

Leeds Geological Association



Founded 1874 - Registered Charity No. 1016696

Field Visit Reports Summer 2007



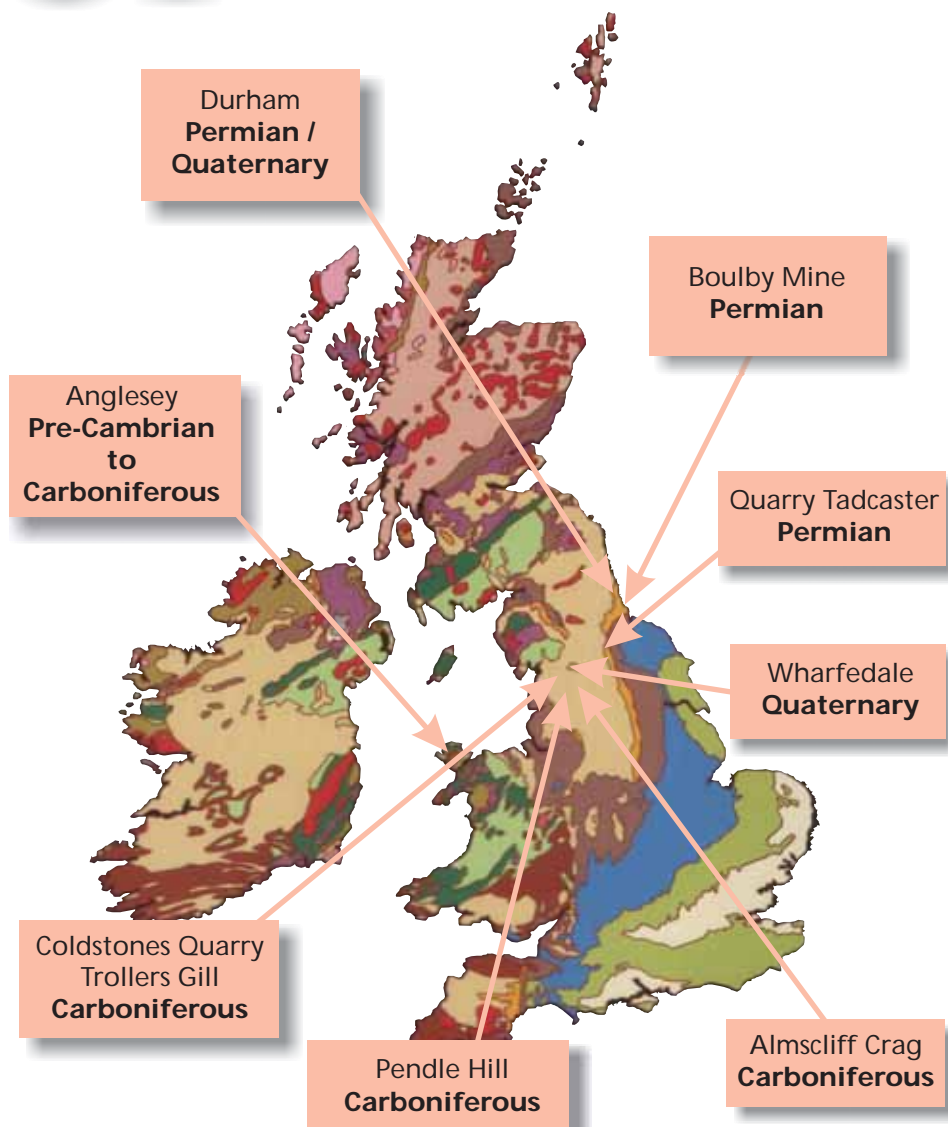
www.leedsgeolassoc.freeserve.co.uk



Looking for the Girvanella Nodular Band at Hell Hole

07

Where did we go?



Contents

2007 Field Visit Locations

Visit	Page
1. Quaternary features in the Barden Bridge - Drebley area of Wharfedale	4
2. Cadeby (Upper Permian) formation at Jackdaw Crag Quarry	7
3. Visit to Coldstones Quarry and Trollers Gill	9
4. Pendle Hill and Clitheroe	12
5. Permian and Quaternary Geology of East Durham	16
6. "Sticking out like a sore thumb" a visit to Almscliffe Crag	21
7. Visit to Boulby Potash Mine	24
8. Residential Weekend on Anglesey - Friday 21st and Saturday 22nd September - Sunday 23rd September	26

Thanks to the authors of the field visit reports who also produced many of the images: Neil Aitkenhead, Tony Benfield, Jon Brotchie, Judith Dawson, Howard Dunnill, Jeremy Freeman, Bob Gibson, David Holmes, Pauline Sweet. Additional images provided by: David Peatfield, Judith Whalley.

Cover Picture: Holyhead Quartzite exposed close to axis of Rhoscolyn Anticline. Holyhead Mountain, also exposing Holyhead Quartzite, just visible on skyline (see visit report page 26)

Quaternary features in the Barden Bridge-Drebley area of Wharfedale. Sunday 13th May

Leader : Dr. Neil Aitkenhead.
11 members attended

Neil Aitkenhead took us to a stretch of Wharfedale he has been looking at recently, that has not been surveyed since J. R. Dakins, prior to the publication of the 1889 geological map.

We made our way from the picturesque village of Drebley, perched on the west side of Wharfedale, down to the valley floor. As we descended there was a good overview of the valley floor showing an arcuate line of small hills interpreted as a dissected esker. The typical narrow-crested symmetrical ridge appearance is only seen towards the north-east end at its nearest point to Drebley (see photo opposite). Elsewhere, parts of it have been removed by erosion and those that remain have an asymmetric profile. This is because the esker abuts against the lower western slope of the valley side so that the eastern side is steep, flanking the valley floor, whereas the western flank mostly forms a terrace-like feature merging with the gentle valley slope.

Then we proceeded to parts of the flatter valley floor which Neil had previously augured and found to be largely gravel. (This was confirmed by a very sociable farmer who told us how quickly his land drained and the problems taking a decent crop of hay). Closer inspection showed an undulating surface 2.5m - 5m above the river level, the lower parts forming hollows elongated down-valley, representing earlier braided river channels formed in gravel (a braidplain or sandur).

Our attention now turned to possible Kame Deltas, flat topped mounds of sand and gravel laid down in standing water at ice margins. We looked at two flat topped hills and a dissected row of three hills all linked with other poor exposures and all to the east of the esker. Excavations by rabbits revealed a base of till covered by a coarse sandy layer a few metres thick and these were overlaid by rounded to sub-rounded coarse gravels, cobbles and large stones of limestone, sandstone, shale and chert a few metres thick.

One of the sites, the flat topped hill at Stangs Laithe, rewarded closer inspection, the eastern side having been eroded by Fir Beck leaving an excellent exposure. This showed 12.5m of finely interlaminated sand, clayey sand, and silt which appeared to be horizontal indicating deposition in a quiet body of water, probably a lake (see photo top of page 6). This contrasted with the overlying 13m of coarse gravels mainly of rounded limestone pebbles, but including cobbles and small boulders up to 60 cm in diameter supported in a matrix of coarse sand. There were also some sub-rounded to sub-angular clasts of coarse sandstone and calcareous shale or

mudstone. The gravels were probably deposited in a vigorous glacial melt water stream.

Neil tentatively suggested an ice bound lake may have filled Firs Gill and the eastern side of the Wharfe valley as the ice receded, whilst the main sub-glacial river was still forming the possible esker under the melting ice sheet. A temporary colder interval may have shut off the supply of melt water. When melting resumed, the main melt water river was forced by the ice to take a different course to the east of Haugh depositing its load of sand and gravel over the top of the former lake deposits to form the Stangs Laithe feature.

We made our way back to the cars along the unofficially-named Drebley Gorge, where the River Wharfe cuts a fine section to the west of Haugh through the Pendle Grit Formation. This is Pendelian (E1c) in age, the lowest sandstone formation in the Millstone Grit Group. It represents the first major influx of coarse feldspathic sand of the Millstone Grit delta encroaching from the north. The sandstones show the massive sharp-based beds characteristic of turbidites i.e. sand deposited out of suspension in turbidity currents that flowed down the pro-delta slope. Islands or stacks of very thick bedded massive coarse pebbly sandstone in the middle of the river probably represent deep channel fills.

A very pleasant and interesting day ended with an unseemly rush for our cars as the threatened rains arrived.



The line of the possible esker curving round to meet the valley side.



The exposure at the back of the flat-topped feature at Stangs Laithe showing the horizontally interbedded sandstones, clayey sandstones and silts overlaid with much coarser material.



The Cadeby Formation at Jackdaw Crag Quarry showing a normal fault with horizontal slickensides. INSET: Close up of the fault with slickensides.

The Cadeby (Upper Permian) Formation at Jackdaw Crag Quarry

Saturday morning 9th June

Leader: Tony Benfield

A party of 15 members and friends paid a short visit on a sunny Saturday morning to Jackdaw Crag Quarry, some 2 miles SW of Tadcaster. This quarry, still working, is one of a number of sites exploiting that narrow band of deposits of Upper Permian age running NNW from Nottingham towards Catterick.

This quarry is an extensive enterprise, some 15 hectares (37 acres) in area, excavated to a depth of at least 12-15m below the thin soiled, mainly drift-free surrounding farmland. It consists of an older operation, now mainly grassed over as a nature reserve, and the currently operating section which the party visited first.

The rocks here, previously known as the Lower Magnesian Limestone, now called the Cadeby Formation, are shallow marine sediments accumulated about 260 Myr ago on the western margin of an unevenly subsiding basin within the ancient Laurasian continent which then extended as far as the present Baltic and Poland regions. At that time it lay much further South, at a latitude of around 25 degrees north. Warm conditions favoured the formation of carbonate deposits, sometimes sandy at the edges of the basin, and evaporites later on towards the end of the Permian as sea levels fell. Although brachiopods and bryozoa, indicating an active and oxygenated environment, have been found in the Cadeby Formation near Durham, time and safety considerations restricted opportunities for the party to try to discover such things here.

The cream to brownish-yellow colouring of most of these limestones denotes partial and not very uniform subsequent dolomitisation by very saline magnesium-rich brines, as does the 2-3 cm diameter drusy cavities found in some of the excavated material. These cavities, resulting from the density increasing effect of the calcium to magnesium carbonate dolomitisation reaction, have not prevented the use of Jackdaw Crag or 'Tadcaster' as a building stone in York and Beverley Minsters, but the present output is reduced on site for sale as crushed aggregate.

Structurally, at a safe distance from all newly disturbed surfaces, it was possible when looking southwards to discern the expected regional dip of a

few degrees downwards to the east. On the western face there seems to be on the right a pink region, lacking a clear bedding structure, which is at a higher level than its position on the left. This would suggest a normal fault downthrowing to the south, contrary to the north-dipping fault which is marked in this region on the 1951 G.S. Leeds 1 sheet. Unfortunately from our position no corresponding confirming feature could be seen on the east wall of the excavation.

The floor of the working area was covered by a pale yellow fine limestone sand, fortunately dry for us, but most of the older abandoned area has been grassed over as a nature reserve, the site being unsuitable for infilling purposes on hydrological grounds. A small part however had been used recently for stacking power station coal and was appropriately stained. Tony reminded us that the Coal Measures strata upon which the Permian lies unconformably, is probably 50-70m. below our feet at this point due to the regional easterly dip.

The back wall of the old quarry is in the Sprotborough Member of the Cadeby Formation, and shows large scale cross-stratification in approximately 8m. sets which were formed from original sediments of an oolite lime-sand, now cemented and dolomitised. There were minor faults in some areas, one particular example, seems to be a normal fault downthrowing by about 2m. to the east, but showing a horizontally slickensided projecting surface, apparently from a subsequent horizontal movement on the earlier fault plane (shown in photo bottom of page 6).

When sea levels fell towards the end of Cadeby Formation deposition, consequent streams from the Carboniferous land areas to the west cut channels in the Permian limestones, causing red staining due to percolation of iron rich solutions. Some lenses of red-brown siltstone seen in the quarry wall might be attributed to transportation by these streams at flood times.

Interestingly the small amount of drift deposit seen towards the east at the top of the old quarry probably dates from the Anglian stage of the Middle Pleistocene and not from the most recent glaciation as this location lies outside the Late Devension ice limit.

The visit was terminated at noon as arranged, with thanks to Tony for his leadership, and to Darrington Lime, the quarry operators, for permitting access and for supplying some protective clothing. Thanks also to what I was told were some peregrine falcons protesting loudly from trees at the top end of the nature reserve, for deciding not to intervene.

Visit to Coldstones Quarry and Trollers Gill Saturday 23 June

**Leaders: Iain Burgess and Murray Mitchell
14 members present, including the leaders, 1 visitor and Sheila
Everett joined us for the afternoon.**

The purpose of the visit was to demonstrate a new interpretation of the Lower Carboniferous Limestone stratigraphy in the area around Trollers Gill.

The weather forecast was not promising and we were greeted with a heavy shower. The outlook worsened when it was pointed out that our first location no longer existed! However, the day improved from then on - both weatherwise and geologically speaking - as arrangements had been made for us to visit the quarry itself and this made for an extremely interesting day.

The Quarry

The Manager, Sheila Everett, explained that the observation point had been removed because the quarry was being extended, and told us about operations there. Iain then briefed us about the quarry's geological location and the formations and structures which were visible.

The quarry is located on the Askrigg Block near its southern edge. To the south is the Craven Basin which was subsiding relative to the Block during Carboniferous times. The lower part of the quarry exposes up to 80m of mid to pale grey limestone of Asbian age succeeded, unconformably, by the 21m-thick, dark grey, Brigantian, Coldstones Limestone. Above are shales, capped by the 40m+ thick Dirt Pot Grit. The Coldstones Limestone comprises the Hawes Limestone (18m, with the *Girvanella* Nodular Bed marked by a shale parting 10m above the base) overlain by the Gayle and Hardraw Scar Limestones with a combined thickness of 3 metres (compared with around 30m at Kettlewell).

In the quarry the Dirt Pot Grit and shales have been recently stripped off a new area for extraction to expose the limestone below. From a distance the upper beds appeared to show wavy bedding and those below dipped away from us in all directions, outlining the dome structure of the quarry itself (see photo top of page 10). Sheila then took us over to walk on the wavy bedding which proved to be huge, quite tight folds, with fractures where the dome fell away. We examined feeding traces in the limestone and other fossils which Murray identified, and also an exposed vein with the usual suite of minerals for the area.

We spent a happy and fascinating couple of hours at the quarry before travelling the short distance south for lunch at Hell Hole above Trollers Gill.



On the top of the wavy bedding - with fractures where the dome falls away



In Troller's Gill - discussing its formation

Trollers Gill

At Hell Hole, (see back cover), the *Girvanella* Band lies at the base of a 3 metre exposure of limestone, above which is shale, with sandy limestone topping nearby hillocks. At the quarry there had been 11 metres of limestone above the *Girvanella* Band - overlain by shale, and the 40-metre thick Dirt Pot Grit. Where were the missing strata?

Iain explained that an east-west trending, south facing escarpment, cutting through the Middle Limestone and underlying beds, was known to exist in the Grassington area, with Bowland Shales of Late Brigantian/Pendleian ages banked against it. The scarp was presumably created by a submarine landslide along the southern margin of the Askrigg Block, related to movement on one of the Craven faults. Iain suggested that here we were probably looking at the sole of the same landslide, which had cut off the upper part of the Coldstones Limestone and later beds, and that the overlying shales and limestones, presently correlated with the early Brigantian Yoredales, might instead have been deposited in a Basin environment and correlate with the Bowland Shales seen at Grassington.

The *Girvanella* Band at Hell Hole was difficult to see after the earlier shower so we walked downhill to a narrowing of the track where the lowest 10m of the Coldstones Limestone are exposed. Here, Murray identified brachiopods and corals, particularly from a 70cm-thick shell bed, 4m below the *Girvanella* Band. This shell bed forms a well marked feature, which was traced along the hillside to above Gill Head Mine.

Further downhill, at the bottom of Trollers Gill, we saw Asbian limestones typical of a back reef environment: intensely bioturbated by worms and other fauna in a nutrient-rich, protected environment, so bioturbated that bedding planes die out after a few metres. These limestones showed strong sub-vertical jointing.

Walking up the narrow gorge with its curving overhangs, Iain gave two alternative theories of its formation (see photo bottom of page 10). The first is that it was a vadose channel which was exposed when the roof collapsed; the second that it is a tunnel cut by a stream flowing under an ice sheet where the hydrostatic pressure would be high, which subsequently collapsed. His own view was that it was probably a combination and he pointed out the large sandstone erratics in the stream bed.

We then walked up the gill to where the Coldstones Limestone crossed the beck. Beyond the ladder stile on the west bank, the shell bed reappeared and 4 metres above was a small exposure of the *Girvanella* Band in the path. We all had a good look and whilst the samples from the exposure itself were poor, one of our party found a nice piece in the gully below.

All in all a really excellent field trip with an informative commentary and handout - and it stayed dry the whole time.

Pendle Hill and Clitheroe Saturday 7th July

**Leader: Paul Kabrna
14 Members present**

Our group met at the Nick O'Pendle on Pendle Hill under threatening skies to examine exposures in the Pendle Grit Formation in this immediate vicinity. Later in the day we would examine limestone deposits bordering the A59 Clitheroe by-pass and on the Salthill Quarry Geology Trail.

Our leader, Paul Kabrna, introduced the day with an overview of the geology of the area from this splendid vantage point. This covered a brief history of the development of the Craven Basin as a NE – SW trending asymmetric half graben resulting from fault controlled extension of the earth's crust in late Devonian – Tournaisian times. The basin's northwest margin is bounded by the Southern Lake District High and the northeast margin by the Askrigg Block (which was controlled by the Middle Craven Fault) with the Central Lancashire High (CLH) to the southeast. This southern boundary of the CLH coincides with the line of the Pendle Monocline. The depositional history of the basin is believed to have resulted from a combination of syndepositional tectonics and eustatic processes. Consequently, the basinal sediments portray a transition from carbonate shelf to slope. Within the basin no pre-Carboniferous rocks are known.

Early deposits were Lower Carboniferous limestones on a gently dipping ramp in shallow tropical seas. As basin subsidence outpaced deposition the depositional slope steepened marking the transition to deep-water hemipelagic sediments with limestone turbidites being fed from surrounding carbonate shelves and platforms. Intermittent supply of terrigenous sand into the basin is related to the emergence and erosion of the surrounding area. Differential subsidence affected bathymetry, resulting in the deposition of the Clitheroe Limestone Formation. Around Clitheroe the sea became sufficiently deep for Waulsortian mud-mounds to grow (see below). There was a shallowing event following the first period of Waulsortian production which is marked by shallow-water, storm generated carbonates of the Peach Quarry Limestone (seen in the A59 road cutting). Waulsortian Limestone (Bellman Limestone in Salthill Quarry) deposition resumed marking a return to deeper water conditions.

Deposition of the Bowland Shale Group (late Asbian to Pendleian) is marked by a reduced carbonate supply to the basin and an increase in oxygen starvation of the basin floor which resulted in an accumulation of organic-rich shales. In the Namurian, the Pendle Grit Formation is characterised by a huge influx of coarse feldspathic sand deposited by turbidity currents from a

major river system from the north-west. The sands were first deposited from suspension in channels on the basin floor, followed by the advance of the delta front across the basin. Large channels were cut across and refilled by smaller ones.

The Pendle Grit which outcrops at the Nick O' Pendle is the type locality at Pendle Hill and also the oldest member of the Millstone Grit Group. Here the basin-fill fan sequence shows various turbidite, mass flow and channel features. We examined exposures at three small quarries close to the parking area at the Nick O'Pendle; although named gritstone, these are fine to medium grade micaceous sandstones with no crossbedding. In the small North Quarry we looked at examples of high amplitude wavy bedding and mud laminations – good evidence of their deep water turbidity current origin – and loadcasts. Wavy bedding and mud laminations were more obvious in the quarry adjacent to the parking area (see photo below). Inconsistencies between dip and features in these quarries show that inter-relationships are complicated with faulting making it difficult to relate between exposures.

Returning from Pendle Hill towards Clitheroe, we visited exposures in the highly fossiliferous Peach Quarry Limestone in the road cutting along the A59. This is the type locality for these largely storm generated limestones. We



Examining wavy bedding and mud laminations in Pendle Grit turbidites in a quarry at the Nick O'Pendle

examined exposures dipping to the south at about 25 degrees, the typical dip in this area, and noted an abundance of brachiopod and crinoid debris. These were originally deposited close to the basin shore in shallow tropical seas in the early Carboniferous.

The afternoon was spent following the Salthill Quarry Geology Trail, a series of exposures surrounding a now disused limestone quarry. Even though the old quarry floor is now commercialised, key geological features of Salthill Quarry are preserved in the form of Waulsortian mud mounds. This quarry is also one of the most important localities for Lower Carboniferous echinoderms in northwest England with crinoids being the dominant fauna. The site is the subject of a Geologists' Association Guide (see reference below) and the whole site is an SSSI.

Waulsortian mud-mounds are very rare seabed limestone mounds, named after the town in Belgium which is a classic area for their study. This quarry complex exposes the unconformity at the Tournaisian/Viséan boundary. There is a wide diversity of carbonate facies draped over eroded Waulsortian mud-mounds, showing dramatic lateral facies change and palaeoslopes. Various biofacies are represented as the sea deepened and the carbonate regime was replaced by black shales. Salthill is in the middle of a series of mounds from Clitheroe (the Norman Keep is built on a mud-mound) stretching over several kilometres to Gerna Hill to the east. They are the opposite of normal limestone sea mounds (reefs formed in shallow water and containing abundant fossils) in that they form in deeper water, have no bedding planes and contain very few fossils; they are also unusual in being very light grey in colour. Mud-mounds formed during the time period in the Dinantian when the basin was sinking; there is evidence of three periods in the Tournaisian and Viséan when conditions, and especially sea depth, was conducive to their formation. Basically they were just a mound of micrite (lime mud) formed at depths from 130 to 300 metres, below the level to which light penetrates (aphotic conditions). The mud is mainly generated in situ and the mounds had steep sides, up to 50 degrees, which is explained by bacteria acting as the agent for growth and also as a binding agent. As mounds grew up to 200 metres in height towards shallower water, their characteristics changing with water depth, and once photic conditions are reached, growth of algae was possible. With the basin deepening, and eustatic sea level changes, characteristics through a mound can change from those typical of deeper water to those of shallower water - or vice versa.

The top of the mound at Salthill (see photo opposite) shows evidence of an unconformity, when a shallowing event at end of the Tournaisian resulted in submarine erosion, crumbling of the top of the mound and deterioration into a mass of rubble and boulders. This now marks the unconformity between the mound and overlying Viséan limestones, which are dark grey, coarse-grained, and rich in crinoids. The overlying beds are thicker between the



Section of Waulsortian Mud-mound showing unconformity between the mound and the overlying Viséan limestones. Salthill Quarry Geology Trail - Clitheroe

mounds than on the ridges.

Basin conditions were ideal for many organisms to thrive, as their fossilised remains make up the bulk of the rock. This wealth of evidence enables palaeontologists to establish how these animals lived and also relationships that existed between them. Crinoids were particularly abundant, with over 35 species identified at this locality.

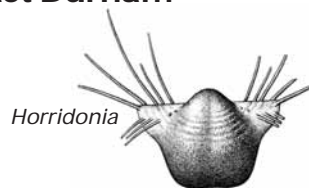
Salthill is one of those places where the fossil hunt of a field visit more than lives up to expectations, and the total enthusiasm of our leader for his subject really inspired the group, some of whom have returned since for further exploration (and fossil hunting). The GA Guide referred to below provides a comprehensive description of the geological background and locations on the trail, and is recommended.

Reference:

Bowden, A, Webster, M and Mitcham, T. (1997) Salthill Quarry Geology Trail Geologists' Association Guide No. 58. Available through the GA website or from Clitheroe museum (currently undergoing major redevelopment work).

Permian and Quaternary Geology of East Durham Sunday 29th July

Leader: Dr. Eric Johnson
11 Members present



Aim: To look at the Late Permian Zechstein Group Stratigraphy and follow the lateral transition from back reef lagoonal facies into reef limestone; a shore to deep water progression.

Although perhaps not quite as warm as Permian times, glorious mid-morning sunshine and warm temperatures greeted 11 enthusiastic members led by an upbeat Dr. Eric Johnson.

The first stop of the day was Tarmac's Coxhoe Quarry, formerly Raisby Quarry. At the south side of the quarry we reviewed the plate tectonic setting of late Carboniferous to early Permian times. Pangea was assembling and what was to become Britain became landlocked in the centre of the supercontinent in the northern hemisphere close to the equator. Oceanic climatic influences were lost and arid desert conditions prevailed for the next 100Myr throughout the Permian and Triassic.

During the late Permian, anticlockwise rotation of Pangea moved Britain northwards to around 25°N causing extension and thinning of the continental crust opening up an intracontinental basin (Zechstein). During periods of high level sea stand a narrow channel and main barrier connecting this basin with the Boreal Ocean to the North was breached during spectacular flooding events, allowing sea water incursion into the basin. At times the link was periodically cut-off and high rates of evaporation ensued. The five flooding and evaporation events recognised in the Upper Permian are thought to be the result of glacio-eustatic sea level variation.

In East Durham superficial drift of Late Devensian age mantles most of the bedrock limiting exposure to the western edge of the limestone escarpment and the deeply incised glacial meltwater valleys known locally as denes. The rocks encountered are dolomitic limestones of Upper Permian age 264-260Myr at the base of the first evaporate cycle (EZ1).

The quarry does not expose the plane of unconformity or underlying middle coal measures. The working face, to the east, displays an ordered stratiform arrangement of Permian beds, (see diagram C centre pages), beginning with a 0-6m Basal Permian Yellow Sand unit exposed in the bottom of the quarry. This was initially lain down as large scale aeolian desert dunes (draa) forming

broad ENE trending ridges. During the Zechstein transgression the top few centimetres of Yellow Sand were reworked and locally contain burrows with the brachiopod *Lingula*.

The sands are overlain by the Marl Slate Fm, a dark grey coloured organic rich, finely laminated silty shale deposited on the sea floor in conditions of anoxia. This Formation dies out westwards towards the Zechstein shoreline. It is usually less than 1m thick but locally it is thinned and thickened by syndepositional slumping and hosts the superb remains of fossilised fish.

In the quarry and a few other locations in South Durham the Marl Slate is succeeded by thinly bedded blue limestone (calcite mudstones and wackestone). The limestones pass vertically and laterally into the more familiar pale buff coloured Magnesian Limestone of the Raisby Formation. Bioturbation is apparent in a hand specimen shown by the mottled appearance of dark and pale patches (see photo 1 centre pages). A sparse range of marine invertebrates are found in the lower beds of this facies including bivalves and the brachiopod *Horridonia horrida*. This unusual brachiopod was not attached to the sea-floor with a pedicle stalk but developed spines as a way of anchoring itself onto the soft sediment. The Raisby Fm is interpreted as a basin slope deposit laid down on a 2-3 degree slope in fully marine conditions of normal salinity.

The next stratigraphically higher beds are the Ford Fm and were viewed in the abandoned Trimdon Grange Quarry which revealed a change in facies. The weak cross bedded packstone/grainstone with ooids and pisoids and sparse shelly fauna are interpreted as being deposited in a back reef protected shelf and lagoonal setting (see photo 2 centre pages).

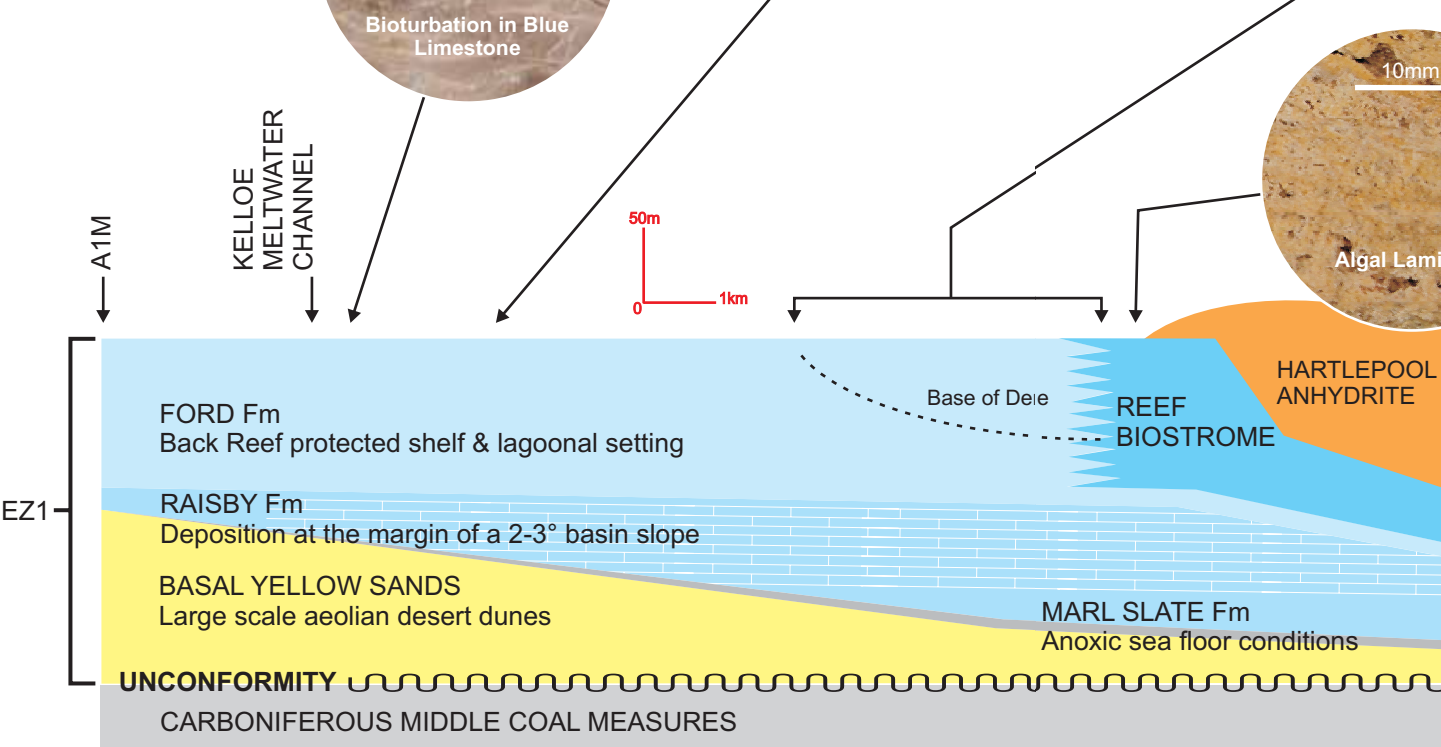
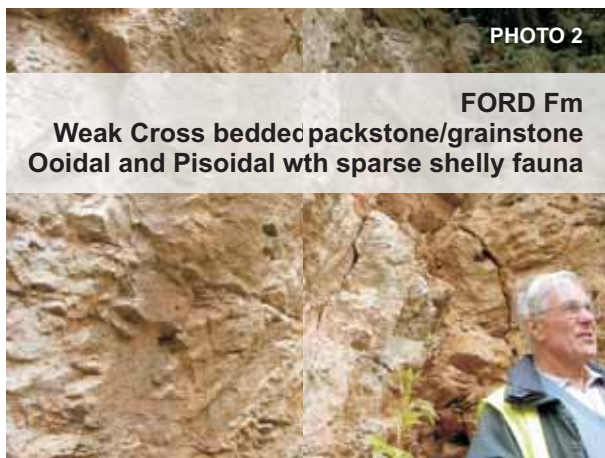
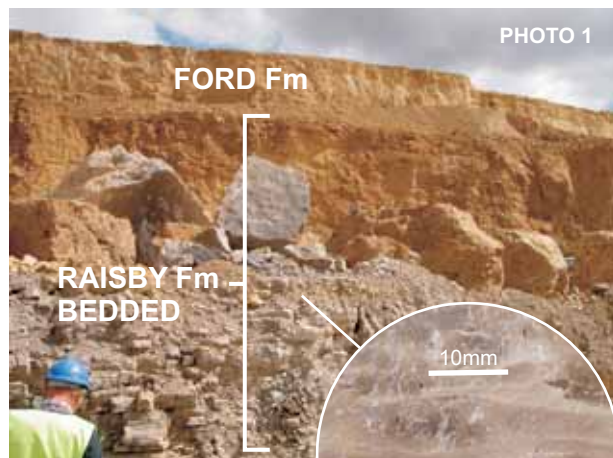
The third stop of the day was a brief visit to the Kelloe Meltwater Channel. The valley was carved through the Ford Fm and underlying Raisby Fm during the Late Devensian and forms part of a subglacial dendritic drainage system on the western edge of the Permian limestone escarpment. The wasting and retreat of ice after the last glacial maximum provided the meltwater for eastward draining rivers to cut steep sided gorges through the glacial succession into the underlying Permian rocks.

The fourth stop was to the largest of the meltwater channels, Castle Eden Dene some 5.5 km long, 0.2-0.8 km wide and up to 60 metres deep. The dene preserves the largest area of semi natural woodland in northeast England and typical of the wildwood that once covered most of Britain. A misfit stream meanders gently along the bottom of the gorge. The lateral transition from bedded back reef limestones into a more massive reef facies in the Ford Formation was seen in the sides of the dene with a fauna of brachiopods,

COXHOE QUARRY (NZ338352)

TRIMDON GRANGE QUARRY (NZ362353)

CASTLE EDEN DENE (NZ428393)



BLACKHALL ROCKS (NZ470392)

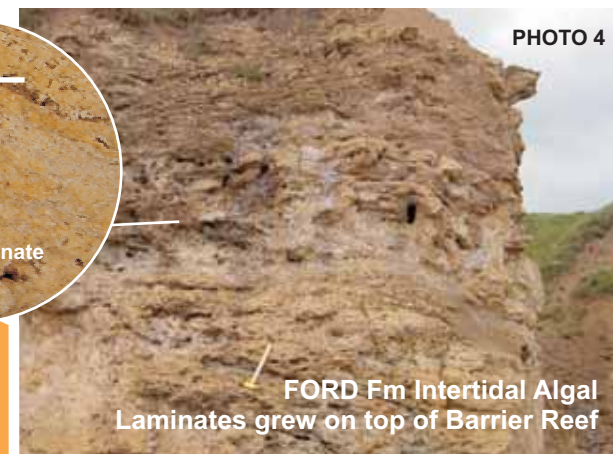


Diagram C - Cross section showing transition from back reef lagoonal facies into reef formations of Late Permian age (Zechstein EZ1) in East Durham.

bivalves, and bryozoa but few corals (see photo 3 centre pages).

The final stop for the day was at Blackhall Rocks. The raised beach there consists mostly of Coal Measures ironstone nodules and sandstone derived from colliery waste that was formerly dumped into the sea. These provide a reminder of the once thriving mining industry that exploited the offshore coal reserves.

The coastal outcrop exposes the uppermost part of the Ford Fm reef facies known as the Heselden Dene Stromatolite Biostrome. Two distinctive rock types are present in the biostrome. At the base there is a boulder breccia formed by rock debris that broke off and fell down the steep seaward side of the reef. This is overlain by a thick unit of algal laminates (stromatolites) which grew within the intertidal zone on top of the reef (see photo 4 & 5 centre pages). The familiar domed structure is clearly visible on a large scale where multiple generations of algae built up the sequence.

Southwards the coastal section reveals younger parts of the Permian succession but sadly closing rain and lack of time brought the day to an end. Our appreciation and thanks were offered to Eric for his superbly led field visit.



LGA Members surveying an exposure of the low-angled fault surface
INSET: Examples of some of the soft-sediment slickensides at the base of the fault-wall (red pencil in rock pocket mid-right, for scale)

“Sticking out like a sore thumb” ...a visit to Almscliff Crag Thursday evening 12th July

Leader: Professor Paul Wignall
27 members present

Many geologists, (including Gilligan (1920), and Versey (1948)), have offered explanations as to the “how” and “why” of this topographic anomaly: a blocky crag poking up, with a “contrary” tilt, on a long and otherwise smooth grassy ridge! Twenty-seven LGA members, equally curious, circumnavigated the Crag with Professor Paul Wignall on a cloudy evening in July, to see evidence for the more recent interpretations of Ian Chisholm (1981) and Andy Sims (1989); though Paul emphasized that even these explanations leave questions unanswered.

Almscliff Crag is formed by the Namurian coarse-grained channel-deposit of what was a vast south-west flowing river, at, or near, its deltaic limit on to the shales of the south-eastern side of the Craven Basin; and previous accounts have noted faults, measured palaeo-currents, suggested “slumping” and diagnosed unusual cementation in this feature.

But following Chisholm we examined an overhanging south-westerly-dipping rock-wall, (See photo opposite), noting the shallow grooves at its base. Chisholm identified this wall as a low-angled listric fault surface, and the grooves as “soft-sediment slickensides,” the result of uncemented sands slipping past each other during movement on the fracture (See photo opposite (inset)). This rotational fault, (now largely in the air, thanks to erosion), which is postulated to bound the curving north-east side of the crag, is significant in several ways:

- It is a syn-depositional structure affecting only the lower part of the sandstone...we saw no evidence of this fault in the top 10 metres of the crag.
- It is a “growth-fault,” which was down-throwing continuously, (or in pulses), during the earlier stages of deposition...possibly on a steep-fronted upper delta-slope. This built a “fan” of dense sand-wedge sediments, which are dipping northwards in to the fault surface, on top of less dense and unstable lower siltstones (See Diagram A page 22). This process convincingly accounts for the additional 35 metre local thickening of this sandbody, (as measured by Chisholm), for around 150 metres along the strike at this location, and, perhaps, helps to explain its relative resistance to erosion.
- Such a fault also gives grounds for the changes in dip seen on the Crag, from the gentle (17° to 20°) south-south-easterly (tectonic) dip of the Millstone Grit succession around the Crag and across the Wharfe valley, to the steeper (22° to 29°) north-easterly dipping bedding-planes in the NE corner of the outcrop. Moreover, (see Diagram A page 22) this process is also reflected

in the south-westerly palaeocurrent measured for these cross-bedded foresets (See also Diagram B below).

Sims, too, found evidence of a series of similarly-formed minor faults “which developed sequentially away from the major fault as new faults formed so the earlier faults became inactive and were rotated passively by continuing movement on the major fault....a progressive kinematic wave.” * Many of us scrambled up to a small face showing clear evidence of just such a small-scale

Diagram A Stages by which a growth-fault builds-up a dip-fan

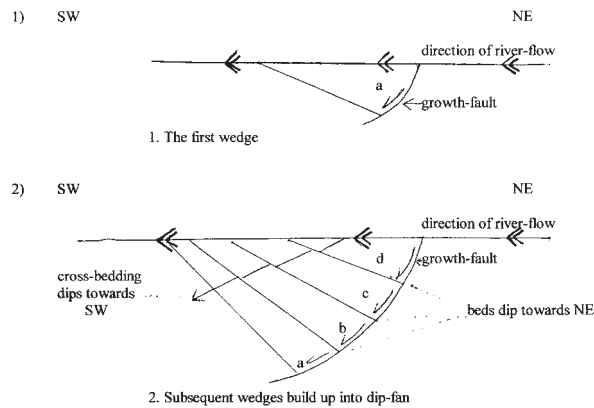
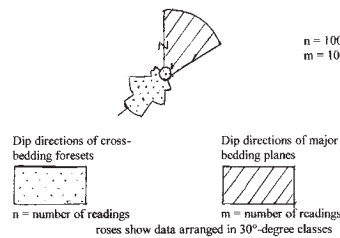


Diagram B : taken from Chisholm “Growth- faulting in the Almscliff Grit (Namurian F₄) near Harrogate, Yorkshire.” LGA Transactions Vol. 9 Number 5, 1981

Cross-bedding measurements for the Almscliff Grit at Almscliff Crag and dip directions of major bedding planes



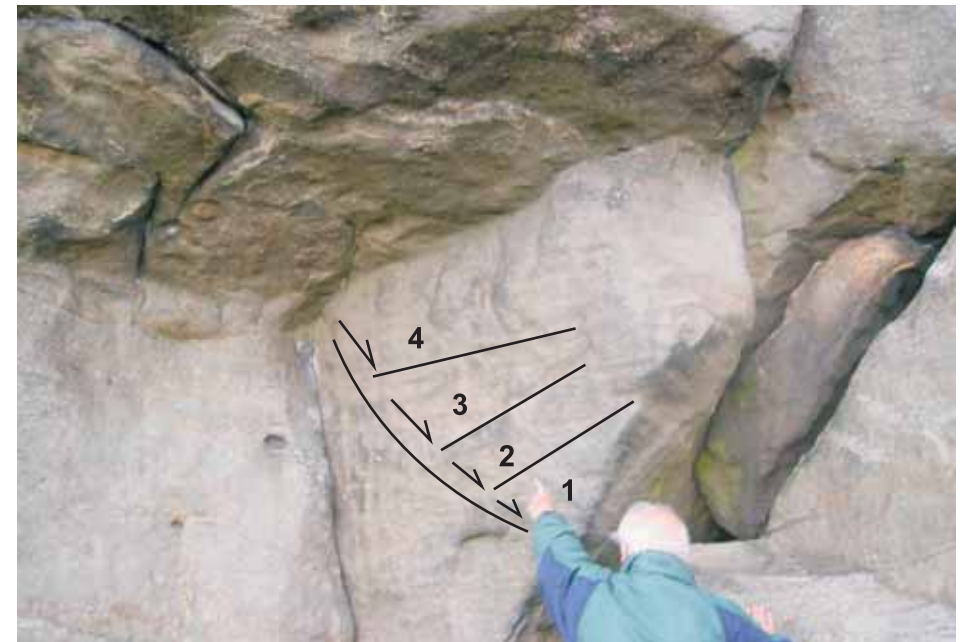
“dip-fan”, and we took many photographs (See photo below). This really showed us the growth-fault in action!

On another small face we could see more evidence of subsidiary growth-faults occurring well before cementation, since movement seems to have involved “grain-rolling, in zones up to 5cm wide, rather than grain breakage” *.

However, as Professor Wignall pointed out, even this interpretation has its problems, growth-faults are rare anywhere in the Millstone Grit and typically develop on an upper delta-slope. But the Almscliff Grit is a truly fluvial sandstone, (with confirming evidence of mudflake-clasts and tree-fossil remains at this location). Perhaps the transition from river-channel to delta-top to basin happened really abruptly here... a scenario supported by the absence of all traces of the Almscliff Grit in a bore-hole a mere 4km to the south of the Crag!

What further explanation of this intriguing feature shall we hear on our next visit?

*from “The Geology of Almscliff Crag, Wharfe Valley, North Yorkshire,” Field Visit notes by Professor Paul Wignall.



Rock face showing evidence of the build up of the dip-fan adjacent to a minor growth fault

Visit to Boulby Potash Mine Wednesday 5th September

Cleveland Potash Representative : Neil Rowley 6 members present

Boulby Potash Mine, operated by Cleveland Potash, is located 2km. west of Staithes, close to a NW – SE trending section of the coast, and extracts the potash ore Sylvite, mainly potassium chloride, from the salt deposits formed in the Upper Permian (260-250Myr) as a result of evaporation at the periphery of the Zechstein Sea. Visits are now restricted to a group of 6 who can conveniently be transported underground to the ore extraction area by Land Rover.

Since extraction and processing commenced in 1973, the production level has risen steadily through various productivity improvements to a total ore and salt extraction currently of about 4 million tonnes per annum, yielding about 1 million tpa. of potash for fertilizer and also a substantial quantity of common salt for road de-icing as a by-product.

Following a presentation on the history and aspects of current operation of the site, our group changed into protective clothing, lamps and safety gear for the mine visit (see photo opposite). There are 2 shafts to a depth of 1100 metres, one for personnel and one to lift product to the surface and for other heavy duty work. Over 34 years of operation, workings have extended some 7 miles to the north, mostly under the North Sea, and about 4 miles to the south. As the salt bearing strata dip at about 3 degrees to the SE, this results in a current working depth of about 800m. and an ambient temperature of 35 degrees C. at the northern end of the workings; at the southern end, the depth reached is 1300m. and ambient temperature of 45 degrees C. We were relieved to be viewing the northern operation, which was quite warm enough!

Main roads throughout the mine are driven through the lower halite deposits which are much more structurally stable over a long period, with roadways up ramps into extraction galleries in the overlying potash rich deposits. [Sylvite ore is 38-40% potassium chloride, 45-50% sodium chloride, 10-15% insolubles (clay minerals)]. All roadways in the mine are twinned with forced circulation in along the vehicle tunnel, air returning along the conveyor tunnel carrying potash ore to the main shaft.

Extraction galleries in the potash are up to 1 km. in length, with a width of about 55m; a central working tunnel is created with extraction to both sides leaving pillars, all to a height of about 3m. About 2 m of potash ore is left above the workings for stability as the marl deposits overlying the potash are very unstable. The roof of the central tunnel is strengthened by drilling and

bolting to a depth of 2m. to stabilise the roof. The pillars are brittle and unstable with fragmented pieces, both small and large, breaking off and creating a potential hazard to miners. When extraction from a gallery is completed, the workings are left to collapse and close over time. The mining operation is a repeated sequence of extraction over a given distance, followed by bolting of the central roof, then forward (and upward) drilling to assess the disposition of deposits to guide the ongoing extraction operation.

The mining machines (4 for potash and 2 for salt) are each operated by a miner from a remote control handset. Each machine rips out ore, gathers the material and feeds it back onto a mobile shuttle platform which carries a 20 tonne batch to the conveyor. There is some crushing of larger pieces at the feed onto the conveyor. Product is raised to the surface up the main shaft in 23 tonne loads, 2 hoppers rising and descending alternately to deliver a load from 1100m depth every 3 minutes.

In a further processing plant, potash is separated from sodium chloride through a foam flotation process. The ore is finely crushed and a saturated salt solution used as the medium to float KCl particles in the foam away from NaCl. It is then scooped off and dried. Large quantities of sea water are taken in for the separation process, and returned to the sea as concentrated brine, feeding up to 1 million tonnes of sodium chloride into the North Sea per annum.



Boulby Mining Party

Residential Weekend based at Cemaes Bay, Anglesey Friday 21st to Sunday 23rd September

Leader: Dr Allan Brandon
26 members and spouses

Friday 21st September.

During the afternoon, members gathered at the Gadlys Hotel, Cemaes, on the north coast of Anglesey. Early arrivals were given details of Excursion 3 (G.A. Anglesey guide) and some went for a first look at the local geology.

After an excellent dinner, the leader gave a brief introduction to the geology of Anglesey, controversial since the first comprehensive account given by E.Greenly, 1919. The succession ranges from beds until recently considered Pre-Cambrian, and making up more than half the island, through to Carboniferous. Recent work indicates that the lowest "Pre-Cambrian" sediments of the Mona Supergroup are at least partly late Cambrian and/or early Ordovician. Intense glaciation moving NW to SE, and coincidentally along the predominant grain of the solid geology, gouged out softer sediments and left a largely subdued topography that has been enhanced by marine peneplanation.

Saturday 22nd September.

On a fine sunny morning, members set off at 9.15 am for South Stack, Holy Island, noting en route the featureless and windswept topography. The leader summarised the succession of the Mona Supergroup, thought to be 5-7 km thick, comprising the South Stack Group exposed along the coast of Holy Island, the New Harbour Group (not visited) and the Gwna Group, see below. The South Stack Formation, the lowest part of the group, comprises lightly metamorphosed greywackes and mudstones, considered to be turbidites derived from a continent to the SE. They have undergone Caledonian compression and developed well-marked cleavage; no shelly fossils have ever been discovered. At South Stack they form spectacular sea cliffs, (see photo opposite), running roughly N-S and some 50m high, facilitating views of the Wicklow Mountains to the west.

Members walked down the zigzag flight of 400+ steps to the lighthouse bridge. From the path members had excellent views of the contorted beds, with alternate bands of greywacke, typically about 1 m thick, and mudstone with bands of white quartzite, perhaps developed along bedding planes on dewatering. The beds formed a series of not quite symmetric folds, of



Sea cliffs exposing folded South Stack Formation, South Stack, Holy Island.
The prominent bed towards the foot of the cliff is estimated to about 1.5m thick

wavelength perhaps 30-40m, slightly tilted towards the south. Small-scale folding superimposed on this has resulted in complex distortions of the less competent mudstones and quartz veins but has hardly affected the thickest greywackes. As the party started the slow climb back to the cars, the bridge was opened and several members crossed to get better views of the cliff face.

Before we drove off, attention was drawn to rock surfaces near the path polished by glacial action, on which glacial striae were seen trending roughly NNE-SSW (see photo top of page 28).

The party drove a few kms SE to Rhoscolyn Church. In this area, beds of the South Stack Group form an important local feature, the Rhoscolyn Anticline. Its core was seen in grassy fields some 500m SSW of the church in the form of a low smooth ridge exposing the Holyhead Quartzite, immediately overlying the South Stack Formation. (See front cover). This clean metamorphosed sandstone originated as marine sands reworked into deeper waters. The anticlinal axis strikes NNW-SSE and plunges to the NNW. On the crest of the ridge there is a plaque in memory of Prof. Dennis Wood, noted for his enthusiasm for the local geology. Some of the party braved thickets of gorse to examine another exposure in a small quarry nearby, where thin white quartz veins were seen along vertical joints and some vestiges of normal and



South Stack Formation greywacke with glacial striae (parallel to pencil) trending NNE-SSW

of current bedding were eventually discerned on one of the joint faces. The party then moved seaward, en route visiting another small quarry where a search for signs of bedding proved fruitless.

In the very rugged cliff top the South Stack Formation was exposed and members scrambled amongst the rocks examining the extreme deformation. Here the large scale folding seen at South Stack was not obvious but the thinner beds showed intense folding on various smaller scales, (see photo bottom page 28), often overturned towards the SE, opposite to what would be formed if slumping had affected sediments arriving from the SE. Some searching was needed before dewatering structures were found in some of the coarser beds (see photo below).

Lunch was taken by the cliff top then, returning to the cars, we passed two deep narrow inlets formed along minor faults roughly parallel to the axis of the anticline and revealing larger scale folding roughly perpendicular to the axis of the Rhoscolyn Anticline.

The party then drove to Newborough Warren, near the southern corner of Anglesey, to see spilitic lavas forming part of the Gwna Group exposed on Llanddwyn Island. Pebbles noticed during a walk of about 1 km along the beach included fragments of dull purple-red jasper derived from the spilites.



Folds in South Stack Formation overturned to SE, seen in cliff top Rhoscolyn, Holy Island



Dewatering structures, cliff top Rhoscolyn

On the spit joining the island to Anglesey, several rocky mounds stood out from the sand (see photo below). These consisted of particularly well-developed pillow lavas, with individual pillows ranging from less than 0.5 to over 2 m wide. Pillow form indicated younging to the SE and overturned strata. Patches of dull red jasper and limestone were seen in the pillow interstices. On the landward edge of the island an outcrop showed pillow lavas overlying agglomerate.

The party returned along the beach and drove back to Cemaes. Those that had not done so on Friday drove a further km north and walked onto a small headland immediately west of Llanbadrig Church, formed by the Gwna Melange. This is a spectacular complex of huge blocks of assorted rock types, also present, but not visited, on Llanddwyn Island. It is supposed to have been formed by an underwater rock slide on a catastrophic scale. Here, the outcrop mainly comprised huge slabs of more or less dolomitised limestone, some brown and much weathered, some paler with beds of chert, dipping fairly steeply seaward. At one point we saw a mass of brecciated quartzite some 2m thick. Returning to the cars, we passed across a large grassy hollow, with weathered and shattered limestone exposed on the coast, which the leader surmised might be part of a collapse structure in "Pre-Cambrian" limestone. The party then returned to the Gadlys Hotel, where another excellent dinner was enjoyed.



Pillow lava, Gwna Group in spit at landward end of Llanddwyn Island

Sunday 23rd September

Parys Mountain Copper Mine

The early morning rain had fortunately stopped by the time our party assembled at Parys Mountain. Here a short walk from a car park took us to a view point overlooking an enormous open pit estimated to be about 300m long, 100m wide and about 40m deep, where a very rich copper bearing lode had been extracted. This pit was excavated mainly between 1768 and the early 1800's by which time mining was largely underground.

At the viewpoint, many of our group commented on the huge size of the pit and on how unexpectedly colourful it was (see photo below). Not only was there much yellow and orange-brown, contrasting with the blue-grey of the slaty mud rocks, but also a conspicuous absence of the blues and greens that would be associated with copper mineralization. When we walked down well-made paths to the bottom of the pit we found that the colours were probably due to fine coatings of iron oxides or hydroxides. Close examination of an unworked pillar of rock in the centre of the pit showed it to be riddled with irregular veins containing an abundance of finely disseminated cubic crystals of iron pyrites. Somewhat disappointingly, this was the only metallic sulphide we could find.



Viewpoint, looking into Parys Mountain Copper Mine

Perhaps the highlight of the visit was the discovery of graptolites in the scree of cleaved slaty mudrocks (Central Shales) below a conspicuous face of this lithology at the western end of the pit. One member pronounced himself to be "thrilled to bits" by this discovery, particularly because the graptolites were well preserved, their thecae having been replaced by pyrite, producing three-dimensional preservation instead of the usual crushed forms. However, because the cleavage was somewhat oblique to the original bedding surfaces we could only see short fragmentary lengths of single stipes on the cleavage surfaces. The Central Shales are said by Dr Jan Zalasiewicz (personal communication) to be of early Silurian (Llandovery) age.

The conspicuous face, referred to above, provided the main evidence for the tectonic structure of the rocks flanking the pit, for the axial hinge of a tight, south-facing, synclinal overfold was clearly visible in this face (see photo below). The north limb of this fold appeared to be vertical whereas the south limb is inclined at about 45° to the north. The presence of this fold suggests that the pit as a whole was aligned along the axial part of this syncline. Poorly exposed highly altered acid volcanic rocks stratigraphically underlying the Central Shales were seen flanking the pit in places and showed some flow banding.

Somewhat surprisingly for a place which has had, and may still have, great economic potential, the basic stratigraphy and structure of Parys Mountain, according to Dr Zalasiewicz, is still not fully understood.



Core of asymmetrical syncline in Parys Mountain Copper Mine

Lligwy Bay

On Sunday afternoon we ascended the stratigraphic sequence of Anglesey and drove to Lligwy Bay on the NE coast to examine rocks of Upper Palaeozoic age. After lunch in a rather desolate carpark (where the toilets were firmly locked up for the winter!), we walked to the south side of the Bay to examine Lower Carboniferous strata. The first exposures were of limestones and mudstones with interbedded conglomerates which suggested that we were close to the unconformable base of these Asbian and Brigantian age rocks. The conglomerates exhibited a variety of clast lithologies including large blocks of dolomitised limestone and rounded pebbles of probable Precambrian origin. At one point, the conglomerates were banked around an upstanding block of limestone which originally had been interpreted as the base of a Dinantian sea stack surrounded by beach gravels. However, the conglomerates were more likely to be of fluvial origin.

Our Leader referred to the development of cycles within the Late Dinantian which resulted from contemporaneous sea level fluctuations, probably of glacio-eustatic origin. During periods of high sea level, limestones were laid down; when sea level fell, the limestones were subaerially exposed and suffered karstic weathering with the development of, for example, potholes. The overlying sandy mudstones represented palaeosols in part, but some must have been deposited during the next sea level rise.

As we made our way along the base of the low cliffs, it became apparent that the dips, which had been at a low angle to the SE, were beginning to increase. In one roughly circular area they became almost vertical and the limestone beds, one of which had a characteristic clotted appearance, broken (see photo overleaf). Below and elsewhere, dips remained low to the SE. The explanation for this phenomenon lay in the sea level fluctuations referred to above. When sea level dropped, karstic weathering of the exposed limestones had resulted in the development of a doline into which higher strata had collapsed. Dr Brandon explained that the vertical extent of such a collapse was indicated by the presence of a limestone with a characteristically clotted lithology which occurred some tens of metres higher in the succession.

After ascending the low cliffs, our scenically attractive walk took us to a point where an ice scraped and striated erosion surface cut in Brigantian limestone revealed large specimens of colonial corals, solitary rugose corals and some productid brachiopods. Dr Brandon pointed out that the glacial striae indicated that the ice which had deposited the overlying red, Trias-derived till, had moved from NE to SW. Continuing to the east and updip, we reached the outcrops of the clotted limestone at its normal position in the sequence. Here it rested on sandy mudstones infilling hollows in the contemporaneously weathered top of the underlying limestone bed.



Lligwy Bay, showing doline collapse structure with almost horizontal beds at far right, slumped thick-bedded limestones in centre, and almost vertical thinly-bedded clotted limestones on left

After walking back to the cars, most of the party drove to the north side of Lligwy Bay, where we walked across the sands, and some of us approached a notice with its back to the direction from which we had come, which warned us of the danger of quick sands!! The beds here were the red beds of the Lower Old Red Sandstone of either Late Silurian or early Devonian age.

The first exposures reached were of red fine-grained sandstones and mudstones of the Traeth Lligwy Formation within which the red colour and the presence of sporadic mud cracks testified to their origin in a probable playa lake environment within an essentially arid region (see photo opposite). The presence of trace fossils showed that such lakes were not without life. The rocks were folded into a shallow syncline plunging to the SE; cleavage developed in its axial region reminded us that these beds predated the peak of the Acadian Orogeny.

Walking to the north, we had just time to reach outcrops of the underlying Porth-y-Mor Formation with its well-developed fluvial sequences of erosively based channel and point-bar sandstones fining upwards into overbank mudstones. At this point Howard Dunnill gathered the party together and thanked Dr Brandon most warmly for spending his week-end with us and for introducing us so comprehensively to the varied and spectacular geology of the Isle of Anglesey.



Mud cracks in Traeth Lligwy Formation, Old Red Sandstone, Lligwy Bay

**For more information visit us at:
www.leedsgeolassoc.freeserve.co.uk**