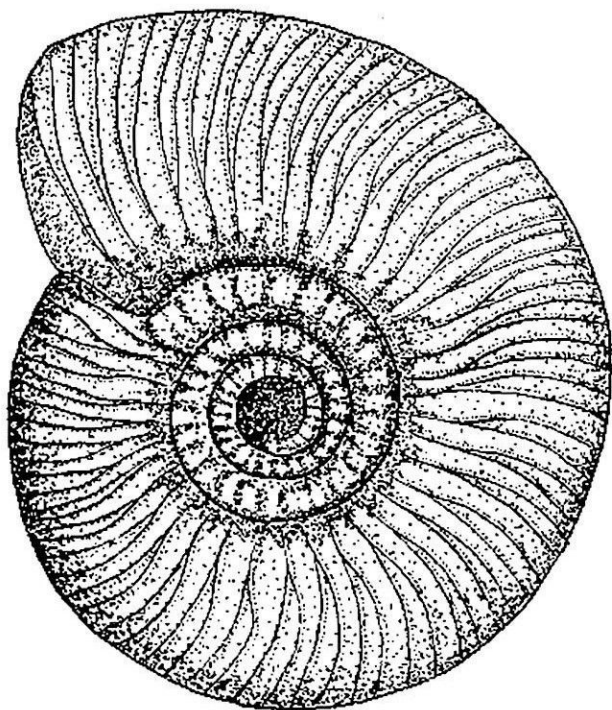


THE CUMBERLAND GEOLOGICAL SOCIETY



PROCEEDINGS

Volume 8 2016-2017 Part 4

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EDITORIAL

This Edition of the Proceedings is the fourth part of Volume 8 and covers the events of the society from Spring 2016 to Spring 2018. During this two year period the society has continued with the usual format of winter lectures and summer field excursions and commenced a field research project. There were field trips to the Isle of Man in 2016 and to the Algarve in 2017.

The annual dinner has been replaced with an annual lunch held in March at the Castle Inn at Bassenthwaite. These were enjoyable occasions at which John Rodgers, the President made a short speech then he and Fiona Harwood presented a geological quiz.

At the AGM John Rodgers was awarded Honorary Life Membership in recognition of all the things he had done for the society over more than 50 years. The Charles Edmond Prize was awarded to Noel Pearson in recognition of his outstanding contribution to the welfare and activities of the Society.

As mentioned in the previous Editorial, Storm Desmond caused severe flooding in December 2015. John Rodgers, our President has compiled a pictorial account of the aftermath for these Proceedings. I am pleased to report that we have been able to continue to publish original articles relevant to our local area.

I thank all our contributors for their articles, excursion reports and other contributions and, in particular, John Rodgers, Noel Pearson and Clive Boulter. I am most grateful to Alan Smith, the previous editor, for all his patience, help and assistance in producing this volume and in handing over the role.

Helen James

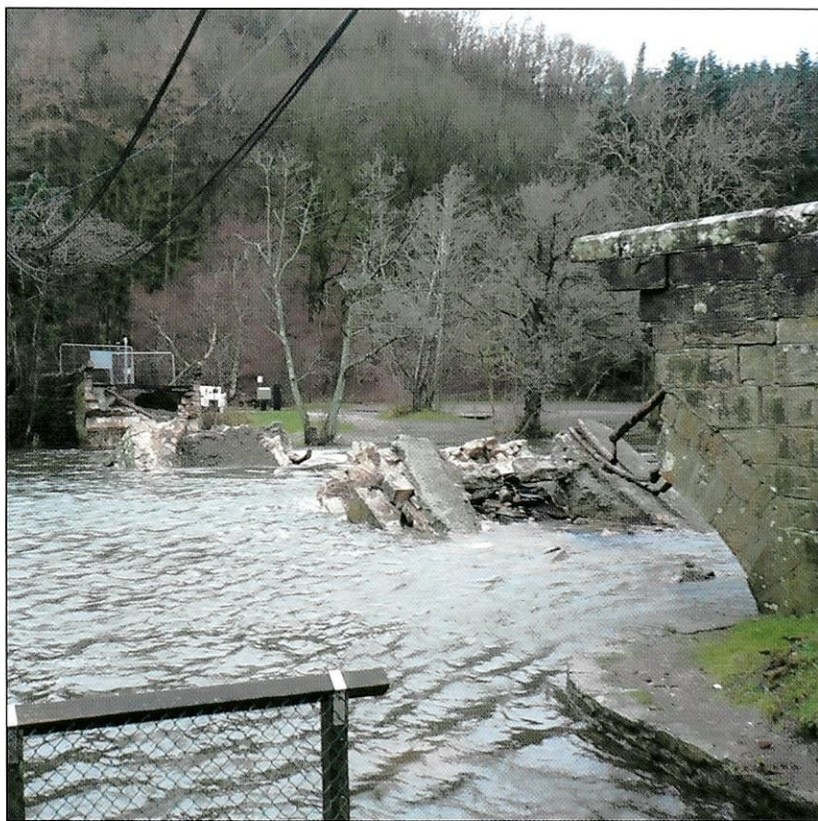
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STORM DESMOND: DECEMBER 2015

John Rodgers

In a 36-hour period during the fifth and sixth of December 2015 record rainfall affected Cumbria. The result was unprecedented damage that was county wide. Thousands of people were flooded out of their homes, businesses were destroyed, roads and bridges were severely damaged, some irreparably, rivers and streams changed their course and tragically one heroic policeman was killed. Emergency and social services were stretched to the limit as we witnessed all around us the savage power of nature. But this was also an episode of geological processes in action showing how one extreme event can effect more change than years of normal conditions. The following section is a random selection of places that were hit by this period of accelerated erosion.



The destruction of Pooley Bridge Ullswater



Grisedale Beck, Patterdale

Erosion of the outer bank threatened the road above and led to swift action by Patterdale Hall staff. Machinery was brought in to emplace boulders and tree trunks as a protective screen.



Barton Fell, Howtown, Ullswater

The debris flow here sliced through walls including the one on the road below, blocking access to the local community.



Glenridding, Ullswater

The village was badly hit by three episodes of flooding in early December. Thousands of tons of gravel and mud were dumped on Jenkins Field, contaminated with tailings washed down from the old Greenside mine. Flood protection work was continuing two years later.



River Greta, Keswick

Complete destruction of one of the iron bridges that carried the railway line footpath and cycleway between Keswick and Threlkeld. A second iron bridge was rotated 90 degrees. Landslips occurred on the steep slopes of Latrigg Fell.



River Greta
Bank erosion occurred in a number of places removing sections of the old railway line track.



River Glenderamackin Mungrisdale

Bank erosion threatened the road into Mungrisdale from the A66 but a rapid response from the Highways Dept. led to remedial repairs within days.



River Eden

Record discharge along the Eden Valley resulted in enormous damage to communities, structures, the main railway line embankment near Armathwaite and farmland. The photos above show a wrecked caravan site near Bolton, Appleby and a landslip near Long Marton which temporarily blocked the road to Dufton.



A591 Thirlmere

A major disruption to transport through the centre of the Lake District was due to the destruction of the road alongside Thirlmere as torrential becks from the eastern fellsides undercut or overwhelmed this main link between Keswick and Ambleside. A temporary road route was established for emergency vehicles, contractors and buses only, from which this photo was taken just below Dunmail Raise. The A591 re-opened months later.



River Eden, Warwick Bridge



River Caldew, Raughton Head

Bank erosion led to loss of large areas of farmland and changes in river courses throughout Cumbria.

SOME OBSERVATIONS ON COLUMNAR JOINTING IN THE ROCKS OF THE BORROWDALE VOLCANIC GROUP OF THE CENTRAL LAKE DISTRICT

Alan Smith

To put this discussion into context, allow me to start on a very personal note. Probably the very first book I ever acquired on geology, back in my grammar school days of the 1950's was *'The Observer's Book of British Geology'* (Evans 1949). On page 184 of this pocket sized volume, which still rests on my bookshelves, is a half page, black and white photograph with a caption reading *'columnar jointing in andesitic lava at Gosforth, Cumberland'*. The choice of this picture to illustrate such a basic structural feature of volcanic rocks is both interesting and intriguing. First it is in andesite rather than basalt, which textbooks traditionally always link with columnar jointing. Second, this is a little known, out of the way exposure which, I believe has never appeared since in any other guide or publication illustrating Lakeland geology until I used it myself in my own booklet *'Lakeland Rocks: an Introductory Guide'* (Smith 2010). The Observer's Book does in fairness deal with the Giant's Causeway in N. Ireland and Fingal's Cave on the Isle of Staffa, but restricts coverage of columnar structures to a small sketch of the former and two very distant black and white pictures of the latter. The other text that undoubtedly had a seminal influence on my schooldays geological education was *'Principles of Physical Geology'* by Arthur Holmes – then in its first edition (Holmes 1944). Looking back on that, again still on my bookshelves, columnar jointing is dealt directly with reference to basalts. Two paragraphs, covering just about one and half pages, accompanied by a diagram illustrating the formation of joints in an idealised regular hexagonal pattern by uniform contraction on cooling towards evenly spaced centres, covers the topic. Since those days our understanding of columnar jointing has come a long way. Subsequent editions of the Holmes textbook have illustrated the twofold arrangement of well developed colonnade columns, surmounted by an entablature of more irregular structures and has looked more into the cooling processes involved in their formation. More recent research has refined our understanding of the physics behind hexagonal patterning. The association of columnar jointing with volcanic materials close to basaltic in composition, remains, I believe, a concept that is still current, inevitably perhaps because it is in thick basalt flows that the feature is so well developed.

On a different perspective, it is interesting to see how columnar structures, particularly the classic ones at the Giant's Causeway, have become a sort of

geological icon. Rocks are not charismatic things to use in illustrations, but hexagonal basalts do have their attraction. The now massive, almost 800 page, weighty volume that the Holmes textbook became in its fourth edition (Duff 1996) has columnar basalts emblazoned in full colour on the front cover. Arguably, it is the hexagonal columns alone that make the Giant's Causeway special - there must be many similar places around our coasts where a rocky promontory runs out to sea, backed by spectacular cliffs, but without the columns never getting particular mention. Harking back to my use of the columnar rocks at Gosforth as an illustration in my book on '*Lakeland Rocks*' I find it striking that the number of enquiries I have received about that site since I published the book have out numbered any of the others by a factor of at least ten. What then is the extent of columnar jointing in Lakeland rocks?

The layout of this paper is first to present an inventory of all the sites known to the author where columnar jointed rocks occur over the outcrop of the Borrowdale Volcanic Group. It is highly likely that other sites exist, but this listing is offered as an initial attempt to bring together information of these structures for the first time. Second, some observations of the size, shape and nature of the column structures will be made. The stratigraphical position within the volcanic pile will also be assessed. The material has been drawn together from a literature search, personal field notes over many years and more recent field visits to check out the present state of some of the sites. I am grateful to several colleagues for pointing me towards some of the locations. The sites are numbered **1-19** in no particular geographical order. The accompanying photographs of some of the sites are titled bearing the same site numbers.

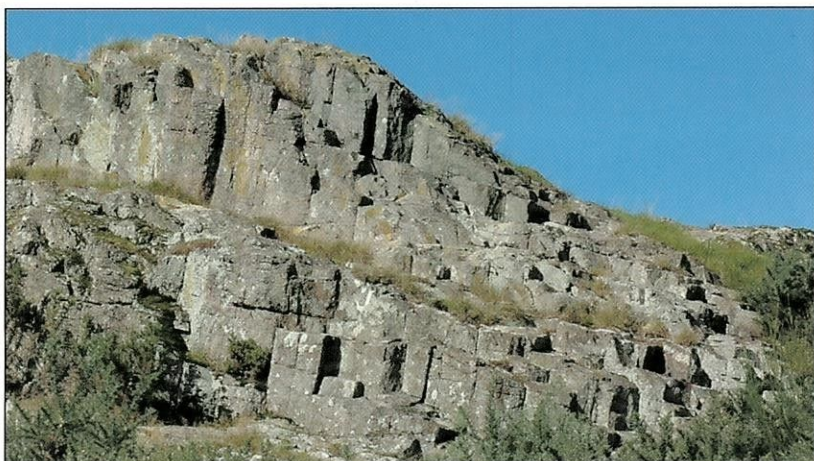
1. Bolton Head, Gosforth. NY 089036
Longlands Farm Member, Fleming Hall Formation.
High-grade, rheomorphic andesitic tuff.

This is the site shown in '*The Observer's Book of British Geology*'. The photograph there is clearly the same as Plate 11 B, facing page 25, in the Gosforth District Memoir of the Geological Survey. (Trotter et al 1936). In this memoir the site is referred to as being '*400 yards, south-west of Rainors*', but it is actually closer to Bolton Head Farm. It lies on private farmland in a field due south of the farmstead (permission to visit required). It forms a tiered, low, upstanding oval mound measuring approximately 45m x 25m. The outcrop is now surrounded by rather vicious gorse bushes, making access at some points difficult. There must be at least 100 tightly jointed columns. For the most part it is only the tops of the columns that are visible, the best sections being on the eastern face. The andesite flow dips south eastwards. A small random sample (from my field notebook) of the

columns gives a mean size of 34.7cms. The majority are 6 sided but many have only 5 sides. There are a few with 7 sides and significant numbers are distorted. Clearly a more detailed, systematic recording of column sizes and shapes is warranted. Overall this probably ranks as the best site in the Lake District to see these structures. In the newest British Geological Survey Memoir, '*Geology of the West Cumbria district*' (Akhurst et al 1997) the site is briefly listed as '*Table Rock*' (page 43) – where this title originates is not known and has, to the author's knowledge, never appeared in any literature before.



1 Bolton Head, Gosforth. Tightly jointed andesite columns.



1a. Bolton Head, Gosforth. The eastern face of the exposure.

2. Hanging Stone, Sourmilk Gill, Borrowdale. NY 233121.
Crinkle Member, Airy's Bridge Formation.
Intensely welded tuffs.

The columns here are found along a prominent set of crags, above a distinct ledge on the hillside. The columns are very small, but well formed and mostly close to hexagonal in shape. The tuff member represents the climax of the Airy's Bridge caldera-collapse related eruption, the material ponding quickly and thickly in the vicinity



2. Hanging Stone. Two small columns from the site, dark welded tuffs with noticeable light coloured weathering rinds. They are approx 5 cm across.

3. Black Waugh, Grainsgill, Borrowdale NY 234107
Crinkle Member, Airy's Bridge Formation.

This is not an outstanding site. A few columns of dark blue/grey, slightly porphyritic andesitic tuff can be found on the rocky ground around the base area of Black Waugh crags. The main crags themselves have very prominent vertical joint structures but they are not hexagonal. It is possible many of these joint features here are not cooling structures. At least three sets of

near vertical joints cuts these materials and the fractured loose blocks are often close to hexagonal.



3. Black Waugh. An individual hexagonal column of dark andesite, Hammer is approx 28 cm.long.

**4. Crinkle Crags – Stonesty Pike (NY 2491 0385), Great Cove (NY 25515 0470) and Rest Gill (NY 2448 0520).
Airy's Bridge Formation.**

Branney (1999) notes briefly that at these three locations acid and basic dykes cut the succession in the Crinkle Tuffs. '*Composite dykes, including porphyritic rhyolite and altered basalt, have columnar jointed garnetiferous silicic centres and basic margins*'. There is no further detail.

5. Rosthwaite Fell. NY 270120
Airy's Bridge Formation.

The Geological Conservation Review account on this location briefly alludes to columnar jointing being 'present locally' in the Crinkle Tuffs adjacent to the small intrusion of rhyolite near the Langstrath Beck. No specific map reference is given, but the area described is on the western side of the beck close to the National Grid reference given above (Branney 1999, p165).

There are seven separate sites in the Coniston area that run NE to SW with the strike of the rocks on the outcrop of the Lincomb Tarns Formation, from Holme Fell north of Coniston village down to the area near Torver (Sites 6-12). All show similar columnar features.

6. Raven Crag, Holme Fell. NY 315005
Lincomb Tarns Formation.
Ignimbrite, dacitic.

Good exposures on the top of the crag. Represent large volume pyroclastic flow eruptions.

7. Long Crag. SD 299983
Lincomb Tarns Formation.
Eutaxitic ignimbrites.

This is a complex but significant site. It has been described in some detail by Millward (1980). Three cooling units are recognised, the middle and upper ones showing significant columnar structures. The middle unit has a consistent column size of 11cm, but the upper unit has smaller columns with a mean size of 5.5cm. Variation in the plunge of the columns suggests unevenness in the original cooling surface.

(This is a site with difficult access – it is on very steep rocky ground with areas of loose unstable material. The columns are on very exposed slabs with precipitous drops in places).



7. Long Crag, Coniston. Ordnance Survey map is 13 x 24 cm.
Columns inclined at 50° into hillside. Middle unit: columns average 11cm.

8. Round How, Coniston. NY 2985 9800

Lincomb Tarns Formation.

Pink weathered, eutaxitic ignimbrite.

This has proved to be a rather problematic site. The author has a field notebook record of this site dating back to May 1966, together with 2 rather poor pictures of the exposure. Knowledge of the exposure at that stage was through a personal communication, no formal record of the exposure in the literature before that date can be located. The site was, however, mentioned in the Geologists' Association '*Guide to the Lake District*' (Mosley 1990) by Millward and Young (Itinerary 15). Since that date no further reference in the literature to the site can be located.

The author has searched this hillside at the given map reference on two separate occasions in the autumn of 2017 (once with a colleague), but has failed to locate the exposure. It is an irregular, damp area of open rocky crags on steep ground with dense bracken and rough grass. It is concluded that either the map reference is incorrect, or more likely the exposure has vegetated over. Many of the slabs now have a moss and grassy cover. The 1966 pictures show an area no more than 2m x 3m across with around 20 or so columns. Size measurements of the columns done from the photo give a mean size of 12.1cm. They are primarily hexagonal. It is striking that many of the exposures on this slope have strongly jointed features, some with noticeably square to rectangular joint patterns. The jointing patterns here are quite similar to those noted at site 3 Black Waugh.

9. Foul Scrow. Coniston. SD 293978

Lincomb Tarns Formation.

Ignimbrite.

The sequence of rocks on this narrow ridge west of Church Beck lie close to vertical. A series of ignimbrite columns with a noticeably hackly fracture are seen close to the summit at around 260m.

10. Torver Beck SD 273963

Lincomb Tarns Formation.

Eutaxitic ignimbrite, essentially andesitic but with inconsistent welding.

This is one of the best and easiest locations in the Lake District to see columnar jointing. The riverbank position affords an excellent section through the material. The columns are flush with the hillside, so unfortunately relatively few sections of the column tops are visible. These were also described by Millward (1980). In the lower part of the sequence, just

above river level the mean column size is 9cm, in the middle section they average 20cm and in the upper part 23cm. The modal number of faces is 4, but 5 sided ones are also abundant.



10. Torver Beck. Stream side columns in the Yewdale ignimbrite.
Close up in lower picture with 7 cm camera lens cap.

11. Little Arrow Moor SD 283973
Lincomb Tarns Formation.
Similar igminbrites to Torver Beck.

This exposure has not been checked recently but is listed in Millward et al (2000). Close to site 10.

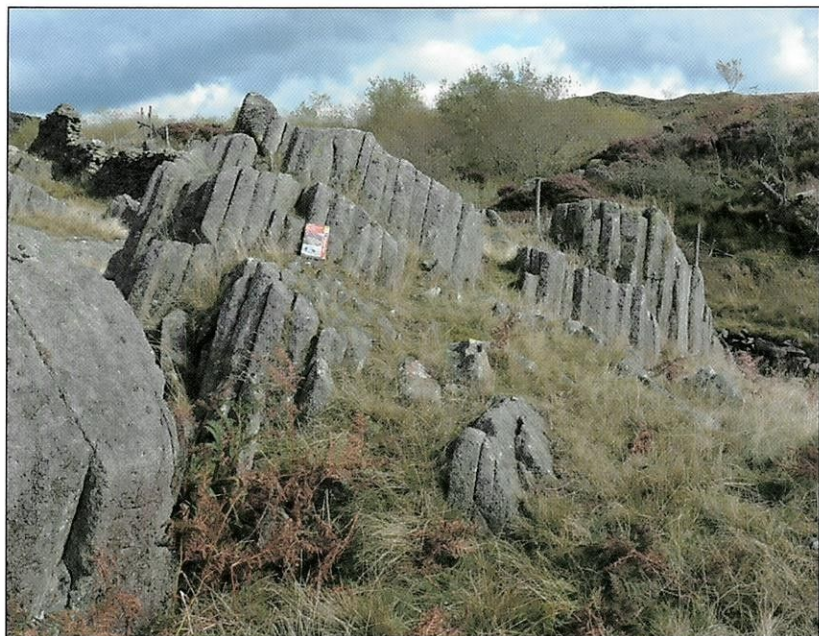
12. Little Arrow Moor. SD 2840 9741
Lincomb Tarns Formation,
Ignimbrite

A site very close to 11. Narrow, even columns, inclined at approximately 60° on several faces of a crag on this open fellside area

13. Head of Lickle Valley, north of Natty Bridge. SD 245947
Lag Bank Formation.
Rhyolites.

This is an excellent site to view columns. It is an irregular craggy area 50m or so across, with most outcrops showing columns. The columns are regular, smooth sided, with the column diameters remaining constant along their length. Most are gently inclined. There are several places where columnar jointing is clear on the edges of exposed slabs, but become indistinct and actually disappears towards the centres. The site shows some slight disturbance through quarrying, the columns being used in the dry stone walling along the stream side on the east of the outcrop. Interestingly there they are used both as capstones on the wall, as well as lengthwise and as through stones in the main body of the walling. Two samples of 50 columns were measured in the field giving a mean size of 17.9cm. 6 sided columns predominate (61%), but 4, 5 and 7 sided forms were also recorded.

(The Lag Bank Formation comprises dacitic lapilli-tuff now interpreted as an ignimbrite. It occurs throughout the Duddon Basin and in the type area on Lag Bank it is up to 600m thick. Columnar jointing is described as being “notable in the lowest and middle parts of this Formation” (Millward et al 2000 p.103). The type area on Lag Bank (SD 246943) and around Postlethwaite Allotment (SD247939), is within a very short distance SE of this site 13. The area is now a densely wooded mainly coniferous plantation that has not been investigated by the author, but it would seem likely that other columnar sites within this area could be found.)



13a.



13b.



13c.

13. Head of Lickle Valley. Columns in rhyolite.

13a General view of crags on site – all outcrops show regular, unbroken columns, gently inclined.

13b Detached columns, some over 1m in length.

13c Well developed columnar structures on left hand end of slab, but columns become vague and indistinct and eventually fade away to the right of the exposure. A feature seen in various places at the site.

14. Stephenson Ground Crag. SD 233934

Lickle Formation, Stickle Pike Member

Welded ignimbrite.

This is a very prominent crag standing above the enclosed fields behind Stevenson Ground farm. The face has clearly seen some quarrying. Long columns are used in a number of places around the farm as ‘water yeat’ features – traditionally constructed barred gaps in the walling to allow streams to pass through. The columns seen in the quarry face form a fanned arrangement, the long columns curving gently outwards. The column joints are developed in the more densely welded central part of the ignimbrite sheet. The columns are around 20cm across and the column size is consistent down the columns with no significant horizontal jointing.



14. Stevenson Ground Crag. Fanned, gently curved columns.
Grey rucksack at bottom right for scale.

15. Unnamed crag 150m ENE of site 14. SD 236935.
Caw Formation.
Ignimbrites.

A short but distinctive line of low crags standing above a small stream that runs from the open fellside (through two water yeats) into the enclosed fields of Stevenson Ground. The columns are around 15cm in diameter.



15. Unnamed Crag near Stevenson Ground.

Rucksack in foreground for scale.

16. Pinnacle Howe, Haweswater, (NY 497167)

Pinnacle Howe member, Whelter Knotts Formation.

A sequence of ignimbrite sheets have been distinguished in a small area around Pinnacle Howe with complex welded structures. Millward (2004) notes that columnar jointing is locally present in this material – no specific references to exact locations are given however.

17. Mardale Ill Bell, Haweswater, (NY 446103).

Andesitic sills in the Woundale Formation.

There is an irregular patch of nicely jointed material spread over this rock strewn fellside. The tops of the columns are visible in several places, but regular hexagonal jointing is somewhat intermittent. Small groups of columns are scattered through more irregularly jointed material. The columns are best seen in some of the rocky debris lying on the slopes. On average the columns are around 12cms across with some of the loose pieces around 1 metre in length. The columns retain their width throughout their length.



17a. Mardale Ill Bell.

Vertical view of columns – boot in foreground is 11cm wide.

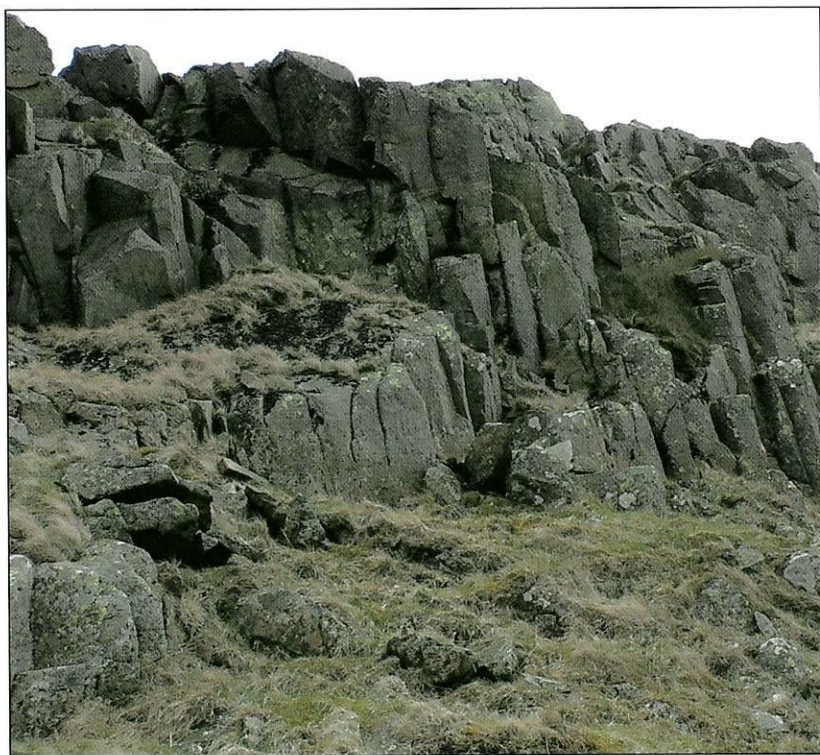


17b. Mardale Ill Bell. Group of detached columns. OS map 13 x 24 cm.

The information and illustrations for the final two sites (18 and 19) in this inventory have been compiled by Sylvia and Peter Woodhead. I am very grateful to them for checking out these two locations and for providing all the data.

**18. Broad Crag, N. slopes of Red Screes, Kirkstone. NY 388093.
Andesitic intrusions into Lincomb Tarns Formation.**

On the western plucked face of this large roche moutonnée above Scandale Beck, a cliff approximately 10 metres high shows large, rather rough, but fairly convincing, cooling columns. Over a length of about 15m there are around 16 columns, varying in size from 120 to 240cm in height and up to 30 cms in width, uniform throughout. Fallen blocks of loose columns are present in the scree below the cliff face. In cross-section, most of the columns appeared roughly pentagonal rather than hexagonal. Some have sharp edges. Smaller, less convincing columns are also seen further south on the same crag at NY 389092.



18a. Broad Crag. General view.



18b. Broad Crag. Typical column. Short edge of compass 5 cm.

19. Ruthwaite Lodge, Grisedale. NY 355134
Helvellyn Formation. Dacitic tuffs.

A small group of columns are exposed close to the Grisedale Tarn footpath just above Ruthwaite Lodge.



19. Ruthwaite Lodge. Columns at right average between 5 and 6 cms.

Discussion.

From the inventory it is clear there are few really outstanding examples of columnar jointing in Lakeland when measured against the classic sites in terms of numbers, scale and perfection of form. Put alongside the Giant's Causeway in N. Ireland where there are some 40,000 large, predominantly hexagonal columns, the Lakeland examples are insignificant. By the same token, a study recently completed on the Isle of Staffa (Phillips et al, 2013) located over 700 columns that could be accurately measured and their patterns analysed. The Lakeland examples are diffuse and scattered by comparison.

Columnar jointing, whilst commonly associated with basaltic lava flows, does occur in a wide variety of materials. It is found in lavas with a range of compositions from basalt to rhyolite. It is also known in welded pyroclastic deposits. Dykes and sills can also be columnar jointed. This Lakeland inventory confirms all of these observations. Beyond volcanic materials, similar columnar features have also been observed in muddy sediments and permafrost. Laboratory experiments have also reproduced columnar structures in starch-water mixtures allowed to cool and solidify. (Ball 2009). The classic basaltic columnar sites such as Fingal's Cave, Staffa, or Preshal Beg on Skye, show two jointing facies – a lower colonnade comprising regular columns with near planar sides, surmounted by an entablature with typically thinner, less regular columns commonly with curving sides. Nowhere is this seen in Lakeland.

Columnar joints form by spatially uniform volume contraction during cooling. Stress due to thermal contraction accumulates as the temperature falls and jointing occurs when stress exceeds the tensile strength of the material. In planar layers cooling from above, jointing thus propagates progressively downwards. In thick layers of material this process does not happen smoothly, instead the fracture pattern progresses downward in layered steps, each successive layer freezing and cracking before the next, leaving striae (breaks) in the columns. This has been shown to relate to thermal gradients and to the presence of water. Striae at the Giant's Causeway are very prominent features which are seen as regular breaks in the huge vertical columns and producing curved concave tops to the exposed columns. Again all of these features are not seen in the Lakeland examples.

All the columns located in Lakeland are small in comparison with the classic sites. At the Giant's Causeway columns up to 12m tall are found and most of the columns lie within the range of 38-51 cm across. On Staffa where detailed work has been completed (Phillips et al 2013) the mean column diameters on the six colonnade sites measured was 88.1 cm, with a

range between 74.6 and 113.5 cm. Faster cooling is generally regarded as producing smaller columns. In Lakeland the structures are associated with small, thin flows of material, not thick ponded basaltic sheets. From the inventory, the Bolton Head site (1) has the largest columns, but columns as small as 5cm were seen at site 2.

A measure of 'hexagonality' has been applied to many columnar sites worldwide, assessing how 'mature' a pattern of true hexagonal shapes are present in exposures (see Phillips et al 2013). All the Lakeland sites would measure very low on such a scale. Column numbers are low, most sites show great irregularity of shape, with much distortion or unclear margins. The Bolton Head site (1) has the best spread of true hexagonal columns. Columns in the Lakeland sites are however significant in showing regular column widths down the columns, with no examples of narrowing or splitting.

In the context of the lithostatigraphical model for the Borrowdale Volcanic Group elaborated by Millward (2002) and used by British Geological Survey in their current 1:50,000 scale mapping, the inventory of sites shows columnar jointing to be widely spread. No sites on the Latterbarrow or Lower Borrowdale Volcanic Group have been located however. All 19 locations are in the Upper Group. They occur in all the seven identified geographical basins and calderas – the Scafell caldera, Duddon Basin, Haweswater caldera and the Kentmere, Rydal, Helvellyn and Gosforth basins. The Cross Fell succession has not been checked. The Airy's Bridge and Lincomb Tarns Formations have the majority of the sites.

This short paper is offered as a starter to the study of columnar jointing in Lakeland rocks. The author is aware that more sites will undoubtedly exist and that the listed sites have not all been exhaustively measured and analysed. Someone in the future will no doubt add to this list.

Acknowledgements: Particular acknowledgements are due to Sylvia and Peter Woodhead for all their efforts to provide the information on sites 18 and 19 as mentioned in the text. I would also like to thank Chris Mitchell, Peter Wilson and Clive Boulter for discussion on this topic. Thanks are also due to Roy Ellis for assistance with the field work in the Coniston area.

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THE FOSSIL CARVINGS AT ST MARY'S CHURCH, WREAY – A GEOLOGICAL INSIGHT

Chris Thompson

In 2016 the Society received an approach, via Tullie House Museum, asking if there was an individual who would be able to deliver a presentation on the theme of 'Fossils' to The Friends of St Mary's Church, Wreay at their Open Day in September 2017. This article builds on that presentation given by the author and on a short talk at the CGS Members Evening on 13 December 2017.

Wreay village and the Church

Wreay (pronounced 'Rhea' to rhyme with 'near') lies 5 miles south of Carlisle between the M6 to the west and the West Coast Main Line railway to the east.

The Losh family were the main landowners in the area in the 18th and 19th centuries. In the first half of the 19th century a significant part of the family's wealth derived from industrial interests (alkali manufacture, iron and coal) in the north-east of England.

Wreay is an ancient settlement – there has been a church there for over 700 years. By 1840 the old chapel was in disrepair and Sarah Losh offered to donate land and funds for a new church on condition that she 'should be left unrestricted as to the mode of building it'.

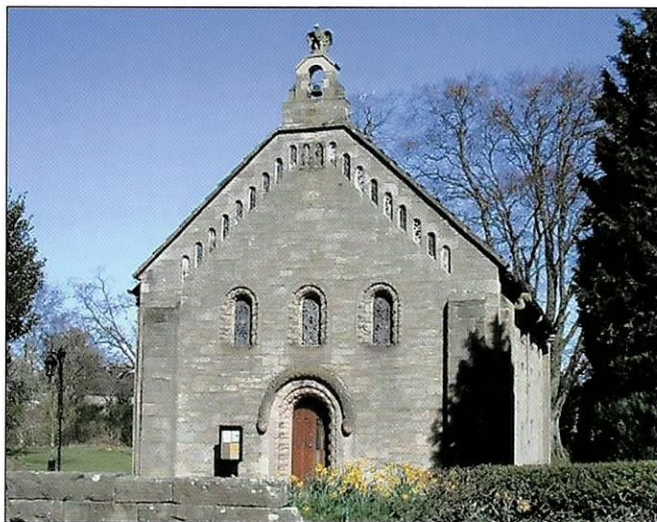


Figure 1.
St Mary's
Wreay, the
west facade,
the 'fossil
window' is
on the left.

The form of the church is based on a Roman basilica, a rectangular nave with a semi-circular apse. The church (Figures 1 and 2) was built between 1840 and 1842 using local labour, including the stonemason William Hindson and his sons. It is constructed largely of locally sourced Carboniferous sandstone. The church is full of symbolic ornament and carvings which refer to death and rebirth, drawing upon Christian, pagan and personal references. The carvings are based on nature with images of animals, insects, flowers and fossils.



Figure 2. St Mary's Wreay, viewed from the south. Note the row of small windows just below the roofline housing the 'apse stencils'.

The church has been described as 'one of the most eccentric small churches in England' (Jenkins, 2012) and 'a crazy building without doubt, even if it is a most impressive and in some ways amazingly forward pointing building – the finest Victorian church in Cumberland' (Pevsner, 1967).

A detailed account of the life of Sarah Losh, her family and of Wreay church is provided by Jenny Uglow in her book *The Pinecone* (2012).

The fossil carvings

Fossil representations can be found at several locations in and around the church;

- The ‘fossil window’ – the surround of the left hand window located on the west façade, above the main entrance door to the church
- In a series of small windows in the wall of the apse
- The pulpit
- The gravestones in the walled Losh Cemetery in the graveyard
- The ‘gargoyles’ high on the outer walls of the church

The bulk of Sarah’s records and correspondence were lost after her death. No information relating to what most of the carvings were intended to represent has been found.



Figure 3. The ‘fossil window’.

The 'fossil window' (Figure 3)

The window surround contains a number of carvings. These are dealt with in a clockwise manner starting at the bottom left of the window.

The first and third carvings (and those at the same level on the right hand side) are of modern pinecones. The pinecone is an ancient symbol of regeneration, fertility and inner enlightenment and carvings can be found throughout the church and churchyard (of special note are the large alabaster pinecones placed on plinths at either side of the aisle close to the entrance to the church).

The second (and second from last) carvings on the surround are considered to represent ammonites, widespread and often common in the Mesozoic strata of England, long referred to as 'snakestones' in folklore, and widely recognised in the scientific community at the time the church was being built.

The fourth carving, with the representation of an almost smooth, but slightly ribbed shell with 4 tentacles is considered to represent some form of coiled cephalopod. Matthews (2007) indicates that this could be either a ceratite or a nautilus. Ceratites were the precursor of the ammonites and restricted to marine Triassic sequences (not present anywhere in the UK). In contrast, fossil *Nautilus* have a wide stratigraphic range, they are found in Jurassic, Cretaceous and Eocene strata in the UK. *Nautilus* is extant – recent *Nautilus* shells have been used as decorative forms from the 1600's onwards. It is considered that this carving was probably intended to represent a *Nautilus*.

The fifth carving is enigmatic – branching, jointed and ribbed. Matthews (2007) describes it as a crinoid. Research has failed to identify any examples of branched crinoids. Whilst it could represent some form of coral, it is considered that the carving is best matched with a modern branched horsetail (*Equisetum hyemale*) with jointed (articulated) ribbed stems and terminal spore cones. The fossil equivalent (*Equisites*) is a common Carboniferous Coal Measures plant genus.

The two carvings at the top of the window surround are considered to be entirely decorative, representing modern flower forms.

The branching textured carving on the upper right hand side of the surround is considered to represent a stagshorn coral (*Acropora*) – these corals range from Eocene to recent and would have been commonly recognised in the early 19th century.

The carving immediately below the stagshorn coral appears to some form of coiled ribbed shell that is partially covered by what appears to be a soft bodied creature with tentacles. Matthews (2007) refers to this as a

nudibranch mollusc. Whilst nudibranch molluscs are thought to have first emerged in the Jurassic they are all soft bodied – similar to what are commonly referred to as sea slugs. A range of examples seen on the internet do not seem to share any characteristics with the features seen on the carving. It is therefore unclear as to what this carving was intended to represent.

The Apse Stencils

High in the wall of the apse at the back of the church is a series of 13 windows. Each window contains a stencil cut out of a thin sheet of alabaster; these are believed to have been created by Sarah Losh. Whilst some of these stencils appear to be entirely abstract in nature, others clearly represent Upper Carboniferous (Coal Measures) fossil plants. Lonsdale (1873) lists 4 of these as *Neuropteris acuminata*, *Pecopteris heterophylla*, *Sphenopteris dilatata* and *Sphenophyllum Schlotheimii*.

Sarah's uncles (William and James Losh, north-east industrialists) are listed as subscribers to the first volume of *The Fossil Flora of Great Britain* (1836), written by John Lindley (first professor of Botany at University College London) and William Hutton (a Newcastle geologist, Fellow of the Geological Society, and authority on the Coal Measures). Comparison of the 4 species names listed by Lonsdale (above) with drawings of these same species in *The Fossil Flora of Great Britain* leads to the conclusion that Sarah used at least some of the drawings in the book as the basis for the stencils (Figures 4 and 5). It is also of note that both of Sarah's uncles and William Hutton were members of the Newcastle Literary and Philosophical Society which had a collection of Coal Measures plant fossils, and which Hutton curated.

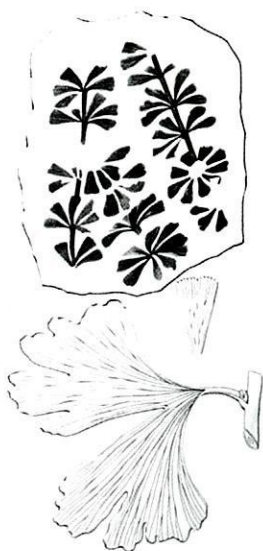


Neuropteris acuminata



Sphenopteris dilatata

Figure 4. Coal Measures plant fossils from Lindley and Hutton (left) matched with stencils from the apse window (right).



Sphenophyllum Schlotheimii



Pecopteris heterophylla

Figure 5. Coal Measures plant fossils from Lindley and Hutton (left) matched with stencils from the apse window (right).

The Pulpit

The pulpit and candleholder are carved from bog-oak recovered from nearby Wragmire Moss. The pulpit has been decoratively carved to represent Calamites, a Coal Measures tree stem similar to modern day horsetails but much larger, with a detailed representation of both articulated joints and leaf scars (Figure 6).



Figure 6. The pulpit.

The Gravestones

There are gravestones in the Losh grave enclosure in the churchyard which carry what are considered to be representations of fossils. The gravestone of Sarah and her sister, Katherine, in the south-east corner includes a carving identical in form to what is believed to be a branched horsetail seen on the fossil window. There are also 2 shells, which resemble modern day giant clams, but which could be based on the large brachiopod *Gigantoproductus*, often found in the Carboniferous limestones of Cumbria (Figure 7).



Figure 7. The gravestone of Katherine and Sarah Losh.

The gravestone of Major William Thain (a local hero killed in the Afghan war of 1842) carries a large carving of what might superficially be viewed as a palm tree but is considered by Robinson (2005) as looking 'suspiciously like a *Lepidodendron* complete with a distinctive stigmarian root spread'.

The 'gargoyles'

On the outside corners of the church, level with the eaves, are the carved heads of what Sarah Losh described as 'emblematic monsters'. These 'monsters' had a practical purpose – they were not gargoyles but they hid ventilators, whilst a 'dragon' on the north-west corner was the exhaust for the boiler in the church (Figure 8). Robinson (2005) believes that 2 of these carvings are contemporary reconstructions of *Megalosaurus* and *Dicynodon* more or less as they were reconstructed for the full scale models for Crystal Palace Park (1854). Given Sarah Losh's description of these, that they precede the Crystal Palace models by at least 12 years and that they predate Richard Owen's definition and descriptions of dinosaurs it is unclear if this is a valid association. It may be that the similarity between the carved heads and the dinosaurs noted is just a 'happy coincidence'.



Figure 8. The 'dragon' hiding the exhaust from the (original) heating boiler.

The Losh palaeontological legacy

Whilst researching the background to the fossil representations at Wreay Church the author became aware of *Neuropteris loshii*, a pteridosperm figured and described in Lindley and Hutton (1833) (Figure 9) and clearly named after the Losh family.

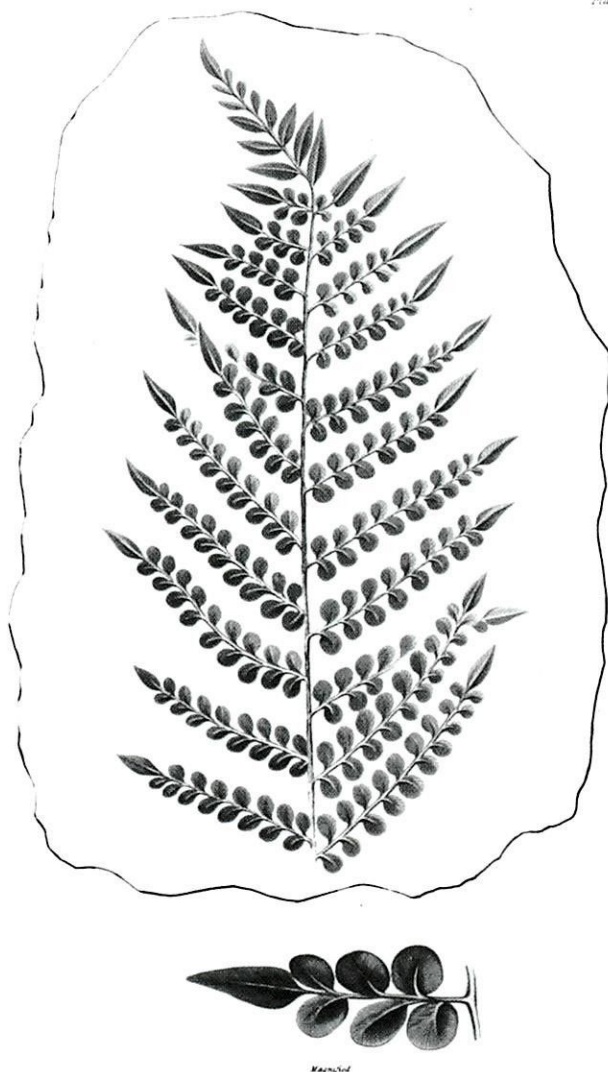


Figure 9. *Neuropteris Loshii* from Felling Colliery, Newcastle.
Plate 49 of Lindley and Hutton.

Further investigation led to the discovery of an acknowledgment of the assistance provided by the Losh uncles to Adolphe Brogniart (often described as 'The Father of Palaeobotany') in his *Histoire des Vegetaux Fossiles* (1836) and references to 6 specimens figured in the work as originating from 'Les mines de Newcastle (Losh)'. An internet search of the French National Natural History Museum collection database identified some 25 specimens from the Losh collection held by the museum. Whilst the collection of the Newcastle Literary and Philosophical Society (of which James and William were members) appears to have been subsumed into that of the Hancock Museum (now the Great North Museum) - details of this collection was not readily available. It is likely that a significant proportion of the material figured in Lindley and Hutton (1833) is (or at least was) in that collection.

Further information

The Friends of St Mary's Church, Wreay have a website:

www.stmaryswreay.org

The website provides a wealth of information on the church and the village along with opening times of the church and the nearby Sarah Losh Heritage Centre. Leaflets describing the church, the Sarah Losh heritage trail and the Wreay Woods walk are available to download from the website.

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THE WESTMORLAND DALES. ASPECTS OF THE GEOLOGY OF THE YORKSHIRE DALES NATIONAL PARK INTO CUMBRIA

Noel Pearson

Introduction

In 2005 The Friends of the Lake District submitted a report to Natural England titled 'Forgotten Landscapes'. Eleven years later, following a Public Enquiry in 2013, it was agreed that the rest of the Howgill Fells and the Karst landscape around Orton merited National Park status. Subsequently on August 1st 2016 the area became an extension to the Yorkshire Dales National Park though remaining in Cumbria.

Following a grant from the Heritage Lottery Fund (HLF) the Westmorland Dales Hidden Landscape Partnership (HLP) project was formed. It had the aim of revealing to the general public the Dales 'rich heritage', including 'internationally recognised geological sites'. Fig. 1 shows the area covered, from Tebay in the west, to Maulds Meaburn in the north, and Ravenstonedale to the south-east. The geology is essentially Carboniferous, with the upland limestone plateau of Great Asby Scar probably best known, following the publication of Wainwright's Coast to Coast Walk in 1972. Currently, an initial geological report is being prepared, along with other aspects of 'heritage', for submission to the HLF in order to secure the total £3.5m grant.

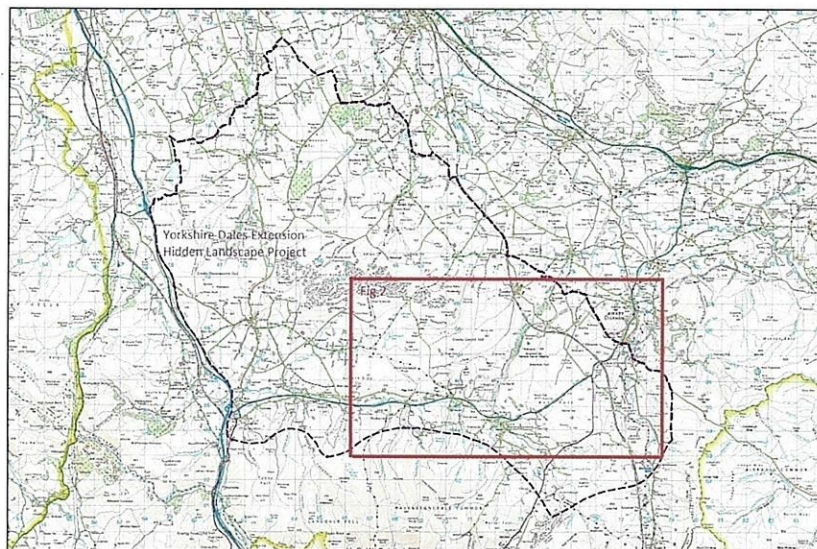


Figure 1. Yorkshire Dales National Park Extension.

Naming 'The Westmorland Dales' has been a useful first step in establishing their identity today as a tourist attraction. However, the area has attracted geologists since the 19th century and it has been their seminal work that has laid the foundations for its 'international' recognition. In October 2015 a visit was paid by members of the International Union of Geological Sciences (IUGS). This was organised by the Yorkshire Geological Society but attended by Susan Beale (then CGS President) and myself. The following year we retraced their steps to Little Asby Scar and Janny Wood (both Geological Conservation Review (GCR) sites) and in July 2017 we explored three sites in the Ravenstonedale area all with members of CGS. The sites are shown in Fig. 2 and the itineraries are explored below.

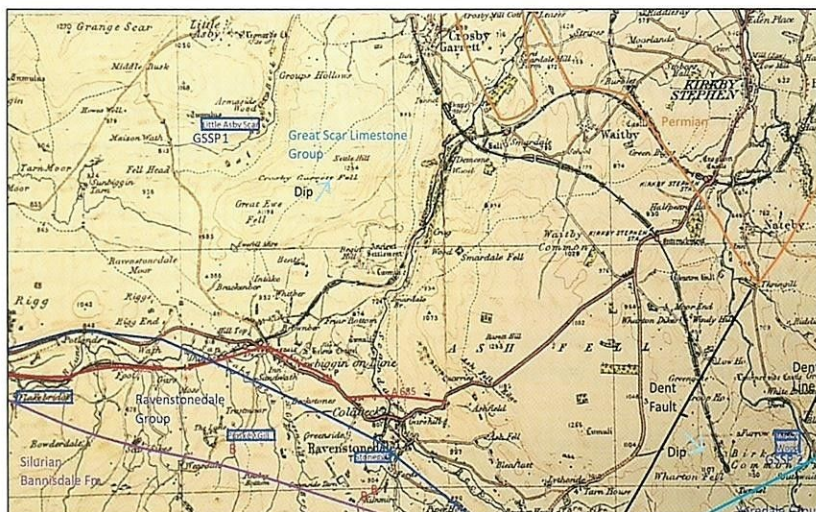


Figure 2. One inch to mile 1924 showing Settle-Carlisle railway and A685 replacing the track to Tebay.

The IUGS Visit

The IUGS was founded in 1961. It has 121 national members whose task is to promote the development of Earth Sciences (see IUGS website). Its scientific work is carried out by various Commissions. Relevant here is the Commission on Stratigraphy whose objective is to: "precisely define global units (systems, series and stages) of the International Chronostratigraphic Chart that, in turn, are the basis for the units (periods, epochs and age) of the International Geologic Time Scale".

There are 16 Subcommissions, from Precambrian to Quaternary, and it was members of the Subcommission on Carboniferous Stratigraphy (SCCS) who visited two sites in the Westmorland Dales.

This then, was the context in which the specialists in lithology and micro-palaeontology of the SCCS reviewed the stratotypes of Northern England in October 2015.

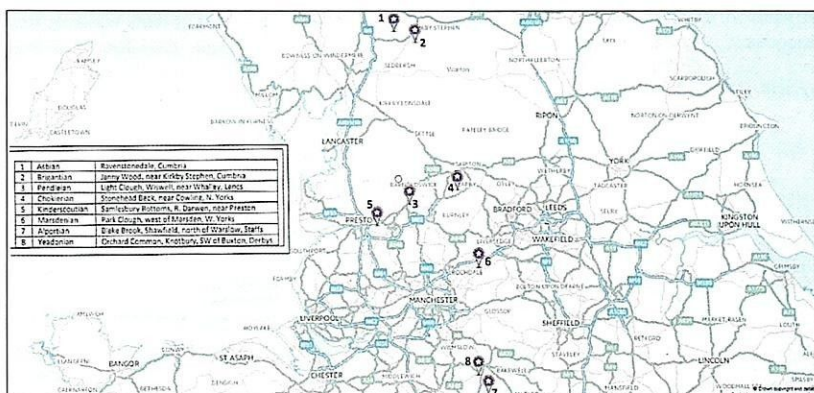


Figure 4. Location of current Carboniferous Stratotypes of Northern England studied October 2015.

Little Asby Scar

Excursions Oct 2015 and CGS June 2016

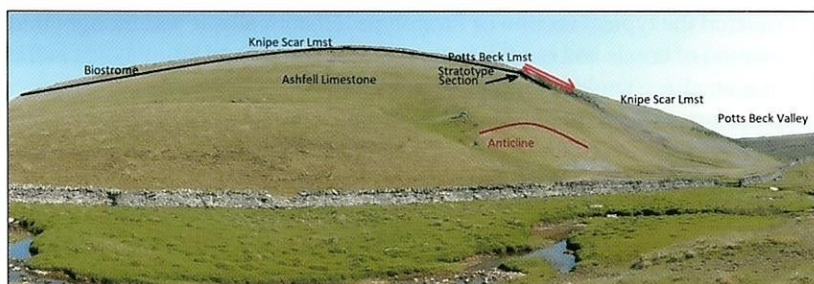


Figure 5. Little Asby Scar.

Little Asby Scar was accessed from off-road parking just north of Mazon Wath at NY 687086. The return walk is no more than 3k over semi-rough, dry, limestone grassland. Fig. 5 shows the extent of the Scar from Potts Beck. The SCCS group, intent on spending their time at the Stratotype Section, walked along the cliff top and, bypassing the main biostrome, descended from above. For CGS, it was felt that a better and safer appreciation of the whole location could be had by taking sheep tracks parallel to the cliff top, half way up the slope, exploring the anticline and approaching the section from below. Returning along the top, but descending a few meters, at intervals, the biostrome could then be explored.



Figure 6. Nick Riley indicates the Stratotype boundary at Little Asby Scar.

Figs. 6 & 7 show the SCCS at 'work'. Fig. 8 shows a close-up of the Holkerian/Asbian boundary, (with a characteristic *Chaetetid* sponge) and Fig 9 its position in the sedimentary log based on Ramsbottom (1981).

Cossey et al. (2004), in the Geological Conservation Review, provides a full summary and description of this site highlighting the difficulties of matching faunal appearances with lithology. Subsequent work by Aretz & Nudds (2005) concludes that the boundary between the Potts Beck and Ashfell Lmsts is a "discontinuous (1-15cm thick) siltstone bed that could not be traced over all the outcrop interval". "The Holkerian/Asbian boundary, as defined by George et al. (1976), is a lithostratigraphic boundary, which is not supported by any biostratigraphy. There are no potential index taxa in either corals, brachiopods, foraminiferans or conodonts at this level".

They also point out that the bases of the coral and foraminiferan biozones do not correspond and a relocation of the boundary will be necessary to define the base of the Asbian. This could be either higher in the sequence or elsewhere, ideally a continuous section "possibly in Derbyshire or North Wales". However Riley (2016) points out that it may be more rigorous to relocate stratotypes to hemi-pelagic settings rather than other carbonate ramp/platform environments.

The CGS walk, on the other hand, concentrated on exploring the 'visible' biostrome. Aretz & Nudds (2007) indicate its extent for 900m west of the stratotype, around 1.4m thick, where "Chaetetid-dominated facies alternate with coral-dominated facies both horizontally and vertically". In some places "*Siphonodendron* debris layers provide the hard substrate for chaetetid sponge growth", much of which is silicified (Figs. 10-13). The variation in the relative abundance of the two main biota within this shallow-water succession is interpreted as showing a cross section "through a marginal part of a shoal and its edges". *Siphonodendron* debris is due to storm events, with chaetetid-dominated facies representing deeper and calmer conditions around the edges of the shoal. It is likely that deepening waters and the deposition of fine-grained, algal rich limestones stopped further development.



Figure 7. International members of the SCCS examine the Stratotype boundary.



Figure 8. Stratotype Boundary with *Cheatetid* (20cmsdia, centre) and core holes.

Two other aspects of the locality were commented on. Firstly the location of Garwood's 'Bryozoa Band'. In Fig. 9a, on his 'Zonation' map, it is prominent enough to be shown cresting beyond Little Asby Scar. Fig. 9 shows bryozoa to be present about 1m below and 3 & 8m above Ramsbottom's boundary. Short of time and given that bryozoa are not the most prominent fauna in this locality we had to take this on trust. Interestingly, this 'Band' is not referred to in Pattison's (1990) resurvey of the area for the BGS, but it is an entry in their Rock Lexicon (although without any detail).

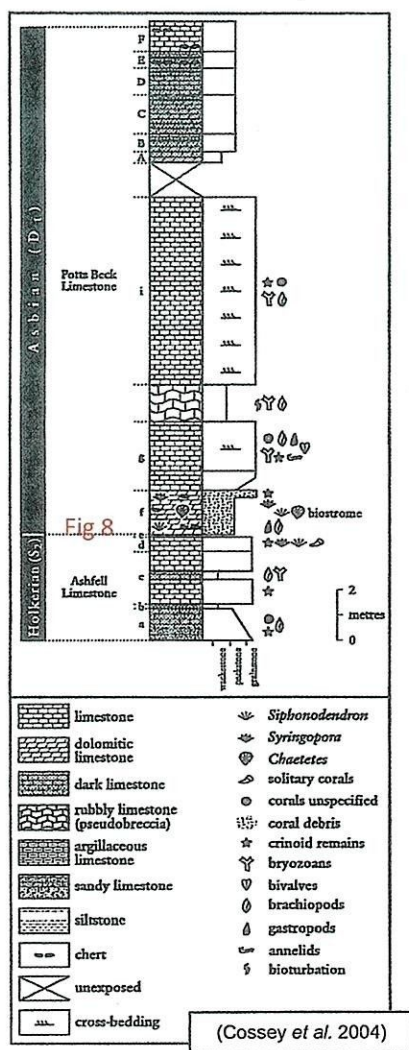


Figure 9. Little Asby Scar.

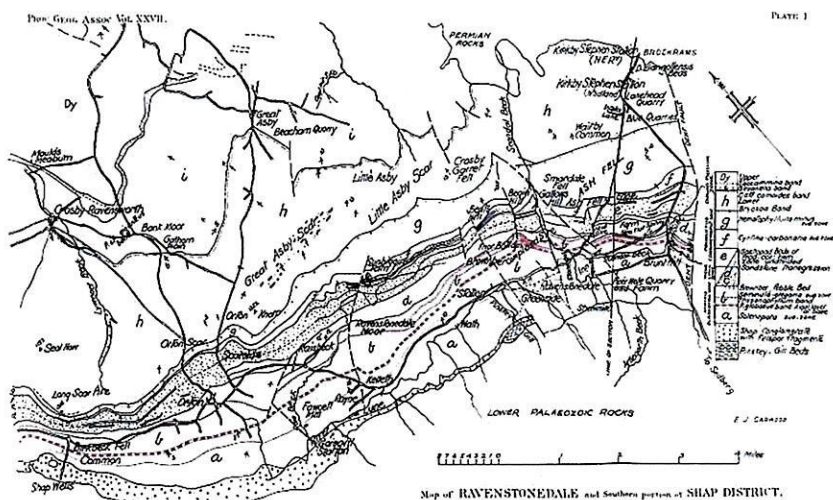


Figure 9a. Garwood's Zonation Map.

Secondly, the view from the Scar was a good opportunity to comment on the deeply incised nature of the Potts Beck valley. The prevailing view King (1976) is that before the Lune gorge existed, drainage from the Howgills and from Borrow Beck west of Tebay was channelled across the Sunbiggin area, cutting the Potts valley. Its underfit stream can, today, be traced all the way to the river Eden at Ormside.



Figure 10. West end of Little Asby Scar with prominent silicified Biostrome.



Figure 11. Typical example of association of silicification and *Chaetetid*.



Figure 12. Biostrome with *Chaetetids* and corals
Siphonodendron and *Syringopora* (above).



Figure 13. Middle horizon of *Siphonodendron* debris within *Chaetetid* dominated Biostrome.

Janny Wood

Excursions Oct 2015 and CGS June 2016

The afternoons of both days allowed sufficient time to visit the river Eden section at Janny Wood (NY 783038, not marked on the 1:25 000 map). Fig 14 shows the start and the view north from the parking on the 'Tommy' road at NY 779030. The walking route follows the bridleway for 1k before leaving it for the river.

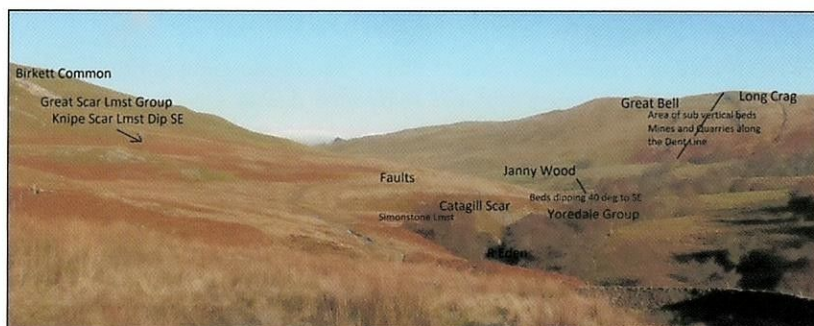


Figure 14 . Mallerstang Valley (northern end) looking North.

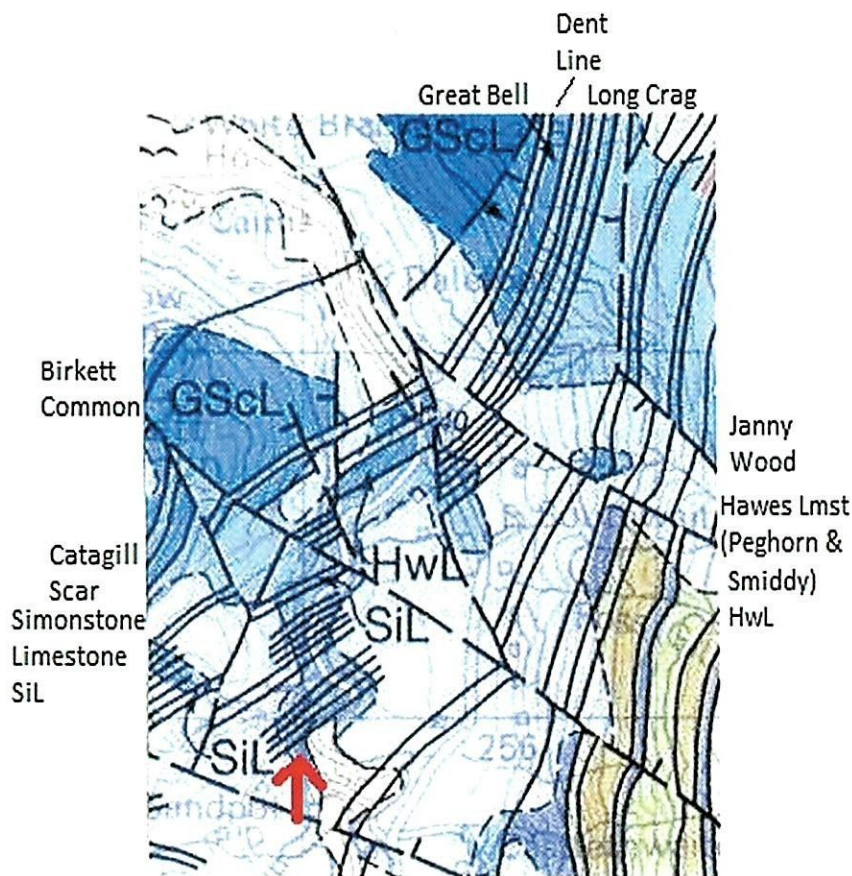


Figure 15. Geology of Fig 14. Viewpoint and start of walk marked.

Fig 15 shows the geological context that underlies the view in Fig. 14. It is structurally more complex than the Asby area due to the Dent Fault east, younger beds are now dipping to the SE rather than to the NE. Transpressive 'Variscan' (end Carboniferous) events led to the formation of the Dent Fault monocline and its continuation along the Dent Line. The latter was subsequently reactivated (Permo-Triassic) "as an oblique-slip zone to accommodate the Vale of Eden half-graben development", Underhill *et al.* (1988). The sub-vertical beds of Long Crag and the associated mineralisation reflect these events.

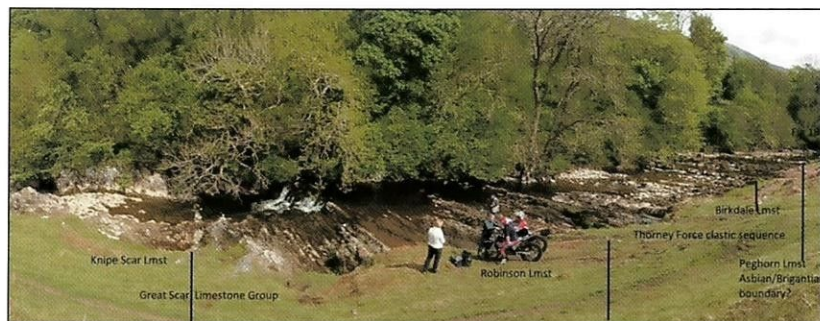


Figure 16. Janny Wood.

The sequence at Janny Wood dips around 40 deg to the SE (Fig. 16 – with the cyclocross club who were testing themselves in the exposed stream bed, but only once a year apparently). Summarising Cossey *et al.* (2004): pale grey cherty Knipe Scar Lmst is followed by a darker unit of Robinson Lmst, then a clastic, mudstone to fine sandstone interval. This is capped by a slightly darker unit of Birkdale Lmst and succeeded by more clastics (with a *stigmara* horizon, Riley 2002). The Asbian / Brigantian boundary was defined by George *et al.* (1976) at the junction between this clastic unit and the Peghorn Lmst lying immediately above it. This is illustrated (Fig. 17) in the sedimentary log by Ramsbottom (1981) who summarised what was then known of the distribution of the various macro and microfossils.

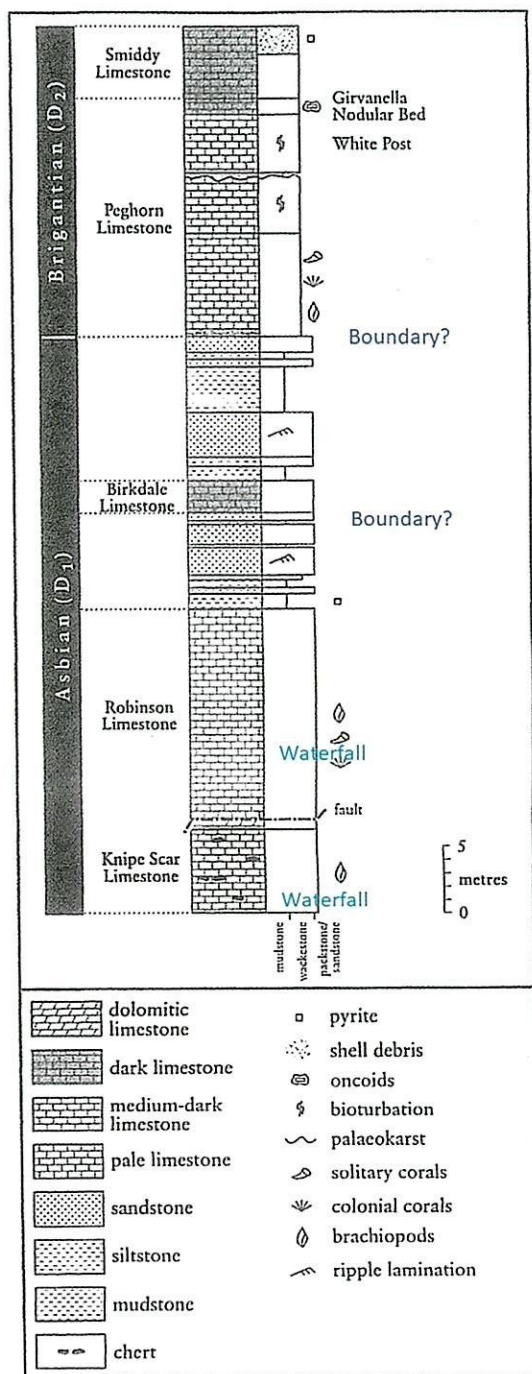


Figure 17
Janny Wood



Figure 18. Core sampling in the Peghorn Limestone.

Further research in the last 30 years, (Fig. 18 demonstrates its enthusiasm) Cozar & Somerville (2004), comparing the foraminifera and calcareous algae assemblages here with sections in boreholes on the Alston and Askrigg blocks, suggests the placement of this boundary also needs revision. “Many common taxa in what is currently regarded as the highest Asbian part of the Janny Wood section are more typical of the Brigantian”. Thus it would be more acceptable to locate the Stratotype boundary “to a lower level, preferably at the base of the Birkdale Limestone”. The presence of Nick Riley and Patrick Cossey (ex BGS) as guide/‘experts’ on the SCCS walk certainly enabled a thorough discussion of all these issues.

The CGS walk also spent time considering the origin of some karst blocks (off the bridleway towards the river) and the Catagill Scar stratimorph. Waltham (2013) defines this as a topographical surface formed by individual beds of strong rock, where weaker cover has been stripped away by erosion. The BGS map identifies this as the Simonstone Limestone, the base of the third cyclothem up in what is definitely now the Brigantian.

The western and southern boundaries of the Westmorland Dales are essentially defined by fluvial features eroding the softer deposits lying between the older Lake District rocks and the younger Scar limestones to the north east. Outside the area, to the west, are the upper river Lowther flowing north from Shap and Birk Beck flowing south from Shap Wells. Within the area, to the south, is the Upper Lune valley. The deposits are characteristically red sandstones and conglomerates in the west, but within the Ravenstonedale area, mudstones, siltstones, vari-coloured sandstones and dolostones occupy the Lune and adjacent valleys. This variation reflects a shift from a primarily continental, fluvial, clastic deposition infilling the uneven Silurian palaeo surface to peritidal marginal marine conditions.

It is only in the last 10 years that the lithological framework and nomenclature of Groups and Formations has been systematised by the BGS, Waters (2007). The western 'red' beds are consigned to the Upper Old Red Sandstone Group of the Late Devonian. Those in the subject area are known as the Ravenstonedale Group comprising three Formations: the Pinskey Gill Fm, the Marsett Fm and the Stone Gill Fm, the first 15My of the Lower Carboniferous. These are succeeded by the Great Scar Limestone Group (previously the Orton Group without the Coldbeck Lmst) visited in the Asby excursion (see Fig. 3 for British/International terminology).

Nowhere in the area do the 3 formations outcrop in their entirety due to the drift cover. However 3 locations plus interpolated data from boreholes, drilled in the 1970s, were visited to illustrate the succession.

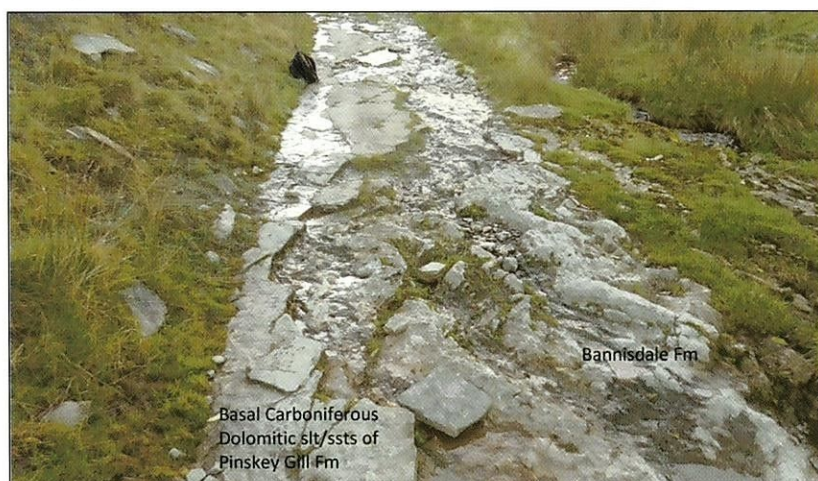


Figure 19. Track south of Flakebridge Farm showing Silurian/Carboniferous Unconformity

Firstly Flakebridge Farm NY 666047. The site lies on the track south of the farm (Fig 19). Although on private land, the owner is amenable to visits. Here the basal 3.5m of Pinskey Gill Beds is seen, overlying the steeply dipping, deformed, eroded surface of the Silurian Bannisdale siltstone Formation. This is the best (only) clear example of the unconformity (60M year time gap) in the area. There are no intervening 'red' beds and the PG beds do not appear to overlap any further west. Their silty sandstones and mudstones are thought to have accumulated within lagoonal tidal flats, see Kimber (1987) for detail.

Secondly Pinskey Gill NY 698039. The formation was originally referred to as the Lower Limestone Shales but renamed by Garwood in 1913. This is a GCR site and designated as the type area. The walk can best be traversed following the stream north from Pinskey Bottom, having appreciated the panorama to the north and east which takes in the first 40My of the Carboniferous to the top of Wild Boar Fell. Of course none of this existed when the Pinskey beds were being deposited in the epicontinental setting of the 'Ravenstonedale Gulf'.

The stream first cuts through the sub-vertical, cleaved Bannisdale 'slates' before reaching the upper section (Fig. 20). Fine grained silty buff coloured sandstones similar to the Flakebridge section indicate the incoming Pinskey beds, but the unconformity is obscured by drift.

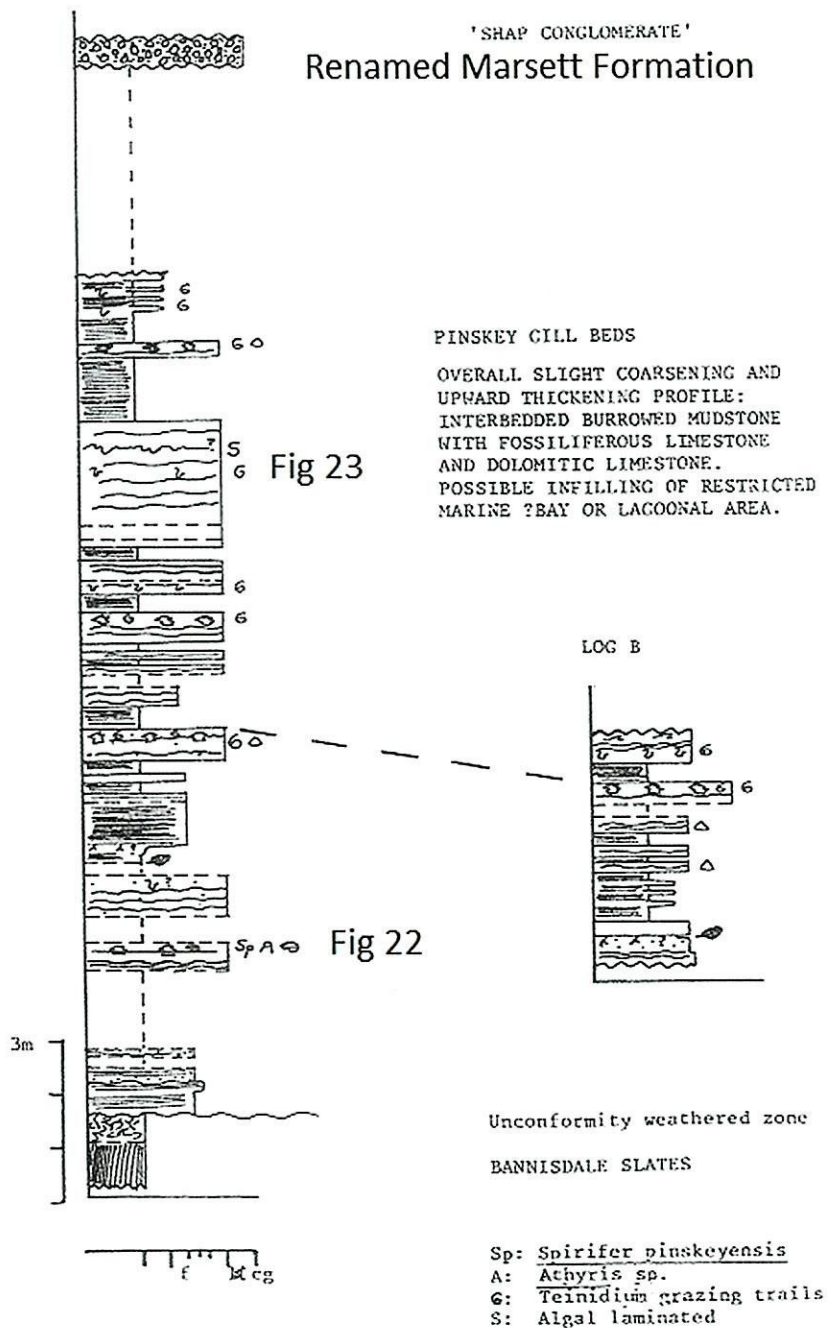


Figure 21. Pinsky Gill log.



Figure 20. Pinskey Gill looking NE down dip.



Figure 22. Garwood's *Spirifer Pinskeyensis* site.

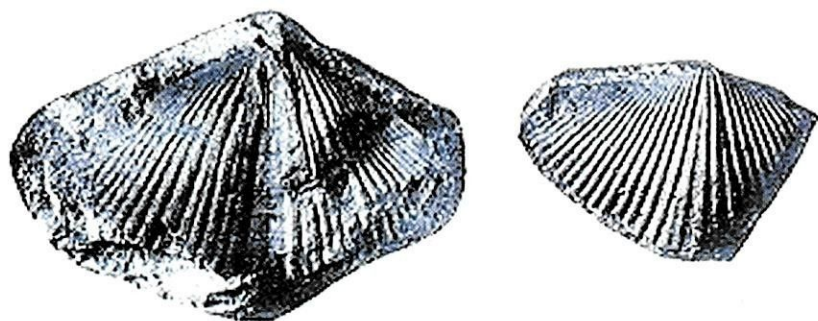


Figure 22a. *Spirifer Pinskeyensis*.

Fig 20 also indicates the site (Fig 22) of the brachiopod (Fig22a) that Garwood thought was unique to this area and therefore named *Spirifer Pinskyensis*. The formation continues with alternating sequences of thinly bedded fine-grained, dolomitic and vuggy limestones, mudstones and siltstones and with some algal banding (Fig. 23). A full and forensic description, including the log can be found in Kimber (1987). Borehole evidence from Holliday et al. (1979). Conodont analysis confirm a basal Carboniferous date. This has been of critical importance for understanding the early evolution of the Stainmore Basin.



Figure 23. Algal Lamination.

A few meters north of the road bridge at NY 698042, after a gap of several meters in the succession, is a conglomerate unit with “clasts of greywacke, quartz, volcanic rock and a distinctive pink . . . feldspar similar to that which occurs in the Shap Granite” Cossey et al. (2004). This was originally named the Shap Conglomerate, but renamed recently the Marsett Formation, after a village in Raydale, near Bainbridge Wensleydale. In 1973 a borehole was sunk to check for the Wensleydale Granite, finding at around 460m a similar lithological succession to the dolostones and clastics just described. Here the formation is around 45m thick. The upper few meters are exposed in the cutting north of the A 685 where the new road follows the course of the old railway and the river was diverted from Flakebridge (see Fig 2) to its present canalised route (Fig. 24, not visited).

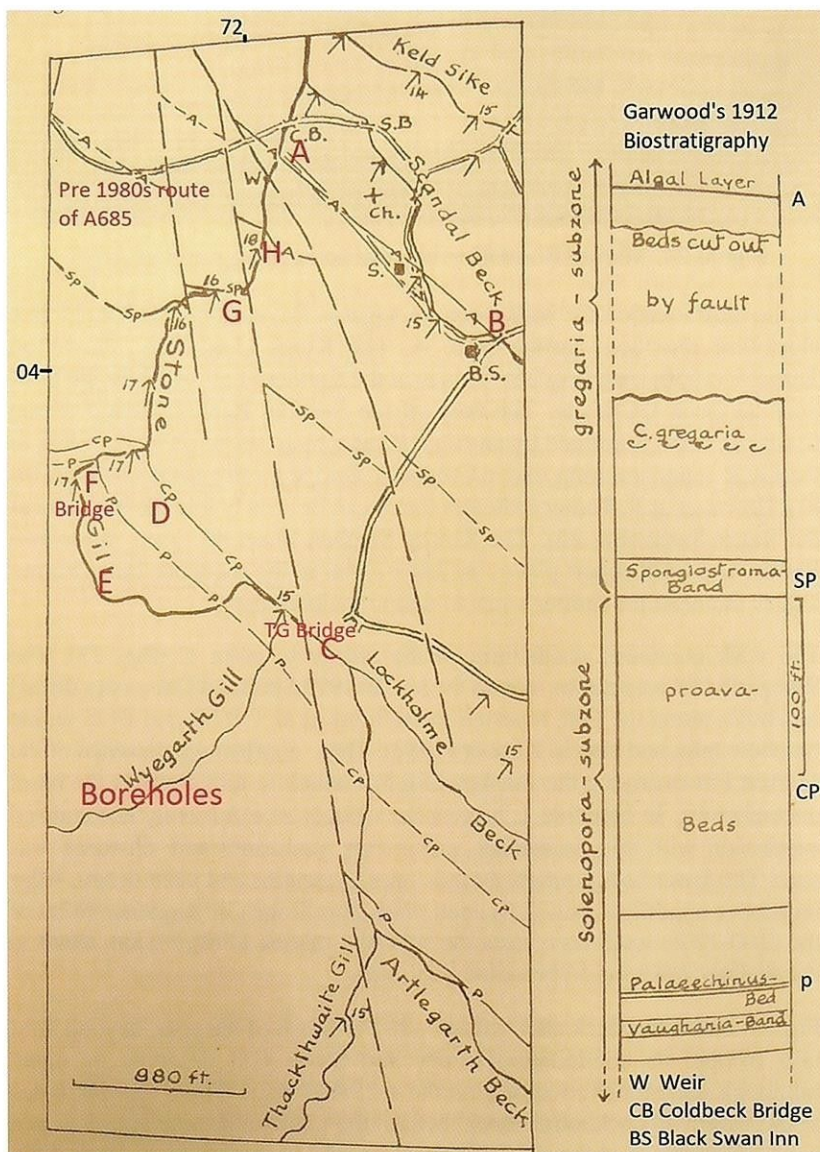


Figure 24. Marsett Formation in canalised cutting north of A685.

At the third location the walk circumnavigated Ravenstonedale Village in a clockwise direction starting from A, The Kings Head Pub, shown on Turner's (1950) map (Fig 25). This is in the southern half of the Stone Gill-Scandal Beck GCR site. The base of the Scandal Beck Lmst/top of the Coldbeck Lmst is defined by an Algal Band which can be seen according to the GCR report running under Coldbeck Bridge (water level too high for us). However at B, Turner indicates that it can be seen below the bridge near the Black Swan (Fig 26). The Kirkby Stephen Sheet 40 'joins' these two Bands. The GCR report places the latter lower in the sequence but acknowledges the need for further work to define the boundary.

The walk continued south through the village to point C (Fig. 27). The Wyegarth Gill area can be seen to the left. In 1975 Sheffield University drilled boreholes along the Gill, reported in Holliday et al. (1979) and BGS online borehole info, and also in Kimber (1987). These confirm the presence of the Marsett Fm overlying the Pinskey Gill Fm which in turn overlies the basal unconformity. In borehole 1, nearest the village, an extensively dolomitised succession with thin limestones, calcareous mudstones and siltstones was seen. The lower beds contained sandstones, seatearths and plant debris. After regressive conditions during Marsett times, this Stone Gill sequence (42m of the c100-120m total) represents the start of a marine transgression, albeit in the shallow waters of hypersaline tidal flats.

Fig. 27 shows the Beck after winter rain. For much of the year, beyond Tarn Gill Bridge, its continuation is dry and Stone Gill deserves its name (although not enough to appear on the 1:25 000 map). There are sink holes in the valley of Lockholme Beck, behind the photo and these continue in a band of limestone under the bridge and beyond to the bridge in Stone Gill. The NE abutment of Tarn Gill Bridge has suffered from settlement and repair is being sought by the Friends of Tarn Gill Bridge. The cause is not known but could be related to the underlying karst surface. Fig. 28 shows the insertion of sodium fluorescein into the sink under the bridge in April 2017 to determine the possible water course.



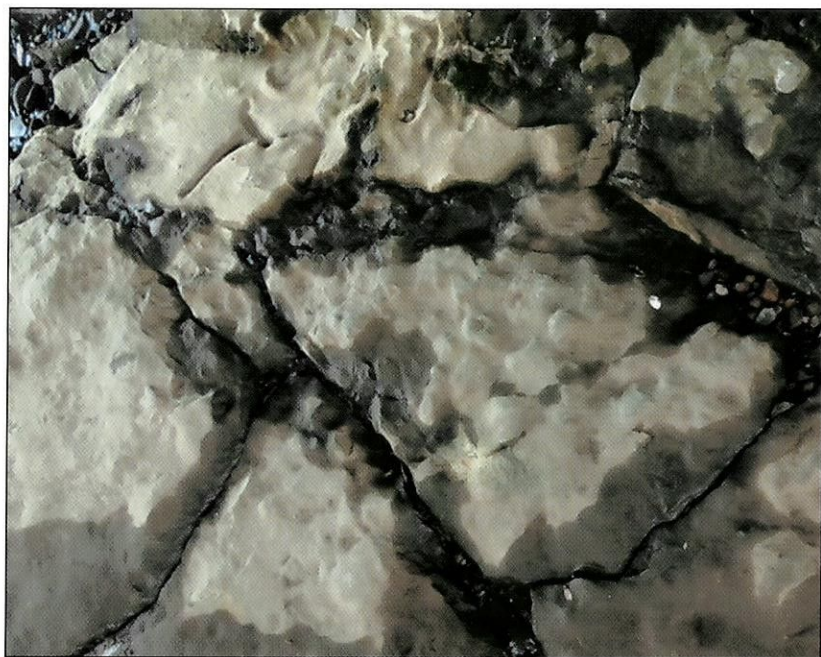


Figure 26. Algal (Oncoid) layer under bridge near Black Swan Inn.



Figure 27. Artlegarth Beck looking NW to Tarn Gill Bridge and beyond to Stone Gill.



Figure 28. Sodium Fluorescein Dye Testing in sinkhole below NE corner Tarn Gill Bridge.



Figure 29. Stone Gill view to NW.

Proceeding to the bridge over Stone Gill the view (Fig.29) appears at D. The fallen block in the 'proava' beds (Turner's log Fig. 25) has proved a popular photo being taken by Garwood in 1916, Rhodes for the BGS in 1933 and Cossey for the GCR in 2004 (only the vegetation has changed). More time would have been needed to search out the faunal 'bands', but having noted the porcellanous limestone by the bridge and the bioturbated beds just to the south at E, attention was turned to looking for the *palaeoechinus* bed. According to Garwood (in Turner) this was 11.5 feet above the *Vaughania cleistoporoides* band. The search was not successful despite finding the coral (Fig. 30) located at F. Was it more like Fig. 30a or 30b? *Michelinia* does occur in Garwood's schema but further up the succession.



Figure 30. Tabulate *Michelinia*-like coral 2 cms across.



Figure 30a. *Vaughania Cleistoporides*.



Figure 30b. *Michelinia Grandis*.

Up until now the water courses in the area have followed a SE to NW trend parallel to the strike of the bedding. Stone Gill now turns north cutting across, down dip, the more massive porcellanous limestone and thinner dolostone beds. This underfit and seasonal stream is presumably insufficient to carve out the small gorge. Possibly periglacial processes have been at work here in conjunction with the changes in the Scandal Beck and Lune watersheds identified in King (1976).



Figure 31. *Spongiostroma* 'Band'.

The penultimate stop was to admire Turner's *Spongiostroma* Band at G, identifiable from his 1950s photo (Fig. 31). The base of the Coldbeck Limestone is defined by this nodular algal band and now marks the lower boundary of the Great Scar Limestone Group Dean (2011).

The walk concluded at point H with the results of the dye test. This was the site of the first 'activated charcoal' detector (2 more were placed downstream) at an underground stream rising. The detectors were left for 86 hrs, treated with a combination of isopropanol and potassium hydroxide and heated. The visual examination was . . . negative! Excluding insufficient or over-diluted dye as an explanation, it was thought possible that a large underground feature (a lake?) might have held back the water for a considerable time. This thesis is supported by the fact that the emerging water in Coldbeck is colder than at the sink by 2-4°C depending on the time of

year. Clearly Artlegarth Beck is taking a short cut and in time Stone Gill will be completely abandoned.

Hidden Landscape – Hidden Geology?

In the introduction reference was made to the limestone pavements of Great Asby, a very visible manifestation of the interaction of limestone with geomorphological processes. This is a scenery familiar to many who have walked in the ‘Yorkshire’ Yorkshire dales. However in the Ravenstonedale district, as these walks have described, there is evidence for what came before the limestone pavements and what happened after. There is the opportunity, then, to describe and relate the very local to the global and even the astronomical scene. A story, therefore, to appeal to the casual visitor without having to refer to the chronostratigraphical debates of the professional geologist.

Nevertheless while these debates continue the geographical centre has shifted far to the east. The 2014 Carboniferous Subcommission reported that ‘all lineages being chosen for GSSP definition are conodont based’. The best known deeper water successions with a continuity of outcrop are in southern China and the southern Urals. This research may, in future, help with resolving the issues raised on Little Asby Scar and in Janny Wood. However the legacy of the last one hundred years of published work is something the Ravenstonedale area can be proud of. Also to be celebrated are the conclusions of Aretz & Nudds (2007) that “a comparable Dinantian biostrome has not previously been reported from the Laurussian shelf”.

References and Acknowledgements

- Fig 1. Permission to use the Ordnance Survey map from the Friends of the Lake District.
- Fig 3. Modified from Waltham, T. 2013. Caves and Karst of the Yorkshire Dales, a BCRA publication p 13.
- Fig 15. Permission to use an extract from Sheet 40 obtained from BGS, Permit Number CP18/005.

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DRY STONE WALLS AS SEDIMENT TRAPS: EXAMPLE FROM RYDAL

Peter Wilson and Tom C. Lord

Introduction

The storms and devastating floods that have affected northern England in recent years have brought into sharp focus the ability of water to erode and transport large volumes of hillslope debris. This is no more so than in the Lake District, where intensive and/or prolonged precipitation in combination with steep relative relief can cause superficial debris to move considerable distances in short periods. The processes involved range from fluvial (water-dominated) flows to viscous debris flows in which water acts as a lubricant, reducing shear strength and causing materials to sludge downslope. Ultimately, upper slopes become denuded of their superficial debris covers while lower hillsides and valley floors accumulate materials. Sediment transfers of this nature have become important land-shaping processes since the ice of the main Late Devensian glaciation began to wane (~22-20 ka), exposing glacial debris to snow melt and rainfall. In upper valleys that hosted glaciers during the Loch Lomond Stadial (~12.9-11.7 ka), the reworking of slope debris began as those glaciers decayed. With climatic amelioration at the start of the Holocene (~11.7 ka), sediment transport rates are likely to have reduced significantly as vegetation colonised and provided a protective surface cover, and humus and root systems helped to bind materials and hold them in place. However, at various times throughout the Holocene, brief periods of climatic deterioration along with the introduction and later intensification of agriculture, and ground disturbance brought about by the mining and quarrying of rocks and minerals, probably caused short-term increases in transport rates.

Many Lake District hillslopes are seamed by gullies that cut into both superficial debris and bedrock. At the foot of these gullies a marked reduction in slope gradient occurs as valley floors are reached and it is there that much debris from the gullied slopes has been deposited. These accumulations of material often take the form of a fan, splaying out from the gully foot, and are termed either alluvial fans or debris/colluvial fans depending on their surface gradient and the dominant process of transport and deposition. In former glaciated regions like the Lake District most fans have been constructed by both fluvial flows and debris flows, and are essentially composite features.

In several Lake District valleys, some fans have been incised or trimmed along their distal margins by trunk streams and reveal organic horizons buried within the mineral sediment. These horizons testify to periods of fan stability, marked by vegetation growth on the fan surface and development of organic-rich soils. Subsequent burial of these organic soils is taken to indicate an increase in the intensity of hillslope erosion and the downslope transport of debris. Such stratigraphic sequences are indicative of episodic fan development.

Buried organic-rich soils have been recorded in fan exposures near Seathwaite in Borrowdale (Parker *et al.*, 1994; Wild *et al.*, 2001), at Iron Crag in the northern fells (Johnson & Warburton, 2006), in the Newlands valley, and at Blindtarn Moss near Grasmere (Chiverrell *et al.*, 2007), and in the Pasture Beck valley, above Hartsop (Clark *et al.*, 2007). Radiocarbon dates obtained from these organic horizons indicate some consistent patterns of recent fan stability/instability. Phases of fan aggradation may be allied to land-use changes brought about by Norse-Irish settlers ~1000 AD, and climatic deterioration in the 14th and 15th centuries AD, associated with the Little Ice Age, is also considered to have caused increased sediment input to fans. Therefore, although fans may have started to develop as the last glaciers decayed, they have continued to be active into the late Holocene.

Fans and walls

In some Lake District valleys, debris/colluvial fans have accumulated against the upslope side of dry stone walls that are aligned across slope, in mid-to-lower slope locations. As a consequence, the fans are perched on the valley sides rather than being at the slope foot. Examples of this phenomenon can be seen on the upslope side of walls that traverse the hillside at ~170-190 m above sea level (asl) between the Old Dungeon Ghyll Hotel and Raven Crag in Great Langdale (Fig. 1): “walls have acted as temporary dams to this down-slope creep of fan material” (Barringer, 1970, p.43). These walls are regarded as ‘Statesmen Walls’ constructed between the late 16th century and ~1750 AD (Lund & Southwell, 2002) and therefore fan accumulation to the full height of the walls (~1.5 m) has taken a maximum of ~300-350 years. Fan surface debris consists of unvegetated angular clasts and is continuous upslope with talus. At these locations, the rate of downslope movement may have been accentuated during the last 100 years or so as a consequence of human traffic along footpaths that cross the talus and lead to the rock climbing routes on Gimmer Crag, Middlefell Buttress and Raven Crag.

Clark (2001) referred to the build-up of soil to the crest of the lower walls as a result of soil creep accelerated by ploughing across slopes in the



Figure 1. Wall above the Old Dungeon Ghyll Hotel in Great Langdale overtopped by downslope movement of talus.

vicinity of Hartsop. He noted that some walls have been overtopped or pushed over and speculated whether the debris behind the walls might carry a record of accumulation rates, and episodes of relative stability or rapid downwash events. From the Lomond Hills of Fife, Scotland, Ballantyne and Eckford (1984) recorded an example of talus creep against a wall. The build-up of “soil” behind an old wall constructed across the lower hillslope was noted to have entirely buried the wall in places.

An additional Lake District location where dry stone walls have impeded the downslope movement of sediment is Dalehead Close in the upper Rydal valley. The perched fans in this valley were described briefly by Wilson (2010, p.148-149). In this paper we provide greater detail of the locations, dimensions and characteristics of these unusual and apparently little studied features, and consider their geomorphological significance.

Dalehead Close, Rydal

Dalehead Close (Grid Reference NY 363096; Fig. 2) is the name of the northernmost enclosure in the upper Rydal valley. It extends north - south for 1.4 km, has a maximum width of 0.65 km, and encompasses 0.75 km² of the valley floor and lower slopes of Great Rigg (766 m), to the west, and Dove Crag (792 m), to the east. The enclosure rises from 300 m asl at its

southern end to 460 m asl near to its northern limit, and its boundary is defined by a dry stone wall 3 km in length. For most of its length the wall is aligned across the local hillslope or is slightly oblique to it and is therefore orthogonal to hillslope drainage routes. At nine locations on the upslope side of the western arm of the enclosing wall, and at two locations on the eastern arm, debris has been transported downslope and has accumulated against the wall. On the west side of the valley immediately south of Dalehead Close, another fan is also banked against the wall. At the margin of each fan the wall stands to heights of 1.25 - 1.9 m, but this rapidly diminishes towards the centre of the fans where the debris is level with the capstones of the wall, or very nearly so. In all cases a length of post and wire fencing has been erected parallel with the obscured section of wall in order to deter sheep from using the fan surface as a platform for jumping into the enclosure.

Fan details

Brief details of each fan as recorded in October 2016 are provided below. The fans are numbered 1 - 12 and their locations are indicated on Fig. 2.

Fan 1: This fan (Grid Reference NY 361090) is immediately south of Dalehead Close where the dry stone wall descends the hillside obliquely and meets the southwest angle of the Dalehead Close wall. Debris is banked against the wall for a distance of 47 m and has reduced the visible height of the wall to 0.25 - 1.1 m. To the south of the fan wall height is 1.85 m and to the north it is 1.4 m. The fan and its feeder gully are predominantly vegetated with only a few small areas of surface debris evident (Fig. 3).

Fan 2: At Grid Reference NY 361093 the Dalehead Close wall is totally obscured on its upslope side for a distance of 20 m, and for another 34 m the wall height is less than 1.5 m. Wall height on either side of the fan is 1.5 - 1.75 m. The fan surface is vegetated, with palaeochannels and levees evident, and current channel flow is along the margins of the fan. Figure 4 shows the fan from the opposite side of the valley, from where the upslope-facing height of the wall cannot be seen.

Fan 3: Wall height has been reduced to less than 1 m for a distance of 88 m around Grid Reference NY 361095, and debris obscures the wall entirely for a distance of 17 m. Wall height adjacent to the fan is 1.5 - 1.7 m. Open channel flow was observed along the north margin of the fan with the water percolating through the wall.

Fan 4: A 33 m length of wall is partly obscured by fan debris at Grid Reference NY 360097. The wall height has been reduced from 1.6 m at the margins of the fan to between 0.5 - 1 m where the debris occurs. The fan surface, with palaeochannels, is completely vegetated. No water flow was seen crossing the fan surface but open channel flow was evident higher on the slope.

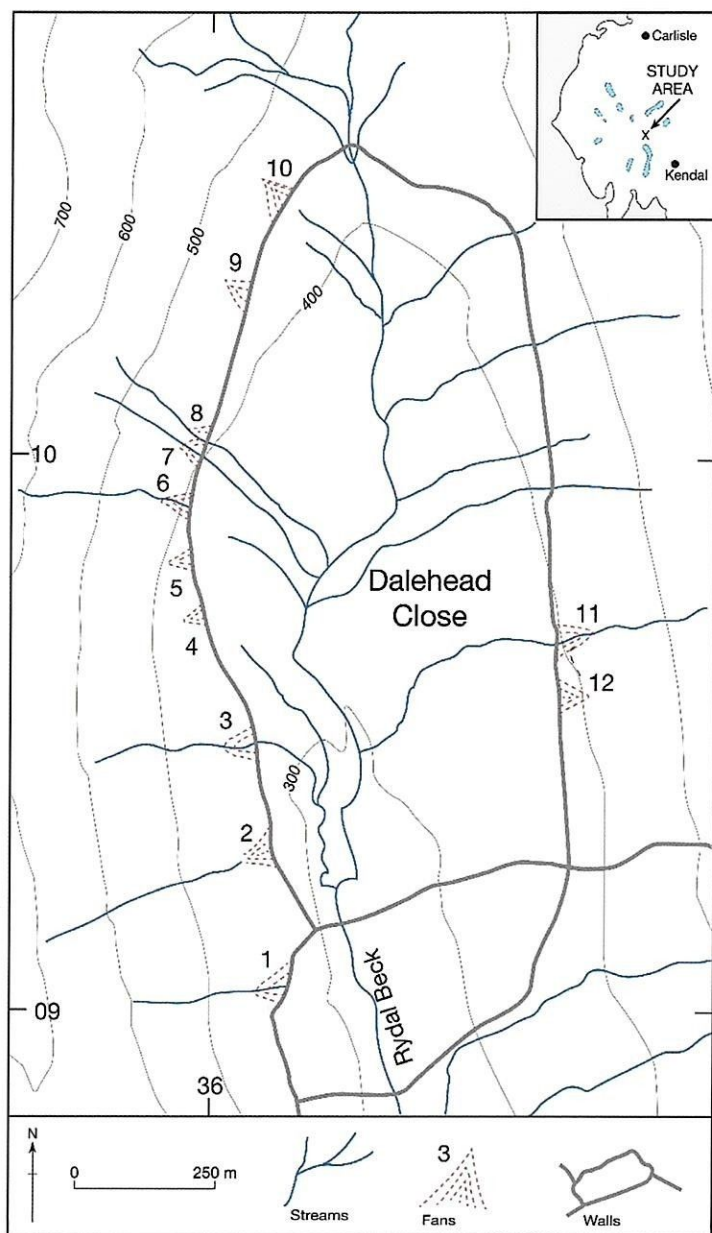


Figure 2. Map of Dalehead Close, Rydal, showing locations of the debris fans. Note that fans are shown schematically rather than at their true scale. Contours are in metres and grid line co-ordinates are given in the margins.
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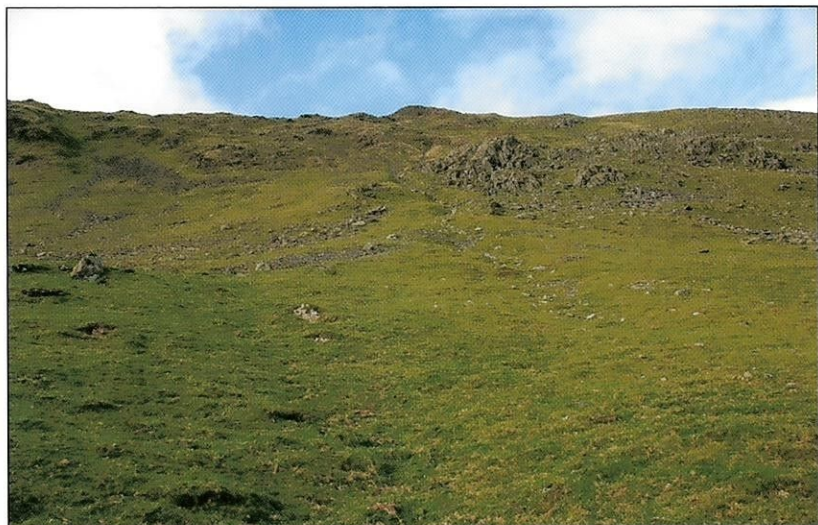


Figure 3. Vegetated hillslope above Fan 1. There is no evidence of recent surface flow or sediment transport down this slope, although shallow palaeochannels are present.

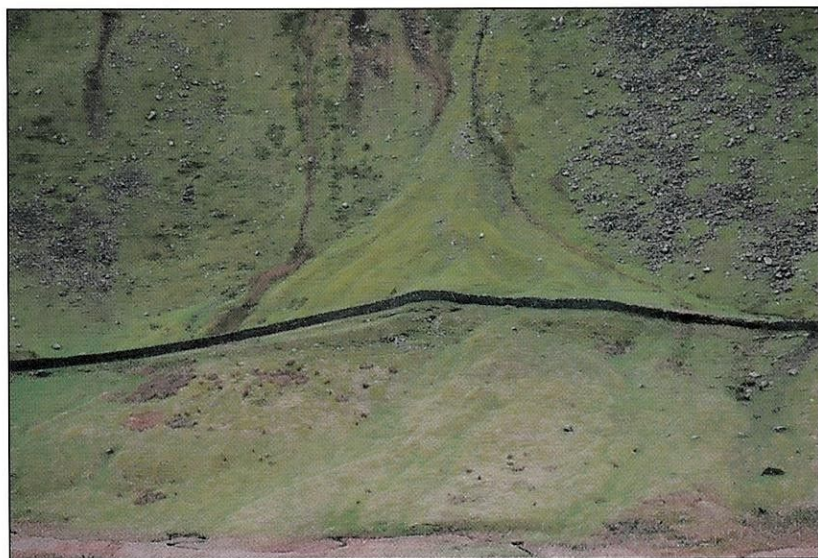


Figure 4. Fan 2 as seen from across the valley. The fan surface is almost totally vegetated although palaeochannels and levees are still evident. Water flow is currently to south (left) and north (right) of the fan, as indicated by the rush-infested (darker vegetation) drainage lines.

Fan 5: Fan debris is banked against the wall for a distance of 24 m at Grid Reference NY 360098 and wall height has been reduced to 0.5 m. The fan surface and upslope gully were dry although the former has a cover of weathered boulders.

Fan 6: This fan, at Grid Reference NY 359099, has a cover of recent debris, 0.5 - 0.6 m in thickness, trapped by the post and wire fence (Fig. 5). Prior to this input of sediment, the vegetated fan surface stood slightly above the capstones of the wall, which were obscured for a distance of 20 m. The recent debris extended for 22 m along the fence and in plan it tapered upslope for 20 m to the foot of an incised channel. The debris is probably a product of the December 2015 storms. Wall height south and north of the fan is 1.3 - 1.6 m.



Figure 5. The surface of Fan 6 with recent debris from the December 2015 storms trapped against the fence. The vegetated surface of the fan to the left of the fence is slightly higher than the wall.

Fans 7 and 8: These two fans are adjacent at Grid Reference NY 360100 (Fig. 6). Prior to the storms of December 2015 water from both gullies was able to pass through gaps in the wall and carry fine sediment to the valley floor; the field evidence suggests that any pre-existing fans were of limited extent and thickness. As a consequence of the storms the wall was breached for lengths of 9 m (Fan 7) and 3.5 m (Fan 8), and at the latter site some debris remains level with the top of the wall adjacent to the breach. At both places the wall has been rebuilt and water is free to flow through as before.

Immediately upslope of Fan 7 is an incised channel 1 - 2 deep, and near the head of each gully there is a shallow landslip scar (Fig. 6). It is inferred that the saturated debris from these landslips was transported rapidly downslope and caused much coarse sediment to be trapped against the wall, and destroyed two short segments of the wall where the streams passed through.



Figure 6. Fans 6, 7 and 8. Shallow landslip scars (ringed) are present near the heads of the gullies that feed Fans 7 and 8. Prior to December 2015 debris accumulation upslope of the wall at Fans 7 and 8 was very limited in its extent and thickness.

Fan 9: At Grid Reference NY 361103 the wall is partly obscured by debris for a distance of 65 m, including a length of 20 m along which only the capstones are visible. Wall height to south and north of the fan is 1.6 m. Several vegetated palaeochannels can be seen on the fan surface but no recent sediment deposition was noted.

Fan 10: The wall is obscured by fan debris for a distance of 9 m and partly obscured for a further 22 m at Grid Reference NY 361104. Wall height beyond the fan margins is 1.7 m. A substantial rowan tree is rooted in fan debris where it abuts the wall (Fig.7). The fan surface has vegetated palaeochannels and scattered boulders. Active channels occur along the south and north margins of the fan.



Figure 7.
Downslope view of
Fan 10 showing a
substantial rowan tree
growing from the debris
where it is level with
the top of the wall.

Fans 11 and 12: These adjacent fans are on the east side of Dalehead Close (Grid Reference NY 366096) and on both the debris is unvegetated. Fan 11, fed by a single incised stream channel, has obscured the 1.5 m high wall for a distance of 18 m (Fig. 8). In contrast Fan 12 is a compound area of debris brought downslope by several shallow stream channels. Debris from these channels extends alongside the wall for ~150 m and in the past may have overtopped or breached the wall. The present wall in this area looks to have been rebuilt recently but does not rise more than 1 m above the debris. While both fans are likely to have had debris added to them during December 2015, they were first recorded as active fans in 2004 by one of the authors.



Figure 8. The debris of Fan 11 is level with the top of the wall and has spilt over into the enclosure. It has also disturbed the fence that was built to maintain the boundary and prevent sheep from jumping into the enclosure.

Age of dry stone walls and Dalehead Close

Dry stone walls are an integral part of the upland landscapes of northern England and have been used as boundaries since late prehistoric or Romano-British times. However, the walled landscapes of the present-day have their origins in the medieval and post-medieval periods (Rollinson, 1972, 1998; Winchester, 2016). For some walls documentary evidence relating to their age may be available; in other cases, wall age may be ascribed to a certain period based on construction style (Lord, 2004). Establishing the age of the Dalehead Close wall would be useful as it would define the maximum period during which the fans had accumulated. However, over time walls may have been destroyed and rebuilt several times so that using them to determine sediment accumulation rates is fraught with difficulty.

Dalehead Close is listed by John Bankes, Steward of the Rydal Estate, in a valuation list of 1655 (Armitt, 1916), indicating that it was a defined area of land and was probably walled. However, no reference to a wall at Dalehead Close has been found in the account books of Sir Daniel Fleming (1633-1701), titleholder of the Rydal Estate from 1653 (Blake Tyson, pers. comm. 2005).

In the absence of documentary records, an alternative means of determining when a wall was constructed is by examination of the shape of the wall profile, where lengths of wall survive in good condition. The profile of the Dalehead Close wall from the footings at its base all the way up to the top stones is visible in the wall head at a gateway near the southwest corner. The wall head shows that it is a double wall with the outer edges of the stones placed on either side of the wall so that the width of the wall gets narrower towards the top. It is an example of a narrow-top double wall (Lord, 2004) where the width of the face stones beneath the top stones rarely exceeds 45 cm. In the Yorkshire Dales it has been suggested that this style of double wall construction was a post-medieval innovation replacing the earlier wide-top double wall forms of the sixteenth century. It is considered that narrow-top double walls in the Lake District are of a similar age (Rollinson, 1972, 1998; Pearsall & Pennington, 1973; Whyte, 2003; Winchester, 2016).

Another aspect of the structure of the Dalehead Close wall enables it to be dated more precisely. Clearly visible in lengths of the structure are two rows of carefully placed through stones that project from the wall (Fig. 9). Narrow-top double walls with regular arrangements of one or more rows of through stones are documented in eighteenth century specifications for new build walls (Raistrick, 1946). It is very likely that the Dalehead Close wall was built sometime between the mid-eighteenth and early nineteenth century, and very likely built to specifications by a professional walling contractor.



Figure 9. A section of the downslope-facing Dalehead Close wall with rows of projecting through stones at 0.5 m and 1.2 m above base. The survey pole divisions are at intervals of 0.2 m.



Figure 10. Remains of a former wall downslope of the extant wall at Dalehead Close. The survey pole divisions are at intervals of 0.2 m.

There is some evidence for a precursor wall, as implied by the 1655 valuation (Armist, 1916), at several locations on the downslope side of the extant wall along its western arm. At these sites, banks of large boulders aligned parallel with the extant wall are visible (Fig. 10). In some places, the extant wall is directly on top of the boulder bank, in others the boulder bank is 1-2 m downslope of the wall. From this field evidence an inference might be that wholesale rebuilding of the Dalehead Close wall as a narrow-top double wall took place no earlier than the middle of the eighteenth century and no later than the middle of the nineteenth century.

Problems determining sediment accumulation rates

Although an approximate age may be assigned to the Dalehead Close wall, deriving and reporting sediment accumulation rates as annual averages is not easy. The surface area of each fan and the underlying slope gradient would need to be measured in order to ascertain debris volume. A representative value for sediment porosity would have to be established and then subtracted to obtain net volume. Most of this could be done by detailed surveying, although coring or trenching of the fans, or geophysical profiling, would also provide valuable data. If this detail was obtained and dates of 1750 AD and 1850 AD assigned as maximum and minimum ages of wall construction, average annual rates of sediment accumulation could be determined for each fan.

However, as was demonstrated in December 2015 at Fans 7 and 8, and probably Fans 11 and 12, large quantities of debris may be added to the fans in single, short-lived events that can cause breaching or overtopping of the wall and result in some debris being transported farther downslope. Therefore, the fans do not necessarily retain all the debris brought down the hillside since the wall was built. Even on those fans (the majority) that appear not to have been affected by the 2015 storms, we cannot assume that they accumulated by small additions of debris on a regular (annual) basis. It is more likely that they too experienced storm-related inputs of debris in the past and that on some of those occasions the wall was destroyed and subsequently rebuilt. Without detailed information concerning the magnitude and frequency of storms during the last 170-270 years and a record of wall rebuilds, reporting accumulation rates in terms of annual averages is not recommended and therefore has not been attempted. A summary of specific storms and destructive flood events in other Lake District valleys is provided by Johnson & Warburton, (2002). From this it may be surmised that Rydal has also been affected by destructive storms in the past, but for which there are no records.

Nevertheless, a crude estimate of the minimum volume of debris trapped by the wall has been made. This is based on the total length of wall against which debris has accumulated (~600 m) and assumes the average thickness of debris to be ~1 m. It also assumes that although debris thickness declines upslope, for the first 10 m it is of an approximate uniform (1 m) thickness. These values indicate 6000 m³ of debris. By applying a sediment porosity value of 25% (cf. Carling, 1987) this reduces to 4500 m³. Using a rock density of 2.65 g/cm³ (2.65 t/m³) this volume converts to ~12,000 tonnes of debris, for the lower reaches of the 12 fans.

Significance of the fans

Although the Dalehead Close fans are small landforms they are significant in at least three ways. First, irrespective of the age of the wall, they indicate that small fans can form rapidly if runoff is sufficient and sediment is available. This has implications for larger fans which are sometimes assumed to represent sediment accumulation over several millennia. Rather, some large fans may have developed in response to extreme climatic events and an abundant sediment supply in relatively short periods (several centuries). Second, because several of the fans do not appear to have been affected by the storms of December 2015 and are now considered to be inactive, it may be inferred that the sediment supply in their source areas has been exhausted. If that is so, then it is only because of the wall that a record of debris flows at those sites is preserved. Without the wall the debris is likely to have been transported and deposited farther downslope. In such circumstances it would be unlikely that debris deposition could be ascribed to the last few hundred years. Third, the active fans demonstrate that on some hillslopes in Rydal sediment supply has not been exhausted and during episodes of intense or prolonged precipitation debris flows continue to be effective means of sediment transport, and can cause temporary disruption and costly repairs for land users.

Conclusions

Dry stone walls in the upper Rydal valley have acted as effective traps to the downslope movement of coarse debris. The age of the wall constrains the age of the fans, which in turn enables debris volumes to be estimated. Field evidence indicates that some of the fans are no longer active and this may be because the sediment supply above these sites is now exhausted. Other fans remain active with the debris flow process continuing to add material during storm events. The fans have accumulated within the last 270 years and although of small size are testimony to the continuing downslope movement of debris and its ability to cause short-term economic impacts.

Acknowledgements

We thank Anna Ratcliffe for preparing Figure 2.

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THOMAS HAY AND PLOUGHING BLOCKS

Peter Wilson

Introduction

The term 'ploughing blocks' was used by Tufnell (1966) to describe surface boulders that have travelled downslope faster than the surrounding soil material and, in so doing, have created a depression on their upslope side and/or a mound of soil at their downslope edge. They are solifluction features, and credit for their first recognition is attributed to Sernander (1905) (Tufnell, 1972; Reid & Nesje, 1988; Hall *et al.*, 2001). In the uplands of northern England, ploughing blocks had been termed 'gliders or gliding blocks' by Hay (1937, 1942). The definition provided by Hay: "a roll of turf pushed up in front of the bottom end of the block and a furrow behind the block running a few yards up the slope" leaves no doubt that these gliding blocks are the same as ploughing blocks. It is with Hay's recognition of gliding/ploughing blocks in the Lake District that this short note is concerned.

Intriguing photographs



Figure 1. Clifton Ward's glider
(from the Thomas Hay photographic archive).



Figure 2. George's glider (from the Thomas Hay photographic archive).

Although Hay did not show a picture of a gliding block in either of his papers that mention them (Hay, 1937, 1942) there are two glass-slide photographs of gliders among the collection of his field maps and slides made available to the late Richard (Dick) Clark in the 1990s. One of these slides carries the title 'Clifton Ward's glider', the other 'George's glider'; they are reproduced here as Figures 1 and 2 respectively. In Figure 1, the boulder seems to lack a frontal mound of soil and, because of the angle from which the photograph was taken, only a trace of an upslope depression can be seen. Part of a frontal mound is visible in Figure 2 and a shallow depression in which the walking stick has been placed can also be seen. Hay regarded both as gliding blocks.

An intriguing aspect of Figure 1 of relevance to the issue of primacy in recognition of the phenomenon is Hay's use of Clifton Ward's name in the title. Clifton Ward (1843-80) was one of the early Lake District geologists and published 22 papers on the district between 1870 and 1879 (Smith, 2001). An implication of Hay's title might be that Ward had identified gliding blocks during the course of his researches and had made particular reference to the boulder that Hay was to later photograph. If that were so, it would indicate the recognition of these types of boulders had occurred at least 25 years before the report published by Sernander (1905). However, an

examination of Ward's publications has failed to locate any such reference and therefore it is not (yet) possible to transfer the tag of scientific primacy from Sernander to Ward.

It might never be known why Hay titled the photograph in the way he did. His period of Lake District research did not overlap with that of Ward, the two could not have met in that context but Hay was clearly aware of Ward's work; his publications cite some of Ward's studies. Hay was encouraged in his Lake District research by J.E. Marr, Professor of Geology at St. John's, Cambridge; Marr had been a lecturer there when Hay was a student of mathematics (Clark, 2001). It is possible that Marr knew of Ward's recognition of gliding blocks and informed Hay of a specific example. Although Marr was clearly aware of the hillside surficial phenomena associated with soil temperature changes, only passing mention of their occurrence is made in his Lake District book (Marr, 1916, p.197).

The title of Figure 2 ('George's glider') is also intriguing, but less so than that of Figure 1. George may have been the dog shown on top of the boulder, or a fieldwork companion of Hay's but he only mentions having undertaken field excursions in the company of geologists Sydney Ewart Hollingworth and John Jerome Hartley, neither of whom were known as 'George'.

The locations at which the photographs were taken are not known but Hay's studies focussed largely, but not exclusively, on the fells to the east of Dunmail Raise. He lived for several of his retirement years in Glenridding and his primary description of gliding blocks is in his 1937 paper entitled 'Physiographical notes on the Ullswater area'. It may be assumed that Figures 1 and 2 were taken within that area.

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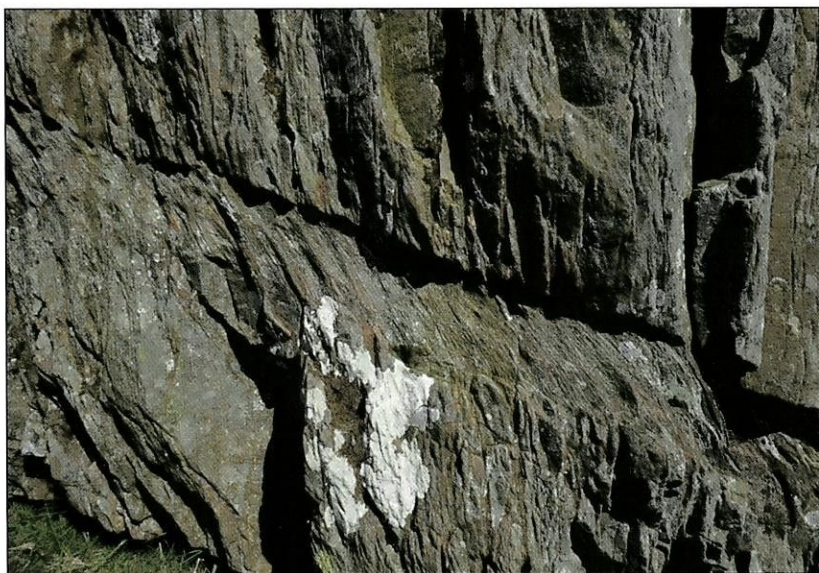
FIELD RESEARCH PROJECTS

GAWTHWAITE

Leader: Clive Boulter

10 June and 30 September 2017

A novel approach was tried here in an attempt to lay the bogeyman reputation of structural geology. At the end of the day it was hoped that participants would have a basic grasp of stereographic projections in terms of gathering orientation data, plotting it, and interpreting the resultant patterns; having gained this knowledge those attending would be better placed to follow arguments presented stereographically at indoor meetings, field trips, and in publications. Such lofty ideals were at the mercy of the weather and the day-long torrential rain meant a truncated approach had to be implemented. 15 members met at 10h00 in the Greyhound Inn, Grizeback, to be briefed on what conventions were to be followed for recording dip & strike of bedding, and plunge & bearing of linear features, using compass-clinometers. Additionally remote sensing images [Google Earth and Bing] of the study area were introduced to show the overall nature of the fold being documented. A final part of the orientation briefing showed some features to be observed in the exposures; the internal subdivisions of the turbidite deposits [T_a, T_b, T_c etc.], cleavage refraction between slate and wacke/arenite beds, and curvature of cleavage in graded beds. Perhaps we should have had a hot toddy to fortify us for what was to come?



Cleavage Refraction NW of the Thrust

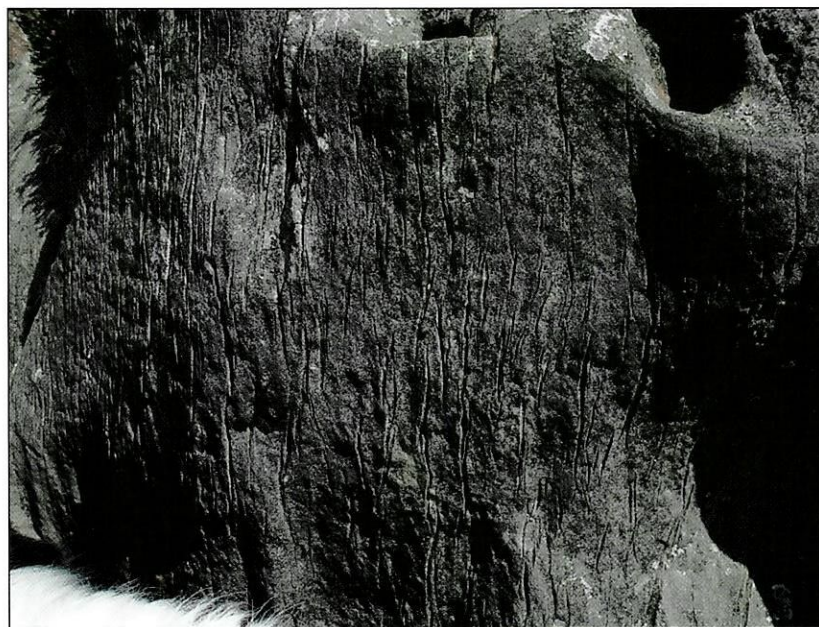
It was then time to head off into the bucketing rain. In the atrocious conditions it soon became apparent that the original programme was not practicable so the group were taken to three localities that demonstrated the nature of this three-limbed fold. Two limbs are gently dipping and right way up whereas the third limb dips steeply and is overturned. Cleavage/bedding relationships were originally to be left for the afternoon session but it was apparent that the return visit was not going to happen so these geometries were briefly outlined. At the first locality the process of using a compass-clinometer, to measure bedding dip & strike and linear plunge & bearing, was demonstrated and the group collected some of their own orientation data here and at other localities.



Cleavage refraction gently dipping limb



Water Escape Structures convolute lamination in turbidite C horizon



Two cm spaced sandstone cleavage



Cleavage refraction and curvature on overturned limb

The saturated participants returned to the Greyhound Inn and, after refreshments, the leader introduced the concepts of stereographic projection, and the mechanics of plotting bedding planes and linear features. To move on to the practical session the leader provided selected bedding readings for the three limbs to supplement the meagre data that members had collected themselves. Tracing paper, stereonet, and drawing pins, were deployed and, after much scratching of heads, members were pleased to find that the data they had gathered all lined up on a great circle which defined the plunge and bearing of this large fold that is too big to measure directly; some measure of success!

The original plan was to return to the field, after the introductory stereographic session, to learn how to measure slaty/sandstone cleavage, and cleavage/bedding intersection lineations. These data could then have been taken home for participants to plot for themselves having already grasped the basics of the procedure; the total database generated was then to be analysed by the trip leader to write-up for a joint publication in the Society's Proceedings. Clearly nowhere near enough data had been collected to contemplate the original objective. A suggestion arose from within the group that we should have a return visit on another day to complete the project. September 30th was chosen but this turned out to be even wetter

than the first day in June with flooding on the West Coast figuring on national TV news broadcasts! Wading through sheet floods to get to the rocks dampened enthusiasm but a couple of hours were spent discussing fold/cleavage relationships, younging information, and the location of the thrust that is genetically related to the fold. No orientation data were gathered!

Subsequent return visits by Clive Boulter and others, in ever cooler conditions, have generated a body of orientation data that indicates a more complicated situation than the initial measurements indicated. For a moderate database the bedding readings have a fairly straightforward distribution but as more data were added it was realized that much more data and analysis were required. A task for the summer of 2018. During the first day members commented on how different the field meeting was compared to many Society days out and expressed a wish for more events that involved activities of this style though with a little less rain!

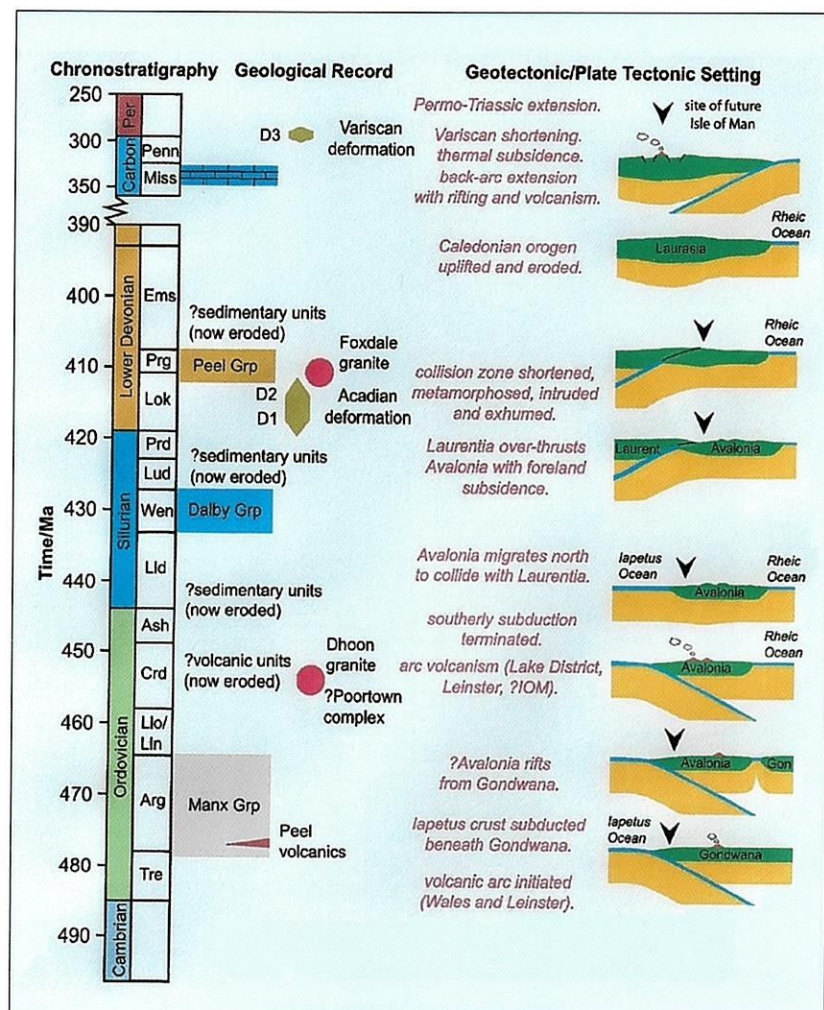
The Greyhound Inn at Grizebeck provided excellent facilities for the two indoor sessions on the first day and are to be thanked for their support especially when a very wet group returned from the morning in the field.

CGS FIELD TRIP TO THE ISLE OF MAN

Leader: Dr Stephen Crowley

11th to 14th July 2016

Our party gathered in Douglas on the evening of Monday 11 July and Stephen set the scene by outlining the Palaeozoic geology of the Isle of Man (IOM). Similarities between the geology of the Isle of Man and the Lake District were summarized and the potential significance of these similarities was discussed.



Tuesday 12 July. Lower Ordovician metasediments, Acadian deformation and metamorphism, Lower Devonian granite magmatism, and base metal mineralization

We started the day at Marine Drive, approximately 2 km south of Douglas, by examining road-side exposures of thinly bedded (cm-scale) turbidites of the Lower Ordovician Manx Group (Lonan Formation). Examples of sole marks (flute casts, tool marks), internal depositional structures (parallel and climbing ripple cross lamination) characteristic of the classical Bouma sequence, and bioturbation were examined. Manx Group sediments are along-strike, stratigraphic equivalents of the Skiddaw Group (Lake District), and together these major sedimentary units (in excess of 5 km thick) represent the product of deposition on a series of evolving deep sea fan complexes developed while Eastern Avalonian was still attached to Gondwana.



Flute casts on Marine Drive

At Port Grenaugh we briefly viewed examples of inter-laminated (mm to cm-scale) siltstones and mudstones (Lonan Formation) deposited from dilute turbidity currents on the distal margin of a deep sea fan lobe before walking the short distance (1 km north) to Purt Veg. Here we examined a package (~50 m thick) of coarse grained clastic sediments (Santon Member) within the Lona Formation consisting of thickly bedded (m-scale), parallel laminated and cross bedded sandstones. The Santon Member is thought to represent deposition in a major distributary fan channel incised into finer grained fan lobe deposits of the Lona Formation.

Lunch was taken at Calf Sound with excellent views of the Calf of Man and the resident seal population basking in the mid-day sun.

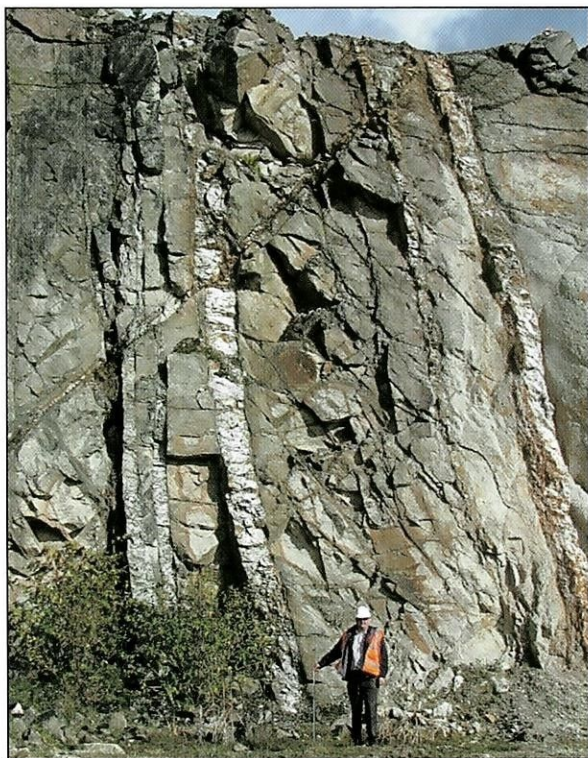


Two phase Arcadian folding at Port Erin

At Port Erin we were introduced to the effects of polyphase structural deformation (refolded folds) of the Lower Palaeozoic sedimentary succession on the IOM and an unambiguous example of upright (F1) folds deformed by flat-lying (F2) folds was demonstrated. The folding and associated low grade (green schist facies) regional metamorphism are assigned to the end-Caledonian Acadian (Lower Devonian) orogenic event responsible for the development of slaty cleavage in Lower Palaeozoic rocks throughout the central British Isles and Ireland. Importantly, the Acadian deformation event post-dates closure (mid-Silurian) of the Iapetus Ocean and the contact of the

East Avalonia microcontinent with Laurentia by approximately 20 to 30 Ma. Consequently ocean closure seems to have had little discernible impact on the deformation history of Lower Palaeozoic sediments and closure appears to have been entirely passive. However, details of the plate tectonic forces driving deformation and regional metamorphism of the Lower Palaeozoic succession during the Acadian event remain the subject of continued argument and a variety of geotectonic scenarios have been proposed to account for observed structural and metamorphic effects.

Following our visit to the south coast we travelled inland to Stoney Mountain quarry to view the only significant exposure of the Lower Devonian Foxdale granite. Here it is possible to see highly fractionated, muscovite granite within the roof zone of a large, pluton-scale, intrusion (proven by gravity survey) that underlies much of the southern half of the IOM. The granite is cut by numerous quartz, quartz-muscovite and, much rarer, quartz-microcline-muscovite-beryl pegmatites. The generation of granite magmas, crystallization conditions and precise temporal relationships between granite magmatism and Acadian deformation were discussed.



Foxdale granite quarry with cross-cutting quartz-mica pegmatite veins

At the nearby 19th century Cornelly Mine (approximately 2.5 km north of the quarry), the site of economic galena mineralization on the west-east oriented Foxdale Trend, we examined a rather unprepossessing, but highly significant exposure of garnet grade contact metamorphism of Manx Group metasediments that resulted from intrusion of the Foxdale granite. Microscopic evidence in the form of refolded microcleavage preserved within garnet porphyroblasts was presented and compared with the two-stage deformation history observed in Manx Group rocks at Port Erin. It was argued that the microstructural evidence proves that granite emplacement was synchronous with the deformation and that the age of the granite, now proven by U-Pb dating of zircon (408.9 ± 2.9 Ma), provides an accurate age for the Acadian orogenic event. The evidence demonstrates that the timing of Acadian deformation is significantly older, by at least 10 Ma, than the currently accepted mid-Devonian (390-400 Ma) age.

Wednesday 13 July. Upper Ordovician basic magmatism, mid-Silurian metasediments, Acadian deformation and metamorphism, and Lower Devonian fluvial sediments

It was intended to begin Day 2 by visiting the large working quarry at Poortown, near Peel. Unfortunately an incident at the quarry during the previous day prevented us from entering. Instead we discussed the geology in a nearby car park. The quarry, developed in a complex of highly altered (actinolite-chlorite-carbonate-zeolite) dolerite sills, represents the island's main source of road stone. Although no radiometric dating evidence is available, the geochemical composition of these rocks suggests that the sills represent basic magmas produced by partial melting of the mantle during southerly directed subduction of Iapetus oceanic crust beneath Eastern Avalonia. In this respect the Poortown intrusions are thought to be along-strike, sub-volcanic equivalents of Upper Ordovician destructive margin volcanic magmatism (Borrowdale Volcanic Group, Eycott Volcanic Group) exposed in the Lake District.

We then travelled approximately 8 km southwest to Niarbyl where the only known contact between Lower Ordovician Manx Group (Creggan Moar Formation) and mid-Silurian (Wenlock) Dalby Group sediments is exposed. Over a distance of 100 m relatively weakly deformed Manx Group metasediments pass into a zone of intense mylonitization and tectonic lamination. The contact between mylonitized rocks and the relatively undeformed Dalby Group is defined by the Niarbyl thrust. A brief explanation of the Niarbyl high strain zone structures was presented and contrasting models proposed to explain tectonic relationships between Lower Ordovician and mid-Silurian sediments were discussed. One

possible explanation suggests that the contact zone might represent a tectonically modified unconformity surface. If this could be proven then it would have important implications for the tectonic evolution of the IOM.



Niarbyl strongly laminated mylonite. The scale is 10cm.

Having explored the transition from Lower Ordovician to mid-Silurian sediments at Niarbyl we then drove 7 km north to Peel. Here we visited Traie Dullish quarry to examine a representative succession of fine grained, turbidite metasediments that characterize the Dalby Group. For many decades the sediments exposed in the quarry were assumed to be part of the Lower Ordovician Manx Group and only recently have graptolites and orthoconic nautiloids been discovered that prove a mid-Silurian (Wenlock) age. By mid-Silurian times the remnants of Iapetus oceanic crust had been subducted beneath Laurentia, and Laurentia and Eastern Avalonia were separated by a relatively narrow seaway. The disused quarry exposes 10 m of thinly bedded, fine grained turbidite (with well-developed climbing ripple cross lamination) and finely laminated hemipelagic sediments deposited at the distal margins of a deep sea fan system. Excellent examples

of cleavage refraction, in which the angle of cleavage dip relative to bedding changes between coarser-grained (steeply dipping) and finer-grained (shallowly dipping) beds in response to differences in the rheological properties of silty and muddy sediments, were observed. The quarry section is also notable for the occurrence of a distinct bentonite (altered volcanic ash band) horizon in which local tectonic shortening has been preferentially accommodated by imbricate stacking of thin thrust slices.

A short, but intense summer downpour precluded the intended examination of coastal exposures of Dalby Group rocks beneath Peel Castle to view Acadian folding, greenstone dykes and a complex array of quartz filled tension gashes. Instead, we sheltered in the minibus, ate lunch and waited for the rain clouds to pass.

The sun reappeared soon after lunch and we proceeded to the northeastern side of Peel Bay where red beds of the Peel Group are exposed. The base of the Peel Group is not exposed and contact relationships with the surrounding Lower Palaeozoic succession are obscure and limited to a single faulted contact. The age of the Peel Group remained the subject of controversy for more than a century until samples containing identifiable plant spores were discovered in 2006. The spore assemblage supports a late Lower Devonian date.

Steeply (50° NW) dipping rocks exposed in coastal cliff sections between Peel Bay and The Stack expose conglomerates, sandstones, siltstones and mudstones that were deposited in a series of evolving fluvial and lacustrine environments. The lower 150 m of the succession consists of an overall fining (sediment grain size) and thinning (bed thickness) upward sequence of predominantly sandy fluvial sediments deposited by braided river systems. The upper part of the succession is essentially a coarsening and thickening upward sequence of silty, gravelly and conglomeratic sediments deposited in temporary lakes and shallow, gravel bed, braided river channels. This upper package of sediments is notable for the occurrence of numerous calcrete horizons (calcareous soil profiles characteristic of semi-arid climates), a diverse range of burrows and trackways attesting to the existence of a complex terrestrial ecosystem, and exotic limestone conglomerate clasts containing a rich, cosmopolitan (including corals, bryozoa, brachiopods, stromatoporoids) derived marine fauna of mid-Silurian (Wenlock) age.

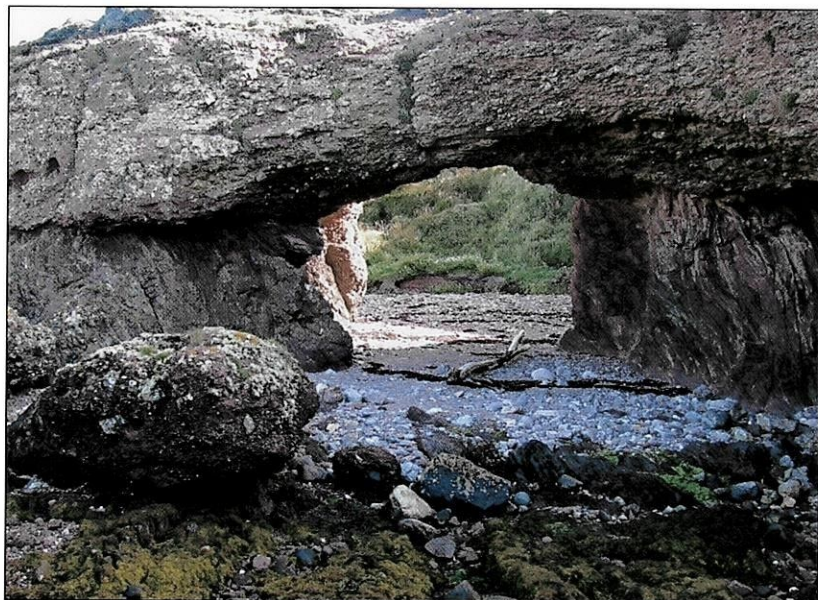


Bioturbation

Having examined the sedimentology of the Peel Group succession we discussed the potential geotectonic implications of the relationship between the relatively undeformed (steeply dipping, but no cleavage) Peel Group and more strongly deformed Lower Palaeozoic metasediments. The evidence suggests that the Manx Lower Palaeozoic succession, deformed and metamorphosed during the early Lower Devonian Acadian orogenic event at approximately 410 Ma, was rapidly exhumed (>2 km/Ma) before the Peel Group was deposited on a late Lower Devonian unconformity surface.

Thursday 14 July. Lower Carboniferous unconformity, Lower Carboniferous limestone dominated sediments and basaltic volcanism, Variscan deformation, and base metal mineralization

We began Day 3 at Langness peninsular where exposures of a classical angular unconformity between steeply dipping and reddened Manx Group metasediments and flat-lying Lower Carboniferous conglomerates and gravelly sandstones may be viewed. The significance of the unconformity surface was discussed.



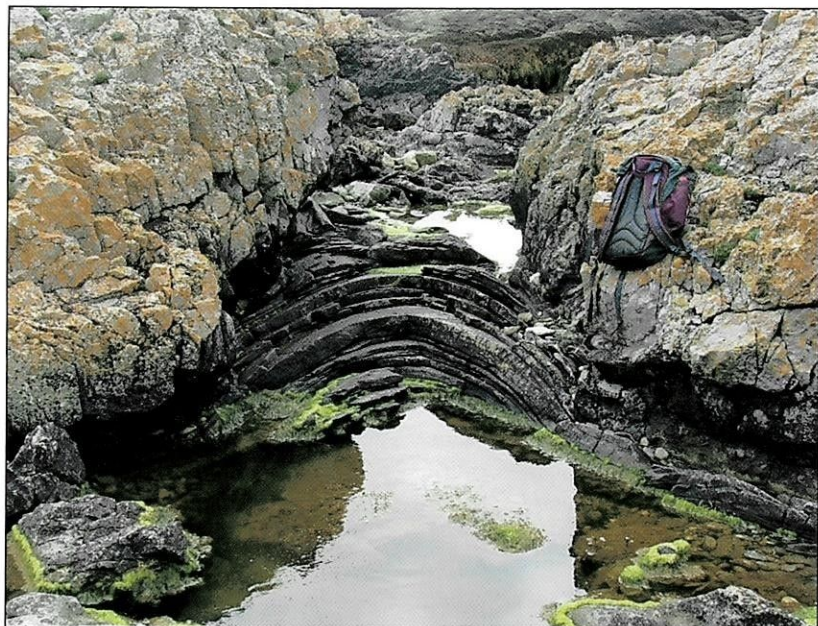
Lower Carboniferous angular unconformity

From Langness we travelled 2 km west around Castletown Bay to Scarlett where coastal sections expose the upper part (Holkerian to Brigantian stages) of the Lower Carboniferous succession. The succession consists of

limestones and interbedded, organic-rich, calcareous mudstones and limestones that represent the progressing drowning of a shallow marine carbonate platform. Examples of tectonic structures produced during end-Carboniferous Variscan deformation, including, monoclinial folding and vertical stylolites representing a spaced pressure solution cleavage, were also examined. Several Tertiary basalt dykes cross-cut the Lower Carboniferous sediments and, in one instance, intrude a small fault plane. These dykes, radiating from centres (North Atlantic Igneous Province) located to the NW of the IOM, result from Palaeocene magmatic activity associated with the opening of the North Atlantic Ocean and the separation of Greenland from NW Europe.

A short distance further west carbonate sedimentation gives way to the products of localised (Brigantian) basaltic volcanic magmatism. The succession, which is exposed continuously for 1.5 km along the coast, consists of a complex sequence of interbedded sub-aerial and subaqueous ashes, breccias and lavas cut by basaltic dykes. Pyroclastic units frequently contain blocks of Lower Carboniferous limestone country rock entrained during explosive eruption, while individual lavas are characterised by columnar jointing and vesicular textures with amygdaloidal infills. At The Stack (accessible only at low tide) an excellent example of columnar jointed basalt is exposed. It has been suggested that this basalt unit might represent the plugging of a volcanic vent, although it is more likely simply the product of a relatively thick lava flow. This phase of magmatism resulted from the partial melting of the upper mantle during extension and thinning of Manx continental crust in response to subduction of the Rheic Ocean several hundreds of kilometres to south of the IOM.

Following our visit to Scarlett we moved a further 2 km northwest to investigate further coastal sections in the Lower Carboniferous succession between Strandhall and Close-ny-Chollagh. We stopped for lunch at Poyll Richie where Lower Carboniferous limestones have been intensely brecciated and dolomitized by the combined effects of faulting and circulation of hydrothermal fluids. Dolomitization is associated with the generation of vuggy carbonate dissolution porosity and minor galena-sphalerite-quartz mineralization. Approximately 0.5 km south of Poyll Richie dolomitized limestones are replaced by unmodified massively bedded reef limestones and thinly interbedded off-reef limestones containing debris shed from the adjacent shallow marine platform and dark, calcareous mudstones with small, lenticular bioherms. A further 0.5 km south, due west Poyllvaish Farm, a laterally and vertically complex succession of reef limestones and black calcareous mudstones is exposed. The dominant feature of the wider exposure (0.06 km²) is the occurrence of large (m-scale) isolated blocks of massively bedded, pale grey, reef limestones that have collapsed into and deformed black, calcareous, off-reef, mudstones.



Two blocks of reef limestone separated by mudstones



Pillow lavas

Beneath the remains of an Iron Age fort at Close-ny-Chollagh the transition from the Lower Carboniferous sediments to Lower Carboniferous volcanics was examined. The contact is marked by localised scouring and bleaching of organic-rich mudstones suggesting erosion and thermal metamorphism of unlithified muddy sediment by hot pyroclastic flows. The final highlight of this remarkably diverse geology was an extensive exposure of pillow lavas formed by subaqueous extrusion of basaltic magmas.

The field trip ended with a curtailed visit to Kallow Point, Port St Mary where sediments representative of the lower part (Arundian to Holkerian stages) of the Manx Lower Carboniferous succession are exposed. The interbedded sequence of organic-rich, black, calcareous mudstones and limestones are notable for occurrence of numerous, intensely bioturbated horizons. Trace fossil assemblages vary depending on environmental conditions (degree of oxygenation). Mudstone and muddy limestone units contain ichnofossils such as *Chondrites*, *Planolites* and *Zoophycos* that indicate oxygen starved, dysaerobic conditions, while cleaner limestone beds are characterised by occurrences of horizontal, branching, tubular burrows (*?Thalassinoides*) produced by large crustaceans in fully oxygenated environments.

That evening Stephen was warmly thanked for leading such an interesting and informative trip, and Susan Beale and Fiona Harwood were thanked for the organization of field trip logistics (SB) and the expert handling of the minibus (FH) while negotiating a variety of hazards presented by Manx roads.

CGS VISIT TO SW PORTUGAL

Leaders: John Rodgers and Fiona Harwood

November 4th to 11th 2017

A party of 15 members assembled at Manchester airport for the flight to Faro and were joined by 4 more at our hotel in Lagos. Rented vehicles were delivered to the hotel that evening ready for an early start.

Sunday 5th Praia do Amado

The west coast of the Algarve region is composed mainly of Carboniferous formations which have been strongly folded by the Variscan Orogeny and are exposed in spectacular cliff sections along the coast with access via a series of beaches. The party was introduced to varied and complex geology at this location starting at the northern end of the beach with a mafic vent agglomerate, a pair of dip-slip faults and at least one basalt dyke which ran steeply down the cliff face before crossing the beach.



Faults at north end of Amado beach

The zone back to the access path consisted of red sandstones, siltstones and shales with a more resistant projecting area of cross-bedded sandstones below the car park. Some discussion was centred on the origin of the variety of pebbles and cobbles along the shore and the age of a polymict conglomerate outcrop resting unconformably on the red sandstone at beach level.



Recently lithified conglomerate unconformably resting
on Carboniferous sandstones.

A walk to the south end of the beach led to a massive N-S mafic dyke with prominent hornblende phenocrysts and a large xenolithic mass of the black phyllitic country rock. Outcrops on the return walk showed more sheet intrusions some of which contained a paler felsic component.

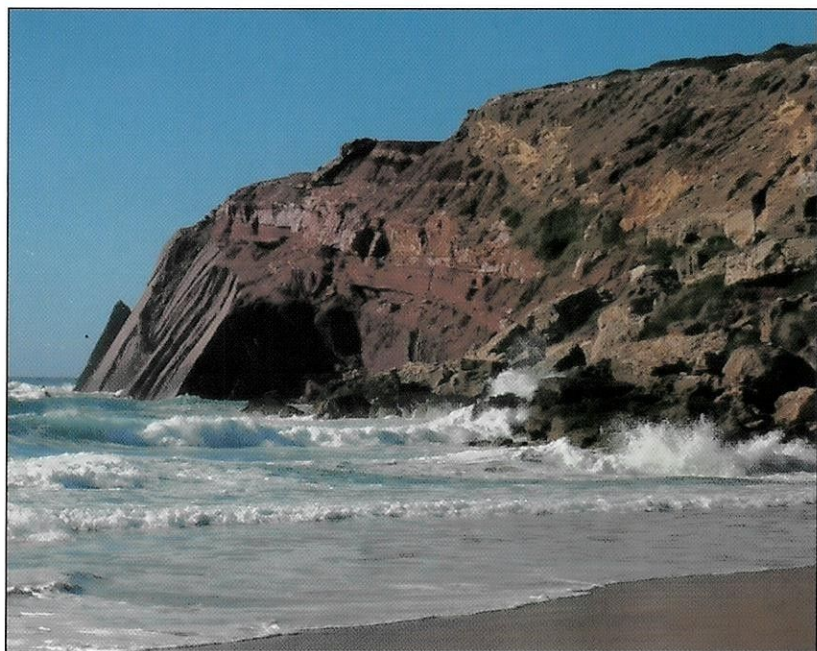
Monday 6th Praia do Castaleijo

The coastal cliff sections in this area display highly folded turbidite sequences of the Upper Carboniferous Brejeira Formation. The first location (below the café) consisted of a recumbent fold the upper surface of which was overlain by a lens-shaped mass of breccia which was in turn beneath a cliff-top bed of coarse calcareous sandstone, blocks of which had collapsed onto the sand. To the north, highly contorted stacks of recumbent folds were found in the steep/vertical cliffs while on the beach outcrops of turbidites with preferential erosion of the finer-grained layers beautifully displayed numerous Bouma sequences.



Complex folds in the turbidites

The afternoon session was a visit to Praia do Telheiro, about 8 km to the south. Here a spectacular view of an unconformity can be seen from the beach looking north. Steep beds of greywackes and shales are overlain by almost horizontal red beds of Triassic sandstones and mudstones.



Unconformity at Praia do Telheiro

Tuesday 7th Sagres and Cabo de Sao Vicente

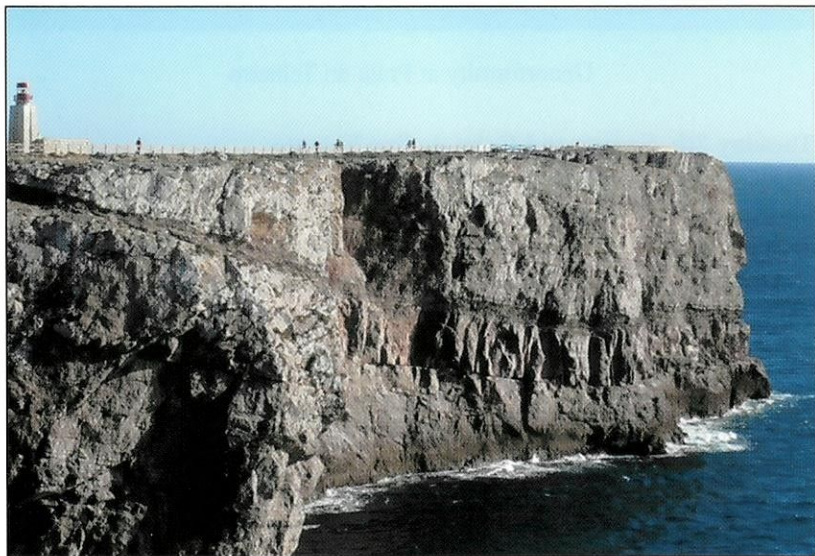
The main theme of this day was Jurassic carbonates which form part of the relatively narrow strip of Mesozoic sediments that run all the way along the southern Algarve coastline. The first stop was the most westerly of the day at the Cabo de Sao Vicente and provided a cliff-top view along the west coast that we had visited in the previous two days.

Lower Jurassic dolostones and dolomitic limestones form massive low dip beds that end in sheer 80m high cliffs. Moving east along the coast road, a brief stop was made for a descent to Praia do Beliche where beds of yellow carbonates contained bands of chert nodules and a large vertical blow-hole was discovered in a big cave at the western end of the beach. The afternoon session involved examination of limestones at Praia do Tonel including a coarse breccia composed almost entirely of clasts of oolite, and gently undulating beds of pale grey bioclastic limestones and shales.



Upper Jurassic limestones, Praia do Tonel

The final stop was at Ponta de Sagres and a walk around the cliff-edge path which surrounded an extensive area of limestone pavement with familiar clints and grykes.



Cliffs at Ponta de Sagres

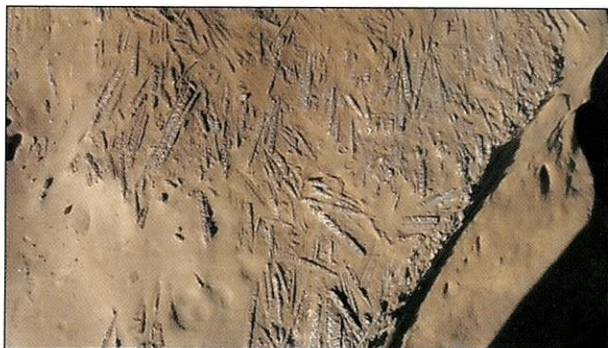
Wednesday 8th Salema and Praia da Luz

Continuing east along the Algarve coast from Sagres brought us into the Cretaceous. At Salema there is a section of yellow mudstones and limestones, where load casts and slump structures can be seen in section as well as on the lower surfaces of fallen blocks. There is also an exposed bed just above beach level on which a fine set of dinosaur footprints can be seen.



Exposing the dinosaur footprints on Salema beach

Towards the western end of the Cretaceous coastline is the resort of Praia da Luz where an interesting variety of rocks is exposed along the beach. At the western end there are extensive outcrops of red-brown cross-bedded sandstones with abundant gastropods which were seen to be aligned in a number of places.



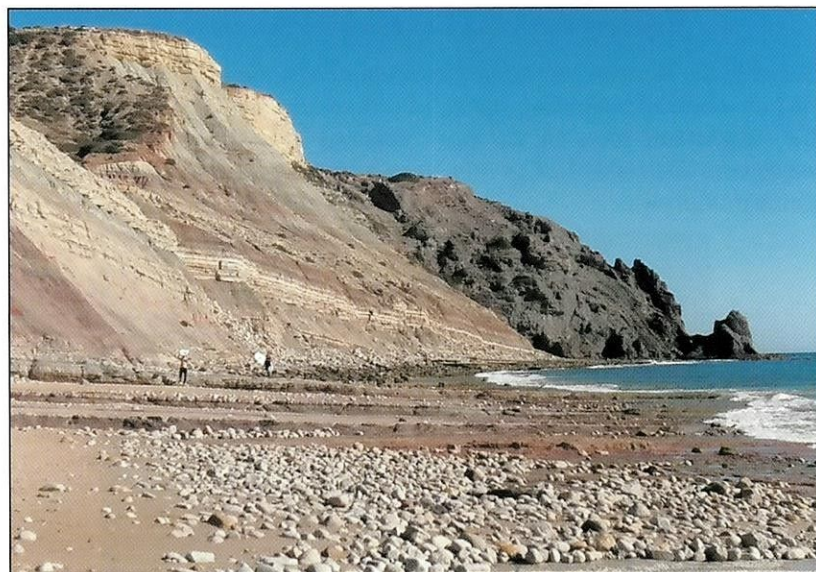
Aligned gastropods Praia da Luz

A walk along the beach to the east goes up the sequence of gently easterly dipping beds, starting with alternating red and green mudstones giving way to coarse white blocky sandstones some beds of which contained numerous carbonised plant remains.

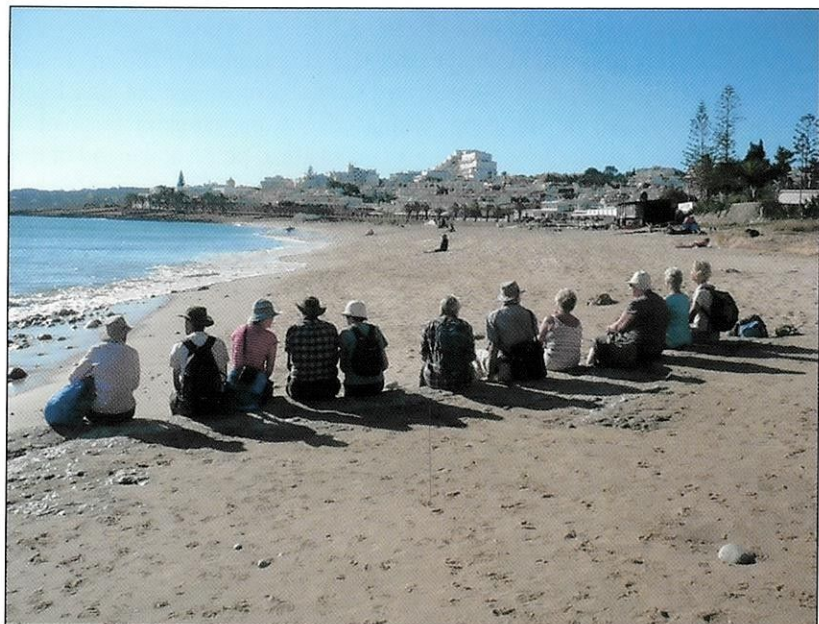


Coloured Cretaceous mudstones Praia da Luz

At the far end, the sedimentary sequence is truncated by a mafic vent agglomerate which is itself intruded by a vertical basaltic dyke that clearly narrows towards the top of the cliffs. Small bodies of basaltic intrusions extend laterally from the base of the agglomerate into the country rock.



The mafic vent agglomerate at the end of Praia da Luz



Taking a break at Praia da Luz



Monchique Summit

Thursday 9th Monchique and Silves

This was our day excursion inland to the Monchique pluton. The spa resort of Caldas de Monchique is situated on the southern margin of this large (15km by 6km) syenite intrusion, emplaced into the Brejeira Formation turbidites of the Carboniferous during an extensional phase at the end of the Cretaceous. The exit route from the village has a roadside section which shows the contact region and the hornfels that forms the innermost zone of the metamorphic aureole. A few kms further north took us to the highest point of the Monchique massif and a fine panoramic view from the jointed blocks of the summit of the SW Algarve.

Returning south a stop was made at the ancient city of Silves and a visit to the massive restored fort completed the day. The outer walls are entirely constructed from the deep red-brown Triassic Silves Sandstone and a circular walk around them allowed a wonderful view of the surrounding region.

Friday 10th Ponta da Piedade and Porto de Mos

This was a shorter day spent close to Lagos. The first part was a visit to the end of the peninsula that projects south from Lagos and affords a spectacular view of the type Algarve coastal landforms carved into the golden limestones of the Lower Palaeogene (formerly Tertiary). Cliffs, stacks, caves and arches are clustered along the eastern side of the Ponta da Piedade. A trip down to the beach at Porto de Mos then led to an examination of the gently dipping pale mudstones and limestones with a number of normal faults clearly visible. A bed of shelly limestone provided an opportunity for close scrutiny and fossil identification.

The afternoon was free time when some members chose to take a boat trip from Lagos. As a finale to the week, an evening meal was booked for everyone at a local beach restaurant allowing us to enjoy a superb sunset. We then all piled into taxis and attended a free lecture on Algarve geology at the museum in Lagos where we made up half the audience, much to the delight of the young Portuguese geologist and museum staff.

Throughout the week we enjoyed warm, dry and sunny weather and very comfortable accommodation in our 4-star hotel. Some of us also managed to swim at the local beach almost every day! As organisers, we would like to put on record our appreciation and thanks for the way members took part in all the activities (and for the lovely warm woollen items bought at Cabo de Sao Vicente and presented on the last night – they have been really useful this winter).

EXCURSION REPORTS 2016

GEOLOGICAL FEATURES AROUND GLENRIDDING

Leader: John Rodgers

16 April, 2016

Twelve members met at the Patterdale Sports Field car park (NY391161) and spent the morning part of this excursion examining the results of the destructive storm that occurred in the area in early December 2015. The party followed the roadside path back to Glenridding where the greatest damage had been done. Record rainfall throughout Cumbria had flooded towns and villages across the county, and destroyed scores of bridges. In Glenridding, the river bed had become filled with debris swept down by the torrential flow and sediment-laden water had overflowed into the hotel, shops and houses. The access road down to the boat jetty had been ripped up, the booking office inundated and thousands of tons of boulders, cobbles and coarse sediment spread across Jenkins Field (in which the finer fraction was found to be contaminated with waste from the Greenside lead mine area). Much of this debris was still evident and a large-scale operation supervised by the Environment Agency was underway to restore the land, while extensive flood defence works were being carried out along the river channel.

The group then returned to Grisedale Beck, and with permission from Patterdale Estate, we followed the beckside path upstream for a few hundred metres observing the effects of erosion on the opposite bank. At one location, a great mass of the glacial till on the steep south side had been gouged out and the road above, up into Grisedale was in imminent danger of collapse. Staff from the estate had organised and carried out immediate emergency work which had involved bringing heavy machinery to protect the base of the bank with huge boulders and tree trunks. Later work on felling upper parts of trees proved necessary to stabilise the bank further.

After a lunch break, the group took the path to Side Farm (NY398163), and then proceeded northwards on the lakeside path for about 1 km noting along the way the outcrops of various formations within the Borrowdale Volcanic Group. These included andesites and dacites of the Birker Fell Formation, tuffs and volcanoclastic sediments of the overlying Lincomb Tarn and Esk Pike Formations. Ascending a short way onto the higher level return path gave the opportunity to look for bedding structures in the slaty rocks of old

quarries. The higher elevation also allowed a view of the landscape in this attractive area at the SW end of Ullswater, with glaciated valleys and post-glacial deltas extending into the lake. Luckily, we avoided localised showers which lingered over the fells opposite and finished the trip at Side Farm café (excellent flapjack!).



A good view of landscape features at the SW end of Ullswater

THE EASTERN CALDBECK FELS

Leader: Fiona Harwood and John Rodgers

14 May, 2016

This excursion examined Skiddaw Group rocks in the Mungrisdale area and then went on to see how the intrusion of the Skiddaw Granite had produced high grade contact metamorphism and had led to mineralisation in the Mosedale valley.

Mungrisdale School House Quarry. NY363305. This small disused quarry is well-known as an excellent teaching location, being easily accessible and having a range of fundamental geological features. The main rock type is a steeply dipping black slate in which the cleavage and bedding planes are more or less the same. Small outcrops in the quarry floor are laminated and were ideal for demonstrating strike direction measurement. Two sub-parallel



Schoolhouse Quarry, Mungrisdale

low angle thrust faults were seen in the quarry face with associated drag folding and minor crenulation. At the eastern end, two parallel dykes of altered dolerite were located and both were shown to be offset by small N-S trending strike-slip faults. The dykes can be traced in the upper level of the quarry where there is also a quantity of loose slate pieces which can be searched for fossil content. (*Didymograptus* graptolites have been found here but not on this occasion). About 100 metres north of the quarry, small fold structures were found in outcrops at the base of the fellside.

The afternoon session was spent in the valley of the river Caldew, in which can be seen evidence of glacial and post-glacial landforms. These included: Corrie development on the north-facing side of Bowscale Fell and the ice-eroded Bowscale Tarn;

Remains of a terminal moraine across the eastern end of the valley which would have formed a temporary dam;

Exposures of glacial till in lateral moraines;

A roche moutonnee in a bedrock outcrop near the Roundhouse;

The flat valley floor indicating a former lake bed.



Small scale folds below Raven Crag, Mungrisdale

Well-exposed bedrock in the river bed showed angular chevron folding in the laminated hornfels, the tough grey product of high grade thermal metamorphism of the slate due to the underlying Skiddaw Granite. The disruption of the Skiddaw sediments into these fold structures was discussed, but is now attributed to contemporary large scale slumping (olistostromes) rather than tectonic compression. At the confluence of Grainsgill with the Caldew the party observed an outcrop of greisenised Skiddaw Granite, and further examples of this highly altered rock were found along the path up to the old Carrock Mine. A brief history of this one-time tungsten mine was given and features of the old workings were pointed out including the former tailings ponds. A future visit to the larger outcrop of Skiddaw Granite further upstream in the Caldew was suggested for 2017.

There was a simultaneous excursion onto Carrock Fell but as the leader was not present Carrock Fell was revisited in 2017.

CARBONIFEROUS LIMESTONE ON ASKHAM FELL

Leader: John Rodgers

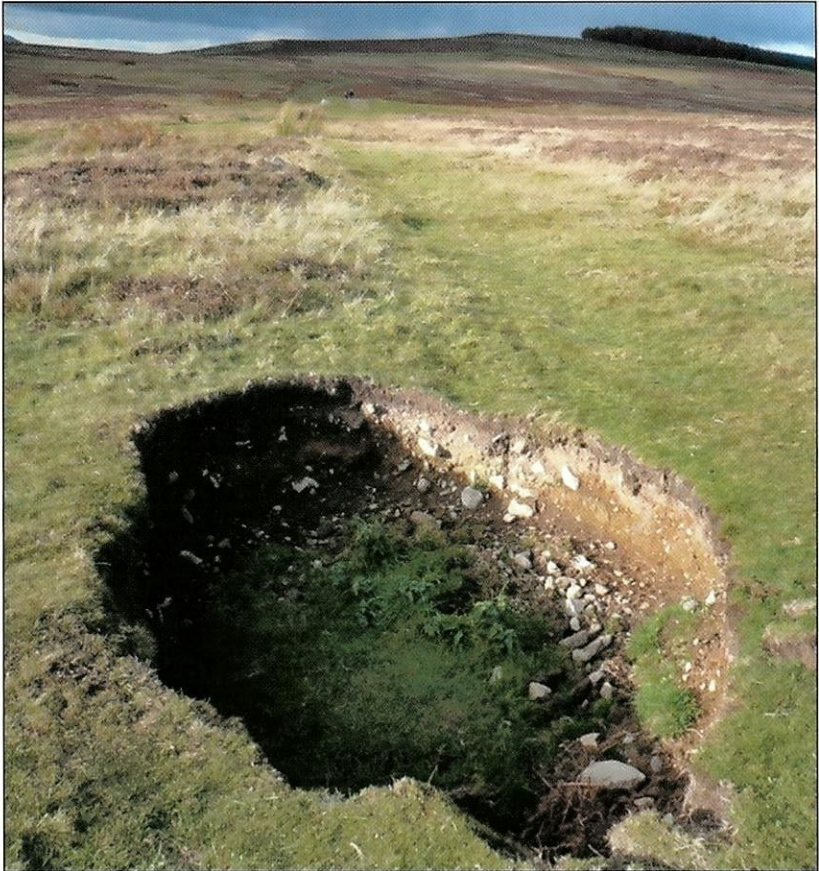
1 June, 2016

This evening excursion started at 6.30 with a description of the geological and landscape features visible from the meeting point on the roadside up from Helton village. To the south is the Lowther Valley, with the wide flat floor underlain by the Skiddaw Group of the Bampton inlier. To the west of this are the rugged formations of the Borrowdale Volcanic Group with the horizon rising steadily up to High Street, while to the east the flat-lying Carboniferous beds form the imposing escarpment of Knipe Scar.



The Lowther valley with the Bampton inlier below Knipe Scar

The party then followed the bridle path across Askham Fell, noting sink holes of various sizes that had developed on either side in the limestones below, one of which had only formed in the last few years. After 1.5 km the group turned north and ascended up to Heughscar Hill, where exposures of limestone pavement were examined. The evening concluded with a search for fossils in the blocks of limestone that used to be part of the now redundant wall around the fenced plantation.



A recently-formed sink hole on Askham Fell

LITTLE ASBY SCAR AND JANNY WOOD

Leader: Noel Pearson

12 June, 2016

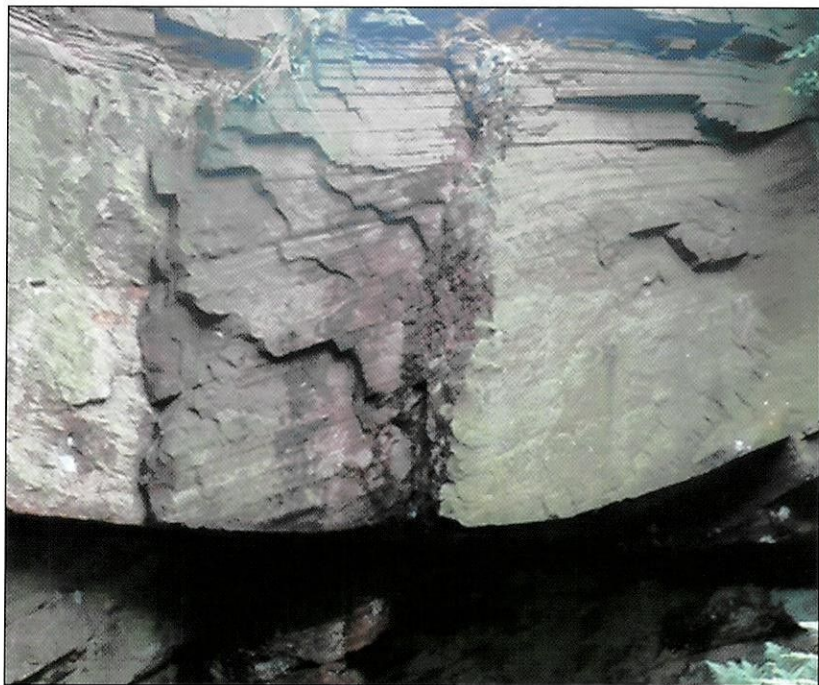
The report of this excursion is detailed in a separate paper in the original papers section of the Proceedings.

THE PENRITH SANDSTONE AT COWRAIK QUARRY

Leader: Fiona Harwood

29 June, 2016

After meeting on Beacon Edge, Penrith, NY517311, from where there was a panoramic view over the Lake District northern fells, the party of 14 members drove 1.5 km to the south east to the entrance gate to the disused quarries area. A plaque just inside the gate gave a few details about this SSSI being an excellent example of Permian dune-bedded sandstone. Following a marked path along the foot of the scarp slope the group gradually ascended to an old quarry face with 3 separate sets of large scale dune bedding. The vertical surface also showed evidence of conjugate strike-slip fault planes with horizontal striations and slickensides.



Dune bedding in Penrith sandstone

A path through the woods was then followed to the north-west and a second quarry face examined. It was explained how this locality was particularly useful as a teaching resource as it showed a number of features:

Red dune-bedded millet seed sandstone (desert environment);

A set of joint surfaces which allowed the concept of apparent dip to be demonstrated;

Well-sorted grain size along bedding planes but changes of grain size vertically (typical of aeolian conditions);

Sparkle of some surfaces due to faceted grains with quartz cement overgrowth;

Further horizontal striations and slickensides.

The opportunity was also taken to point out the drumlinoid landforms seen below the prominent escarpment of Beacon Edge, formed as glacial ice was deflected along the line of the Eden Valley.

CARBONIFEROUS LIMESTONE AND HEMATITE DEPOSITS AT HODBARROW

Leader: David Kelly

13 August, 2016

A large group of members and friends met at Haverigg, to study a locality at the southern tip of Cumberland not visited before by the Society in its 50 year history. The starting point provided a view of the Skiddaw Group inlier of Black Combe and the Borrowdale Volcanic Group and lower Westmorland Supergroup rocks at Harrath and Millom Park. However, the entire day would be spent within the outcrop of the Carboniferous limestone and would visit three formations of the Chadian and Arundian Stages not represented further north in west Cumbria. These were the Martin Limestone Formation (ML), Red Hill Limestone Formation (RHL) and the Dalton Formation (DF). Further north along the coastal belt these rocks are buried beneath great thicknesses of Permo-Triassic rocks.

The party walked south east along the Outer Barrier, completed in 1905 to protect the Hodbarrow Mine from inrushes of sand and sea water. This provided an opportunity to view the ruined Inner Barrier (1890), the early mining area of the Old Mine, the New Mine area around Steel Green and the location of the most recent shaft, Moorbank No. 11. The main ore body

was a "flat" in the ML and RHL, dipping very gently towards the south west. This was the largest single ore body in Cumbria and Hodbarrow Mine was the most productive single mine. There was much discussion about the ore bodies, the mining methods and the rôle of the mine in the development of the settlements of Millom and Haverigg.

Having walked the length of the outer barrier, the party visited the low cliffs at Hodbarrow Point. The ML here is dark grey and well bedded. It is much coarser grained than in the Furness peninsula on the other side of the Duddon estuary. Dolomitisation and hematization are extensive, with small-scale veins and flats. In Furness, close to the top of the ML, there is a characteristic fossil band. This band may have been seen just north of Hodbarrow Point. There were large gastropods and solitary corals (*Koninkophyllum*) in a death assemblage but the characteristic algal nodules were not seen. This may be because the environment of the coarser limestone was not suitable for the growth of the algae.

South east across the Duddon Estuary, the hematite mining area at Askam was seen. It was noted that the Millom and Askam ore bodies were not continuous beneath the estuary, which is mostly underlain by the conglomerates, sandstones and shales of the Low Furness Basement Beds.

The party then ascended the cliffs to examine the small, disused quarries a few metres inland in the RHL. The rock here was pale grey, poorly or thickly bedded and lacked shale partings. Large gastropods and crinoid fragments were common.

The party then walked 300m to the north-west to the extensive flooded quarries used to provide rock to build the outer barrier. At one locality a large solitary coral and a large gastropod were seen.

The final stop was at the edge of the Hodbarrow lake, just south of the old lighthouse, close to what must have been the original shoreline. The survey mapped this as DF and recorded the characteristic brachiopod *Delepinea carinata*. A search for this fossil proved unproductive, although an excellent example of *Syringopora* was seen.

THE RIVER GRETA GORGE TO EXAMINE RECENT FLOOD DAMAGE

Leader: Alan Wise

17 August, 2016

The trip was to examine some of the flood damage caused by storm Desmond on the night of 5/6 Dec 2015.

The first location was the Briery Caravan Site where the bank on the Latrigg side of the river had collapsed into the river leaving a scar over 50 m high. Parts of Latrigg are landslide material and so unstable and prone to sliding. On the South East face of Latrigg a large landslide left the very obvious scar of Horseshoe Crags and there is a less obvious slide to the East in Brundholm Woods. This area is still active and cracks and vertical displacement of the road can be seen along the now closed unclassified road that runs from Keswick to Brundholm Farm.

Below the farm (NY 228243) the river has eroded the bank leaving a 5m high vertical face with a steep sloping area above it over 40m high where the soil and woodland has slid into the river. This bank has fluvoglacial gravels at the base resting on the Skiddaw Slates bedrock with boulder clay forming most of the banking. The gravels at the base eroded easily allowing the banking to be undercut and fall into the river.

The final location (NY 231247) was the site of one of the railway bridges that was washed away. The massive stone abutment on the Keswick side was undermined by the river and the bridge was washed down stream.

Due to the track being washed away we were unable to examine the second bridge below Brundholm Farm (NY 299229). The railway embankment was also washed away as the river changed course reverting back to an old river channel that was filled in when the railway line was constructed.

CRINKLE CRAGS

Leader: Clive Boulter

3 September, 2016

Gathering at Three Shire Stone at the top of Wrynose Pass members prepared themselves for the long slog up to the heights of the Crinkle Craggs interrupted by a brief pause at Red Tarn to look at small samples of kidney ore in drill cuttings from exploration work. Near perfect weather greeted the party soon after leaving the main path as we plunged into Adam-a-Cove and the mist melted away. The topic for the day was the main eruptive phase of the Scafell Caldera perhaps the world's best example of a piecemeal caldera containing the record of the largest phreatoplinian eruption in Earth history. The caldera is deeply dissected giving rise to superb exposures of the innards of a caldera, an opportunity not normally available in young calderas because the latest eruptions have blanketed earlier features. In total over 600 km³ of magma were erupted during the evolution of the Scafell Caldera.

NY 24649 04227 the point at which geological hell was unleashed i.e. the abrupt change from dominantly effusive to violently explosive behaviour marking the onset of caldera-forming eruptions which buried the Birker Fell andesite plateau. Ignoring the uppermost Birker Fell Formation [either the top of a peperitic sill or of an autobrecciated lava flow] the focus was on the lowest few metres of the overlying Whorneyside Formation which is an alternation, on a metre-scale, of welded, andesitic ignimbrite and cross-bedded non-welded ignimbrite. Because of hydrothermal, and regional metamorphic, overprints it is very difficult to identify non-welded ignimbrites in the Borrowdale volcanics and in this case their recognition is mainly based on association with the welded examples but the cross-bedding is typical of that seen in other deposits from low-density pyroclastic currents. Above this basal zone there are approximately one hundred metres of andesitic welded ignimbrite of the Wet Side Edge Member characterized by recessive fiamme [welded pumice] and the gloomy exposures contrast with the overlying lighter crags of the Airy's Bridge rhyolitic ignimbrites. An eruption volume in excess of 20 km³ is likely to have formed in hours to a few days and represented the first significant evacuation of the magma chamber initiating piecemeal caldera subsidence. The resulting fracture network allowed tens of cubic kilometres of water to enter the magma chamber to dramatically change eruption behaviour.

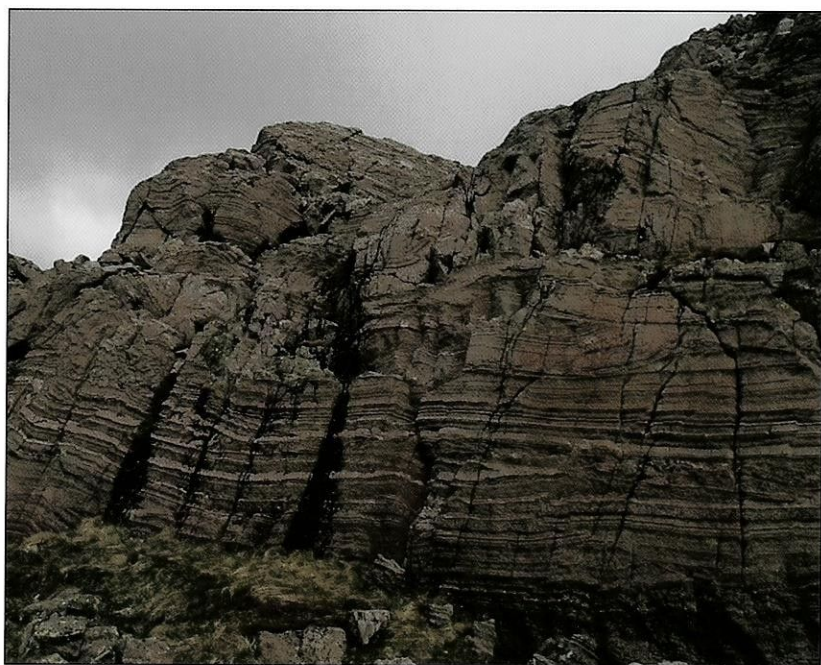


NY 24649 04227 Bed Ignimbrite



Wet Side Edge Andesite Ignimbrite

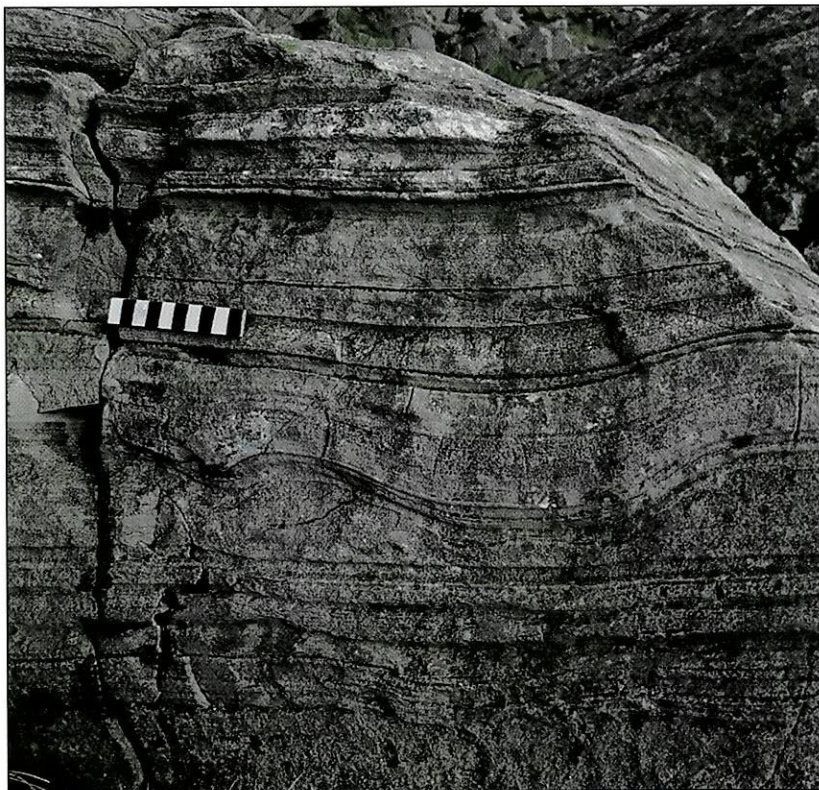
NY 2487 0403 Stonesty Pike: following water ingress into the magma chamber, over weeks to a few months, violently explosive eruptions intensely fragmented the magma in the world's largest ever phreatoplinian event. More than 100 km³ of pyroclastics were deposited to create the Whorneyside bedded tuff. Ash from caldera fissures was propelled more than 40 km upwards, dispersed over large distances, and deposited mainly in showers of damp ash. Air fall pyroclastics from magmatic eruptions are well-sorted but these deposits are poorly sorted. The air fall origins of the Whorneyside bedded tuff are demonstrated by the perfectly-parallel lamination only broken by localized erosion rills infilled by layers with almost constant vertical thickness, a definitive discriminant between deposits of pyroclastic currents and air fall processes.



NY 2487 0403 Whorneyside bedded tuff

Further support for the origins of the deposit comes from the abundant ash aggregates [accretionary lapilli – coated pellets in the latest classification] and the exceptionally high fragmentation index [85%] typical of external water playing a major role in fracturing the magma.

The Stonesty Pike locality has abundant soft sedimentary structures created by the piecemeal nature of the caldera collapse when blocks in the magma

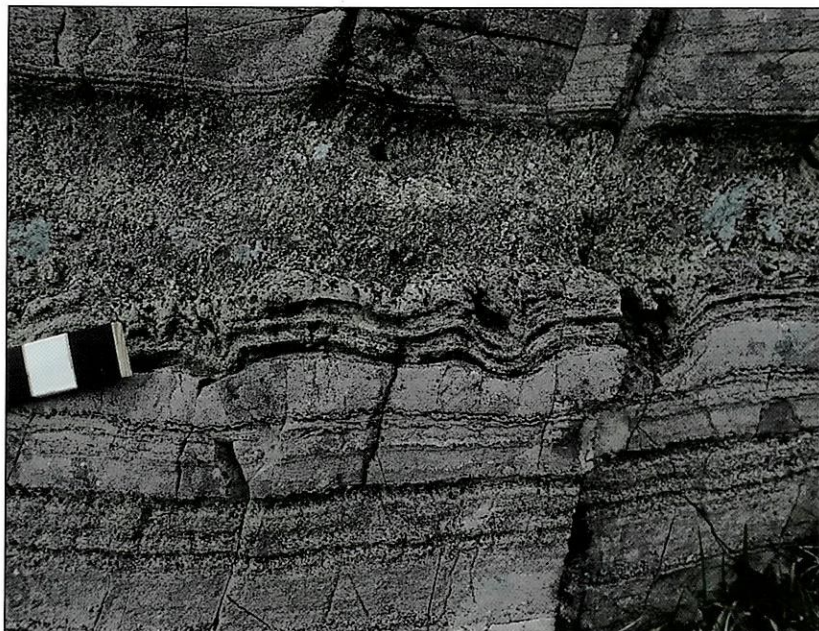


Erosional Rills Whorneyside Bedded Tuff

chamber roof rotated differentially. Most obvious at this locality are the thrust faults vividly displayed over the crag face by the duplication of accretionary lapilli layers. Significant contraction happened when blocks above the emptying magma chamber tilted triggering gravity slides. During the soft sedimentary deformation sediment was mobilized, now expressed as injectites.

Above the main crag face there are several horizons of erosional rills some of which have slumped margins because their steep margins were unstable. The channels were created in brief lulls in the near continuous ash showers when rainfall easily removed unconsolidated ash.

NY 24867 04085 impact sags in the Whorneyside bedded tuff. At this locality one layer has a series of centimetre-scale impact sags created by lapilli-sized ballistic pyroclasts. The impactors were small so the term bomb-sag can't be applied.



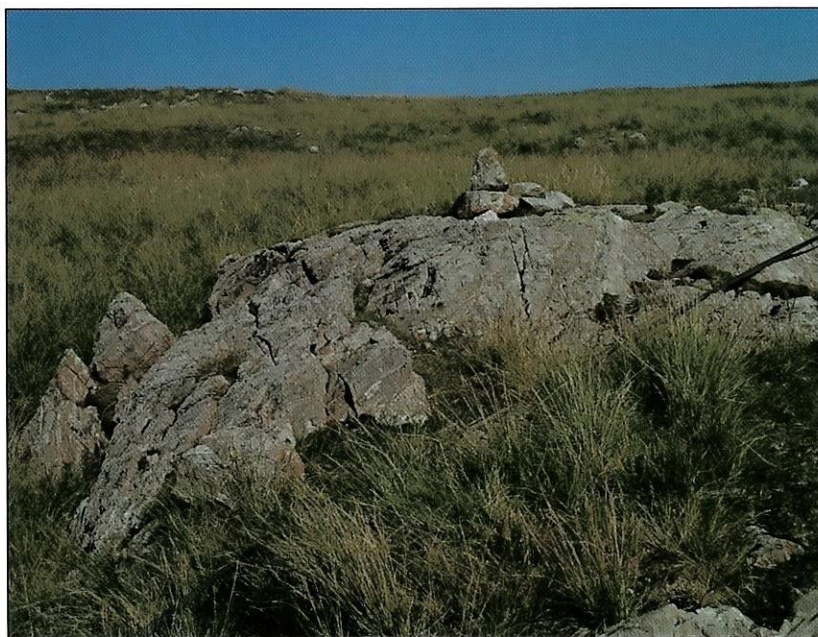
NY 24867 04085 Impact sags in the Whorneyside bedded tuff



NY 24855 04111 Stonesty Tuff Angular Unconformity

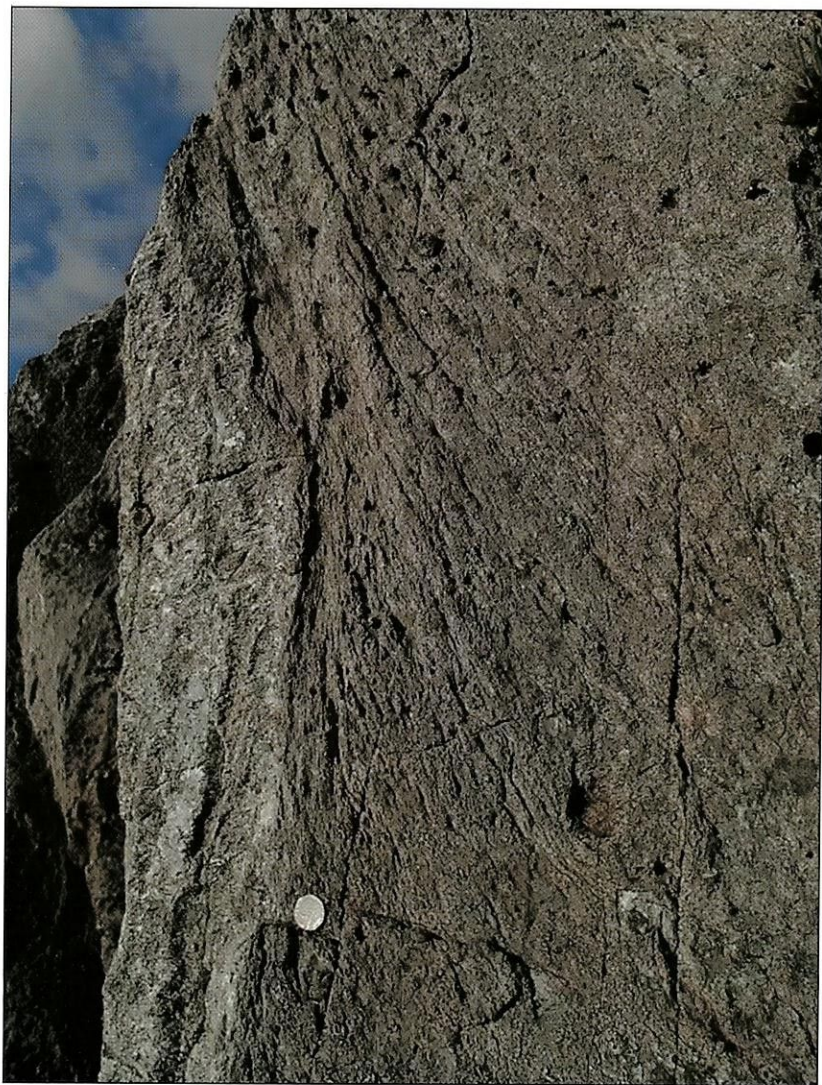
NY 24855 04111 an angular unconformity between the Whorneyside bedded tuff and the rhyolitic Stonesty Tuff, the basal unit of the Airy's Bridge Formation. Here we have the start of felsic volcanism and further evidence of caldera formation. Angular unconformities normally imply a complex and lengthy history. Not so here and some interpretations hold that the Scafell Caldera formed in a more or less continuous event. Unconsolidated pyroclastic deposits can erode very quickly as shown by piles of ignimbrite two hundred metres thick being eroded in ten years at Mt Pinatubo. Block rotations in piecemeal caldera collapse events take place on the same days/weeks/months timescales as the eruptions. Hence the unconformity at this locality could have formed very quickly.

NY 24849 04316 Isaac Gill volcano-tectonic fault. At this locality the bedding in the Whorneyside bedded tuff bends abruptly from its typical gentle attitude to become sub-vertical just before a slack which is the line of the fault. Movement on the fault brings Airy's Bridge rhyolitic ignimbrite against the andesitic tuff. Isaac Gill is on one of the larger faults formed during the piecemeal collapse of the magma chamber roof and has been termed a volcano-tectonic fault. To the east, in Isaac Gill itself, very complex geology is revealed demonstrating that these faults were the sites of fissure eruptions as the caldera collapse evolved.



NY 24849 04316 Isaac Gill volcano-tectonic fault

NY 24815 04417 ductile deformation of welding fabrics in Airy's Bridge ignimbrite along a volcano-tectonic fault. Crucial to the interpretation of the rapidity of events, during the formation of the Scafell Caldera, is the observation that welding fabrics have been folded whilst still hot along the lines of the faults that formed as the magma chamber roof broke up. These features probably have the same origin as "fault drag" in hard-rock situations being folds that form ahead of the fracture propagating to the observed level.



NY 24815 04417 Volcano-tectonic fault welding fabric ductile deformation

NY 2487 0481 Hanging Stone Tuff. Within the Airy's Bridge Formation several thick ignimbrite sheets are recognized and mapping their boundaries is made easier by the presence of metre-scale phreatomagmatic deposits. These were generated when water periodically gained access to the magma chamber briefly changing the eruption dynamics to produce moist low-density pyroclastic currents. As was seen at the first locality such events form sedimentary structures such as cross bedding which are very clearly displayed here.



NY 2487 0481 Hanging Stone Tuff

Another feature of the Hanging Stone Tuff is the presence of abundant accretionary lapilli with multiply laminated fine-grained coatings [accretionary pellets in the latest classification].



NY 2487 0403 Accretionary Lapilli



Accretionary Lapilli Detail

All that remained to do was to complete the hour walk back to Three Shire Stone and admire the views of Great Langdale and Pike o' Blisco on the way.

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EXCURSION REPORTS 2017

THE EASTERN CALDBECK FELS-REVISITED

Leader: John Rodgers

14 May, 2017

This day was designed to cater for a higher altitude group (the Carrock Fell Complex with leader Alan Wise) and a lower altitude group (Mosedale and Eycott Hill) led by John Rodgers. All participants met at Mosedale Bridge (NY357320) and decided on which option.

Mosedale

The main purpose of the morning session was to take advantage of low water levels in the River Caldew and examine the outcrop of the Skiddaw Granite in the river bed beyond the confluence with Grainsgill. The smaller greisenised granite outcrop was noted below Grainsgill Bridge and then the group followed the north bank of the Caldew for several hundred metres, noting the grey laminated hornfels of the metamorphosed Skiddaw Group. At NY315314 the exposed bedrock had changed to the pale jointed Skiddaw Granite which then occurred in a series of outcrops for a further several hundred metres upstream. Some of these outcrops, representing zones close to the roof of the Skiddaw Granite pluton had previously been hidden below river gravel, but had been scoured clear by the exceptionally high flow of the previous winter storms. This location has the largest area of granite outcrop, c. 2 km² is indicated on the GS Cockermouth sheet but actually much of this is covered with vegetation.



Skiddaw granite in River Caldew



Skiddaw granite in River Caldew

Eycott Hill

The afternoon session was a guided walk around the Cumbria Wildlife Trust site with emphasis on the Eycott Group lavas. The area immediately below the car park is underlain by Carboniferous Limestone and a line of sink holes can be seen to the north of the path. This limestone rests unconformably on the Skiddaw and Eycott Groups to the west but the unconformity itself is concealed by superficial deposits. The party then followed the way-marked trail around the site, traversing the series of linear ridges formed by lava flows which are now gently inclined to the east at first but gradually increase in dip angle in the western part of the reserve. Various features were pointed out en route, including columnar jointing, flow banding and the generally fine grain size in the dark grey-green andesites. Extensive wetland meres occurred between some ridges inferring the presence of thicker ash layers which have been preferentially eroded, forming basins for temporary post-glacial lakes before being colonised by vegetation. Finally, the special Eycott-type lava was located towards the base of the sequence and several outcrops of this distinctive porphyritic andesite with its large plagioclase feldspar phenocrysts (up to 4cms long) were seen.

The high vantage point also allowed the general geology of the surrounding landscape to be pointed out viz. the Skiddaw Group Caldbeck Fells (including the Carrock Complex), the Borrowdale Volcanic Group of the central Lake District to the south west, the rounded hills of Great and Little Mell Fell to the south, and the limestone escarpment to the east.



Eycott type porphyritic andesite



Eycott Hill Reserve with BVG in the background

CARROCK FELL REVISITED

Leader: Alan Wise

14 May, 2017

There is no report of this trip.

MAPPING GEOLOGY AROUND ULLSWATER

Leader: John Rodgers

21 June, 2017

Meeting at the Hause above Howtown (NY435192) on a warm mid-summer evening, the party ascended Hallin Fell from where a panoramic view around the central area of the Ullswater valley could be seen. Participants in this relatively simple exercise were then given sections of the local 1:25000 OS map and a brief description of the way in which the shape of the surrounding landforms was influenced by the underlying bedrock, the softer Skiddaw Group formations occupying the lower ground areas while the harder volcanic rocks formed the rugged topography of the local fells. The rounded hills underlain by the Mell Fell Conglomerate were also identified. Group members were then invited to draw in on their base maps the likely position of the major junctions between these three divisions. Results were then compared with the geological map of the area and a further discussion took place about other controls of the landscape, most obviously tectonic features (such as the Ullswater Anticline and Howtown Fault), and erosional features such as the glaciated valleys.

Somewhat unusually for a CGS field excursion, the evening concluded with a swim in the lake by some of the party and a picnic supper supplied by Susan Beale. A fitting end to the longest day.

RAVENSTONEDALE GROUP IN UPPER LUNE VALLEY

Leader: Noel Pearson

2 July, 2017

The report of this excursion is detailed in a separate paper in the original papers section of the Proceedings.

EXPLORING THE GEOLOGY ON THE WEST SIDE OF DERWENTWATER

Leader: John Rodgers

29 July, 2017

Society members assembled in short-lived showery conditions at Lingham car park (NY 252223) and followed a path through the estate identifying a range of rock types that had been incorporated into walls along the route. Evidence was sought for the 900m long lamprophyre intrusion shown on the GS map and a few loose weathered specimens were found but no obvious bedrock outcrop.

The party then moved on 3 km along the Grange road by car, parking close to a small disused quarry which was generally accepted to be an extension of one of the diorite dykes that are exposed down at the edge of the lake. After descending to the lake shore and a lunch stop, members spent some time searching the spoil heaps of the old Brandlehow Mine for galena. The lakeside path was then followed towards Keswick crossing the dark slaty Skiddaw Group outcrops along the shoreline and in which changes in dip and strike direction were measured to show the fold structures.

THE PARKSIDE AND KELTON FELL TOP MINES AND THE WHITEHAVEN, CLEATOR AND EGREMONT RAILWAY

Leaders: Mervyn Dodd and David Powell

13 August, 2017

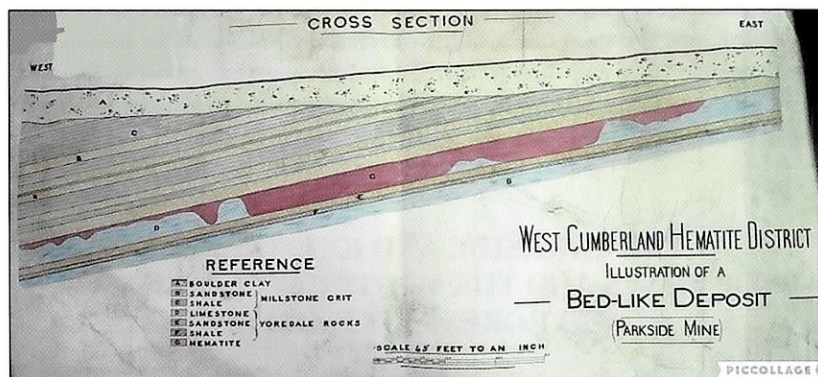
This was a 2-part excursion with about 20 members and friends present. The morning was spent along the Cycleway (previously the track of the Whitehaven, Cleator and Egremont railway) between Parkside (NY 035 152) and the former Yeathouse station (NY 056167). The afternoon, led by David, was to Kelton Fell Top (NY 082182). Surprisingly for an excursion led by Mervyn it was a dry sunny day.

Parkside Mine

The Parkside area had 2 large mines. Both opened in the early 1850s, the 525 feet deep High House and the 600 feet deep eponymous Parkside, south and north respectively of the housing terrace. Their outputs in their busiest

years were over 100,000 tons. Both worked 2 major local ore bodies. A big "flat" in the Namurian Great Limestone (locally known as the 1st limestone by the miners as it was the first limestone encountered in the shaft sinking) was up to 40 feet thick and extended over 40 acres. It was almost at outcrop in the High House Mine but thinned and deepened below the surface to the north with the dip of the Carboniferous beds. Lower down were workings in the Dinantian 4th limestone, locally the most productive formation with similar very low levels of .01% phosphorus or so but slightly higher iron content (around 55% by weight).

There were around 10 smaller mines to the North and East of Parkside—deeper (up to 1000 feet), less productive and shorter lived, mainly worked between 1860 and 1900 after the development of the Bessemer Process. Thick diamicton, said by the 19th Century mining geologists to be up to 75 feet of boulder clay, locally covers the solid rocks which are heavily faulted along North to South lines. These Carboniferous rocks "young" westwards and northwards.



There is considerable subsidence, very clearly seen in the tilted layers of brick in the Parkside railway bridge. The small mines north of it have massively subsided. Generally, the Parkside area has been "tidied up" since the closure of all the mines by 1925. These closures occurred during a serious recession after a coal strike with the high costs of finding the ore and mining at depths up to 1000 feet or so in hard limestone making mining unprofitable in times of low demand.

The Cycleway running east from Parkside is close to the hidden unconformity (below the track) between the Dinantian Limestones and the Buttermere Formation of the Skiddaw Group which is generally to the south. A branch line which turns off northwestwards to serve the smaller mines can be seen at about NY 040 156. The original track of the Whitehaven, Cleator and Egremont railway which had to be abandoned due to subsidence "peels off"

just south of the Cycleway near Frizington Parks Farm. Further on where the Cycleway turns northwards towards Yeathouse station there are chaotic outcrops of heavily weathered, dark coloured, Buttermere Formation rocks. These show rapidly changing bedding thickness with generally steep dips very variable in direction, with "folds" of various types and small faults in the walls above the track. A small exposure of the almost horizontal dark coloured Marsett Formation of the Tournaisian at the local base of the Carboniferous in the west wall above the track can be recognized by the sandy residue below it.

Kelton Fell Top Mine

Kelton Fell Top Mine is quite different. It is part of the Knockmurton and Kelton Fell mine worked between 1850 and 1914 which produced about 1.25 million tons. This moderate sized mine was the largest iron ore mine in the old, hard rocks of Lakeland. It is in Skiddaw Group rocks close to the Loweswater Thrust, and its veins lack the showy specimens found in the limestones. This rough pasture area has not been "tidied up" so there is more of the old mine landscape to be seen than near Parkside. Its ore content at about 45% is rather less than the Parkside mines.

Walking west from tip No. 1 at NY 083182 a collapsed gallery is passed. As you then walk north up Kelton fell several roughly circular collapses up to 25 feet deep on south to north and south east to north west trending veins occur. Near the crest of the hill is a small outcrop of thinly bedded, almost vertical Skiddaw Rocks with quartz stringers. Beyond the hilltop on its northern side is a still active collapse, (perhaps 50 yards long and 50 feet deep,) down to a working gallery. There is a rather badly weathered exposure of a hematite vein at its cliffed western edge. An approximately East to West fault with dextral (right handed) slip of beds is clearly seen below the steep northern wall of this collapse. Lower down the slope a 50-yard curving collapsed adit occurs. This runs into a small tip with a small fenced off area containing a shaft (Kelton No.4). This shaft led to an unsuccessful cross cut (which it was hoped would discover another ore body) towards Kirkland village. These workings were the last attempts to find ore before the mine closed as its resources were exhausted. Even lower down the hill below the head dyke the grass is strikingly green on the Carboniferous Limestone beyond the Lake District Boundary Fault.

The Whitehaven, Cleator and Egremont Railway

The morning excursion was along the Cycleway that now follows the old track bed of the Whitehaven, Cleator and Egremont Railway (WC&ER). This was the first railway into the iron ore field of west Cumbria.

Rowrah quarry was closed in 1954 and the track lifted in 1964. After 1970 the branch that served the Florence iron ore mine at Egremont went only as far as the mine. British Steel ceased operations at Rowrah quarry in 1978, and at the Florence mine in 1980 – complete closure of the line followed soon after.

SEATHWAITE FELL

Leader: Clive Boulter

3 September, 2017

27 members from the Cumberland and Westmorland Geological Societies met at Seathwaite Farm where it was decided to go ahead with the Seathwaite Fell option despite a not overly favourable forecast. The focus of the field meeting was the sedimentary fill of the Scafell Caldera, formally named the Seathwaite Fell Formation [SFF]. In an almost Yellowstone-like volcanological, but not tectonic, scenario more than 600 km³ of magma was explosively erupted from the caldera. This left an enormous hole approximately 20 x 20 km, hundreds of metres deep, which rapidly flooded with fresh water to form the first phase of the Ordovician Lake District. For those interested in studying primary structures Seathwaite Fell is a wonderful place because the thick granitic sheets under the Central Fells have buttressed the area from distortional overprints associated elsewhere with tectonic cleavage development.

Two garnetiferous units are found in this area immediately pre-dating the SFF and these were briefly examined. The first of these is the Lingmell Formation which is mainly welded ignimbrite. The second is the Scafell Dacite which is interpreted to be degassed magma that oozed out of the magma chamber to form a lava dome after most of the volatiles had been removed by the massive caldera eruptions. A characteristic feature of this dacite is the almost pervasive autobrecciation highlighted by the prominent flow-banding varying in orientation from clast to clast. Garnet-bearing volcanic rocks are rare worldwide and are normally attributed to the assimilation of aluminium-rich rocks which in this case were probably from the Skiddaw Group. The only problem with this suggestion is that the crustal level at which it would have taken place may have been insufficient to produce the high-pressure garnet.



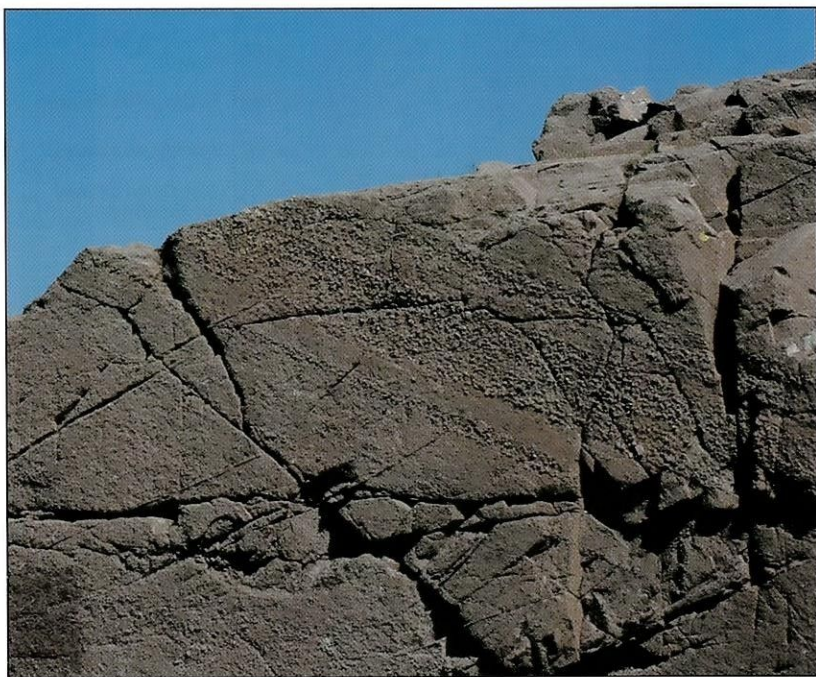
NY 22361 10127 Autobreccia Scafell Dacite



NY 22458 10012 Scafell Dacite Cam Crag Contact

NY 22428 10012 the first of the SFF localities. Gaps between fragments in the brecciated upper contact of the Scafell Dacite are infilled with white, exceptionally fine-grained, volcanoclastic mud. Components of the Scafell Dacite are believed to have locally intruded the carapace it produced so there is the residual thought that this locality could be a peperitic contact but it more likely that sediment filtered down a cracked, upper autobrecciated top surface. Continuous exposure passes into bedded pebble-grade sedimentary breccias of the Cam Crag Member of the SFF which is a Gilbert-type deltaic deposit. The delta prograded into the caldera lake from the northwest forming a 275 metre thick fan-delta deposit. All the clasts are pale-weathering dacite to rhyolite distinguishing it from the next subdivision, the Pavey Ark Member [not present on the traverse], which is andesitic.

On the traverse to the next locality a brief stop was made to examine cross-bedding and other sedimentary structures in the Cam Crag.

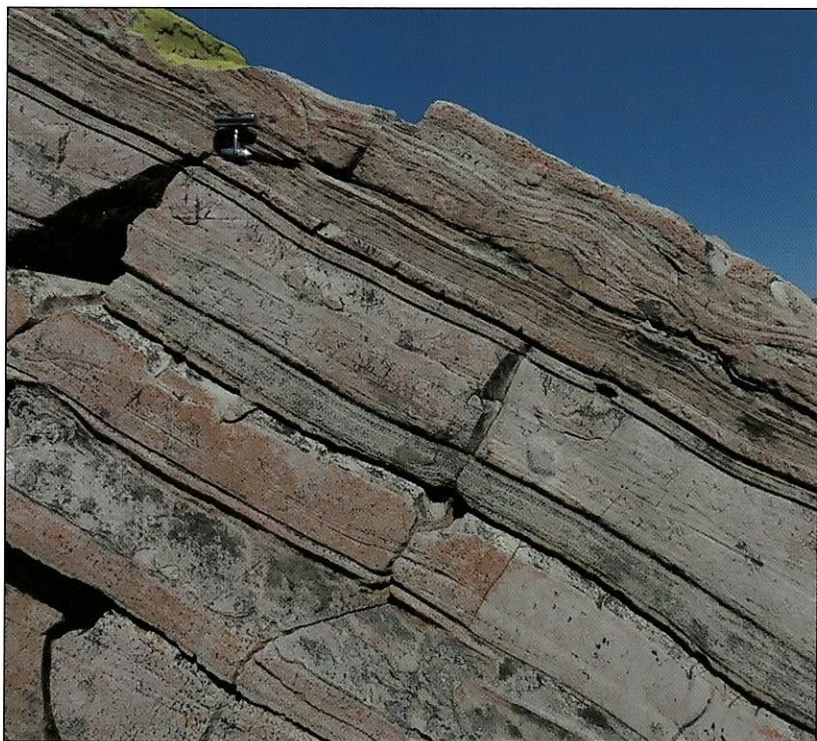


NY 22484 09942 Cam Crag Pebbly Sedimentary Breccia.

Lunch was taken at the last spot affording protection from the strong SSE winds. The exposed aspect of this side of Seathwaite Fell is a mixed blessing; the main benefit is that the near constant wind inhibits organic growth on the rock faces which are beautifully clear displaying delicate primary features.

Estimates of water depth in the caldera lake have varied considerably. Because the style of sedimentation did not change after deposition of the Pavey Ark Member [125 m thick after compaction], it is inferred that the depth of water at this time was several hundred metres.

NY 22522 09846 around ten metres of transition into the Bowfell Links Member which is predominantly well-bedded fine- to medium-grained turbiditic volcanoclastic sandstone [wacke]. The transitional zone is an alternation of metre to half metre packets of gravelly graded beds and well-bedded wackes.



NY 22537 09835 Bowfell Links Turbidite Deposits.

The latter show abundant soft-sedimentary deformation which could be seismically generated but the association with the coarse-grained beds suggests the driving force for the deformation could have been rapid loading caused by the arrival of the gravelly deposits. There is much evidence of sediment mobilization in the form of injectites, and rafting of laminated sediments by injected sands and gravel. Convolute folding is widespread and pre-lithification faulting is in abundance some of which is listric.



NY 22522 09846 Soft Sedimentary Basal Bowfell Links.

Load and flame structures at this locality show asymmetry which has been considered to be the result of growth of these structures during the deposition of the beds and to reflect the flow direction of the turbidity current.



NY 22640 09824 Bowfell Links Soft Sedimentary Overturning of Load and Flame.

Conditions were deteriorating forcing a modification of the planned itinerary. Brief stops were made to examine the typical well-bedded turbiditic sandstones of the Bowfell Links Member and a couple of examples of metric-scale soft-sedimentary folding both of which displayed inverted load & flame structures; the implication is that the beds underwent liquefaction to create the loads and flames and then down-slope movement folded the layers and their soft-sedimentary deformation structures. Some turbidite beds have excellent dish and pillar structures produced by early dewatering of the beds soon after deposition.

NY 22697 09760 is a notable location for the presence of the largest breccia dyke on the fell. This dyke cuts the stratigraphy at high angles and is several metres wide. Highly angular fragments of the wall-rocks are tens of cm long. Breccia dykes, on a variety of scales, are common on Seathwaite Fell.



NY 22697 09760 Largest Brechia Dyke Bowfell Links.

NY 22714 09738 sees the start of the Cockley Pike Member which is predominantly thickly-bedded coarse to very coarse-grained poorly-sorted sandstone [wacke] interpreted to be the result of catastrophic high-density turbidity flows. These deposits have, in the Lake District, frequently been referred to as a Disordered Turbidite Facies [DTF]. Commonly they contain

metric scale cross-bedded horizons where sets are tens of cm thick. The turbulence that formed the cross-bedding was part of the turbidity flows rather than an independent transport event. Abundant elutriation channels attest to the rapid deposition and poor sorting as these water-escape features form soon after deposition when the original loose grain-packing collapses and forces out pore water removing some mud grains as it goes. Wilf's Café at Staveley and the Castle Dairy Restaurant in Kendal have fine examples of elutriation channels in serving-counter tops.

NY 22721 09687 thin beds [20 to 30 cm] of diagenetically flattened pumice fragments show explosive eruptions were contemporaneous with the sedimentary filling of the caldera lake. Such thin beds were once thought to support a subaerial-environment interpretation for their formation by hot compaction. Several studies have now shown that a welded-ignimbrite-like fabric can be formed by normal diagenetic burial compaction in subaqueously-deposited sedimentary piles. Discriminating between hot and cold compaction of pumice can be a challenge in ancient terrains.



NY 22721 09687 Cockley Pike Diagenetic Compacted Pumice.

NY 22765 09624 a breccia dyke where the fragments are clearly Cockley Pike lithotypes. In particular one clast contains folded elutriation channels implying a history of rapid expulsion of pore water followed by ductile soft-

sedimentary deformation, and finally brittle behaviour to fracture the clasts in the fluidized flow that created the breccia dyke.



NY 22765 09624 Cockley Pike Breccia Dyke Cast Soft Sedimentary Elutriation Channels.



NY 22768 09655 Cockley Pike Elutriation Channels.



NY 22714 09705 Disordered Turbidite Facies Cockley Pike.



NY 22866 09267 Perfectly Parallel Bedded Airfall Tufts.

NY 22866 09267 was chosen some way into the Sprinkling Tarn Member to be representative of the unit which is characterized by several-metre thick packets of perfectly-parallel bedded airfall tuffs alternating with similar thicknesses of Cockley Pike Member lithotypes. The tuffs are remarkably similar to the Whorneyside bedded tuff which is an airfall deposit from a phreatoplinian eruption. Water depths in the caldera lake were shallowing towards the end of Seathwaite Fell Formation deposition but the alternation of DTF deposits and subaerial pyroclastics is puzzling.

Close to the end of the SFF, the Glaramara Tuff is clearly the product of a subaerial tuff ring but the unit does not occur on the traverse taken by the field party – perhaps a target for another time?

Those who persevered through the strong wind, and stinging rain, headed back to the cars via Styhead Tarn, and the path alongside Styhead Gill, thankful that we had been in a warm front not a cold one and that the rainfall total had not been great in the wettest place in England!

The main reference for the excursion is Kneller, B.C. and McConnell, B.J., 1993, The Seathwaite Fell Formation in the Central Fells, *British Geological Survey Technical Report WA/93/43*.

LECTURE MEETINGS

WINTER 2016/17

21 September 2016

The Yorkshire Potash Project

Dr Tristan Pottas

12 October 2016

Storm Desmond and A591: Damage and Repair

Dr. Simon Ferley

9 November 2016

Glaciers and Climate Change and their relevance to Cumbria

Prof Mike Hambrey

14 December 2016

Members Evening

25 January 2017

Graphite in Borrowdale

Dr Dave Millwood

22 February 2017

Geology and International Development: Interdisciplinary Work across Three Continents – The role of geology in fighting poverty and supporting sustainable development.

Joel Gill

22 March 2017

AGM and Presidents Talk: **Relations on the Celtic Fringe.**

LECTURE MEETINGS

WINTER 2017/18

13 September 2017

Wolves and wildcats: mammalian response to abrupt climate change at the end of the last Ice age.

Prof Danielle Shrieve

11 October 2017

Teacher at Sea

Angela Bentley

22 November 2017

Discussion on the Interpretation of the structure of the Canadas Caldera

Clive Boulter

13 December 2017

Members Evening

24 January 2018

Limestone pavements in Cumbria

Dr Peter Standing

21 February 2018

The geology and business of oil and gas exploration off the Falkland Islands.

Dave Bodecott

21 March 2018

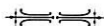
AGM and Presidents Talk: Society field trips to the Isle of Man and S.W. Portugal.

OFFICERS AND COUNCIL OF THE SOCIETY

2017 and 2018



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Junior Vice President.....	Vacant
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OBITUARIES

Morley Burton



Morley Burton, who died in Cockermouth in January 2017, aged 91, was a founder member of the Society and of its predecessor the West Cumberland Geology Group. He was very active in the first 25 years of the Society's existence, serving on Council until 1986. In 1965 he established the Society library and remained Librarian until 1986. His particular geological interest and expertise was in the volcanic and igneous rocks of Lakeland. The earlier Society Proceedings have many accounts of several excursions he led to locations such as Blea Crag and the igneous intrusions in Eskdale. He was ready to add to his knowledge, well illustrated by arranging to have the Armboth dyke rock professionally analysed at his own expense.

Fred Lawton tells us Morley, who left school at 14, was one of the many whose education was disrupted by the 1939-45 War. This led to him enlisting in the Royal Navy in 1943 as an 18 year old, where he worked as a communications rating decoding messages on the aircraft carriers he served on in the North Sea and the Far East. After demobilisation he became a civil servant in Preston where he met and married Joyce in 1950. They took advantage in 1952 of a transfer as a civil servant to Sellafield with an offer of a house in Whitehaven, where they lived for many years. When Sellafield became a separate nuclear establishment he transferred into the employ of BNFL, where he remained until retirement.

I remember his amusing comments about the early years and early members of the Society at a lunch in 2012 to celebrate the 50th anniversary of the founding of the Society. It was fascinating to listen to his anecdotes. He is survived by Joyce, his son who is Professor and researcher in Southern California and his daughter, a talented artist.

Mervyn Dodd



Mrs Enid Roberts



Enid died at her home in Keswick on July 17th 2017, aged 93. Along with her late husband Trevor they were early members of the Society and continued to take part in Society events well into their later years. They were regular attendees at lecture meetings and came on field excursions for many years. As they aged we saw them regularly at the Society Dinner each year.

Enid was born in Aberdare, South Wales and graduated from Cardiff University with honours in French. With her first husband Elwyn she moved to Workington where he worked as a solicitor. Tragically Elwyn died at the age of 36 leaving her with two young daughters. Enid taught in several schools in Workington and it was there that she met her second husband Trevor, who was head of modern languages at Workington Grammar School. She was a natural explorer, curious about the natural world and remained energetic well into her 80's. Her interest in Lakeland geology fitted well into her lifestyle. She and Trevor retired to Keswick in 1982.

Alan Smith



Trevor Purnell

1934-2018

Trevor was all too briefly a member of our Society, enthusiastic and stimulating, enjoying our lectures and attending our excursions as far as his health allowed. Geology was one of his many wide ranging interests, previously latent until after the death of his wife when he had to rebuild his life. Before her death they were much involved with the work of the Lowes Court Museum, Egremont.

Trevor originally came from Stockton on Tees. After graduating in Chemistry he was appointed in the late 1950's to the scientific staff of the Sellafield/Winscale nuclear plant where he spent his entire working life.

Mervyn Dodd



Dr. Arnold Currall

1924-2018

The Society has also recently learnt of the death of Arnold Currall earlier this year. He became involved with the Society when he retired from university teaching and came to live at Great Strickland near Penrith in the 1990's. Latterly he moved to Carlisle where he was heavily involved with work in the Cathedral and the Church of England in Cumbria. He and his wife regularly attended the annual dinners for many years. He came to lecture meetings in Penrith and Carlisle and we called upon his academic expertise with our Proceedings on several occasions.



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