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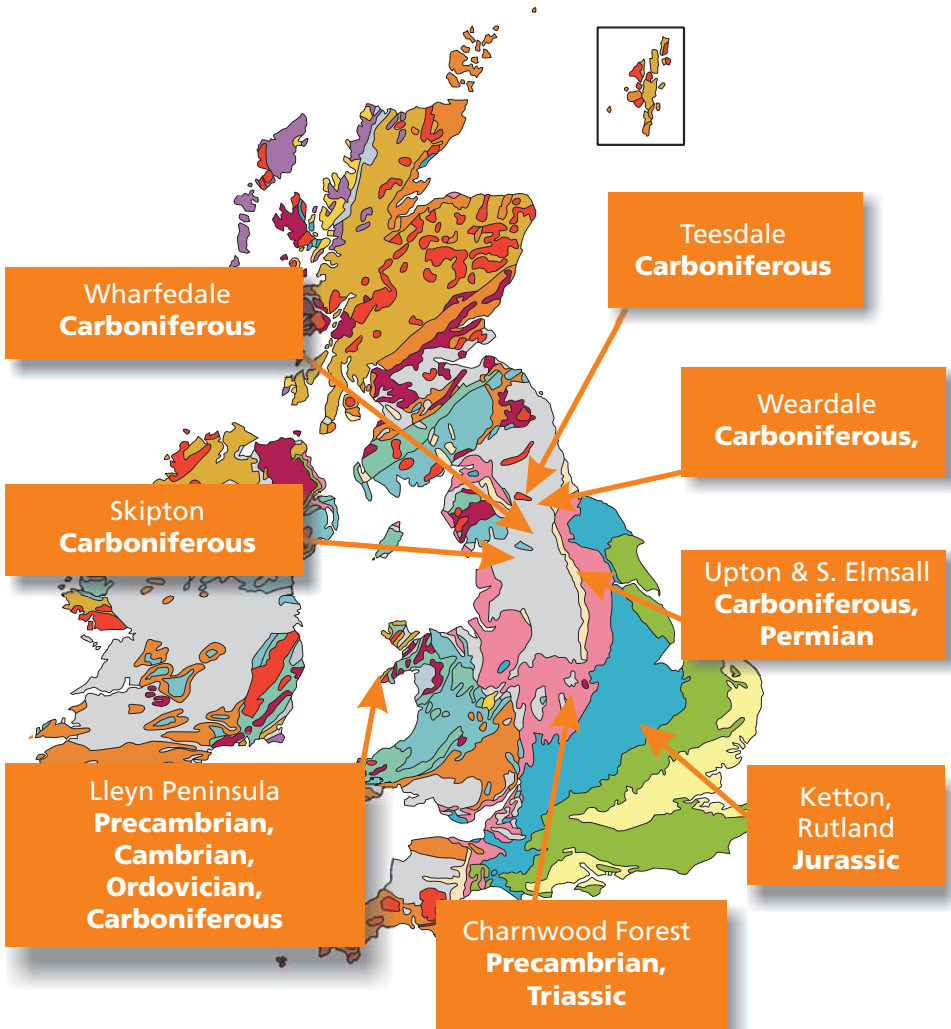
Field Visit Reports Summer 2012



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Where did we go?



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2012 Field Visit Locations

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Thanks to the authors of the field visit reports who also produced the images:

Tony Benfield, Anthea Brigstocke, Judith Dawson, Howard Dunnill, Bill Fraser, Jeremy Freeman, Shirley Leach, Judith Whalley. Extra images provided by Charlie Bendall and David Leather.

Cover Picture: Participants standing on Marchup Grit above Kex Gill with the landslide site on A59 in the distance.

Cronkley Fell – Upper Teesdale. Sunday May 12

Leader: Brian Young, BGS (retired), Dept Earth Sciences Univ. of Durham
23 members present

While the participants had followed the instructions to arrive at the meeting point early, spring hadn't! The daffodils were still blooming, the trees only just coming into leaf and a cold wind, which got stronger as the day progressed, was blowing. However, the infectious enthusiasm and humour of the leader Brian Young as he outlined the day ahead meant the party set off in eager anticipation. The main purpose was to look at aspects of the type example of a sill; the Whin Sill. This sheet of quartz dolerite underlies approx. 4,500km² of Northumberland and Co. Durham and was intruded 295Ma ago in late Carboniferous times. Most of the day was to be spent considering the structural and stratigraphical relationships of the Sill with the other rocks forming this part of the Alston block and the metamorphic features developed in the roof rocks which, as Brian pointed out, have been poorly described compared to the masses of other information available on this important structure.

The starting point at Forest in Teesdale was a good point to begin to understand the structural and stratigraphical aspects. The north side of the valley here is typical 'dales scenery', being a series of steps and benches developed on the rhythmically bedded sediments of the Alston Group above which are shales and sandstones of the Stainmore Group (Namurian). In marked contrast the south side of the valley is dominated by the dark dolerite cliffs of Cronkley Fell (see inside back cover) formed by the Whin Sill intruded into the Melmerby Scar Limestone and its underlying conglomerates; the lowest members of the Carboniferous rocks that cover the Alston Block. The reason for the difference is that the valley here is bisected by the Teesdale Fault and the Burtreeford Disturbance (a complex, faulted N-S trending monoclinical structure), both of which have a net downthrow effect to the east.

Crossing the valley floor, small scale crag & tail features, drumlins and 'moraine deposits' were seen before meeting the first solid outcrop in the bed of the River Tees; dolerite from the middle portions of the Sill which here is approx 70m thick. Looking up to Cronkley Scar, the base of the Sill could be seen approx. 100 m above us which gave a good measure of the effect of the Burtreeford Disturbance.

Climbing up out of an overflow channel across an outcrop of the Whin Sill the

path led through a thick growth of juniper; a relic Arctic flora. Continuing uphill to Cronkley Fell the pace slackened as the path steepened and the wind strengthened and lunch was taken in a hollow that offered some respite from the elements. The spot overlooked White Force, a waterfall formed where a stream cascades over the edge of the Whin Sill. An unusual feature of this fall is that the water doesn't reach the base. (See photo below) This is because the lower part is formed of the Melmerby Scar Limestone into which the stream has opened a sink hole which, except in spate conditions, all the water disappears into; rather like the plughole in a sink. A few hundred metres downstream the water, having flowed horizontally through the limestone, reappears and tumbles down to regain the dry stream bed. At the entrance to the small gorge formed by White Force are the spoil heaps of a 19th Century prospecting level driven through the Melmerby Scar Limestone beneath the Whin Sill. The purpose of this was probably to intersect a series of veins seen at the surface to the south. While the venture was unsuccessful, blocks of brecciated marble on the spoil heap containing magnetite show that some sort of mineral deposit was found. In the shelter of the lunch spot Brian took the opportunity to show specimens of minerals that may be found on the top of Cronkley Fell. The garnets, pyroxene and serpentine he showed did the trick and battle with the wind and gradient was rejoined.



White Force – a waterfall to nowhere. Spoil from old lead mine in foreground

Reaching the top proved worthwhile. The cloud base had stayed high and so, despite the now howling wind, fine views were enjoyed. Underfoot the first thing noted was the sandy nature of the soil. A drop of acid caused it to froth violently showing it to be sand made of calcite! The source of this is the 'Sugar Limestone', a coarse grained marble formed by metamorphism of the Melmerby Scar Limestone. This thin, mineral rich but organic poor, soil supports a rare group of alpine wildflowers. Although too cold to see them in all their glory, Gentian and Bird's Eye Primrose were seen. Moving slightly higher to an even more exposed spot the ground was found covered in platy rock fragments. These were metamorphosed shales lying above the Melmerby Scar Limestone which here the Whin Sill magma had punched up through. The position of the shales on the upper surface of the Sill, the thickness of the magma below, and the complex chemistry of the magma fluids (and shales) has produced very high temperature metamorphic minerals. The shales have been intensely altered to hornfels and contain mineral filled cavities. Examples of garnet and specimens rich in magnetite were found as well as other minerals whose identification was impossible in the now extreme conditions. A search was maintained for some time before it was decided to abandon the planned circular route and beat a retreat by the way we came.

On reaching the valley floor those of the party who hadn't succumbed to hypothermia took a detour to view the oldest rocks that make up the Alston Block. Arriving at a ruined building by the river, attention was directed to the mole hills as it was in these that fragments of 'Widdies', (slate pencils), could be found. The building was once a pencil mill working the Skiddaw (Ordovician) Slate that makes up this exposure of the Teesdale Inlier. On the opposite bank of the river several lamprophyre dykes formed prominent features.

Back at the car park Brian was thanked for providing such an excellent day, despite the weather conditions. Not only did we benefit from his enormous knowledge of the geology of the area but his easy manner and ability to link it to many of the other natural and manmade features of the countryside as well as folklore tales, made it a day to remember.

Upton Railway Cutting and South Elmsall Quarry Thursday evening 17th May

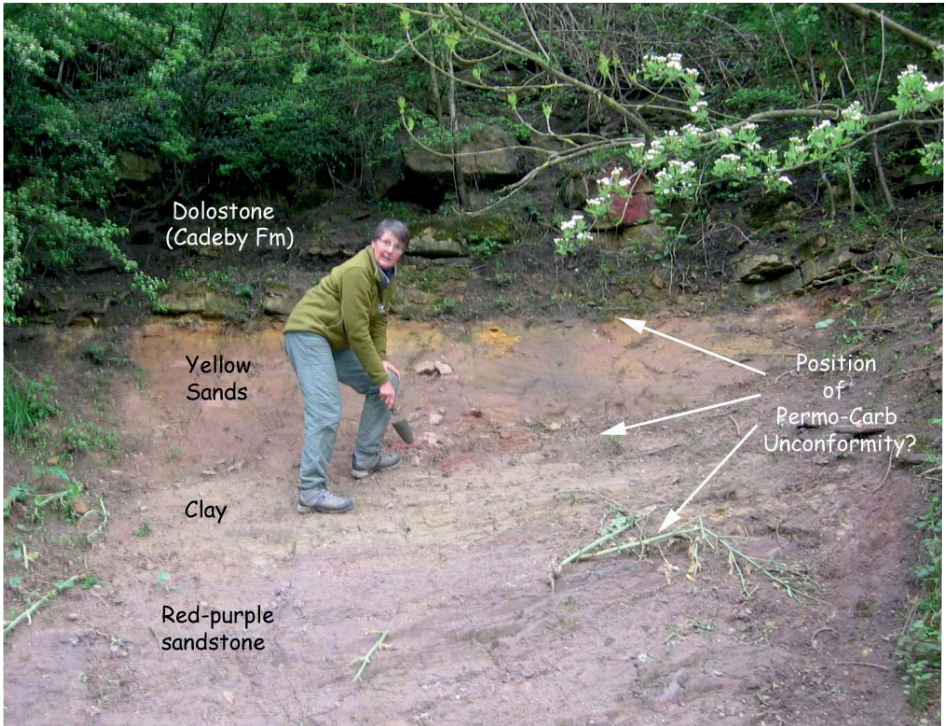
**Leader: Alison Tymon. West Yorkshire Geology Trust
16 Members present**

The group met Alison in Upton on a cool May evening. She explained that first we would examine a rare and special exposure of the unconformity between the Permian and Carboniferous, and then we would travel the short distance to look at a very good example of a Permian patch- reef in the South Elmsall Quarry, a SSSI.

Upton, which lies on the boundary between the Permian and Carboniferous, developed in the 1920s with the onset of mining from the underlying Carboniferous Coal Measures. The mudstones associated with the coal seams were used for brick making. Upton Colliery closed in 1964, and the large area has now been landscaped into a country park with interesting flora associated with the underlying Permian Magnesian Limestone (dolostones). We walked across the park to the disused Hull and Barnsley Railway cutting and noticed a broken brick in the spoil of the footpath engraved with 'Upton'!

Alison explained that the Permo-Carboniferous unconformity was weathered in arid conditions during the erosion of the late Carboniferous rocks which were uplifted during the Variscan Orogeny. This location was at latitude of 10-15° north, and following a marine transgression, was at the very edge of the shallow, hot, salty Zechstein Sea which lapped up against the eastern flanks of the Pennines. There were big sand dunes and sabkhas on the shore, intermittently covered by this evaporating sea. These unconsolidated Yellow Sands, (Basal Permian Sands), are preserved in some areas of West Yorkshire, up to 10m thick and, where present, underlie the Cadeby Formation, the lowest dolostones of the Magnesian Limestone.

The Upton Cutting starts quite abruptly, and sections were drawn by geologists in 1872 prior to the opening of the railway, copies of which had been obtained by Alison from the Proceedings of the YGS. A fault, which is not directly visible, cuts obliquely across the cutting in a NE-SW direction with a 100m displacement, bringing the Cadeby Formation down to the level of the Cutting. Wakefield Council excavated the Cutting in 2008 in order to expose the Permo-Carboniferous unconformity and the country park warden had recently cleared undergrowth so we had a clear view of an area on one side (See photo overleaf). Near the top of the bank were slightly dipping beds of the Cadeby Formation and below this, yellowish unconsolidated sand.



Upton Railway Cutting. Where is the Permo-Carboniferous unconformity?

Examination with a hand lens indicated it had very fine round quartz grains with very little mica. Below this was a grey-blue clay layer, and underlying it, red/purple sandstones with fine angular grains, shiny mica, clay particles and clasts. There has been much discussion about where the unconformity lies in this succession. It is possible that the upper sands are aeolian, even if redistributed by water, i.e. Basal Permian Sands, and the sandstones below the clay layer are fluvial Coal Measure rocks. It was noticed that all rocks below the Cadeby Formation have been stained red by iron to a considerable depth.

Walking a little further along the cutting we noticed bedded Cadeby dolostone with irregularly shaped 'lumpy' algal mounds above, containing solution hollows (vugs) of various sizes, which may contain crystals of calcite or dolomite.

We then drove the short distance to South Elmsall Quarry. This quarry face was preserved because it shows a superb example of a Permian bryozoan-algal patch-reef. The rocks exposed are dolostones of the Cadeby Formation, an oolitic limestone rich in magnesium.

Along the northern face the dolostone is well bedded, but moving towards the north eastern face there is an obvious contact with the curving layers of the reef which is in two parts and well shown (See photo below). There is a lower unbedded part formed, it is thought, by small branching bryozoa linking up to form large mat-like colonies which, built up mounds by trapping sediment.

The bryozoa eventually died out possibly because of increasing salinity in the evaporating shallow sea, but formed the base for an upper part of the reef where larger mats of cyanobacteria which coped well with the salinity, formed calcium carbonate and lime mud, trapping sediment round them in the very quiet marine conditions. They built up very obvious domed laminated algal mounds, (stromatolites) easily seen because of differential weathering of the sediments. At South Elmsall they continued to develop on top of each other to form a very large, complex reef, visible up to 80m along the rock face. The reef probably survived because the water had become too saline for gastropods and other predators to graze it away. By this time the light was fading and we concluded with a vote of thanks to Alison for a most instructive and interesting evening.



South Elmsall Quarry showing a section through a patch-reef in the Cadeby Formation

Park Wall North Surface Mine (UK Coal) & localities in Weardale Saturday 30th June

Leaders: Tony Benfield with, in the morning, Kevin Glasper UK Coal

Present: 8 Members

After the wettest June since records began, the visit having been cancelled once for safety reasons and flash floods on the preceding Thursday, we were pleasantly surprised to find ourselves at Park Wall North on a dry and sunny morning. Here, Tony gave us a short overview of the geology of the area, explaining that we were on the edge of the Alston Block where the Westphalian Pennine Lower Coal Measures Formation was only some 200m thick compared with 500m in West Yorkshire. The succession at the mine includes most of the economically important coal seams in the Formation, from the Brockwell up to the Harvey and Kevin told us that they were currently working seams between the Three-Quarter and the Tilley.

We stopped first at a view-point overlooking the huge 80m deep excavation which was a hive of activity with huge diggers and dumper trucks moving about. At 11.30am sharp, dumper trucks converged on the ramp from all directions and scurried up at great speed as the shift ended. Our Landrovers were then allowed to descend to the bottom where we disembarked. Here Kevin drew to our attention various faults and exposed coal seams as we progressed across the floor.

We examined pieces of coal in which vitrain was interbedded with fusain, lumps of hard shiny fireclay with the outlines of plant roots, burrowings of non-marine bivalves, stigmara, some with rootlets visible, and ironstone concretions. We observed cross bedding in the sandstone which probably represented crevasse splays in an alluvial plain environment. Old workings were visible in the face of the excavation - some brought to an abrupt end by a fault. At one point we actually walked through some old 2ft high pillars and stalls with their adjacent roadway. The mine was particularly notable for its numerous faults of various sizes, angles and throws. We stood in the angle between two fault planes; elsewhere a near-vertical fault exhibited a throw of some 10m. One really exceptional fault with a 60m throw showed clear evidence of compression followed by extension (See photo opposite). We finished by walking out on to the top of a 2m high ridge which proved to be a vertical coal seam, 1m thick. The same seam, but horizontal, could be seen 20m away in the wall of the excavation. As Tony pointed out, such geological complexities cannot be deduced from surface features, outcrops and



**60m fault showing evidence of compression followed by extension.
Tony Benfield about to add to the loose rock.**

boreholes; you really have to strip off the cover to see them. Returning to the site office, we thanked Kevin and UK Coal for such an interesting morning and then drove to West Rigg Quarry where, at long last, we had lunch.

The Slitt Vein is exposed as a 10 to 12m wide upstanding rib within the quarry which is about 200m long and extends about 60m on either side of the vein (See photo overleaf). Tony explained that we had moved down the succession into the Great Limestone, the basal unit of the Namurian, with the Dinantian Yoredale cyclothem below us in the valley and that mineral veins had been exploited throughout the area in the 18th and 19th centuries, largely for galena. Circulating highly saline hydrothermal fluids, heated by the underlying Weardale Granite, had scoured minerals from the granite and country rock and re-deposited them in vertical faults and fissures as the fluids rose and cooled, probably in Permian times. In addition, metasomatism had taken place where the mineralising fluids flowed into and reacted with the adjacent limestone beds. These sub-horizontal ore bodies (flats) occasionally produced workable amounts of siderite and ankerite, being particularly concentrated where impervious mudstone overlay the limestone. Above the water table, these were altered to limonite by percolating rainwater. Quarrying of the limonite at West Rigg had revealed the earlier workings for galena in the Slitt Vein.

Entering the quarry we examined the near vertical Slitt Vein which is the longest mineral vein in the North Pennines, extending for 13.5 miles. Extensive slickensides could be seen on the south side of the vein, showing sub-horizontal lateral movement. The vein is largely composed of micro-grained quartz but small areas of brecciation displayed quartz crystals infilling the cracks. Other gangue minerals were visible - fluorite crystals, some stained brown, and barite deposited on a fault plane. Galena was evident but in minuscule amounts. Moving away from the vein we discovered crinoid stems, Zoophycos feeding trails on blocks of brown limonitised Great Limestone and examined the limonite itself - a soft, crumbly, brown rock. A grey coloured sample of rock from the edge of the open quarry proved to be limestone. Finally, looking into the 1m wide stope, the remains of wooden stemples and drainage pipes could be seen.

After a welcome afternoon tea at the Stanhope Visitor Centre, we had a brief look at the Little Whin Sill which is visible in the River Wear at Stanhope Bridge and the adjoining, now flooded, Greenfoot Quarry. The Little Whin Sill lies above the Great Whin Sill and is only exposed in Weardale. Here, we thanked Tony for an excellent day and set off home, pleased that we had only had two showers, one of which was whilst having tea.



The Slitt Vein at West Rigg Quarry viewed from the road

The Precambrian of N W Charnwood Forest

Saturday 8 July

Leader: Keith Ambrose. BGS
16 members 1 visitor

This field visit was complementary to that of July 2010 when members examined the Charnian Supergroup, which dates to around 560 Ma, at Bradgate Park in the south east of Charnwood Forest. This year the party met at Mount St Bernard Abbey, 10 km further to the northwest, on a cloudy, but at this stage dry, morning. Our leader outlined the geology of the Charnian rocks we were to see, emphasising their volcanic origin and their folding into a south eastwards plunging anticline.

Our first task was to examine the building stones of the mid-nineteenth century Abbey. The walls were built of dark grey blocks of Peldar Dacite Breccia (See photo below) quarried from the Whitwick Volcanic Complex, now thought to represent one of the Charnian volcanic vents. The Breccia contained blocks of a spectacularly porphyritic dacite set in a matrix, which, under the microscope, reportedly showed spherulitic textures suggestive of its origin as a hyaloclastite, formed when dacite magma was intruded at shallow depths into water-saturated sediments. A few metres away, in



Volcanic breccia in the walls of Mount St Bernard Abbey

exposures of the St Bernard Tuff Member of the Charnwood Lodge Volcanic Formation, bedding was initially difficult to discern, but was revealed where fine grained tuff was sharply overlain by coarse tuff. Dips were around 60 degrees to the SW on the SW limb of the Charnian anticline. In places, a well developed cleavage, striking WNW and dipping at approximately 85 degrees to the N, was clearly visible. Age dating of the cleavage-forming micas has shown that they date to the Late Silurian and, therefore, to a late stage in the Caledonian Orogeny.

Our next locality was within the Charnwood Lodge National Nature Reserve, a broad area of undulating heathland, in which isolated knolls of Charnian rocks emerge from beneath a cover of Triassic Mercia Mudstones. We made our way to one of the best known localities in this area, the so-called "Bomb Rocks" which expose very coarsely fragmental volcanic rocks within the 1000m thick Charnwood Lodge Volcanic Formation. The clasts range in size from a few centimetres to nearly 2 metres and most are angular, though some have rounded corners (See photo opposite). Their lithology is of grey andesite with sporadic small feldspar phenocrysts, but no sign of vesicular textures. The absence of the latter, together with the angularity of the blocks and their lithologies which match those of the andesites within the Whitwick Volcanic Complex, have suggested to recent BGS workers that this is not an accumulation of volcanic bombs, but a deposit from an ash-and-block pyroclastic flow. Drawing on studies of the recent Montserrat eruptions they have suggested that these flows possibly originated from the collapse of viscous extrusive dacite domes, the "Bomb Rocks" being an example of a very proximal deposit of such a flow. At this point, as rain threatened, members returned to their vehicles for a short lunch break.

In the afternoon, the party headed southwards on a faint track through dense bracken to reach small crags of homogeneous grey Grimley Andesite, a component of the Whitwick Volcanic Complex, which may represent a feeder to an overlying volcanic dome. Continuing south westwards through more open, but boggy, ground, we reached outcrops of the youngest part of the Charnwood Lodge Volcanic Formation at Warren Hills. Here massive or stratified tuffs and lapilli tuffs were dominant with only a few slightly larger blocks showing the volcanic environment was much more distal compared with that of the "Bomb Rocks". A short distance to the west, very coarse grained tuffaceous sandstones were exposed, which mark the base of the Bradgate Formation. They contained rafts of contorted, probably originally partly lithified sediment and this horizon has been correlated with the Sliding Stone Slump Breccia seen in Bradgate Park. At this point, a torrential thunderstorm curtailed our activities, and we returned to our cars down a road running like a stream!

To reach our final locality we drove some 3 kms to the outskirts of Coalville and then walked up the slopes of Bardon Hill to see into the large quarry cut into its side. This quarry has removed the cover of Mercia Mudstones to work the Charnian rocks for aggregate. Large blocks from the quarry have been placed alongside the footpath and include specimens of andesitic breccia and the Peldar Dacite Breccia, seen earlier in the day, from the Bardon Hill Volcanic Complex. The rocks of the Complex were probably formed in the conduit of one of the Charnian volcanoes.

After ascending a steep slope through a wood, we stopped at the quarry perimeter fence. The view into the quarry (See photo overleaf) showed, within the Charnian rocks, the Bradgate Formation faulted against the Bardon Volcanic Complex, but the striking feature was that of a steep-sided palaeo-valley or wadi at the sub-Triassic unconformity, infilled by stratified Mercia Mudstone exhibiting catenary dips resulting from differential compaction. Finally, the summit of Bardon Hill, the highest point of Charnwood Forest was reached and afforded extensive views of the surrounding countryside while below, in the quarry, several more gullies, or wadis were visible at the base of the Trias in the south face.

On returning to our vehicles Keith Ambrose was thanked for an excellent day's geology, in spite of the torrential thunderstorm!



"Bomb Rocks," a deposit from an ash-and-block pyroclastic flow.



Bardon Quarry: Mercia Mudstone exhibiting catenary dips filling a palaeo-valley at the sub-Triassic unconformity.

Grange Top Quarry, Ketton, Rutland Sunday 5 August

Leader: Peter del Strother, MBE, PJDS Consulting & Manchester Geological Association, formerly of Hanson (Heidelberg) plc.
Present: 10 members.

This trip followed the lecture given by the leader to the LGA in May 2012. The very extensive quarry, opened in 1927, contains a Jurassic succession from the Upper Lias to the Oxford Clay (see Table 1 below). It is worked to a depth of about 50 m for clays (principally the Rutland Fm.) and limestone (Lincolnshire Lst), producing 1.5 million tons of raw materials for the Ketton Cement Works. Oolitic limestone within the Lincolnshire Lst also provided the famous Ketton Freestone, widely used in towns and villages around Ketton, at various Cambridge colleges as well as St Anne's Cathedral in Leeds.

Table 1 Succession in Grange Top Quarry	Thickness (m)	Environment
Oxford Clay	Not seen	
Kellaways Sand	5.5	marine
Kellaways Clay	3	marine
Cornbrash	2	marine
Blisworth Clay	5	marine
Blisworth Lst	4	marine
Rutland Fm: (formerly Up Estuarine Series) rhythmic units R1 - R6 Stamford Mbr. 2 units	7 5	largely non-marine
Lincolnshire Lst.	22	marine
Grantham Fm (formerly Lr Estuarine Series)	1.5	non-marine
Northampton Sand Fm (= Dogger)	5	marine
Upper Lias	Not seen	

At 11 am the group gathered outside the quarry office and donned high visibility jackets and hard hats for a long walk to see quarry faces, roadside blocks and blocks set aside for study. The first of these was a block of Collyweston Slate from near the base of the Lincolnshire Lst. This is not a true slate but layers 1 to 2 cm thick of quartz silt cemented with calcite. It was formerly mined nearby and, after exposure to frost, it split into roofing 'slates'. Other limestone blocks from the same horizon contained about 25% quartz, with shelly fragments and a few well preserved bivalves as well as pieces of wood. Nearby were blocks of grey Blisworth Lst., rich in molluscs and belemnites (see photo overleaf) and weathering to give a shaley appearance. Specimens collected included a small echinoid, *Clypeus*.

Descending to the lowest beds in the quarry, blocks of oolitic ironstone from the Northampton Sand Fm. were passed showing boxstone weathering which was also seen in a nearby face. The lower part of this Formation



Gastropod and other molluscs in the Blisworth Limestone.

weathered grey and an upturned block showed the base with a network of large *Thalassinoides* burrows and numerous pebbles which the leader had found to be phosphatic. The iron mineral, green when fresh, formerly described as chamosite, was now considered to be berthierine, structurally similar to serpentinite. The underlying Lias, presently hidden under groundwater, we were told contained fossils similar to those from the Yorkshire, Alum Shale.

In a low face exposing the Grantham Fm., which here rested on ironstone, two beds of rather crumbly sand or silt, the lower part of each crowded with truncated rootlets, were seen. This underlay about 0.5 m of loose / poorly cemented sand at the base of the Lincolnshire Lst, just below the Collyweston Slate facies. Moving to another low face, we examined Lincolnshire Lst immediately above this horizon, which included bands rich in calcareous worm tubes and others with tiny steep-spined gastropods.

Retracing our steps, we set out for the upper part of the succession, passing blocks showing the fresh grey colour of unweathered Lincolnshire Lst, and contrasting ones of the usual pale brown colour; due to oxidation of microscopic pyrite crystals. In one face, two large cross-bedded units were seen below a darker hard ground about 1.5 m from the top of the limestone. Below this, the cement enveloping the oololiths had recrystallised in discrete calcite crystals 1 cm or more long, forming a poikilotopic texture. The leader

handed round in a fine specimen in which crystals could be seen glinting in the sun.

While enjoying a picnic lunch sitting on top of the Lincolnshire Limestone, the leader pointed out the hard ground just below, also a layer of fibrous gypsum capping the limestone resulting from oxidation of pyrite in overlying beds. The top three rhythms (cyclic units) of the Rutland Fm. could be seen above the scree in the face beyond us. The leader explained that R5 contained a pale limestone passing down into shelly clay; R4 was capped by a carbonaceous clay, but included an oyster-rich sandy limestone. Lower parts of the Formation were seen elsewhere in the quarry later in the day. Quarrying at this point had removed the Blisworth Lst.

A quarry face nearby, exposing the horizontally bedded succession from the Rutland Fm to the Kellaways Sand, was interrupted by a roadway. The leader told us that a small exposure of Oxford Clay had been found there but was not easily visible. An approximately east-west fault cut the quarry face about 100 m to the N and where it re-emerged we could see the Kellaways Sand downthrown, by about 7m, against the Cornbrash. Walking up the roadway, we reached a bench cut into the Cornbrash, a massive brown limestone. In the floor, a band of fibrous cone-in-cone calcite marked the top of the Blisworth Lst, here faulted against the base of the Cornbrash (See photo below).



Effects of faulting in Ketton Quarry with the leader pointing to cone-in-cone calcite at the top of the Blisworth Lst.



Upturned fallen block of the Rutland Formation, Rhythm 1, with rootlets.

Climbing up to the next bench the Cornbrash was marked by a bed crowded with large oysters of genus *Lopha*, possibly another hard ground. Nearby, preserved blocks of Lincolnshire Lst contained the hard ground seen at lunch time; here about 10 cm thick and heavily bored by marine organisms.

The party opted out of scrambling to the Kellaways Beds and walked through thick mud towards the southern end of the quarry to reach a face in the Rutland Formation where R2 was seen capped with a thin coal underlain by a shelly seatearth with rootlets. R1 was capped by an impressive seatearth full of rootlets (See photo above) and the shelly clay below was said to contain *Lingula*, hence at least partly marine. After scrambling up some very muddy scree, we were able to look more closely at R2 to R4, noting particularly the abundant bivalves in R3. Further along, the two units of the underlying Stamford Member were seen.

On the way back to the office, we were engulfed in a heavy downpour. Under shelter, the leader, who had been a fount of knowledge, shown us some fascinating and unfamiliar geology, as well as providing an unusually comprehensive handout, was thanked as well as Messrs Hanson (Heidelberg) plc for permission to visit this fascinating quarry.

Residential Weekend to the Brymbo Steelworks and Lleyn Peninsula, North Wales

Friday 7th to Sunday 9th September

Leaders: Brymbo Steelworks - Peter Appleton, Lleyn Peninsula - Dr Charlie Bendall, Dept. of Geography and Earth Science, University of Aberystwyth
21 members and spouses present

Our weekend party met at the Brymbo Steelworks site on the way to the Lleyn to see an important find of fossilised Carboniferous tree ferns discovered in 2005. Our guide for the visit was Peter Appleton, a metallurgist and local geologist who was an employee and manager at the steelworks through his working life. During reclamation of the final steelworks site, and extraction of some coal close to the old ironworks not removed in early workings, developers encountered several fossilised tree remains which proved to be only a part of the full extent of the 'forest' which is now recognised. When these deposits were discovered, Peter was called in as a local geologist, realised the importance of the find, and is working with geologist Jacqui Malpas towards protecting and preserving the site.

We were given a comprehensive tour of the whole site by Peter, the party gathering briefly (but memorably) inside the 1795 Brymbo Number One blast furnace, and what a journey into the past it was, a very rare example of our national heritage. We finally arrived at the fossil site, still largely unexcavated to preserve all that exists beneath the surface. Exposures of fern stumps and other fossils were not immediately obvious, but once the 'eyes were in' we were surrounded literally by a 'forest'. Also, exposed immediately above the site in the usual Coal Measures cycle is the remaining 2 meter high face of a coal seam; it is clear why the prospect of this site exposed and preserved is so exciting. The most important fossils found so far have been dominated by lycophyte bases (club mosses), over 20 found in situ preserved in sandstone or mudstone - the largest being about 2.5m long and 1.5m diameter, and many sediment-filled casts of *Calamites* (horse tail) stems 1.5m long and 10cm in diameter. Several of the early extracted examples have been painstakingly reassembled into their original form by the Preservation Group under cover in one of the old steelworks buildings, where the Group also have an extensive display of information about the project. Because of the proximity of the fossil trees to the historic steelworks site, the Preservation Group is working hard to secure funding to preserve the whole site as one important heritage area in which the coalfield geological remains can complement the theme of iron and steel manufacture.

Lleyn Peninsula

Saturday, September 8th

Our itinerary for the weekend was to visit a series of 8 localities which displayed key features of the geology of the Peninsula.

Locality 1: Meillionydd Mawr

After a short drive from our base at Nefyn, the group climbed the slope of the NE – SW trending Meillionydd Mawr to reach a small outcrop. This was an exposure of the Sarn Complex which, together with rocks of the Monian Supergroup, is the oldest on Lleyn. The Sarn Complex has been zircon dated at approx. 615Ma, making it Precambrian. At this locality the Sarn rock ranges from diorite to granite, is quartz rich with some biotite. The base of the Cambrian in Snowdonia is known to be marked by an unconformity, whereas the equivalent boundary in Newfoundland, adjacent to here before the Atlantic opened, is a conformable boundary. In the west of the peninsula Ordovician sits unconformably on both the Precambrian (Sarn) and Cambrian; in the east of the peninsula it is conformable with the Cambrian.

Dr Bendall explained that the Sarn Complex is separated to the NW from rocks of the Monian Supergroup by the Lleyn Shear Zone which may be an extension of the Menai Strait Fault System.

The Monian Supergroup sequence has been described in detail in the north of Anglesey where it comprises several units; the only member of the Group to outcrop on the Lleyn is the Gwna Melange. Recent work suggests that the melange in Anglesey and the Lleyn are not the same; in the Lleyn it may be Precambrian, and the one in Anglesey may be as young as Early Ordovician. The Sarn Complex is faulted against Monian sediments and is not present in Anglesey.

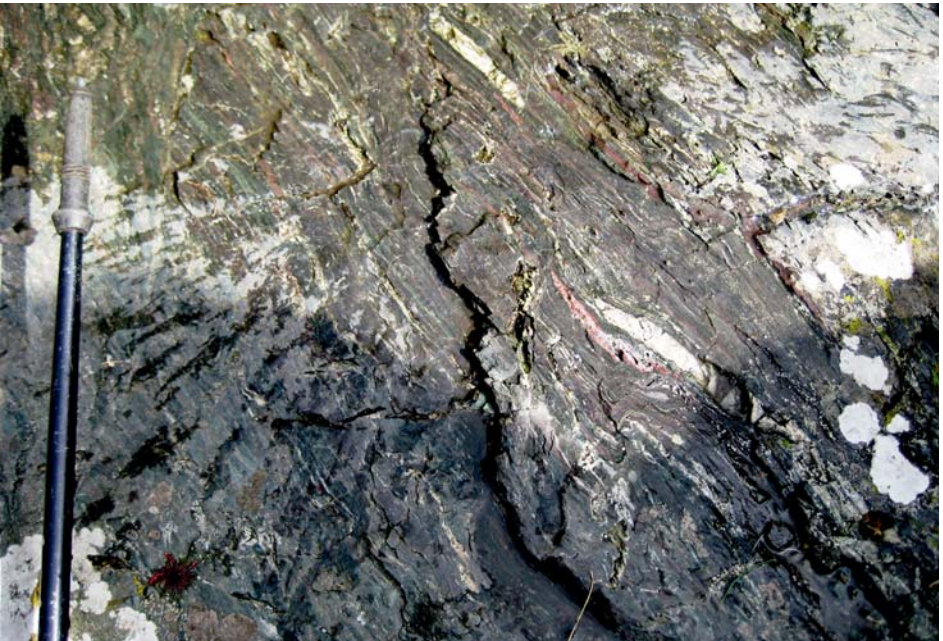
The Gwna Melange, Lleyn shear Zone and Sarn Complex form the NW coast of the western half of the Peninsula, with only the Melange having extensive outcrops.

2: Uwchmynydd Peninsula

From a parking area at Uwchmynydd at the western extremity of St. Tudwal's Peninsula, we ascended the shoulder of Mynnydd Mawr past exposures of acid tuffs dipping steeply towards the sea. A cleft cut in the cliff top gives access to a small, unlikely quarry, one wall of which is a fine grained limestone. The whole limestone exposure is one clast in the Gwna Melange! Descending from the cliff top opposite Bardsey Island we suddenly met with the classic view of the Melange (see top photo opposite) with huge white clasts of quartzite embedded in the cliff. In addition to the obvious quartzite, the entire face is a chaotic mix of a wide range of igneous and sedimentary rocks, blocks and boulders of limestone, grits, pillow lavas of all sizes; clasts are known to range from a few millimetres up to, in some places, several hundred



Gwna Melange at Uwchmynydd Peninsula showing huge clasts of quartz



Striated structure in the Lleyn Shear Zone

metres across. The whole of Bardsey Island offshore is part of the Melange and more enormous quartzite clasts can be seen in its SE facing slope. The Melange was originally the result of an enormous submarine slide, and similar modern events exist, for example in the Bay of Bengal. The matrix is sand or mudstone. It can be seen that many of the clasts are clearly lensoid in shape as a result of enormous tensional forces experienced prior to their current position. Further round the cliff top the melange matrix was thrust against a large clast of pillow lavas.

Progressing further along the headland to the SE, after 1 – 2 km we examined an exposure showing a very different structure. The material is darker and quartz rich with a striated appearance showing extension by shearing (See bottom photo, previous page) and has undergone sufficient dynamic recrystallisation through this process to be called a mylonite. Deformation of this sort in which the material shows tension cracks or necks which are filled with material from each side is known as boudinage. Further to the SE we reached a narrow bay with again a totally different structure. At the head of the bay, steeply dipping slates and mudstones had been eroded to form a cleft. The cliff opposite was mainly bedded Ordovician sediments and, although not clearly visible, BGS survey data indicates gneisses (which may be Sarn Complex) at the base. The Ordovician sequence was itself overlaid by an Ordovician sill which formed the erosion resistant cliff top.

3: Mynydd Penarfynydd

We had now travelled to the headland south of the village of Rhiw, some 8 km east of St Tudwal's Peninsula. Mynydd Penarfynydd is one of 3 hills, with Mynydd-y-Graig and Mynydd Rhiw, formed by an igneous sill-like intrusion, one of many Ordovician intrusions forming higher, rugged ground on the peninsula, left prominent by erosion of the surrounding, softer mudstones. The crest was reached (with an end of the day pull) to a sea cliff headland with fine views over Hell's Mouth Bay to the east and St. Tudwal's Peninsula to the west.

The sill material is a coarse grained pegmatitic gabbro with brown hornblende, but notably with a very knobby surface. Dr Bendall explained that as a result of the gabbro being hydrous, pyroxene crystals were able to grow to large size and partially or totally enclose crystals of plagioclase. Less erosion of the pyroxene then produces the uneven effect on weathered surfaces. Enclosure of crystals within a larger crystal in an igneous rock is also known as poikilitic texture; in the case of pyroxene overgrowing plagioclase it is known as ophitic texture. A gatepost of this material at the farmyard where we left our cars showed this effect very well. A further feature of the outcrop is very strong rhythmic layering with layers about 15 cm thick; analysis has shown each layer to be relatively rich in pyroxene and olivine towards the

base and in plagioclase towards the top, with sharp contacts apparent between the layers. This exposure is a noted example of the effect. There are several theories to explain the phenomenon. One is simply that there was a series of successive pulses; another that the pyroxene and olivine, being more dense, settles out.

Sunday September 9th

4: Porth Dinllaen

On an overcast morning at Porth Dinllaen the group walked across Nefyn golf course to the headland beyond the lifeboat house to see a spectacular exposure of spilitic lavas with well formed pillow structures (See photo back cover). They are part of the Gwna Group. Coloured jasper and brecciated quartz form an infilling between the individual pillows.

5: Mynytho

On arriving at the next locality, the elliptical Ordovician igneous plug which forms the hill Foel Gron, we were slipping behind our time schedule for the day. We therefore elected not to climb the hill and so sadly missed the opportunity for a grand overview of geological features, but inspected the composition of the granite in a small quarry at the base. The material is a pinkish microgranite, the Caradocian intrusion emplaced into Llanvirn shales.

6: Porth Ceiriad

The tide had just beaten us to the headland at Trwyn Llech-y-doll and so we were not able to see the unconformity of Arenig coarse-grained, current bedded sandstones overlying Cambrian sedimentary rocks. Fortunately our resourceful leader produced an impressive image of the exposure (See photo overleaf). A key feature is that traversing westwards along the headland the Arenig overlays successively lower members of the Cambrian until, further westwards around Aberaron it overlays the Precambrian. The explanation is that as Avalonia separated there was uplift and erosion. This is probably the reason for the absence of Tremadoc sediments at this point, although they do occur further to the east of the Peninsula where the land mass was sinking as the Welsh Basin extended.

On the beach at Porth Ceiriad we inspected Upper Cambrian mudstones; early sediments in the Welsh Basin as Avalonia separated. There were several dewatering structures and one notable feature was a small sedimentary dyke where sand had been carried upwards during dewatering and become folded as the sediments then consolidated.

7: Carreg y Defaid

1km NE of Llanbedrog we inspected beach exposures of the Llanbedrog Ignimbrite Group, part of the Upper Ordovician volcanic sequences. The first



Unconformity at Trwyn Llech y doll; Arenig Sandstones over Cambrian Sediments

exposure was a coarse volcanic breccia displaying a wide range of clast sizes set in a pumice matrix, (See photo opposite) formed from a collapsing ash cloud in a subaerial environment. Further on we encountered outcrops of strongly welded tuffs which, to the experienced eye (of our leader) demonstrated eutaxitic texture, where the structure shows a series of discontinuous, streaky bands, and also a rhyolite filled vent where large spherulites have weathered out from the rest of the rock.

8: Ogof Ddu

As a result of a heavy shower and the late hour we decided to leave investigation of the conformable boundary between Upper Cambrian, Ffestiniog, beds and Ordovician / Tremadoc, Moel-y-gest beds, until a future field visit.

We heartily thanked our leader Charlie Bendall and his wife Angie for a most informative and enjoyable weekend (again) and, happily, were just ahead of the poor weather all the way back to Yorkshire.



Ignimbrite at Carreg y Defaid

Carboniferous Exposures in the Wharfe Valley near Bolton Abbey and Kex Gill near Blubberhouses

Saturday 15 September

Leaders: Dr Colin Waters and Dr. Tim Kearsy, British Geological Survey.

14 members, 2 visitors and 3 BGS personnel present.

On a beautiful day we met in the crowded car park at Bolton Abbey and Dr. Colin Waters introduced the next generation of mappers of the Pateley Bridge Sheet: Dr. Tim Kearsy and Gareth Jenkins, who was unable to attend but had contributed to the handout. Dr. Waters presented the focus of this visit which was to examine the deep plunging limestones of the Pendleside Limestone Formation from the Asbian Craven Group above the Hodder Mudstone Formation; move up the sequence to the Bowland Shale Formation; then see the Pendleian, Warley Wise Grit from the Namurian Millstone Grit Group. We would conclude with exposures of the Marchup Grit west of Blubberhouses and look at its relationship with the active landslides affecting the A59.

At the wooden bridge upstream from Sandholme Car Park, looking southwest, Dr. Kearsy showed how we were standing on a parasitic fold at the nose of the Skipton Anticline which ends at Bolton Abbey. Warley Wise Grit rises on the high ground to the east and west, with the nose of Hodder Mudstone terminating abruptly below the bridge. This is bounded by a fault, seen in the River Wharfe, the timing and nature of which is still somewhat unclear.

Upstream, on the west side of the Wharfe toward the Strid, we examined the massive gritstone blocks beside the river (See photo opposite). The blocks were of the lower part of the Warley Wise Grit showing trough cross bedding and containing up to 25% floating pebbles. The quantity of pebbles and the associated palaeosols represent a fluvial origin with deposition in the front of a deltaic basin. Wood fragments are found in the bases of these beds which differ from those of the underlying turbiditic Pendle Grit which have fluting on their bases and no cross bedding. The presence of the Warley Wise Grit at such a low stratigraphical position remains somewhat enigmatic: possibly due to faulting out of the Pendle Grit Member.

Higher up the Strid we examined the upper beds of Warley Wise Grit (See photo page 30). These have fewer floating pebbles and large dune like cross beds 2-3 metres high which show an overall flow direction from the North-NorthEast. Current thinking holds that the first real sinuous rivers occurred in

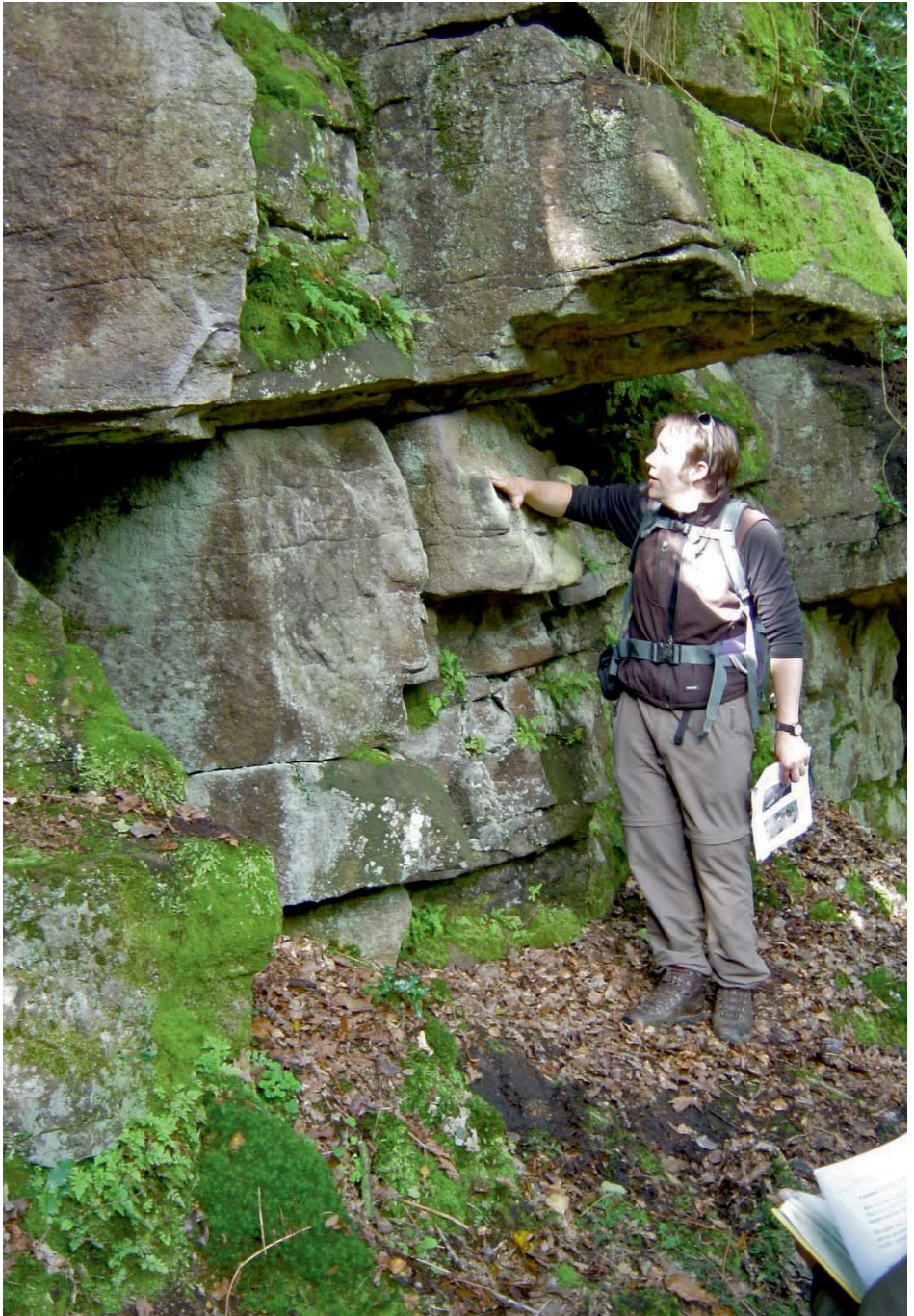


Lower beds of the Warley Wise Grit

the Carboniferous with a stable, vegetated flood plain giving room for meanders to develop: so this may be the first delta, laid down in a developing valley with straight edges.

South-eastward, along the river terrace, we found the steeply dipping Pendleside Limestone Formation at Lud's Cave with evidence of its turbidite origin. Opposite the picnic site was an outcrop within the Hodder Mudstone Formation, the lowest part of our stratigraphic column visited on the day. The succession included small folds which could have been caused either by local faulting or faults parasitic with the Skipton Anticline. We examined some exposures in the river itself where the anticline plunges 80 degrees north with steeply dipping bedding planes and internal folding within fold zones.

In the afternoon we transferred to Kex Gill to examine the Arnsbergian Marchup Grit which here is medium to coarse grained and distinctively not as pebbly as the underlying Warley Wise Grit. Dr Waters explained previous workers evidence that this fluviodeltaic sandstone should be slightly older than the Red Scar Grit of the Askrigg Block and that the current project is working to test this theory. Regionally, the Marchup Grit is underlain by a succession of siltstones containing *Sanguinolites*, a bivalve associated with the Saleswheel Marine Band. A succession with similar appearance exists lower down the slope at this locality, but the marine band has yet to be found.



Upper beds of Warley Wise Grit

From an outcrop of the Marchup Grit we looked at the landslides affecting the valley (See photo front cover). On the north side of the valley a stone wall marks the approximate area of a translational slide which includes terraced blocks of Marchup Grit. Along the southern side of the valley more superficial slides, affecting just the siltstones and mudstones present beneath the Marchup Grit, are evident. Although lined with aggregate, after heavy rain in June 2012, the slope gave way above this level taking the aggregate with it. A wall has now been erected to prevent slumping onto the A59 road.

Walking along to an old, now flooded and inaccessible quarry, we viewed from behind the fence, the top beds of the Marchup Grit. Interesting differences in lithification were seen with beds of loose orange coloured sands lying both above and below competent beds of lithified gritstone. There is no obvious cause for the differences in cementation but it was suggested that differential weathering may have been caused by over-pressure of groundwater beneath a glacier, evidence of which, associated with till deposits, has been recorded in a nearby quarry.

After a blustery walk to the car park we thanked our leaders for an excellent outing. The good turnout reflected the general interest in hearing the BGS update on this important area and how this may in turn need to be reflected in adjoining sheets.

Skipton District: Giant Bedforms in the Millstone Grit. Saturday 13th October.

**Leader: Jochem Bijkerk, School of Earth & Environment,
Leeds University
8 members and 2 visitors**

We met Jochem at Emsay Reservoir with his talk on the same topic the preceding Thursday fresh in our minds. With reference to his excellent handout Jochem briefly recapped the geological setting and the sequence of events he considered that had occurred before, in fine weather, we set off to the first site of the day; Witshaw Quarry, which could be seen across the reservoir. The quarry, which was opened in 1905 to provide stone for the construction of the reservoir, exposes approx. 20 m of medium to coarse grained, bedded sandstones belonging to the Pendle Grit. Above it, a bracken covered slope of shale led to more sandstone outcrops that form Emsay Crag. These belong to the Warley Wise Grits which we were to examine in the afternoon at another location. The Quarry lies on the northern flank of the Skipton Anticline and it is this that accounts for the strong northerly dip of the beds.

The Pendle Grit was the first of the Millstone Grit Sandstones to be deposited in the Craven Basin and Jochem explained how these are interpreted as turbidite deposits. Features that support this were: numerous amalgamation surfaces within the sandstones picked out by changes in grain size which represent discrete events of deposition, large rafts and small fragments of shale that had been ripped up by turbidite flows (See photo opposite) and transported a short distance before being deposited, usually on the base of channel structures that were seen in both cross and longitudinal section and scour marks on the undersides of many beds which seemed to show a roughly WNW – ESE direction. These features are interpreted as representing a falling sea level in the Craven Basin which previously had been receiving (mostly) muddy sediments that had been carried over and around the Askrigg Block and deposited as the Bowland Shale. The fall in sea level (possibly eustatic due to changes in a polar ice cap) resulted in rivers flowing across the Askrigg Block incising a deep valley before depositing their loads on its faulted margins from where it periodically cascaded down to the basin floor as turbidity flows. The lack of fine grained sediments within the turbidites points to it being a high energy environment, probably within a channel, resulting in relatively little sediment being deposited by each flow and some of that being eroded by subsequent ones. Before leaving the quarry a good example of a sand volcano (a dewatering structure) in a thick bed of sandstone was examined. Back at the car park we looked south to Skipton



Turbidite sandstones in Witshaw Quarry showing an amalgamation surface and shale raft.

Moor (which is made of Pendle Grit younger than that at Witshaw Quarry) where a number of gullies formed by lenticular sandstones could be seen. These represent small deltaic distributary channels formed before the deep valley was incised into the edge of the Askrigg Block. Lunch was taken in the car park in the warm autumn sunshine before we drove through Skipton to the second location, Hardacre Quarry.

Hardacre Quarry lies approx 8 km south of Witshaw and exposes approx 8m of the Warley Wise Grit which had been seen in the morning lying above the Pendle Grit. The bedding here was very different from that at Witshaw. The lower third of the main face consisted of beds of generally medium grained sandstone all dipping at between 10-15° to the south. Above these, separated by a noticeable discontinuity, was 2m of thinner bedded, but very coarse sandstone, still dipping in the same direction (See photo overleaf). What we were looking at was an excellent example of a Gilbert-style delta. These are sand deltas, built where fast flowing rivers empty into lakes. This is an indication that this was now a time of low sea level and that the Central Pennine Basin was probably filled by fresh- brackish water. The similarity in density of the river and lake water resulted in them mixing readily (as opposed to fresh water sitting on top of denser saline water) and transported sediment falling out quickly. The lower beds are the delta foresets and on



Foreset and topset beds in Gilbert- style delta deposits at Hardacre Quarry

close examination we saw that many showed well pronounced graded bedding, formed as sand avalanched down the front of a delta resulting in it building out into the water body. The upper unit of very coarse sandstones are the topset beds, formed as rivers flowed across the top of the advancing delta, carrying their sediment to the delta front. The larger particles were dropped within the channels building small dunes and bars.

With reference to the flume tank modelling he was also carrying out, and which he had talked about in his lecture, Jochem outlined his interpretation of what we had seen at the two locations. As sea level fell, a valley was deeply incised into the margin of the Block and provided the path for the sediment deposited as turbidites. Then, as sea level rose, the deep valley became filled with stacked Gilbert-style deltas to be followed by the progradation of a delta system as sea level fell. The key factor in allowing the development of giant bedforms is the additional depth of incision which occurred when the river flowed into a deep basin. During the day Jochem had highlighted some of the problems of working in the Millstone Grit Series which included; lack of continuous exposure (especially difficult when the units can laterally change rapidly in thickness, texture and composition); lack of conformity to 'classic patterns' (especially true for turbidites) and, particularly, problems of correlation. As the sun began to disappear we thanked him for an excellent day, wished him well for the remainder of his research and departed for home.



Cronkley Fell, formed by the Whin Sill, viewed across the Tees Valley



Pillow/lavas at Porth Dinllaen