow path to the quarry proper. Either side of the path was quarry spoil, some pieces of which contained fossilised plant matter and thin (1 to 2mm) layers of organic matter. At the centre of the quarry the Horbury Rock has clear cross-bedding, indicative of a low energy braided river system. One bedding plane between two sandstone units had a thin layer of siltstone containing a 20mm thick *Calamites* fossil. At the north-west end of the exposure were more beds of siltstone and cross-bedded sandstone with examples of channel deposition and erosion (see photo above). Gareth gave the opinion that we were looking at right angles to the general flow direction of the main channel.

Our final visit of the day was again to the Horbury Rock, but this time behind the Quarry Inn in Horbury. Though we were looking at the same deposit as at Storrs Hill we were now looking along the axis of the general flow direction. Close to the rock face the sandstones appeared massive and featureless, the only exceptions being evidence of scour surfaces and in the rock at the back of the pub car park an infilled abandoned channel. Walking back to the cars and standing on the pavement further back from the rock quarry the overall structure of the exposure could be appreciated with some 16 planes of erosion and deposition visible (see photo below).

On returning to the vehicles David expressed the group's thanks to Gareth for a most interesting and informative day.

Massive sandstones. Horbury Quarry

Residential weekend to Northumberland
Friday 7th to Sunday 9th October

15 members and partners present
Weekend leader: Alison Tymon

Friday: Wards Hill Quarry

Having gathered at Heighley Gate Garden Centre we made our way to Wards Hill Quarry (GR07923196570) 2.5 miles SE of Rothbury on a self-led visit suggested by two of our members and found the quarry along the highest point of the NE-SW trending ridge. The tenant farmer, whose family had farmed at Wardshill Cottage on the Duke of Northumberland's estate for 100 years, told us that in the past they had simultaneously quarried limestone (used at a nearby kiln where they also used the local Top Coal) and the Great Whin Sill which was used for road dressing. The BGS Rothbury map showed that we were in the Great Limestone at the top of the Alston Formation and up into the shales and sandstones of the lowest part of the Stainmore Formation.

Entering the top end of the quarry we could clearly see the reddish, poorly developed, vertical joints of the quartz dolerite Great Whin Sill whose base, in contact with the shale that was just above the Great Limestone, showed signs of chilling. The shale was baked and bleached and displayed small scale thrust faults and folds near the contact (see photo at top of page 29).

Further down into the quarry the base of the sill is lower and in contact with the Great Limestone. The sill then envelopes an area of shale and re-joins the Great Limestone (which here forms the eastern limb of a plunging anticline) where the farmer told us that potholers have made their way down through the limestone into the valley below. In the quarry where the limestone has been cleared of the sill by quarrying, there is little sign of any re-crystallisation and bedding surfaces are densely covered with *Spiriferid* and *Gigantoproductid* brachiopods and other fossils at lower levels (see photo opposite bottom).

Further down slope the top of the sill becomes visible in contact with a sandstone. At this point some of our members climbed a sloping path to look closer at the sill and found it divided into three leaves from between which they extracted a few pieces of clearly slicken-sided calcite that must have entered the joints during or after later movements.

At the bottom of the quarry where the Great Limestone plunges down there


Lower contact of Whin Sill. Wards Hill Quarry


Fossiliferous Great Limestone. Wards Hill Quarry

is a 15m cliff of the Sill, still with the sandstone on top. The cliff is jointed NE-SW with calcite partings showing on many of the faces. The quarry face goes back into the poor vertical jointing as it curves back round to complete the oval shaped quarry sides. Thanks to our sharp-eyed members for discovering so much of interest in this quite small quarry.

Saturday: The Cheviots and Adjacent Areas

We met Alison in the Harthope Valley, west of Wooler, on a sunny morning with the mountain ash trees in all their autumn glory where she gave a brief introduction to the geological history of the Cheviot massif. She explained that the Cheviot Volcano had erupted at the end of Early Devonian (about 396 ma) following closure of the Iapetus Ocean: initially explosively but followed by largely andesitic lava flows which may have been up to 2,000m thick. Magmatic pressure varied over time so the volcanic cone built up and then collapsed periodically leading to the formation of calderas and their eventual collapse resulting in pyroclastic flows embedded in the lavas. Eventually eruptions ceased and, somewhat unusually given the size of the pluton, the magma appears to have solidified at the relatively shallow depth of between 1 and 2 km to give a microgranite. Subsequent erosion has revealed a central pluton, about 10 km across, surrounded by andesitic lavas and tuffs with a metamorphic aureole extending up to 2 km.

Metamorphosed andesitic lava flow. Hawsen Burn

Although the Cheviots are largely covered by glacial drift there are places where the rocks are exposed - generally along stream sides and on the high tors which were nunataks during the last Ice Age. North from Langleeford by the side of Hawsen Burn we were able to examine the metamorphosed andesite in a cliff face. The face was heavily fractured (primarily vertically) and the fine to medium grained rock was dark grey in colour and very hard (see photo opposite). Walking about 100m upstream we came across a small patch of microgranite in the stream bed and bank. Here the crystalline rock was fine to medium grained with small phenocrysts. The weathered surface appeared pink although the rock, when split, was dark grey.

We then drove north across the flat low-lying Milfield Plain to our next site which was a disused quarry on Flodden Hill. This is a ridge at the north-western edge of the Cheviots overlooking the Tweed Basin. Here was andesite which had not been metamorphosed and a lava flow, about 15metres thick, displayed no vertical jointing. Towards the western end of the quarry face was a fault with fault breccia and there also appeared to be a dyke, perhaps 2 to 3m wide, with horizontal joints. The rock was a typical andesite: purplish grey in colour, fine grained with phenocrysts of plagioclase feldspar, augite and hypersthene which had started growing before eruption.

Our next site was the Flodden Field battlefield memorial where Alison entertained us with a description of the battle which took place here in 1513 between the Scots and the English, and the influence which the geology had on the outcome. Apparently the Scots had set up base on Flodden Hill, facing south, but, having been outflanked by the English, they turned round to face them and moved north to the next ridge - Branxton Hill. Branxton Hill is the most northerly outcrop of the andesite which is truncated by the Flodden Fault on the hill's north facing slope - with the Lower Carboniferous Ballagan Formation to the north. Much of the area is covered by glacial till but the English had gathered on glacial sands and gravel on the next ridge - where the memorial stands. Looking towards Branxton Hill we could see damp patches on the hill side indicating a spring line where the andesite is faulted against the Ballagan Formation. Apparently it had rained heavily for three weeks before the battle so much of the ground would have been wet. When the battle started, the Scots' artillery proved to be ineffective due to the steep gradient below them. The Scots lost patience and, with their unwieldly 5m long pikes, charged down the hill into valley bottom where their energy was quickly sapped by the heavy, waterlogged ground, before even grappling with the English.

During the last glaciation an ice cap formed over the Cheviots but it was cold-based and remained stationary so there is little evidence of glacial erosion, only the periglacial features of the high tors. Warm-based ice flowed from the north-west through the Tweed Basin, almost encircling the Cheviots, depositing thick glacial till and moulding features such as drumlins – which we could see from the battlefield memorial and across some of which we drove. The flat land of the Milfield Plain has been interpreted as the remains of a glacial lake, formed when the Tweed ice-front dammed the River Glen which flows through Wooler.

Lunch was taken in the village of Milfield before visiting Bowden Doors, a west-facing vertical scarp about 8m high, which runs N-S for about 400 to 500 metres. Here Alison explained that during the Early Carboniferous crustal extension produced a rifted topography of upstanding blocks and subsiding basins in Northern England, with the Cheviot Block separating the smaller Tweed Basin from the Northumberland Trough. The Tweed Basin is a half-graben bounded on its south by the Flodden Fault and, as a consequence, the sediments are thicker the closer they are to the fault. The Fell Sandstone Formation is 250m thick at Bowden Doors and even thicker further south and was formed by fluvial systems advancing from the northeast.

The crag is on the eastern limb of the Holburn anticline, a significant N-S fold resulting from Variscan compression against the Cheviot Block. It displays two facies (see photo opposite), both of which are made up of fine to medium-grained, sub-angular sandstone: the lower is massively bedded and well jointed whereas the upper displayed an amazing array of sedimentary structures. We saw cross-bedding of varying amplitudes and style including trough cross-bedding, overturned cross-bedding, wash-outs and channel infills, de-watering and slump structures to name but a few and, towards the northern end, some incredible overhanging barley sugar twisted cross-bedding (see photo back cover). Spectacular runnels caused by rainwater were also visible at the top of the crag. The Fell Sandstone has been interpreted as a complex of fluvio-deltaic alluvial plain sediments with braided and meandering river bedforms.

As by now it was approaching time for afternoon tea we drove to Holburn Mill where the owners had kindly invited us to join them and to look at surface expressions of the Hetton Fault which truncates the western limb of the Holburn anticline. Here, in the mill stream which runs through their garden, could be seen steeply dipping Fell Sandstone indicating that we were very close to the fault which is only about 250m to the west. After enjoying a very welcome cup of tea and cakes, we thanked the owners for their hospitality and departed after a very interesting and satisfying day.

Contrasting facies. Bowden Doors

Sunday: Carboniferous rocks around Berwick-upon-Tweed.

Sunday was spent on the coast near Berwick-upon-Tweed studying the Yoredale type cyclothems of the Tyne Limestone and Alston Formations deposited in the Tweed Basin during Lower Carboniferous times. Although we had some rain at the start the weather improved and as the tide was going out we were able to reach rocks covered at high tide.

Our first goal was apparent from the road to Cocklawburn Beach near Scremerston where the waves were beating on the Skerrs to the south and the Saltpan Rocks lying below us to the north. We admired the overturned and overthrust crest of the anticlinal overfold at Saltpan Rocks, (see photo below) a much-studied outcrop of rocks of Eelwell Limestone of the Alston Formation. This is the southernmost manifestation of the east-facing Berwick Monocline formed during the Variscan Orogeny in the Late Carboniferous by east-west compression against the Southern Upland block to the north-west. It has a NNW-SSE trend, and extends 14 kilometres to the north of Berwick. North of Berwick, the steep limb of the monocline is a high angle reverse fault which members of the 2013 field weekend with Alison had been able to see at Burnmouth.

Folds at Saltpan Rocks

Possible buried reed beds. Saltpan Rocks

Looking at the overfold from the south side we noticed that we were standing on the smooth whaleback folds of the Alston Formation group of limestones which lie at beach level and plunge gently to the north displaying anticlines and synclines. The horizontal eroded beds contrasted with the steep angles of dip of the overfold. Red calcite veining has formed in the crests of the anticlines.

Walking south toward the Skerrs we noted that the limestones were dipping to the east. Alison's limestone succession chart of the area showed there are exposures of the Alston Group from the Oxford Limestone Group up to the Sandbanks Limestone so we were walking up the succession. Rocks of the same period are seen in the Dales where they are massive limestones: here muds and sands were interspersed with limestones because the area was nearer to the source of sediment eroding from the Caledonian Mountains to the north in the early Carboniferous.

The different angles of limestone dipping east were noted with some sandstone dipping toward the north as a result of a slumped section. On the beach we found pebbles of Upper Bath-House Wood limestone containing Chonetes (a brachiopod) with spines which are not generally shown in illustrations. There are many examples of bioturbation to be found in the sediment above the Eelwell Limestone indicating deposition in an active shallow sea environment. Small, regular, circular holes on siltstone bedding-planes were seen which, from their regularity, appear to originate from reeds and sedges with straight single tap roots which were inundated by mud and silt (see photo overleaf). Further on we found, lying above very thick fireclay, a thin seam of good quality coal here repeated by a thrust fault dipping at a low angle to the north (see photo opposite). Coal was worked from mines in Scremerston for domestic use until the 1960's.

The afternoon was spent north of Berwick-upon-Tweed where we walked from Fisherman's Haven to Green's Haven and Burgess Cove, passing the position of the lime kilns at Green's Haven used for working the Shotto Wood limestone. Here the Berwick Monocline is cut by two major faults: the Meadow Haven Fault with a throw of 100 metres and the Green's Haven Fault with a throw of 130 metres. Both are probably Caledonian faults related to the Iapetus Suture which were reactivated during the Late Carboniferous and have dextral strike-slip movement with vertical displacement to the south. In Burgess Cove there are two faults down-throwing to the south, thought to be splay faulting associated with the Green's Haven Fault. The gentle folds we saw on the Berwick foreshore were caused by dextral shifting of the two faults. The synclinal basin at Green's Haven trends at right angles to the Green's Haven Fault and has gently dipping limbs as has the domed anticline

Yoredale cyclothem sequences.   Saltpan Rocks

at Ladies Skerrs, where the far limb is cut by the Meadow Haven Fault.

At Burgess Cove we saw the herringbone pattern of the chisel marks in the early workings of the sandstone and Alison demonstrated the way the quarrymen worked to produce this effect. She told us of the hereditary Guild of the Freemen of Berwick who owned the cove and the use of the cove for exporting seaweed, stone and salmon. The sandstones, siltstones, mudstones, fireclays and coal beds in Burgess Cove have been down-faulted between two major faults at each end of the bay and are thought to be the lowest beds of the Alston Formation. We found outcrops of the Wood End Limestone on the beach, very eroded but with traces of crinoids still visible. Tufa is forming in the Dodd's Well stream which marks a fault not shown on the maps. We searched for sharks' fins with no success but found corals, brachiopods, bioturbation and slickensides

Returning up the many steps and around the caravan park to the car park we thanked Alison for a fascinating explanation of the area in time for her to ring the bells in Berwick Town Hall, one of the few secular bell towers in the country.

Coal seam with thrust. Saltpan Rocks

Sedimentary structures. Bowden Doors