LGA

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Field Visit Reports Summer 2015

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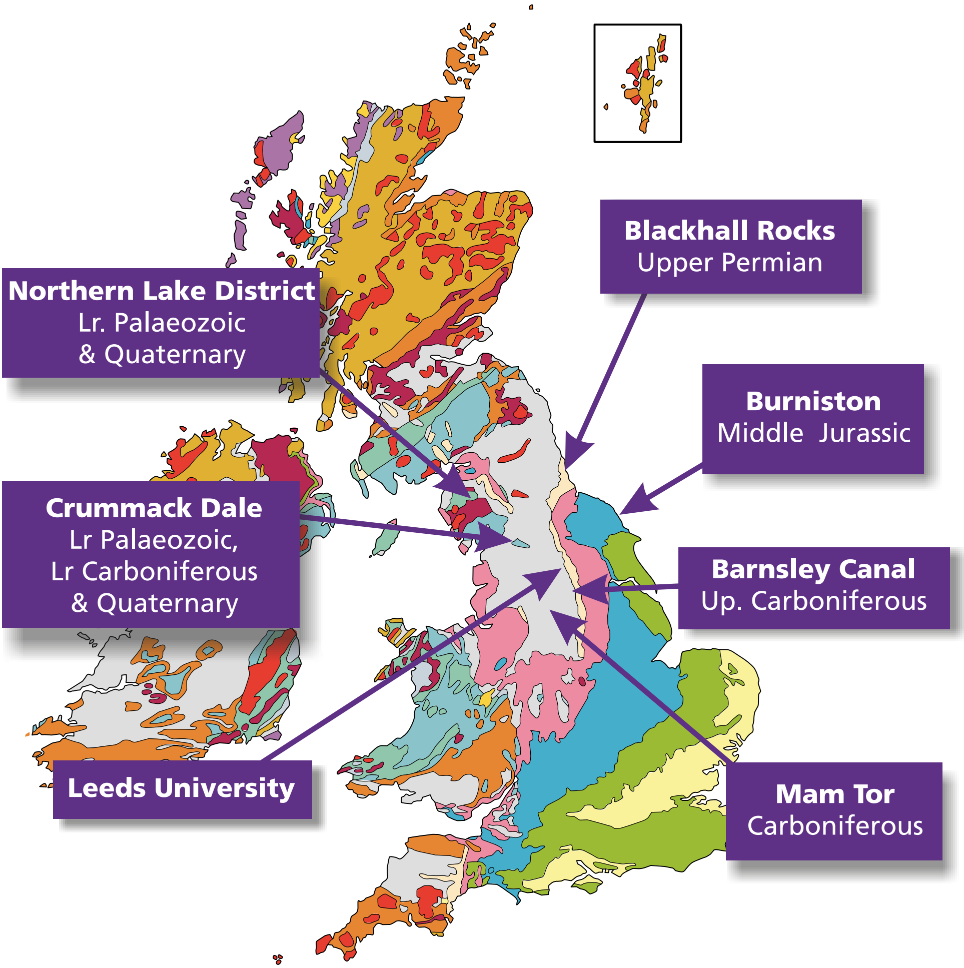
15 Where did we go?



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2015 Field Visit Locations

In addition to the above excursions last year's visit to Hetchell Wood was repeated as an LGA contribution to Yorkshire Geology Month. Details of that excursion can be found in the 2014 Field Visit Reports Booklet.

Thanks are due to the Field Visits Secretary, Judith Dawson, for arranging the programme and Howard Dunnill for the Residential weekend, to the leaders who gave up their time to take us and to the authors of the reports and photographs.

Cover Picture: Norber Erratic 'No. 2', Crummack Dale

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Demonstration of Leeds University's Flume Tank
Thursday evening March 12

Leaders: Professor Jeffrey Peakall & Gareth Keevil.
Leeds School of Earth and Environment
14 Members present

The field season got off to an earlier and slightly different start to the year than usual with a visit to the Sorby Environmental Fluid Dynamics Laboratory at Leeds University. The Laboratory is named after Henry Clifton Sorby (1826-1908) who is widely considered to be the 'Father of Sedimentology' and one of Yorkshire's greatest ever scientists, and the pioneer of the descriptive and hydrodynamic study of sedimentary structures. We quickly discovered however that this nationally recognised centre does an awful lot more than Sorby, in his time, would have recognised! Essentially the laboratory can, and does, deal with anything that involves current flow. What they are able to do with their tanks is to obtain highly detailed information on what is actually happening within fluid flows and to test laboratory results against numerical models, whether it be for academic or commercial purposes. While numerical modelling is very good it can't always be relied on. One example of this is in the investigation of the mixing that takes place in turbidity currents. Numerical models suggest turbidity currents shouldn't travel very far whereas in reality they can travel 1000's of km.

The laboratory is sited in a basement, essential considering the size of the some of the tanks we saw, but even this Jeff told us, had not prevented there being signs of deformation in the substructure. As well as various sizes and shapes of glass tanks and their associated pumps, pipes and reservoirs there was some very sophisticated particle imaging equipment consisting of a Laser Doppler Anemometry system, a Phase Doppler Anemometry system and a range of acoustic Doppler Velocity Profiler systems. These instruments allow collection of high resolution velocity data from within currents and allow complex turbulent flow fields to be quantified in three dimensions.

The group spent a fascinating time climbing round the tanks, pipes, machinery and equipment and squeezing into small spaces to witness demonstrations of some of the sorts of things Jeff and his team work on. We had a model of a jökulhlaup (the outbursts of glacial meltwater from beneath ice sheets), the flow of water on river beds around obstacles (see photo opposite) and of a downdraught of the type that occur in pyroclastic flows, thunderstorms and dust storms. The understanding of downdraughts is clearly vital in hazard prediction scenarios but is also of great value to engineers in assessing wind stress on oil rigs and similar structures and to

Members observing river flow in a flume tank

weather modellers for use in the airline industry. In addition Jeff mentioned other work that the lab had done which ranged from measuring flow within pipes for the oil and nuclear industries to measuring flow over fossil fish and fabrics for swimsuits for the 2012 Olympics!

At the end of this fascinating insight into a truly interdisciplinary facility Jeff and Gareth were thanked for giving up their evening and providing such an informative visit to the start of our 2015 field season.

Bill Fraser

Middle Coal Measures, Barnsley Canal, Near Notton, South of Wakefield

Saturday 18 April 2015
Leader: Tony Felski, West Yorkshire Geology Trust

On a gloriously sunny, but breezy morning, 12 members set off with our leader from Cold Hiendley Bridge to walk south along the towpath towards High Bridge. After about ½ km the towpath entered a cutting giving us shelter from the wind so that we enjoyed a very pleasant walk in the sun. The cutting was heavily overgrown but there were several exposures to examine.

The first exposure was of thinly cross-bedded, grey-coloured, micaceous siltstones, iron-stained and with carbonaceous material in places. Interestingly, some beds showed overturned foresets. Further on an overgrown quarry to the side of the towpath indicated where the Houghton Thin Coal Seam had been removed whilst excavating the canal. Here, several loose samples of poor quality coal and dark grey mudstones were collected. Some of the mudstones contained bright orange brown discs about 1mm in diameter. These were subsequently identified as spat; in this case the spawn of tiny bivalves.

The next exposure was a near vertical cliff about 10m high of massively bedded, pale grey sandstones with interbedded shale which dipped gently to the south east. Below were a number of fallen blocks several of which displayed, on a bedding plane, nodule-like 'protuberances' of between 5 and 10 cm in diameter. One such block had the impression of a Stigmaria and several rootlets and was rather intriguing, causing much discussion both during and after the meeting. The protuberances had no internal structure but appeared to have some alignment and so were initially thought to be load structures on the base of the bed. However, the existence of two burrow structures at right angles to the bedding plane, one of which was U-shaped (See photo opposite), clearly showed that this could not be the case. Tony's later opinion was that the protuberances were probably caused by the disturbance of worm casts by subsequent current flows. The writer visited the site subsequently (that shows commitment! Ed.) and a close examination of the protuberances where they had been partially removed by weathering revealed several burrow structures, thereby supporting Tony's view.

Continuing on the towpath we passed a shallow gulley in the heavily vegetated hillside which Tony said was evidence of a normal fault with a downthrow of about 30m to the south. We then passed a section of massively bedded sandstones with interbedded shales, some of which pinched out, together with an extremely thin coal seam where several pieces of **Calamites** were seen. Approaching High Bridge a second excavated area indicated where the Sharlston Yard Coal had been removed and, in the spoil heap below, pieces of good quality coal and ironstone nodules were found.

Although exposures had been limited they had been more than adequate to display sediments typical of the Pennine Middle Coal Measures Formation – mudstones, siltstones, sandstones and the occasional thin bed of coal together with plant fossils.

Returning to our cars we drove to the Anglers Country Park Visitor Centre and, after using its facilities, walked to another exposure. This was again by the side of the towpath but about 1km to the north of our previous location. Here the canal had been cut by hand through solid rock - the Oaks Rock Sandstone – because the landowner at the time, Squire Waterton, had refused permission to go through his pleasure park. The 400m long excavation took three years (between 1799 and 1802) and tool marks were occasionally visible in the vertical face to the side of the towpath.

The Oaks Rock Sandstone is a thick bedded, fine to medium grained, buff-coloured sandstone and, walking by the side of the 5m high rock face, we were able to view at close quarters an impressive display of large and small-

U-shaped burrow structure and 'protuberances'.

scale erosional features. We walked south in the direction of what appeared to be a main channel through which had cut numerous smaller channels (see photo above). These small channels had flowed in various directions, some cutting down into, or across, others and were of varying sizes (some complete channels being less than 1m wide): all features of a braided river system.

Returning to the Visitor Centre, Tony was thanked for showing us such interesting features, typical of the Pennine Middle Coal Measures Formation, in a very pleasant landscape.

Judith Dawson

Tracking Jurassic Dinosaurs
Saturday, 6th June 2015

Leader: Dr Mike Romano (Sheffield University)

On a dry and sunny morning 12 members and 4 visitors met Mike at the small car park at Crook Ness, east of Burniston village, for a field visit that was a follow on from the lecture he gave the Association in May. Mike first led the group southwards, along the cliff-top path, to a point where we had a clear view of the wave-cut platform below. He explained that the sediments within which the dinosaur footprints occurred were stratigraphically located in the Long Nab Member of the Scalby Formation, the youngest subdivision of the Middle Jurassic, Ravenscar Group. Looking down, a pattern of intersecting sets of arcuate, inclined bedding planes was clearly visible (See photo below). These Mike explained, represented sands laid down on the point-bars of rivers meandering across a broad vegetated flood plain. The finer grained sediments found in the Member were deposited in levee and overbank environments with the finest clays probably in temporary lakes.

We then returned to a point where a steep path led down to the flight of steps which gave access to the rocky and boulder-strewn foreshore. Immediately north of these steps the cliff exposed clays, silts and fine sands overlain by a prominent over-hanging, sharp-based sandstone, probably

Point-bar deposits in Long Nab Member

Partial print of a large sauropod dinosaur

deposited as a crevasse-splay. This, Mike told us, was the horizon of the well-known Burniston Footprint Bed which, in the past, has revealed many well-preserved tridactyl dinosaur footprints. Despite much craning of necks to look at the base of this overhanging bed, on this occasion no footprints were to be seen. The attention of the group was turned to examining boulders on the beach and eventually our efforts were rewarded by the discovery of a large rounded mass of sandstone which Mike identified as the print of the hind foot (or pes) of a sauropod dinosaur (See photo above). The individual digits and the striations made as the foot passed through the soft sediment could be clearly seen. A celebratory lunch-stop followed!

After lunch the group moved carefully south across the boulder-strewn foreshore, eyes peeled for any evidence of passing dinosaurs. Unfortunately, despite good light conditions, such tracks proved to be rather elusive. However, a clear example of what must originally have been a tridactyl print but which now only exhibited two digits, was found. Later on, examination of a bedding plane on a fallen block of fine-grained sandstone revealed a footprint, only some 3 cms wide and vague marks suggesting a possible trackway. This was of a type which Mike said he had not seen before, was certainly not that of a dinosaur but might be that of a crocodilian (See photo opposite).

Footprint of unknown origin

A transmitted print

Further south Mike, drew our attention to some very large fallen blocks of fine-grained sandstone which exhibited large, linear erosional structures. Looking at the cliffs above, it was clear that they had come from a 2m thick sharp-based sandstone bed with prominent basal scour structures. To some, these were reminiscent of the gutter casts occurring in the Cleveland Ironstone Formation at Old Nab, south of Staithes, where they had been attributed to storm generated rip-current erosion in a shallow marine environment. The structures seen at Burniston, in an essentially non-marine environment, must have a different origin being possibly related to eddy-generated rapid erosional cut and fill in a crevasse channel experiencing flood conditions.

Finally, as we reached the southern limit of our traverse, we examined vertical faces within the sediments exposed at the base of the cliffs. These showed good examples of transmitted prints formed where dinosaurs had trampled across water-saturated sediment causing extensive deformation of the primary stratification. (See photo above).

Before leaving, David Holmes, speaking on behalf of the group, thanked Mike most warmly for what had been a most interesting excursion.

Tony Benfield

Mam Tor
Saturday, 4th July 2015

Leader: Prof. Dan Faulkner. Liverpool University

Five members and one visitor met Dan at the Blue John Cavern car park. The objectives of the visit were to (i) examine Carboniferous (Dinantian) limestones, and Namurian mudstones and sandstones (ii) see how these have influenced the formation of the Mam Tor landslip and (iii) to look in more detail at the scale and nature of the deformation within the landslip.

We walked round to the base of Mam Tor (See Photo overleaf top), on the edge of the landslip and, looking southeast towards slopes of limestone, Dan explained how the topography was very similar to how it would have appeared some 340 m.yrs ago with tropical seas forming the edge of a shallow carbonate platform (an apron reef) cut by submarine valleys which gradually filled with mud. Mam Tor itself comprises of Edale Shales overlain by the Mam Tor Beds (Namurian) resting disconformably on limestone (Dinantian). The Edale Shales consist of dark, pyritic, organic-rich marine mudstones, derived from terriginous material brought down by rivers and deposited in deeper water ahead of a delta front advancing from the north. We found scanty shell fragments, (probably pectenids), goniatites, and small burrows. Needles of gypsum were also present, derived from the oxidation of pyrites in the mudstone to form iron oxides and sulphuric acid, the acid then reacting with calcium ions derived from the nearby limestones to form gypsum. The Mam Tor Beds consist of interbedded mudstones and medium-grained sandstones, and are turbidite sequences formed as material was intermittently transported from the front apron of the advancing delta. In situ the beds showed features typical of these sequences, such as a fining upwards of the grain size, laminations in the finer layers, and rip-up clasts. Fallen blocks showed mica flakes, asymmetric ripples, load structures, and flute casts. Slickenlines were also seen, and also a **Calamites** fossil.

The Mam Tor landslip is one of several in the area, but the only one that has been actively monitored for ongoing movement. Radiocarbon dating of ash tree material obtained from boreholes at the base of the slope dates the slip at around 3600 years ago, possibly caused by destabilisation of the slope due to deforestation by Mesolithic people. The material that has slipped down the eastern slope covers an area 900m long and 270 – 450m wide, with an average thickness of 20m and it is thought that the slip occurred on a basal fault surface. This is listric in nature and has caused significant back rotation of the strata, which otherwise are almost horizontally bedded, and was clearly visible towards the top of the slide. (See Photo overleaf bottom) Water, permeating down through the Mam Tor Beds, reaches the

Mam Tor with landslip

Dipping beds caused by back rotation

Upper section of road

impermeable Edale Shales and accumulates, building up the pore pressure. This is exacerbated by a minor fault which runs obliquely through the slipped zone, downthrowing the shales by up to 20 m on the south side, causing water to build up behind the fault and making slippage more likely.

The remains of a tarmac road runs across the landslipped material in two places, the upper section of road being at the junction of the Mam Tor Beds and the Edale Shales, while the lower section runs across the Edale Shales. This used to be the main road between Sheffield and Manchester but after repeated problems caused by continuing subsidence, was abandoned in 1979 and rerouted further north. Sections through the upper part of the road were clearly visible, and it could be seen that the thickness increased from north to south as the road was repaired with extra layers of hard core and tarmac. (See Photo above) This mimics the sedimentation found in natural sedimentary basins where subsidence results from vertical fault movements.

Several studies have shown that the slippage is still active, moving along the basal fault about 20 m below the present land surface at a rate of about 0.5 m per year. Smaller curved slip surfaces within the main slip also influence the movement. One study carried out over 3 years from 2006 – 2009 looked at the correlation between creep and pore water pressure within the Edale Shales

Hummocky, Mam Tor Beds above bracken-covered Edale Shales.

section of the landslip using wire creep meters, borehole piezometers, and rainfall monitoring. It was shown that although the amount of rainfall is a factor, particularly single, very high rainfall events, creep rate generally tends to be highest during the winter months. This is mainly because the lack of vegetation cover (mostly grass and bracken) allows greater penetration of the rainfall, thereby increasing the pore water pressure. This rate of creep has remained remarkably steady throughout the 200 years since the road was first built.

The landslip showed a clear demarcation between the two lithologies. The Mam Tor Beds forming the upper section were steep, lumpy and grass covered, whereas the lower section of Edale Shales was shallower (about 15° slope), smoother and bracken covered, with pools and marshy areas due to the impermeability and lack of a mature drainage pattern. (See Photo opposite). The forward edge of the slip was shown by a return to farmed land and a pressure ridge, formed as the slipping material builds up against the stable ground.

On the lower section of road a series of cracks in the tarmac was seen showing en echelon structures due to the extensional pressures caused by the slippage. Continuing down the road we came off the landslipped material and encountered the Dinantian limestone at Odin Mine. This is a strike-slip fault that was mineralised post faulting to form the Odin Vein, the most northerly of the Peak District veins. It is thought to have been worked for galena during Roman times and again by the Saxons and Danes, although there is no clear evidence available. It was worked extensively throughout the C18th and finally ceased production of lead in 1869, although small scale working occurred in the early C20th for fluorite and barite. Although the vein had been worked out, minerals including galena and barite were still visible on the sides of the fault, and also slickenslides, indicating strike-slip movement along the fault. Below the mine the old gritstone ore crushing wheel was seen, still in its circular iron track, and this is where the visit finished and Dan thanked for a fascinating and very enjoyable day looking at engineering and mechanical aspects of the landslip in addition to the purely geological side.

Robert Chandler

The Upper Permian Zechstein Group at Blackhall Rocks, County Durham.
Saturday 1st August 2015

Leader: Dr. Mike Mawson, Durham University

12 members and four visitors met Mike in the car park at Blackhall Rocks, a SSSI five miles north of Hartlepool, where, before descending to the shore, Mike gave us an outline of the stratigraphy that we would be seeing during our 2 km walk south along the beach.

During the Permian, north-west Europe was situated in the interior of the supercontinent Pangea, at around 20 degrees north where a hot, arid climate led initially to the deposition of continental desert facies of the Rotliegend Group. Following a marine incursion from the north, the Zechstein Sea was formed which, being largely landlocked, was subject to periodic, partial or complete, desiccation when communication to the open ocean was restricted or cut off. Thick cycles of evaporite deposits were formed and it is by these that the Upper Permian Zechstein Group, which is approximately 300m thick, is conventionally divided. (See Table below) Each cycle, formed of packages of carbonates and evaporites, is considered to record episodes of transgression followed by regression and/or desiccation of the Zechstein Sea. The rocks seen on this excursion were from the cycles Z1, Ford Formation and Boulder

	Formation	Thickness	Description
Z3	Seaham Formation Z3C	35m +	Offshore – transition zone facies containing tube-like fossil, *Calcinema*. Contains concretionary fabrics and is affected by collapse brecciation. Collapse breccias contain red marl from overlying Roxby Formation. Top not exposed.
Z2	Fordon Formation Seaham Residue Z2A/1, Z2S & Z2A/2	1.8m	Dissolution residue of khaki green to brown clay originally consisting of 20 – 30m of nodular anhydrite or gypsum.
	Roker Formation (inc. Crinkly Bed) = Z2C	56m	Shallow to very shallow-water facies of various types with 1.3m Crinkly Bed near base forming part of 20m interval of stromatolite and pisoid grainstone shoal facies. Oolitic facies near top of succession. Consists of three smaller-scale packages, Z2C/1, Z2C/2 and Z2C/3.
Hartlepool Anhydrite (Z1A) absent - not deposited here			
Z1	Boulder Conglomerate Z1C/2	7m	Clast-supported rock consisting of cobbles and boulders derived from reef-crest and reef-flat facies. Interbedded intervals of laminated microbialite and wackestone and packstone contain Z1 fauna and define clinoform units.
	Ford Formation Z1C/2	100m	Reef-front facies composed of reef-rock with bryozoan framework and also much microbialite and marine cement. Also steeply inclined sheets of laminated microbialite. Reef-flat facies composed of wackestone and packstone interbedded with laminated microbialite. Well preserved fossil biota including brachiopods, nautiloids and bryozoans. Only top 2m exposed.

Table 1. Upper Permian, Zechstein Group Stratigraphy seen at Blackhall Rocks

General view of the Ford Formation in the cliffs

Conglomerate; Z2, Roker Formation and Seaham Residue; and a small part of the Z3, Seaham Formation. The outcrops represent the rocks formed at the western edge of the basin, and do not contain the thick evaporates deposits which formed further out into the basin to the east.

The first outcrop on the foreshore was the top 2m of the 100m thick Ford Formation (Z1). With dipping clinoforms it represents a reef spur and is thought to have formed during a hiatus in reef formation. In nearby cliffs (shoreward in the basin) was a stromatolite reef with interbedded dolomite and calcite with on overall antiformal structure, (See Photo above) formed in a shallow, subtidal environment. The poorly preserved laminations are due to de-dolomitisation during uplift when Mg was removed by fluids. A short distance south, the cliffs revealed a shelfwards outcrop of reef flat with interbedded grainstones and microbialites and contained well-preserved nautiloids, brachiopods and bryozoans. (See Photo overleaf top) The reef facies are overlain by the Boulder Conglomerate, a storm-beach deposit consisting of reef-derived cobbles and boulders and which have a very blocky appearance. The conglomerate was formed after a relative sea-level fall that occurred towards the end of Z1C times but prior to a major low stand during which the 100m thick Hartlepool Anhydrite was precipitated in more basinward (easterly) locations.

At the next locality, the Gin Cave, the Z2 Roker Formation directly overlay the reworked top of the Boulder Conglomerate. (See Photo overleaf bottom)


Nautiloid moulds in the Ford Formation


Boulder Conglomerate overlain by the Roker Formation

This marks a return to carbonate production following a relative sea-level rise and it consists of various types of shallow to very shallow-water facies. At its base are about 20m of pisoid shoal facies and subtidal stromatolites, the latter containing unusual ripple-like sedimentary structures which are well seen in the distinctive 1.4m thick Crinkly Bed which contains filamentous cyanobacteria and peloidal grains and has well-preserved fine laminations of micrite with thicker, granular laminae in-between. In the roof of the Gin Cave oval features, which appear like linguoid ripples with a north – south orientation, are interpreted as being formed by wave action. Finer structures superimposed on these are thought to be of tidal origin. (See Photo overleaf).

Overlying the Crinkly Bed were large, generally linked, flat-topped domical stromatolites up to 18m across and with a relief of ~ 1m. The stromatolites are associated with grainstone shoal facies composed of pisoids, the same as those found in the Crinkly Bed. The grains commonly show over-compaction caused by subaerial exposure and minor dissolution indicating a shallow-water, frequently emergent environment, for these rocks.

Oolite grainstones capping the Roker Formation were seen where they were downthrown to the south by a fault and again illustrate a shallow water, high energy shoal environment. These are of economic significance as they form important oil and gas reservoirs. It is also thought now that the source of the hydrocarbons may be the microbial layers within the rock itself. Above the oolites, forming the highest beds of the Z2 cycle, was a thin layer of greeny brown clay. This was the residue of a 20-30m thick bed of anhydrite or gypsum that had been formed as the sea evaporated. Percolating groundwater has since dissolved the evaporite leaving the insoluble clay.

The final outcrops were of the Z3, Seaham Formation. Once again these are shallow water facies showing a return to marine conditions following the low-stand during which the underlying (now dissolved) evaporites had formed. The dissolution of those evaporites has resulted in the Seaham Formation collapsing resulting in a brecciated fabric. Fine specimens of concretionary limestones were observed and these led to further discussion of the processes by which dolomitisation may have occurred.

These Zechstein rocks have much evidence for changing palaeoenvironments and are very important for oilfield geologists. Mike showed us a well completion log for the whole section and explained that work is ongoing to understand the processes seen in the outcrops, how hydrocarbons are formed and how they are stored. He was then thanked for unravelling such an amazing amount of detail of both large and fine scale structures in such a short stretch of coast and the party departed for home.

Phil Robinson

The roof of Gin Cave with complex ripple structures

Crummack Dale
Sunday 23 August

Leaders: Jack Soper (Sheffield & Leeds University retd.) & David Turner

18 members and 4 visitors met Jack and David at Townhead in Crummack Dale. Under clear blue skies and a strong warm breeze Jack introduced us to the area before the party set off to the first outcrop which was limestone of the Kilnsey Formation, part of the Great Scar Limestone Group. This was seen to be conglomeratic with bands of pebbles in a calcareous matrix separated by layers of pure limestone. The pebbles were angular fragments of quartz, sandstone and slatey looking material up to 1cm in diameter as well as larger fragments of limestone. These features, along with signs of cross bedding, suggested that the material was deposited under a high energy environment in shallow, clear seas with a shoreline close by. Climbing up to a higher level in the Kilnsey Formation the number and size of rock fragments reduced to be replaced by fragments of crinoids, corals (solitary and colonial) and brachiopods suggesting that while the sea was still shallow and energy levels high, the supply of terrigenous material was now reduced.
Attention now turned to the Norber Erratics (of which there are many hundreds) which lie in a band of just over 1km in length, stretching from just south of Norber Brow to a point half way up Crummack Dale. They are almost all of Silurian greywacke and while the majority lie in shallow grassy turf, some stand on low, limestone pedestals of Carboniferous age. The southern boundary of the erratic field was identified and its implications discussed. Did it indicate the limit of the ice that was transporting them or was it that it was only very late in the glaciers life that it exposed the source rock?

The Lower Palaeozoic rocks forming the various inliers along the southern margin of the Askrigg Block were all affected by the Caledonian Orogeny which resulted in them taking on cleavage and in the first erratic examined Jack asked us to test us our ability to identify this from bedding. At first this proved to be difficult with the structure many thought to be bedding turning out to be cleavage. One reason is because the bedding planes are widely spaced and so not obvious in loose blocks. Another is that the varied composition of turbidites results in contrasting cleavage; the mudrock component cleaving more readily and at a steeper angle than the greywacke.

The Norber Erratic field is probably the best known example of its kind in Britain and the fact that some erratics stand on low limestone pedestals has been taken as an indication that since they were deposited the limestone surface has been lowered by dissolution. The traditional theory that the erratic protected the limestone beneath it from solution by rainwater by acting like an umbrella has been challenged and some of the alternative ideas were briefly discussed. Whatever the process, by measuring the height of the pedestal and knowing the date the erratic was dropped, it should be possible to work out the rate of lowering. Establishing each of these however has proved difficult. There are relatively few erratics resting on pedestals and their heights vary from between 5 - 50 cm. Establishing when the erratics were dropped has been done using Cosmogenic Isotope Surface Exposure Dating. At Norber four different erratics that all stand on a pedestal have been sampled and their exposure age measured; armed with photographs and maps we set out to locate them. Once this had been achieved Jack informed us that three of them had provided mean ages of 18,000 yrs +/- 1,600 yrs - late Devensian. The erratic that didn't fit these dates is Norber 'No 2', the classic text book erratic, (Photo on front cover) which gave an age approx 4,000 years younger than for the others. The reason for this was realised when earlier photographs and sketches of the erratic showed that sometime in the past 50 years a piece of rock approx 30 cm thick had been cut off its top! Discussion took place regarding the reliability of the dates themselves and how these dates affect those geomorphologists trying to establish rates of lowering of the limestone surface.

After a lunch we climbed higher on the hillside to view the erratic field from above. The upper limit of erratics, which marks the maximum thickness of the ice from which they were deposited, was soon reached and, looking down onto the erratic field, it was noted that they appeared to lie in lines. Again various possibilities were suggested; was this some form of alignment that took place within the moving ice or was it a reflection of the decay of the ice with erratics being dumped at its margins as it shrank?

Dropping back down into Crummack Dale the Kilnsey Limestone was again encountered at Nappa Scar where a patch of Lower Palaeozoic boulders occurs within conglomeratic limestone. The chaotic arrangement of the material, the angularity of the clasts and their range of sizes (up to 2m diameter) indicate a very nearby source, with little or no transport involved. Collapse of a steep rock face adjacent to the Carboniferous shoreline was agreed as being the most likely cause. A couple of metres below this outcrop the basal Carboniferous unconformity was inspected where conglomeratic, Kilnsey Limestone, rests on cleaved Ordovician mudstones of the Norber Formation. (See Photo opposite).

While this was supposed to be the final outcrop of the day the excellent geology and fine weather resulted in a detour. Walking back up Crummack Dale northerly dipping outcrops of the Silurian Austwick Formation were

Basal Carboniferous unconformity

Variation in cleavage in turbidites

crossed that revealed approximately 30 turbidites flows. Sections through these gave excellent views of how their varying lithology affected cleavage, (See Photo above) as noted in the erratics seen earlier. A narrow band of cavities within some of the upper turbidite layers were created by solution of calcite nodules they once contained. Entering a narrow lane a 20m stretch of its floor was seen to be made up of shale of the Austwick Formation. The surface dipped north at approx 30° and though polished by ice, was scarred by glacial striae aligned almost north - south showing the direction of ice travel. (See Photo opposite top) On the western edge of the Dale we were able to identify the head of the Norber Erratic Trail as a series of low crags of the Austwick Formation, smoothed on their up- valley side. From these the trail of jumbled blocks stretched south to Norber Brow, confirming the direction of ice flow through Crummack Dale. (See Photo opposite bottom).

Returning to the cars Jack and David were thanked for providing such an excellent day in this classic location and we departed for home as dark clouds gathered overhead which, after a few miles, produced a violent thunderstorm.

Bill Fraser

Glacial striae

Source of Norber Erratics

Residential Field Visit: Northern Lake District
Friday 2nd – Sunday 4th October 2015

Leaders:
Saturday 3rd October - Alan Smith, Cumberland Geological Society
Sunday 4th October - Alan Wise, Cumberland Geological Society (Accompanied on both days by Susan Beale, President, Cumberland Geological Society)

Present: 15 members

Friday :

On Friday afternoon a group of early arrivers went to examine two exposures of Skiddaw Group rocks on the shores of Bassenthwaite Lake. The first, on the western side, alongside a disused stretch of the old A66 at Beck Wythop is a 100m long, approx 10m high cliff section which, along its length, shows the complex character of the Group. Originally deposited in the early Ordovician as submarine muds and silts in the closing Iapetus Ocean, these rocks have been folded and cleaved through several tectonic events resulting in an extremely complex structure. From north to south the original bedding changes from vertical to large complex folds, with smaller thrust zones and minor faults with the main cleavage plane approximately parallel to the cliff face. At the southern end there are full folds within the height of the cliff. Despite close inspection we did not reach unanimous agreement in which direction the beds were younging.

The second exposure, on the eastern side of the lake at Long Close, was an approximately 3m wide dyke in Skiddaw Group rocks. Although close to the roadside, access to the dyke face was difficult, but a sample obtained confirmed it to be a pale grey, fine grained rock (which the book says is mainly composed of feldspar). Limited quarry workings up the hillside indicated that the dyke material had been worked for building or roadstone.

Having worked up an appetite we then returned to meet the rest of the group at our hotel for dinner.

Howard Dunnill

Saturday :

At 9.15 prompt, we set off from Braithwaite in the mist and drove south into Borrowdale to Seathwaite where we met Alan and Susan. The plan for the day was to look at Borrowdale Volcanic Group rocks in the morning then, after lunch, move a short distance north and look at glacial landforms.

The Borrowdale Volcanic Group is of Ordovician (Caradoc) age, approximately 460 million years old and is divided into 'upper' and 'lower' parts. The rocks are extremely varied and mapping in the 1980's identified more than 100 different formations. From the hamlet of Seathwaite, looking west, Sour Milk Gill, which marks the boundary between the upper and lower parts, could be seen tumbling down the hillside. The lower rocks are to the north of the Gill and represent 5 million years of volcanic activity in the form of quiet, andesitic lava eruptions with ash deposits indicating occasional explosive activity. The rocks all dip to the south and were originally part of a low profile, sub-aerial, volcano.

The upper rocks were laid down differently. At the head of the valley, in Ordovician times, was a complex caldera in a watery environment. Water accessing the vents caused violent explosions resulting in vast volumes of ash. Some was sorted and graded as it fell through the air to be deposited on the land surface as tuffs while some formed pyroclastic flows running down the sides of the volcano. After deposition some of both forms were periodically reworked by water, some flowing down slopes as lahars, others in shallow lakes. On the hillside we examined a large boulder of the Whorneyside Formation which contained fragments up to 2 metres diameter set in a matrix which was deposited as a lahar. (See Photo overleaf top) In outcrops we saw a rare example of current bedding in a volcanic rock as well as ripple marks (See Photo on back cover) which, along with desiccation cracks that have also been found, show that some material was deposited in shallow, ephemeral lakes. Alan showed us a photo, taken in 1992, of a rock fragment with tracks 5 – 6 mm wide left by an early life form, a miriapod, which lived both in the water and on the land. Further up the sequence deposits became more regular and consistent. Some fine ash with mini-faults were noted and also an erosion surface marking the base of a lahar. (See Photo overleaf bottom).

Back down by the River Derwent the mist had thinned and the spoil tips from the graphite mines could just be seen forming a line up the hillside. Graphite was mined from Elizabethan times, when it was strictly controlled. It was used to line cannon ball moulds, which made the balls smoother, faster and more deadly. More prosaically, the local shepherds used it as “wad” to mark their sheep and from the seventeenth century, the pencil trade developed. The graphite occurs in irregular nodules (some only 2 – 3 cm long), originally

Large fragments in lahar deposits

Erosional surface at base of a lahar.

found on the surface but then in pipes, 8 of them, 1 – 2m across and up to 100m deep, in a diorite intrusion on the hanging wall of a fault. The source of the carbon is thought to be sediments removed from the Skiddaw Group rocks as magma moved upwards. Huelva in Spain is the only other place in the world to have graphite in volcanic rock. Back through Seathwaite and a short distance up the hillside, we looked at a crag we had seen from across the valley. It was volcanic ash, a grey-green andesite, laid down sub-aerially and contained a volcanic bomb which must have travelled at least 6km from the caldera.

Borrowdale is a major, north facing glacial trough and at this point looking south, up the valley, particularly on the west side, we could see a series of glacial moraines which have been cut by streams. North, down the valley, the valley floor was flat suggesting a possible lake bed. After lunch we moved to Stonethwaite to look more closely at glacial features around Longthwaite. Here we saw three terminal moraines and were able to view the structure of one where it had been eroded by the Derwent. (See Photo overleaf) Cosmic radiation dating has confirmed that these valley-head moraines were formed during the Loch Lomond Stadial event. (12,700-11,500 yrs BP). While ice clearly flowed north and then west into the Solway, erratics from Stonethwaite found near Seathwaite, and others from Langstroth found in the moraine near the Derwent south of Longthwaite, show that at some earlier time it had flowed south. Looking northwards we could see where meltwater was stopped for a time by the hard, andesite rocks of the Jaws of Borrowdale. When the water eroded the softer Skiddaw Slates it was able to flow north. Precisely what happened and when is still not clear. For us though, at the end of a very interesting day, the sun had come out and the skies were clear and we thanked Alan and Susan and returned to our hotel.

Ann Roberts

Sunday :

We convened at the School House Quarry in Mungrisdale to renew our acquaintance with the complexities of Skiddaw Group rocks; in this case fine-grained mudstones and siltstones of the Kirk Stile Formation. We were challenged to determine the bedding and cleavage planes and find an igneous intrusion. This proved quite difficult, especially as the bedding and cleavage planes were not much separated. The igneous intrusion, a quartz felsite, although vertical in the quarry wall, was parallel to the original bedding, and so probably intruded as a sill. Vesicles to one side of the sill were indications of the magma cooling.

On our way into the Caldew valley we stopped at Mosedale Bridge to examine pebbles and small boulders in the riverbed as it left the Dale after

Eroded terminal moraine

passing over the metamorphic aureoles caused by the Ordovician Carrock Fell Complex and the Devonian Skiddaw Granite. The intrusions produced different types of hornfelsing in the Skiddaw Group rocks; the Carrock Fell intrusion hardened the country rock whereas the Skiddaw Granite caused long white needles of Chiastolite and dark spots of Cordierite to form. Examples of both were found, along with many other specimens at this very interesting sampling point.

In the Caldew valley the gabbros of the Carrock Fell Complex are to the north and the Skiddaw Group to the south, the latter hornfelsed by thermal metamorphism resulting from proximity to the underlying Skiddaw Granite. Enormous pressures from the intrusion has also produced dramatic folding in the hornfels, large chevron and parallel folds (See Photo inside back cover) can be traced over substantial distances. As would be expected, within the large fold structure are many complex small-scale folds and thrust faults, and in some places areas of complex crumpling of the structure. Further upstream the Skiddaw Granite is exposed in the river bed (the source of examples seen at our previous stopping point), and its contact with the hornfelsed Skiddaw Group can be found.

We paused for a lunch stop at the Friends Meeting House in Mosedale village where, courtesy of the Quaker Community, we were grateful to receive steaming mugs of tea and freshly ground coffee together with homemade ginger cake and flapjack, an unusual but very much enjoyed break in a day's fieldwork!

Our afternoon was spent traversing the lower slopes of Carrock Fell, starting from Mosedale and progressing northwards to follow the sequence of igneous intrusions. To the east of Carrock Fell the landscape changes abruptly from severe mountain environment to low lying common ground due to a substantial fault with a down throw to the east of about 600m. A few kilometres to the east, towards Penrith, the raised ground on the skyline is the start of the Carboniferous Limestone Series. In the nearer foreground, beneath lower uneven hillocks, lie the Eycott volcanics from the earliest Borrowdale Volcanic activity.

At Carrock End Quarry close to Mosedale we examined dark, coarse grained gabbros, the large crystals resulting from intrusion at depth and slow cooling. At this location xenoliths of Borrowdale Volcanics are found in the gabbros, the result of 'sedimentation' in the original magma chamber. At Buck Kirk, 100m further north, the gabbros are lighter in colour and finer grained. Examples were shown of gabbros with an oriented fabric as a result of crystal sedimentation within the liquid magma; other examples, without any fabric, may have cooled more quickly as the magma was intruded. We saw an example of a quartz porphyritic dyke with a very fine crystal structure from the adjacent gabbro. Further north, at Further Gill Syke Pit, we reached the granophyre zone, the material in the pit having fallen from Scurth Crag above. The granophyre has weathered to a pink colour, but a freshly broken surface is much darker. The rock contains no xenoliths or veining and is extremely hard with a very complex crystal structure. The granophyre was intruded later than the Carrock Complex and in 3 pulses, leading to slight differences in the granophyre formed.

Finally, we crossed a fault to an area of rough ground to the north-east and examined a long low hill (approx 5m high), oriented SW – NE, which had been excavated at its northern end to reveal its origins. This is an esker from the Devensian glaciation and contains rocks from small pebbles to middle sized boulders all of which have been rounded giving an indication of the strength of currents required to transport them. The juxtaposition of in-situ boulders in the exposed side walls indicated glacial flow to the north-east. At our leader's suggestion we assembled a number of 'different' rocks which he then identified as: gabbros originating from the Carrock Fell Complex to the immediate south; Skiddaw granite and the microgranite from the Caldew valley; a distinctive granite from St John's in the Vale and finally (triumphantly) a pink igneous rock from the Armboth Fell Dyke, a small intrusion which is only exposed in a small outcrop on the east slope above Thirlmere! Altogether conclusive proof that Devensian ice from the north east fells flowed northwards around the Carrock Fell complex into the Solway. A very satisfying end to an enjoyable day in the field.

We thanked Alan and Susan for their leadership and enthusiasm on behalf of the group and our Association.

Howard Dunnill

Chevron folds in the Skiddaw Group

Ripple marks in the Whorneyside Formation