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Leeds Geological Association

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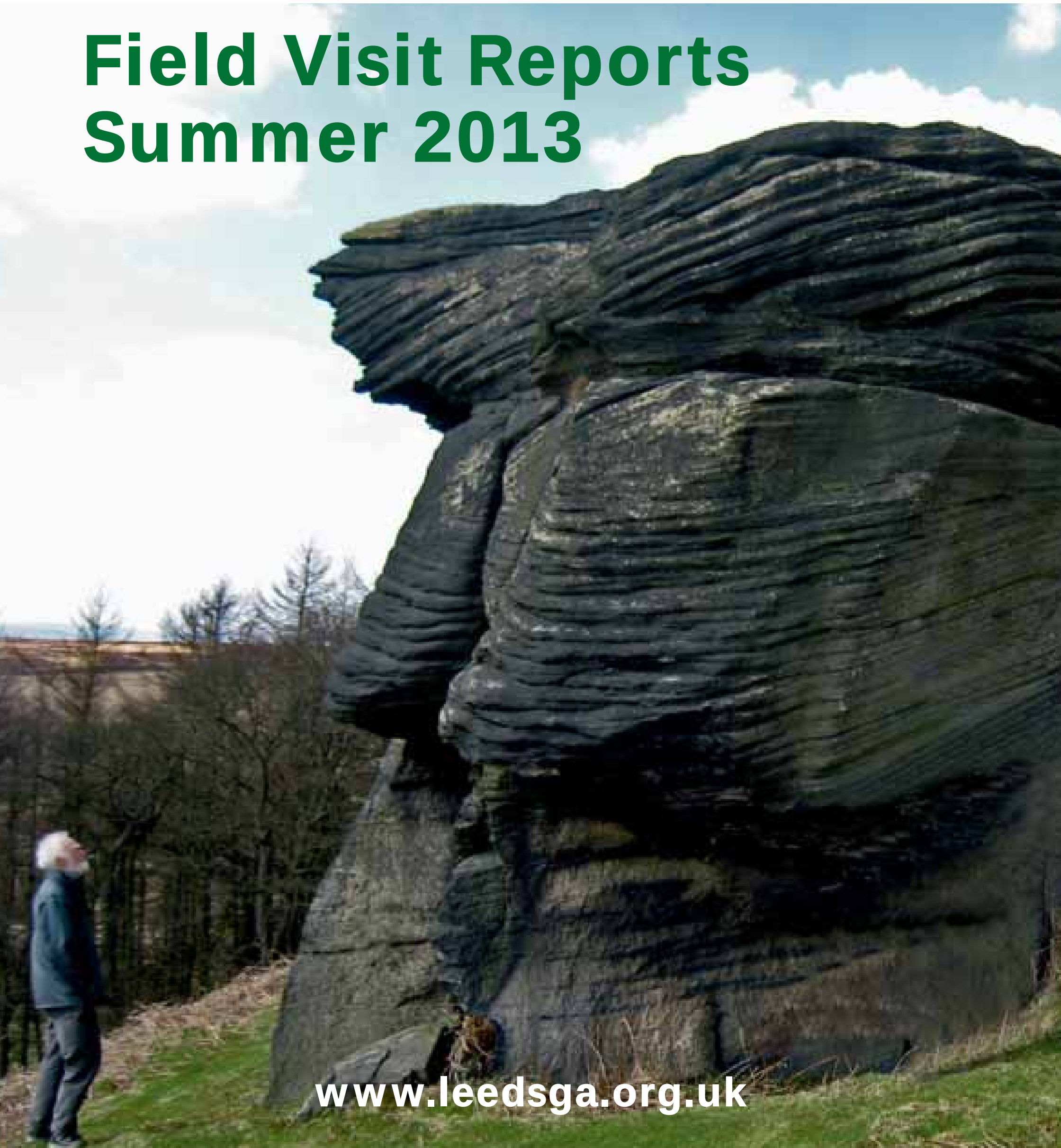
Field Visit Reports Summer 2013



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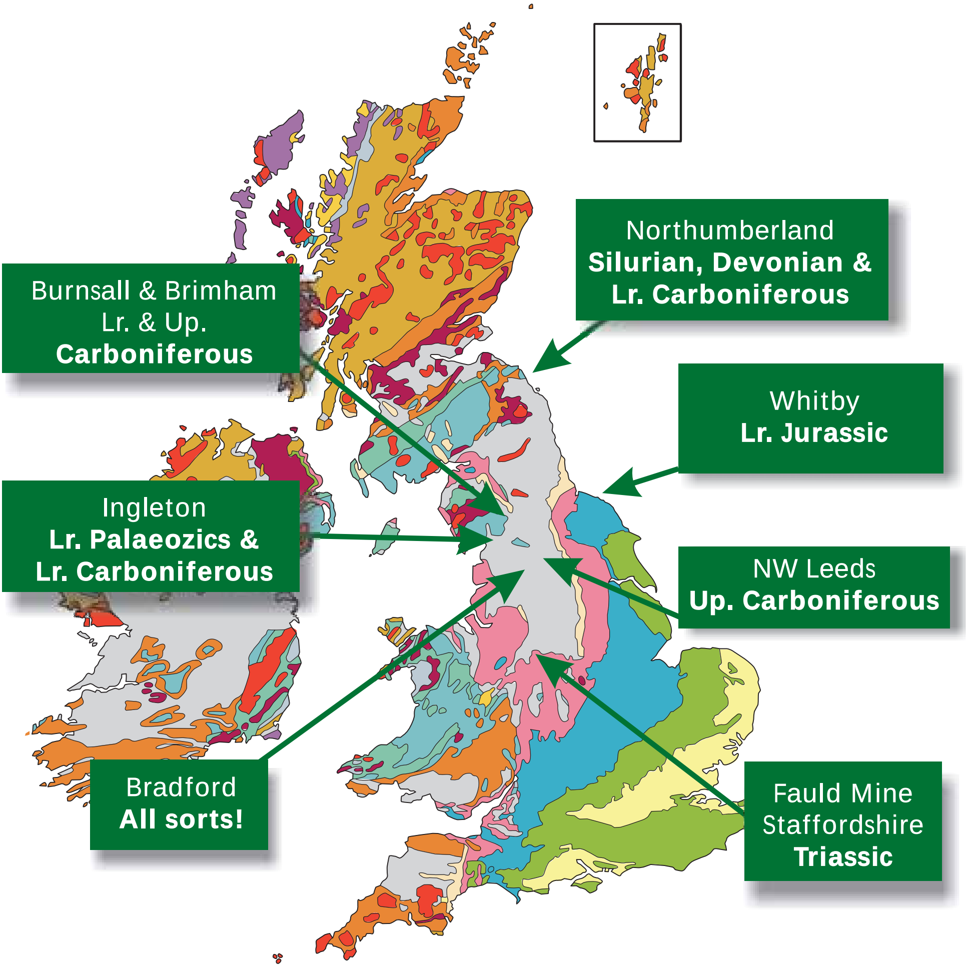
13 Where did we go?



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Cover Picture: Harthill Cock, a rock stack of Rough Rock at Eldwick

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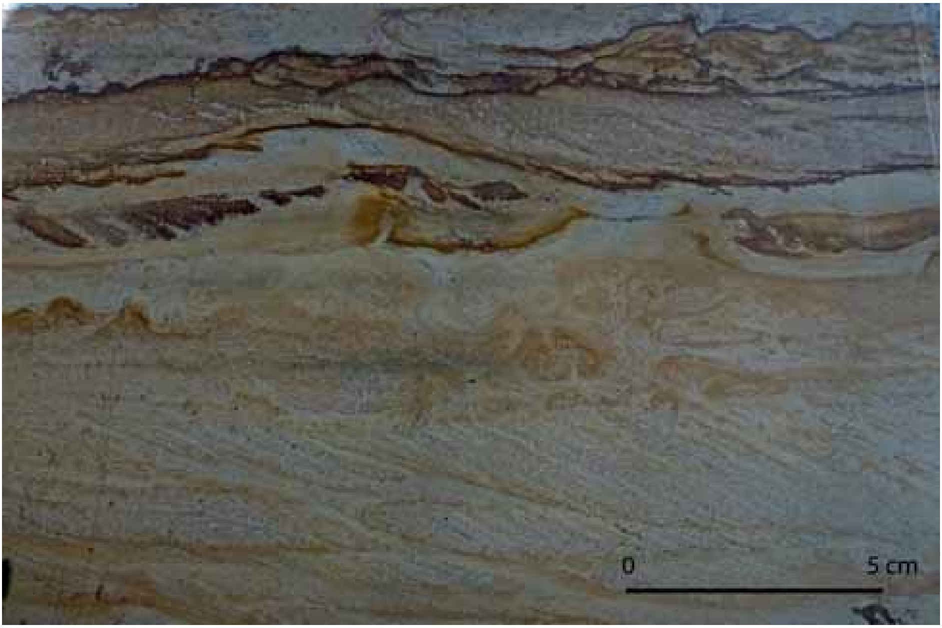
Northwest Leeds : Millstone Grit sandstones and shales
Saturday, 20 April

Leader: A C Benfield
Present: 18 members

On a thankfully dry and sunny Saturday morning, members were warmly welcomed by Craig and Stacey Morell on behalf of Mone Brothers to their Blackhill Quarry, Bramhope, which provides durable building stone from the late Namurian Marsdenian Stage, Midgley Grit. Working plant prevented access to the lowest levels in the quarry, but an approximately 10m sequence of mainly coarse grained, commonly cross-stratified, often micaceous, sandstones was clearly seen from an access ramp. The rocks themselves could be examined in large blocks by the side of the ramp, most exhibiting metre-scale cross stratification and variable iron pigmentation. Some showed clear evidence of large plant stems transported by the strong fluvial depositing currents. One block of ripple laminated, fine grained sandstone revealed abundant *Pelecypodichnus* trace fossils formed by burrowing bivalves. Midway in the section an approximately 30 cm thick bed of dark silty mudstone reflected sedimentation in even quieter water conditions.



Sedimentary structures in a cut surface of the Midgley Grit

Tony Benfield reminded us that at this time in the Upper Carboniferous, Yorkshire lay in equatorial latitudes and that the structurally controlled Central Pennine Basin was the site of cyclic deltaic deposition from a major river flowing from the north or north east.

We were then taken into the cutting shed where it was explained that it took three to four hours to cut each large block with a 1 m diameter diamond-tipped blade. The cut surface of one fine grained sandstone block - (see photo opposite) exhibited a particularly spectacular range of sedimentary structures, leading one of our members to consider purchasing a similar block as an artistic wall decoration.

Our second visit of the day was to the former Yeadon Brick and Tile works pit where some 18 m of late Namurian shales are exposed in a steep face. When these strata were being worked in the 1930s, the Geological Survey recorded two Marine Bands within them; the lower, the *Cancellatum* Marine Band, is no longer exposed but it was hoped to locate the higher *Cumbriense* Marine Band on our visit. Most of the strata were dark silty mudstones with bands of siderite nodules, probably formed from iron rich pore-waters squeezed out during post-depositional compaction. Fortunately our more active members (See photo overleaf) were able to locate a 3m thick unit of black rather earthy shale, containing a fauna of bivalves and goniatites midway up the exposure which represented the *Cumbriense* Marine Band.

Our leader pointed out that such thick shales, though forming an important part of the late Namurian succession were very rarely exposed. They represented a period in which the sea had risen to transgress over the sandy deltaic plain deposits, such as those seen earlier at Blackhill Quarry, before very fine grained argillaceous sediments were laid down in water depths of perhaps some 40-50 m. These Namurian cycles are now thought to be related to glacio-eustatic processes. This site is currently the subject of a development plan which would see houses being built in it. As it is a SSSI the Association has made representations to the relevant planning department stating our objections. We await the outcome.

A reduced party of 10 continued to the last locality of the morning, Eldwick Crag, near Dick Hudson's Pub where sandstones of the Rough Rock Flags and the Rough Rock, stratigraphically overlying the shales seen at Yeadon, are exposed. At our first stop, some discussion ensued as to whether the sandstones exposed there were in fact within the Rough Rock Flags, as indicated on the Geological Survey Map, as they were uncharacteristically coarse-grained and not really flaggy!

Searching for the *Cumbriense* Marine Band at Yeadon Brick and Tile Works quarry

Walking to the west we entered a large disused quarry where the Rough Rock displayed similar features to those seen in the Midgley Grit at Blackhill Quarry; 3 to 4 m thick massive beds of coarse-grained sandstone being overlain by thinner beds above. Weathering had emphasised the cross-stratification in the uppermost beds, but on closer examination, large-scale cross bedding was visible in the massive beds, some of which appeared to be trough-shaped. Tony pointed out stress release features, prominent jointing and a small fault.

Further west we briefly examined Harthill Cock, a rock stack of Rough Rock (see front cover) where erosion had etched out the cross-bedding which displayed varying directions and dips reflecting the rapid switching of smaller river channels. As the time was now approaching 2.00 pm we thanked Tony for a most interesting and entertaining morning and departed, some for a late lunch at Dick Hudson's.

Ingleton Waterfalls Walk
Saturday 11th May 2013

Leader: Dr Andrew McCaig, Leeds University
Present: 9 members

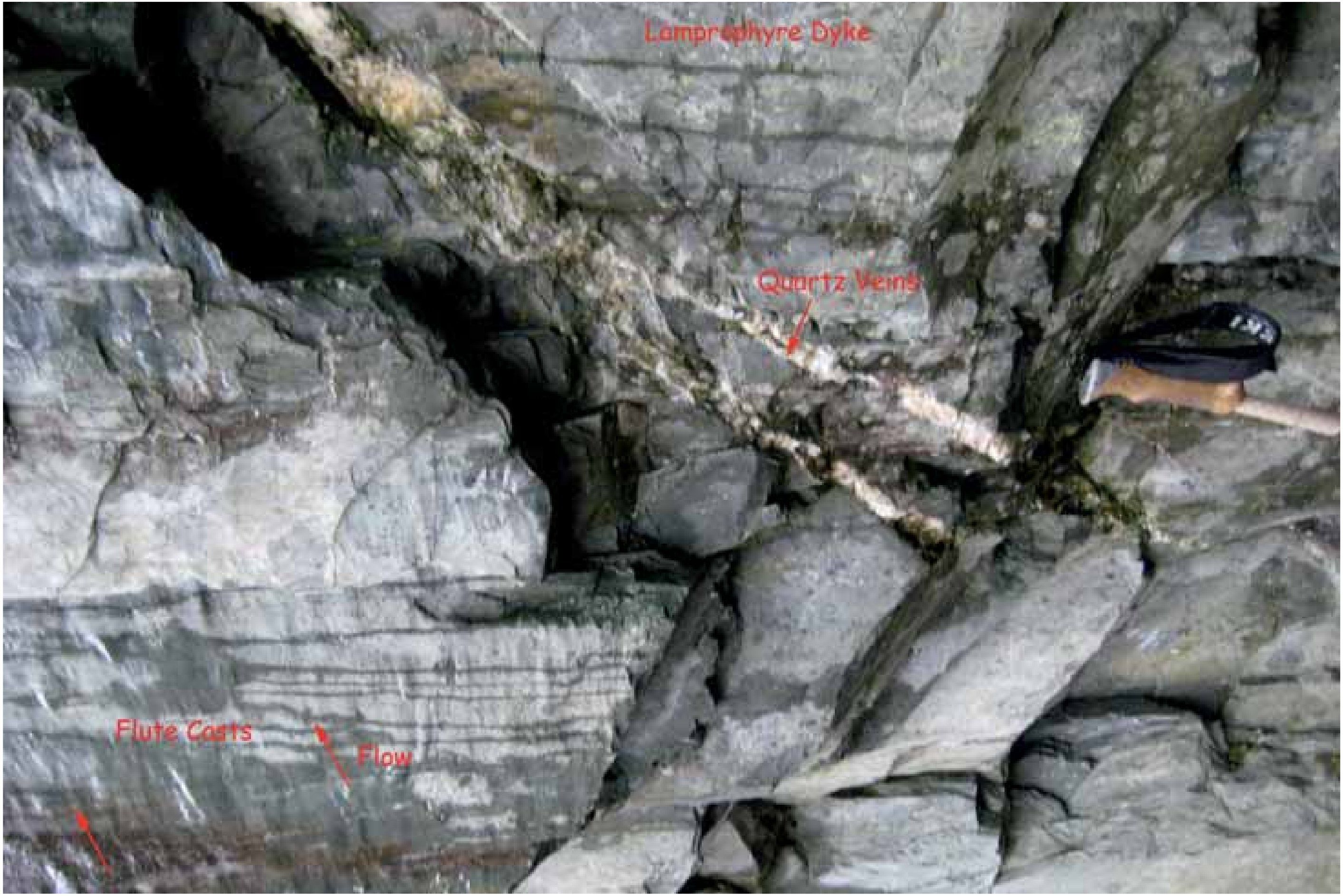
In pouring rain the leader, his dog and 9 undaunted LGA members commenced the trail in an anti-clockwise direction. Although Ingleton is on Upper Carboniferous (Westphalian) Coal Measures we soon crossed the (hidden) South Craven Fault on to the older Lower Carboniferous (Visean) Limestone.

Our first location was a limestone quarry which beautifully displayed the difference between apparent and true dip. Beyond, at Storrs Common, we looked across the river into Meal Bank Quarry where a projecting bed, apparently dipping to the south, indicated where a thin coal seam lay beneath - evidence that at some stage the sea bed had been exposed long enough for vegetation to grow. To the north the beds dipped in the opposite direction, outlining an anticline, before being brought to an end by the North Craven Fault (NCF), the line of which was pointed out by Andrew. The NCF separates the Carboniferous Limestone from the older Dent Group (Coniston Limestone) of Ordovician (Ashgill) age. From here could also be seen the line of an unnamed parallel fault which down-faults that Group from the much older and enigmatic Ingleton Group.

Having crossed the two faults (hidden) we entered a disused slate quarry in the Ingleton Group. Here thin-bedded siltstones, deposited as distal turbidites, had subsequently been folded and metamorphosed. The beds were near vertical (slightly overturned) with the cleavage being almost in the same plane. Current lineation indicated that the beds younged to the northeast. The contact with the overlying thick-bedded (sandstone) greywacke, deposited by denser turbidity currents, was visible. A brief discussion took place on whether the Group was Ordovician (Arenig) in age or possibly Neoproterozoic.

Having crossed the river, we climbed a hillside through young trees to view a small outcrop of the thick-bedded greywacke. Here the relationship of the angle of cleavage to the dip of the beds indicated that we had crossed the Skirwith Syncline and the beds were now younging to the southwest.

At a second roofing quarry close to the river's edge, flute casts were visible on near vertical beds (See photo overleaf) indicating that these, again, younged to the southwest. The flute casts gave stratigraphic evidence for the Skirwith Syncline consistent with the cleavage-bedding relationships and also showed a palaeocurrent from the southeast. A coarse grained lamprophyre dyke penetrated the beds with several quartz veins running obliquely across it at



Lamprophyre dyke, quartz veins and flute casts regularly spaced intervals. Andrew explained that the quartz had been deposited by hydrous fluids which had penetrated brittle fractures where the dyke had resisted deformation during late stage folding. Here, there being an apparent slight let up in the rain, we had lunch only for hailstones to fall!

Feeling slightly damp but replenished we continued past the impressive Beezley Falls and on to the hillside near Twistleton Hall where the weather began to improve. Looking towards Ingleborough with its capping of Millstone Grit we could see water pouring out from below White Scar Caves and showing the contact between the impermeable Ingleton Group and the overlying Carboniferous Limestone. On the map the spring line follows the contours round Chapel-le-dale, indicating that the unconformity is planar and horizontal.

Continuing past the Hall and Ice Cream Van (no partakers in our party - definitely too cold!), Andrew pointed out Raven Ray Moraine at the end of Kingsdale. This had caused a lake to pond at the front of the receding glacier which eventually overflowed at its eastern end, diverting the river and creating Thornton Force. The glacial till was examined on the way down to the Force.

At Thornton Force (See photo overleaf) the angular unconformity was clearly visible but, in view of the high water level and waterfall spray, nobody risked venturing beneath the overhang to examine the basal conglomerate. We therefore continued past Cuckoo Island, where the relationship of steeply dipping beds and vertical cleavage indicated that we were approaching the Skirwith Syncline again, and up a faint path towards a limestone quarry. Halfway up this path the angular unconformity was briefly exposed.

The quarry face displayed cross-bedding, wavy bedding, erosional surfaces and lenses of coarser material. A close examination of the limestone showed grains of quartz, broken shells and small green clasts from the Ingleton Group; evidence of beach deposits on a wave-cut platform in a high energy tidal or long shore current environment.

Continuing down the gorge we saw a series of impressive waterfalls and plunge pools created by the river flowing over the greywackes on to the less resistant siltstones below.

Immediately below Pecca Bridge the valley opened out and the river turned direction to run between the two parallel faults. Andrew pointed out the line of the unnamed fault running obliquely across the hillside and, further on, the NCF where it was exposed on the far bank with a trial adit visible. Now on the down faulted Carboniferous Limestone we crossed the anticline seen earlier in the day and returned to the car-park - in sunshine! Here, we thanked Andrew for a most enjoyable day, made all the more interesting by the spectacular waterfalls following the earlier rain.

Angular unconformity at Thornton Force

Fauld Mine, British Gypsum (St Gobain), Tutbury

Leaders: Noel Worley, Yorkshire Geological Society
Present : 12 members

Our party was welcomed to the mine by our leader Noel Worley and Peter Firby, the mine production manager. Faulds is the largest mine in the British Isles and extracts evaporites, anhydrite and gypsum from the, up to 6m thick, Tutbury Evaporite Bed. The drift entrance into the mine passes through a karstified zone mantled by glacial till on the south side of the Dove Valley on the Derbyshire / Staffordshire border. Our plan for the day, following an introduction by Noel, was to visit shallow room and pillar workings in the older part of the mine on foot to examine key features of the development of the evaporite deposits, and to visit briefly the remains of the old surface quarry workings. We would then visit the crater created by a huge munitions explosion in 1944, and see alabaster grave ornaments in the church of St Werburgh in Hanbury nearby and at the church of St. Mary in Tutbury.

The evaporites were originally deposited about 230Ma in the Upper Triassic when the UK was just north of the equator on the edge of a sedimentary basin in the Tethys Ocean. The gypsum formed sub aerially on mud flats or sabkhas along the water table, just below the surface where it was saturated with sea water. The evaporites were developed in the Mercia Mudstone Group, within which are two evaporites, the Staffordshire Halite Bed and the younger Tutbury Bed. The Tutbury Bed is developed in the Branscombe Mudstone Formation, which consists of red/brown and grey/green interbedded mudstones and sandstones.

Extraction of alabaster started in shallow quarries at the outcrop in the Dove Valley as far back as the 12th Century; blocks were prised out of the karstified deposits and its whiteness and translucent properties used to advantage in sculptures and religious artifacts. The mine was opened in 1838 to supply gypsum for plaster and plasterboard to meet the demand of the Victorian property boom, and was the earliest to develop the gypsum industry on a large scale. Plaster was made at factories in Tutbury and on the mine site, the latter finally closing in 1995. During the late 1900s the quality of the extracted gypsum deteriorated as the deposits are deeper and the anhydrite has not been hydrated to gypsum, and mining switched to anhydrite to supply the cement industry. All cement now manufactured contains 4% of a mixture of anhydrite and gypsum (called 'cement rock'), added to the cement ingredients at the grinding (post-calcining) stage. This retards setting of the cement and produces a much stronger product, vital to the modern construction industry. The central location of the mine has been important to its success in this industry. Today the mine produces only anhydrite, and the gypsum is supplied as a byproduct from extraction of power station flue gases using ground limestone.

We walked about 400m into the mine drift to see features showing evidence of the formation and development of the sulphate deposits. The old workings are a huge matrix of shallow mushroom shaped domes supported by pillars. The Tutbury Bed formed on the eastern margins of the Stafford Basin by sub aerial growth of gypsum in a matrix of mudstone driven by solar evaporation. The gypsum was deposited initially as isolated nodules that gradually increased in size and coalesced forming larger masses reaching several metres thickness. Burial of the sediment basin led to conversion to anhydrite that subsequently reconverts to gypsum following uplift as meteoric water is encountered. The reconversion or hydration is not uniform and creates stress within the Tutbury Bed causing the development of mushroom-shaped diapiric structures. The latter have a foliated structure and are the source of the large alabaster blocks. Mudstone trapped and entrained between nodules develops to become coloured vein impurities in the dome which gives Tutbury alabaster its character and is one of the main reasons why it was much sought after. Tutbury alabaster blocks were extracted by sawing in situ, and historically are found in important works worldwide.

After lunch we climbed the slope of drift covering the mine to witness an awesome crater about 5 hectares in area and 30m deep which resulted from 'the largest non-nuclear explosion ever' in November 1944. Noel described the pre 2nd world war events which led to the RAF using a worked out part of the mine workings to store ordnance, initially en route to airfields but later as a store and disarming depot for unused bombs returning from missions. In the accident some 4,000 tonnes are believed to have detonated, killing a total of about 70 people. They included workers in the nearby plaster factory who drowned when a dam burst; RAF personnel and Italian prisoners of war in the mine and farming personnel whose farm stood above the blast. The force of the explosion lifted up to 1 million tonnes of debris, the force being predominantly upwards as the material immediately above the store was mainly sand and gravel and not rock. The cause of this horrific wartime event was kept a state secret until the 1980s; a memorial to those known to have been killed, with their names on a block of white Italian granite and donated by the people of Italy, was dedicated in 1990.

A short walk took us to the village of Hanbury and the Hollington stone church of St Werburgh, which is on the site of a Saxon church. Parts of the existing building date from the 12th century. Here we saw several examples of carved decorative work from Tutbury alabaster dating from the 14th century and which display the characteristic colouring and coalesced nodular texture for which the material is renowned. We also enjoyed a restorative cup of tea and cake served by the vicar and his helpers which put us in good spirits for the walk back to the mine. Finally, some members of the party who had time to divert on their journey north made a stop at St. Mary's Priory Church in Tutbury to examine the Norman doorway, which contains a series of carved alabaster segments believed to be the oldest surviving alabaster carving in Britain.

Bradford Building Stones
Sunday 14th July 2013

Leader: Richard Butcher, West Yorkshire Geology Trust
Present: 9 members

The group met Richard in Bradford's Centenary Square on a hot, sunny July day to investigate some of Bradford's building stones. The main areas studied were the City Park area of Centenary Square, the Central Library, the prestigious buildings of the Wool Exchange and various Banks, and the Town Hall. This allowed us to examine building stones cut from metamorphic, igneous and sedimentary rocks of a wide range of geological ages.

Centenary Square has been redeveloped to include a large paved shallow pool and fountain area, with a surrounding low wall of Scottish granite and paving comprising metamorphic granite slabs. We examined the granite slabs and identified numerous dark xenoliths (See photo below). Jeremy Freeman later contacted Marshalls Natural Stone and found that these came from the Trento quarry in Italy. The pool itself is paved with small square setts which include larvikites, granites, microgranites and diorites. Marshalls informed Jeremy that these were all sourced from quarries in China. These setts are encircled by a decorative ring of dark red rhyolitic lava setts.

Xenolith in Granite. Centenary Square

As we left Centenary Square, and headed uphill to the Central Library, we stopped to examine distinctive ripple marks in the sandstone paving. The source of the paving is unknown but the grain size seems to be too fine to be local Rough Rock. Cross-bedding was also spotted in the adjacent sandstone wall.

The Central Library is approached by steps bounded by a distinctive wall of Elterwater slate blocks of thickness from about 20 mm to 150 mm. Richard explained that these were formed about 450-500 Ma ago from volcanic ash deposited in water as the Iapetus Ocean was shrinking, were transformed to mudstones and shales then metamorphosed to slate. The blocks are highly laminated with clearly visible cleavage planes. On closer examination, we were also able to identify the original bedding planes, and to see how the angle between bedding and cleavage varied (See photo opposite and back cover). Closer to the Library, we examined fossils, including oyster shells, in a tall wall of Portland limestone. This rock was deposited in the Upper Jurassic about 150 Ma years ago.

Outside the nearby Magistrates Court we studied the large irregular blocks of highly durable Rough Rock from Bolton Woods Pickard's Quarry which formed a rockery and spotted marks made for the crane hoist attachment and holes drilled for the emplacement of explosives.

Between the Town Hall and St George's Hall, Richard showed us a non-working fountain decorated with spectacular mosaics of ornamental minerals. He challenged us to identify the minerals and we were able to spot blue sodalite, green amazonite, ironstones, limestones, basalts, dolerites and slate.

Walking down Market Street to once wealthy Bank Street, we admired the Wool Exchange which is built from high grade fine yellow sandstone with red sandstone decoration around the window arches. The NatWest Bank building flaunts its affluence with multiple columns of grey and red Scottish granites. The lower courses of the Santander Bank building comprise large vermiculated Rough Rock blocks but the upper courses are finely-worked fine grain sandstone with intricate vermiculation patterns.

An empty building at 49 Kirkgate is faced with very dark syenite and 'Blue Pearl', a larvikite from Norway. Richard explained that the larvikite came from the Fjølling quarry; it is Permian in age and formed by the Oslo Rift, associated with the Variscan orogeny.

The Simpson Duxbury solicitors building at 2 Tyrrel Street is faced with a particularly impressive polished limestone. Numerous large fossils, including

Cleavage and bedding in Elterwater Slate. Central Library

rugose corals and the pale ghostly impressions of bryozoans showed this to be of Lower Carboniferous age.

The distinctive red terracotta facing the Co-op Bank (originally the Prudential building) is an example of Burmantofts Faience (a glazed earthenware from Leeds) and makes the building stand out among those of the local grey sandstone and this brought us back to Centenary Square. Richard explained that the Town Hall was built on local Rough Rock foundations, with finer Elland Flags used for the more intricate components. The town Hall building has 35 statues, each carved from a single piece of rock.

We duly thanked Richard to whom we are indebted for guiding us and opening our eyes to the wide range of building stones used in Bradford.

Whitby
Sunday 11th August 2013

Leader: Dr Liam Herrington. Durham University
Present: 22 members

Our group met the leader at Whitby to study the Jurassic Whitby Mudstone Formation between Saltwick Nab and Whitby. They were joined by 4 palaeobotanists, friends of Liam, including Dr Sarah King who is one of the curators of natural history at the Yorkshire Museum.

The group walked down to Saltwick Bay via a steep path south of the Whitby Holiday Park. From the beach we could see the Whitby Mudstone, which is a package of shales interbedded with thin beds of secondary limestone. These were used as marker beds for the map of the section produced by M.K. Howarth.

The fossil evidence in the mudstone is patchy and not widespread. The group went across Saltwick Bay onto the reef which contains the Jet Rock where we found well preserved ammonites, belemnites and bivalves on exposed beds of hard, well cemented mudstone. Some fossils were pyritised and Liam mentioned that these organic rich shales have been receiving more interest recently as work on Shale Gas has increased. Typically, black shale can contain hydrocarbon gas and oil. Although the Whitby Mudstone does not contain gas, the depositional environments of low oxygen and low sedimentation are typical of rocks that do contain natural gas and could be exploited commercially.

A resistant limestone layer was seen to lie above the Jet Rock. Jet was formed from ancestors of present day Monkey Puzzle trees, the family *Araucariaceae*, a relative of coniferous trees. The Jurassic had plenty of plant life including flowering plants e.g. *Caytonia*, an extinct seed plant, named after Cayton Bay.

Faults could be seen in the mudrocks, generally trending north-south, with conjugate faults, associated with movements in the Cleveland basin and the later Alpine Orogeny. These fault systems are part of the renewed study of these mudrocks for the recovery of hydrocarbons by fracking.

After lunch we walked over the lower part of the Alum Shale with bands of iron-rich limestone. Shale above this horizon is 'hard' shale, rich in plant life. Holes in the surface of shale beds are where limestone nodules have weathered out.

A bed with infaunal bivalves was seen that was used as a marker bed for Alum miners. These, together with a nearby isolated patch of bioturbation, indicated that conditions suitable for life existed for a while, in contrast to previous rocks seen in which conditions were unsuitable for life. Liam said that these burrows, which have diameters greater than 5 mm diameter, were being examined in detail. Some contained mudstone and pyrite, while others contained carbonates. It is hoped that the studies will give a better indication of Jurassic seabed conditions.

At the location known as Long Bight, the adjacent cliff wall had evidence of multi-phase tectonics i.e. extensional faulting followed by inversion during the Alpine orogeny. A shallow syncline (See photo overleaf) was seen in the cliff that has brought the upper part of the Alum Shale member, known as the Cement Shales, down to shore level. These are the highest parts of the Whitby Mudstone here and have abundant calcareous nodules. The Dogger Formation overlies the Alum Shale disconformably. The formation is a pebbly sideritic sandstone with much bioturbation. The base of the bed overlaid conglomerate. Nearby sandstone fallen blocks contained roots and leaves A fossil tree trunk was also found. Further west another block was found which contained unidentified plant fossils (See photo below). which the visiting museum curator took away for identification.

Back at Whitby Liam was thanked for such an informative visit and for providing such good weather.

Fallen sandstone block with plant fossils

Shallow syncline in Alum Shale at Long Bight

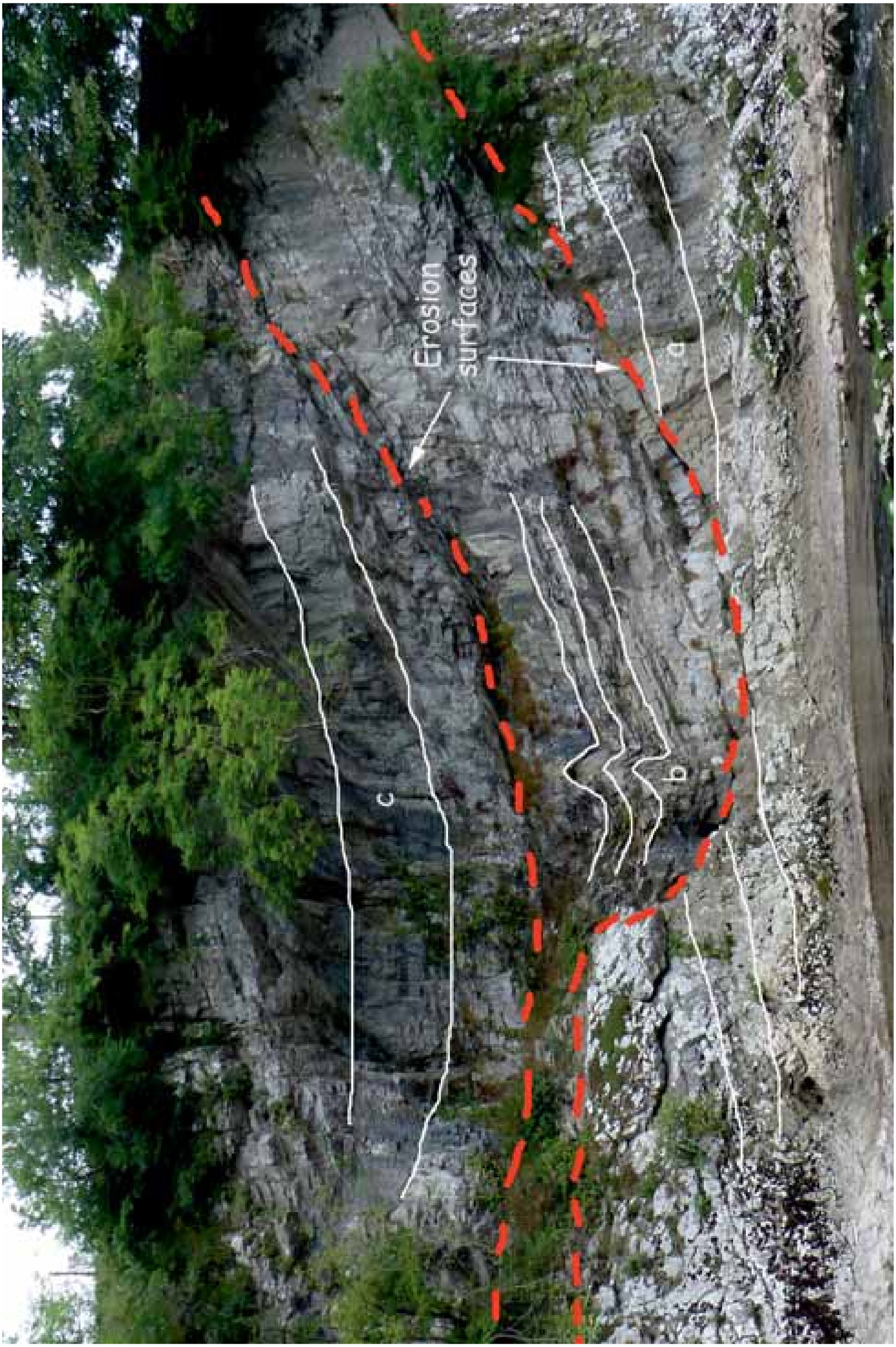
Burnsall & Brimham Rocks
Sunday 15 September 2013

Leaders: Dr's Richard Haslam & Oliver Wakefield. BGS
Present: 13 members

13 members braved the dire weather forecast and met our leaders on the village green at Burnsall. Richard and Oliver are both involved in the remapping of the BGS Pately Bridge sheet. Richard was to lead the morning session at Burnsall to look at limestones and consider their depositionary environments and history, with Oliver leading the afternoon session at Brimham Rocks to look at various sedimentary structures within the Brimham Grit and relate them to its depositionary environment.

Burnsall is located on the boundary between the Askrigg Block and Craven Basin which is marked by the Craven Fault System and so it is not surprising that bed lithologies, thicknesses and structural features are varied and can change rapidly in short distances making it a complex region to map. One of the problems that the mapping team also have is trying to tie in the stratigraphy to that of the neighbouring Settle map. Richard began with a discussion of the landscape seen from the village green at Burnsall. Rising immediately above the village to the south is Burnsall Fell composed of Bowland Shale capped by Warley Wise (Grassington Grit). A number of prominent landslides, caused by the failure of the weak shales beneath the strong sandstones in postglacial times were noted on its lower slopes. Further down the valley, on the opposite side to Burnsall Fell, the dome shaped Hartlington Hill is one of a series of marginal reefs that run along the southern boundary of the Askrigg Block. The hill has a steep south face which would have fronted into the deeper water of the Craven Basin whereas its more gently sloping north face, composed of reef fringe limestones washed off its top, led back to the shallower waters and back reef limestones of the Askrigg Block. Whether these reefs are a series of separate, isolated reef knolls or if they form a continuous belt was briefly discussed. The boundary between the limestones and shale/gritstones is a fault, one of the many that comprise the Craven Fault System and may be an extension of the Mid Craven Fault.

Moving upstream the first location was Loup Scar, a prominent cliff carved in the Pendleside Limestone Formation, on the opposite side of the River Wharfe which displayed two different limestones and some prominent structures. (See photo overleaf) While the group were able to identify differences in the limestone, the various folds and erosion surfaces, it required Richard to provide a full interpretation as a channel feature cut in a



Loup Scar; an infilled erosion channel

limestone (a) on the back slope of a reef knoll which became filled by further calcareous debris which then slumped to create the tight fold (b). This was then followed by a second phase of erosion and deposition of more calcareous debris (c) after which the whole section was slightly rotated.

Walking a short distance upstream the boundary between the Malham Formation and the Alston Formation was crossed. This was clearly seen by the change in nature of the limestones. The limestone of the underlying Malham Formation are pale grey while those of the overlying Alston Formation are dark grey and have a strong smell of bitumen when freshly broken. The Girvanella Band which occurs in the Hawes Limestone just above this boundary is recorded as occurring in this locality. However, as is the case in many other places where it has been observed in the past, it is not easily visible today due to the heavy growth on lichens and mosses on so many limestone surfaces (due evidently to the Clean Air Acts of 1956 & 68!) so time was not spent looking for it.

The final outcrop of the morning was a section in the Hawes Limestone that showed, by its cyclic nature, that it wasn't deposited as a continuous bed. An erosion surface in the limestone forming the bed of a small tributary to the Wharfe is overlain by limestone containing large coral (Lithostrotion) colonies. Upwards these are replaced by large brachiopods before the beds are cut off by an irregular erosion surface and the cycle begins again in the next bed above with more large corals. Three cycles could be seen in this outcrop and clearly illustrate the fluctuating state of the sea levels during these times.

After a lunch taken in cars while the heaviest of the day's rain fell, the group emerged into an almost deserted Brimham Rocks. (apart that is from a group leading a train of llamas with whom we exchanged puzzled glances!) Brimham Rocks are a fine exposure of the Lower Brimham Grit which formed in a fluvio-deltaic setting of Namurian age. The rocks are nearly all coarse-grained, poorly sorted, angular, feldspathic sandstones and illustrate a variety of cross-bedding structures.

The first locality (See photo overleaf) showed 4 sets of planar cross-bedding the lowest of which was, internally, heavily deformed. This is a dewatering structure and there was discussion as to the cause; overburden pressure or seismic induced. The fact that this is the only set at Brimham show this structure suggests the pressure of the overriding sets forcing the water out is the most likely cause.

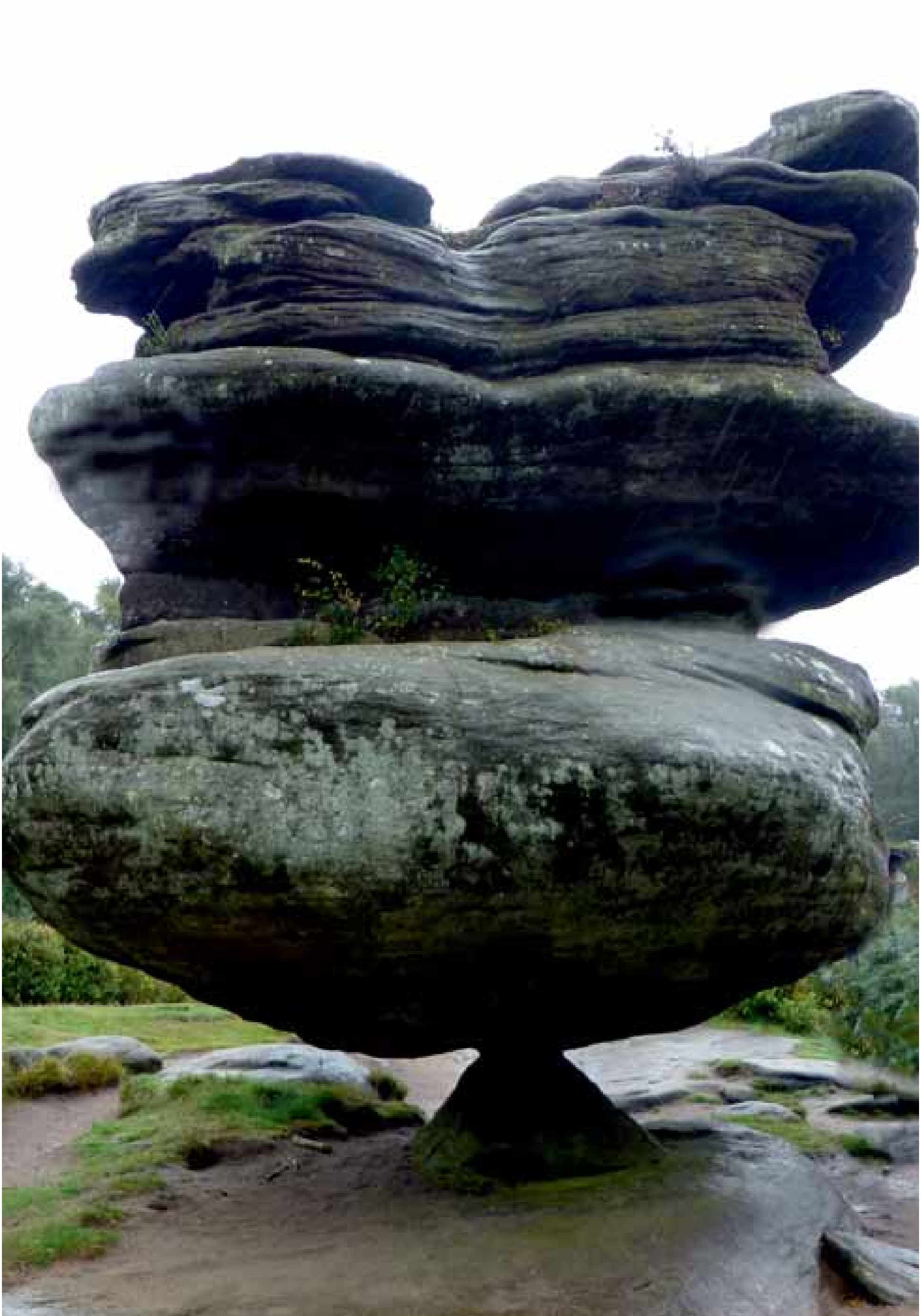
From here we moved to a large outcrop that showed a complex series of cross-bedded units in which the outline of a deep, sediment filled channel could be

Planar cross-bedding deformed by dewatering structures seen cutting down into underlying cross bedding sets. Within the channel fill and the underlying sandstones examples of planar and trough cross bedding were seen facing in a variety of directions consistent with a series of braided channels.

The third locality was the well known Idol Rock (See photo overleaf). Here Oliver put our brains to the test by asking us to calculate the weight of this rock that balances precariously on a tiny pedestal! Using approximate calculations of its size and average weight of sandstones he arrived at the equivalent of 193 Vauxhall Astras (~ 188 tonnes) stacked on a pedestal with the area of 2 dartboards- which made us all take a couple of steps backwards! The origin of the feature by aeolian processes during the later stages of the Devensian when the locality was a cold dry desert, were discussed.

The final locality showed several crossbed sets with thicknesses between from ~ 10 – 70cms. At one end of the outcrop the cross beds of the thickest unit, rather than having their top surface cut off sharply by the overlying set, showed a flattened S shape (See photo inside back cover). Oliver explained how this illustrates that this set was being formed by an in-channel bedform that was accreting laterally as well as downstream.

At this point, as the sun began to break through, Richard and Oliver were thanked for providing such a varied an interesting day and for being so willing and able to respond to a wide range of questions.



‘The Idol';   '193 Vauxhall Astras resting on a big dartboard!'

Residential weekend to Northumbria
Friday 27th to Sunday 29th September

Weekend leader: Alison Tymon
13 members and spouses present

Friday 27th Holy Island

The weekend party gathered at our hostelry The Lindisfarne, situated on the road to Holy Island, ready for a brief visit to exposures on the island which we last examined during our 2005 weekend when we had spent a full day making a circuit of the island's geology.

After a picnic lunch we reviewed the general geology of the island. Under a cover of boulder clay and wind blown sand is a series of Brigantian age cyclothems dipping generally to the SE and gently folded by Variscan compression at the end of the Carboniferous. Of the three limestone members outcropping on the island, the Eelwell, Acre and Sandbanks, the Sandbanks was quarried in the nineteenth century to provide feedstock by a rail system to limekilns adjacent to the castle in the SE of the island, where it was burned using coal imported from the Newcastle area. The quicklime was generated exported to 'the mainland' mainly for agricultural use; at its peak in the 1860s about 5,000 tpa was generated from 10,000 tpa of limestone.

The Variscan Orogeny also allowed the emplacement of the Holy Island Dyke on the foreshore to the south of the island. The dolerite dyke echelon has the same composition as the Whin Sill and is considered to be a feeder to that system. The dyke is offset to form a series of islands from St. Cuthbert's Island on the west foreshore to Castle Hill in the east. On St. Cuthbert's Island the surface is a chilled margin with very small amygdales, but exposed surfaces 150-250 mm below show much larger amygdales up to 0.5 m long, trending generally NNE, which exhibit good examples of 'ropey structure' formed when lava continues to flow in the floor of the cavity when the upper surface has chilled; the calcite which had subsequently filled the cavity has been eroded away; later in the weekend we saw amygdales in the surface of the Whin Sill with calcite both partially and completely filling the cavity. Our group followed the sill outcrops across to the castle looking at features of the emplacement. At the southern margin of Heugh Hill the vertical chilled margin of the dyke has in several places a 'skin' of pale brown Acre limestone trailed a metre up the dyke surface from a wave cut platform, showing that the lower wall is formed of the chilled surface of the intrusion.

Having worked up an appetite for dinner and the weekend's geology we returned to our hostelry ready for action!
(See Field Visit Reports, summer 2005 for an account of the visit that year)

St Abbs to Berwick
Saturday 28th September 2013

Leader: Alison Tymon West Yorkshire Geology Trust
11 LGA Members present

Purpose: to examine the succession along the coast from the Llandovery up to the Lower Carboniferous and signs of the Iapetus ocean closure.

We started the day with Alison in the picturesque village of St Abbs which stands on a Lower Devonian vent agglomerate, well exposed around the harbour. It consists of chaotic basaltic and andesitic agglomerates and pyroclastic rocks, part of the Eyemouth Volcanic Series formed by oceanic subduction (See photo opposite). The igneous contact of the agglomerate was crossed in a gully north of the village. It was just possible to see some rocks at the foot of the cliff which have weathered yellow which were the country rocks, Silurian greywackes laid down in the subduction trench of the Iapetus Ocean. The rocks in the next section of cliff, Bell Hill were Lower Old Red Sandstone conglomerates (Great Conglomerate Formation), dipping steeply to the north. In the footpath they are cut across by a dark igneous rock with different joint patterns. This is a lamprophyre dyke, about 5-6m wide, containing a high proportion of biotite, one of an extensive swarm of dykes running across the Southern Uplands. Their formation is associated with subduction of continental crust. It has been dated at about 400ma. Because it cuts through the Eyemouth Volcanic Series, they must be older. Our view showed the line of the St Abbs Head Fault, which follows the valley NW.-SE.in which Loch Mire is situated. The fault crosses the coast to the west of White Heugh in a gully where there is about 2.5m of fault breccia. The fault downthrows several hundred metres to the NE, bringing the St Abbs Head volcanic rocks into contact with the Silurian greywackes. Descending into the valley, the volcanic rocks of St Abbs Head could be seen. The Eyemouth Volcanic Series here is about 600m thick and consists of alternate beds of explosive andesitic ashes/tuffs and lavas. The tuffs are usually bedded but the lavas are massive, sometimes with erosive bases. The more resistant lavas stand out as crags over the hillside. To the north the fault reaches the sea at Pettico Wick. Along the cliff line to the west are Silurian Gala Group greywackes folded into large synclines and anticlines. Sole structures were found in the steeply dipping beds which showed the rocks here are not inverted.

Lunch was followed by a drive down the steep road to Burnmouth. The cliffs north of the harbour are highly folded Silurian greywackes. Above them lie the Ballagan Formation rocks (Cementstones) which are Lower Carboniferous in age. They are nearly vertical here (See photo overleaf), as they lie on the steep limb of the Berwick monocline, formed at the end of the

Inspecting the Vent Agglomerate at St Abbs village

The vertical Ballagan Formation at Burnmouth

Carboniferous period. Alison told us of the new research work being undertaken here. The rocks consist of cementstones , mudstones, siltstones and sandstones, all deposited in arid region rivers and lakes. The cementstones probably formed in lagoons which were drying up, leaving desiccation cracks and carbonates, possibly precipitated by algae, forming a calcite-rich mud. Further round the coast can be seen the Fell Sandstone Formation which is an extensive 400m thick group of pale sandstones which forms the line of hills inland of the A1. The rocks are usually cross-bedded, showing deposition in wide delta river channels. Above the Fell Sandstone lies the Tyne Limestone Formation (formerly Scremerston Coal Group) and the Alston Formation (formerly the Lower and Middle Limestone Groups). The rocks show a marked change in the Carboniferous landscape, as the low lying land surface became flooded with sea-water. The first limestones found in the Lower Carboniferous in this area occur at this time and show the delta suffered repeated marine transgressions.

At Berwick the Alston Formation rocks here are warped into gentle basins and domes that were best seen from the cliff top path (See photo below). Most prominently the Eelwell Limestone which is well exposed on the shore at Fisherman's Haven has many fossils, particularly very large Productus shells and colonies of corals. The sequence is cut by the Green's Haven fault in the north, which faults Eelwell Limestone against cross-bedded sandstone, and the Meadow Haven Fault in the south. This brought to an end a very varied and interesting day along this really beautiful stretch of coastline.

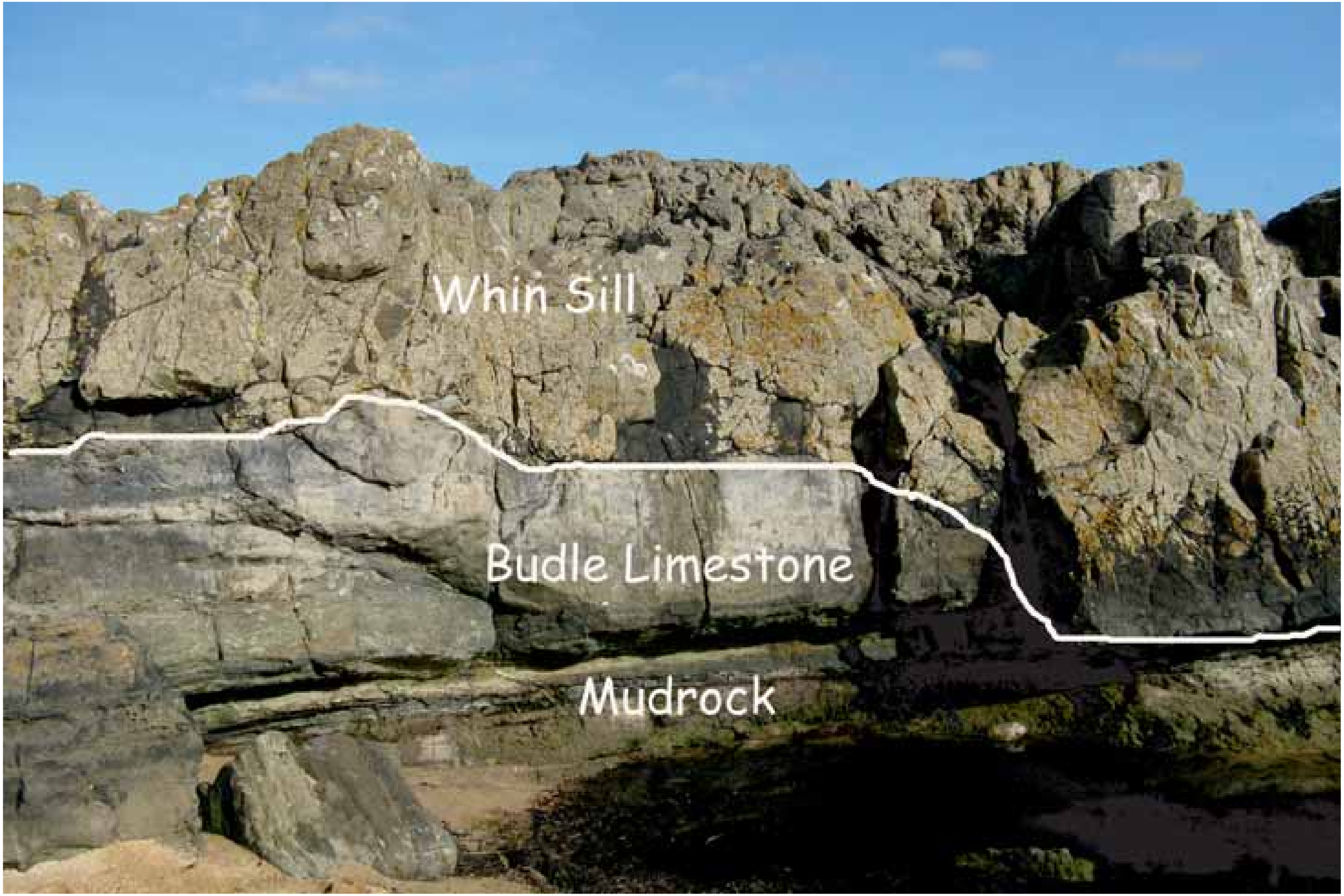
A dome structure in the Alston formation at Berwick .

Bamburgh to Howick Haven
Sunday 29th September.

We met in the car park along The Wynding at Bamburgh, on a bright sunny day with the castle standing high on a prominent Whin Sill outcrop. A short walk north along the beach took us across outcrops of the top of the Whin Sill which showed large amygdale cavities similar to those seen in the Holy Island dyke on Friday. Ropy flow structures within some of the cavities, especially the more elongated ones, indicated a horizontal east to west flow in this part of the Whin Sill. At Stag Rock (with its white painted carving) the base of the Sill is exposed. (See photo opposite) Some time was spent inspecting the contact of the Sill with the country rocks which here is a transgressive one. Baked fragments of both the Budle Limestone and its overlying shale could be seen as inclusions in the dolerite.

Returning to our cars we left Bamburgh for Craster where we parked in an old Whin Sill quarry and walked down to the harbour. On joining the coastal path, two limestone reefs of Little Carr and Muckle Carr were clearly visible in the sea on either side of the harbour entrance. To the north there was a good view of Dunstanburgh Castle on its Whin Sill crag. Walking south, the shore was dominated by the hexagonal to polygonal dolerite rocks of the Whin Sill. After passing Cullernose Point we looked back to the spectacular columnar jointing of the Whin Sill cliff marked with the white guano of nesting sea birds. At this point we descended to the foreshore onto the Sandbanks Limestone, part of the Alston Formation, which is fossiliferous with crinoids, brachiopods and corals. (See photo overleaf) A fault along the south side of Cullernose Point is thought to be responsible for the 'whaleback folds' developed in the Sandbanks Limestone which here forms the shore. On the platform formed by the limestone, nodules of stromatolites which formed in warm shallow marine waters were also seen. Close by, striking across the shore, the dolerite Cullernose Dyke was examined. This is approx 1.5 wide with some sections standing proud of the wave cut platform by almost 2 metres while others have been broken out, leaving an almost artificial looking trench.

Walking south on the shore we were descending the stratigraphic sequence which consists of a series of cyclothems (analogous to the Yoredale series). Cyclic sedimentation started with thin, dark, marine shales above which are limestones followed by more marine shale which coarsens upwards into rippled and cross-bedded sandstones capped by palaeosols and thin coals. These are the products of flooding of a delta plain forming an open marine environment before a gradual return to land as deltaic shoreline advanced. The top of the Acre Limestone cyclothem showed a good example of a white sandstone seatearth (ganister) containing burrows, roots (*Stigmaria*) with a



The transgressive base of the Whin Sill at Stag Rock cutting through Rocks of the Budle Limestone cyclothem

Alston Group Sandbanks Limestone in foreground with columnar jointed dolerite of the Whin Sill forming Cullernose Point beyond.

thin coal seam on top. (See photo overleaf) Immediately above this was the Sandbanks Limestone which is the beginning of the next cycle.

Continuing south the fossiliferous Acre Limestone at the base of the cyclothem was seen forming a dome structure. Good examples of calcite filled tension gashes were noted on the wave smoothed surfaces.

The east-west Howick Fault with a throw of 200m, thought to have occurred as part of the Variscan Orogeny at the end of the Carboniferous, interrupted the sequence. The fault was clearly seen in the cliffs where the almost horizontal bedding is tipped to a steep angle. On the foreshore Whin Sill dolerite is intruded along the fault line as a dyke and, in places, spreading out between the sedimentary layers to form a small sill. South of the fault, although the rocks are still of 'Yoredale facies', they are now of Upper Carboniferous age and we were now walking up the sequence.

Further south at Rumbling Kern, cliffs, formed by quarrying of a thick sandstone, stand above the Howick Limestone exposed on the base. Thin shales above the limestone contain iron nodules, known locally as 'fairy's pockets'.

At Howick Haven the fossiliferous Howick Limestone (bryozoans, gastropods, brachiopods and crinoids) was exposed on the beach with a classic coarsening upward succession above it. This began with mud rock which passed up into sandy mudrock showing ripples and flaser bedding; alternating beds of rippled sandstone draped with mud, then a thick cross-bedded sandstone. This is another example of an environment shallowing as a sandy shoreline approaches. At the top of the cliff were large angular sandstone blocks and an infilled erosion channel from recent glaciation.

From this point we then returned to the cliff path and walked back to Craster. Here, Alison was thanked for stepping into the breach at short notice, providing such an informative weekend and the excellent weather.

Rootmarks and burrows in ganister at top of Acre Limestone cyclothem

Oliver Wakefield explaining cross-stratification at Brimham Rocks

Examining Elterwater Slate
outside Bradford Central Library