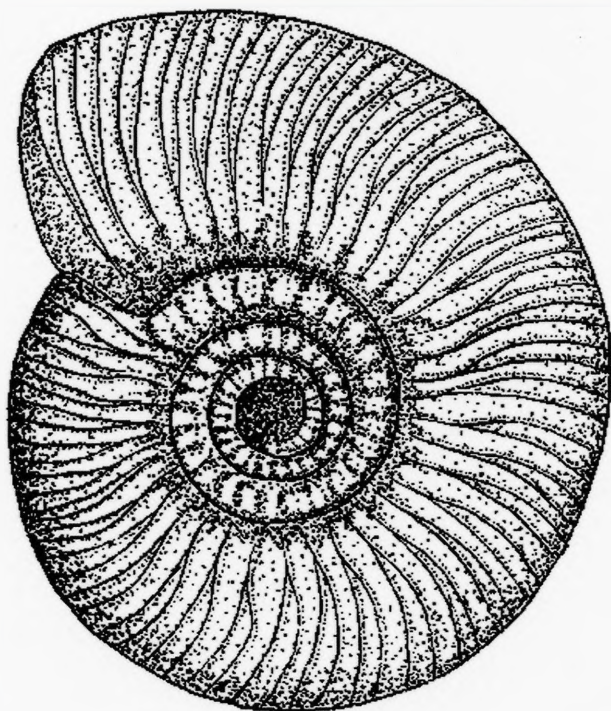


THE CUMBERLAND GEOLOGICAL SOCIETY



PROCEEDINGS

Volume 8 2012-2013 Part 2

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2012 – 2013

Volume 8, Part 2

Published by the Cumberland Geological Society

www.cumberland-geol-soc.org.uk

2014

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EDITORIAL

This edition of the Proceedings is the second part of Volume 8. It follows on from Part 1 which was the special 50th anniversary edition. In order to fit in with the 50th anniversary celebrations, Part 1 was published slightly earlier in the year than has been the norm. As a result, Part 2 records the activities of the Society for a period of slightly longer than two years.

I was particularly pleased to receive the three original articles published here. The Society has a long history of publishing original articles on the geology of Cumbria and it is good to see that this is being maintained.

There is also a short piece written by my members which records some local exposures which are under threat from natural processes or human activity. Perhaps this will stimulate members to submit other short communications in the future.

Finally I would like to thank all those who have contributed to these Proceedings through original articles, obituaries, accounts of field visits or other records of the activities of the Society.

Editor

David Kelly

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AN ILLUSTRATED GUIDE TO THE SILURIAN (LUDLOW) CRINOIDS OF THE SOUTHERN LAKE DISTRICT

Stephen K. Donovan and David N. Lewis

John Bolton (1790-1873) was a notable pioneer amongst the geologists of the Lake District (Kelly, 2001). His *Geological Fragments ...* (Bolton, 1869), an early description of the geology of part of the region, gives an account of the collection of an unusual Silurian crinoid from the southern Lake District. This species is now referred to ‘*Scyphocrinites*’ *pulcher* (M’Coy, 1851), but it was originally classified as *Actinocrinus* (= *Actinocrinites*) and, later, *Periechocrinus*.

The preservation of ‘*S.*’ *pulcher* from the Lake District is exceptional in some specimens (e.g., Figs 1-4), with pinnules undisturbed and arms articulated. Although no longer exposed, Bolton (1869, pp. 157-158) described the occurrence and rarity of these specimens in the southern Lake District in some detail:--

“We had in the course of a few years made several visits to Knott-hollow Quarry, but were unsuccessful in finding the least trace of Organic Remains ... At the time of our first geological visit to Knott-hollow, the quarry had lain silent and neglected for many years, but in 1857, the owner of the spade forge at Rosshead, constructed a weir for a reservoir, a little below Knott-hollow Tarn, for which we had to take a series of levels. At this time he obtained and placed near the quarry, about one hundred tons of stone, all in flaggy pieces, something like drain covers, not in a heap, but spread on the ground in cart loads, precisely as we had long wanted. We therefore began at one end of this great mass of stones, and, examining carefully every one on the ground on both sides, as well as on the edges, succeeded in finding two specimens of a Silurian Encrinite, *Actinocrinus pulcher*... Soon after,

Osmotherley Common was enclosed, stone was required for fence walls, so the quarry was worked again for a considerable time, and we did not neglect to visit it two or three times every week and carefully examine nearly every stone used in the construction of all the fence walls required for the enclosure. In this manner we obtained several good specimens of the *Actinocrinus*, some containing two or three almost perfect heads of that beautiful and scarce fossil.”

Bolton’s description demonstrates that, even when examining a great volume of rock in considerable detail, crinoids were ‘scarce’ and that only one species of fossil crinoid was present (Figures 1, 2). Conditions were sufficiently quiet at the time of burial that early stages of disarticulation resulted in ‘domino’ disarticulation of columnals in some specimens, yet eventual burial must have followed soon after. The longitudinal crushing and collapse of some pluricolumnals (=preserved lengths of stem) happened subsequently and was presumably the effect of overburden on stems with broad axial canals that were incompletely infilled with sediment.

‘*Scyphocrinites*’ *pulcher* is rare, but is nevertheless the commonest crinoid from the Silurian (Ludlow) of the Lake District. This paper is a guide to the few species of Silurian crinoids from the region, intended for the use of collectors and, perhaps, as a way to ‘flush out’ unidentified specimens of rare and perhaps even new species. Specimens discussed herein are in the collections of the Natural History Museum, London (BMNH), the Sedgwick Museum, Cambridge (SM) and the British Geological Survey, Geological Survey Museum, Keyworth (BGS GSM). For a detailed introduction to the morphological terminology of the Crinoidea, see Ubahgs (1978) and Moore *et al.* (1978). The text has been adapted from relevant entries in Donovan *et al.* (2010, 2012).

‘*Scyphocrinites*’ *pulcher* (M’Coy, 1851) (Figures 1-4)

Specimens, localities and horizons. ‘*Scyphocrinites*’ *pulcher* is known from a number of localities in the Lake District, North Wales and

Ireland. Museum specimens from the Lakes include the following. BMNH EE 5799 (Fig. 4), locality and horizon unknown, from a fireplace in the English Lake District. BGS GSM 89997, 73997 (Fig. 3B), Knott Hollow Quarry, Ulverston, Lancashire. BGS GSM 103637 was presented by J. Bolton, Esq., and comes from the *ludensis* Biozone near Ulverston; it preserves the higher part of the theca with fixed, branched arms and, although somewhat incomplete, is probably conspecific. BMNH 40284, E 3/1321 (two artificial casts of crowns, not the same specimen as 40284, but one was taken from the specimen figured by Bolton, 1869, frontispiece; Figure 1 herein), Coniston Grits, Osmotherley Common, Ulverston, Cumbria. BMNH 42905 is from Benson Knott, Kendal, probably from the Ludfordian Kirkby Flag Formation (Fig. 3A). The specimens recorded by Salter (1873, pp. 92, 162) are from Osmotherley Common, Ulverston, and Shepherd's Quarry, Kendal. Bigsby (1868) recorded a locality at Gameswell, Ulverston. None of the slabs from the Ulverston district are recognised to be part and counterpart, so no specimens were visible through 360°. Some specimens in the BMNH collection from the Ulverston area are recorded from the Coniston Grits (Coniston Group, Windermere Supergroup). Cocks *et al.* (1992, fig. 6) placed this unit in the *scanicus* Biozone, Gorstian, Lower Ludlow. However, Bolton (1869, p. 156) noted that Knott Hollow Quarry, above the tarn of the same name, is “one and a half miles north-west” of Ulverston and formed part of Osmotherley Common. The 1:50,000 geological sheet (British Geological Survey, 1997) shows Knottallow Tarn on Osmotherly Moor to lie within the outcrop area of the Wray Castle Formation, the lowermost Ludlow unit (*nilssoni* Biozone) in this area and underlying the Coniston Group. Knott Hollow Quarry is no longer working (Johnson *et al.* 2001, p. 51).

Distinguishing features. ‘*Scyphocrinites*’ *pulcher* is a member of the class Camerata, the crinoids with a robust theca, the ‘roof’ of the cup commonly being plated over by multiple small plates (=tegmen), although this feature is poorly seen in this species. It is a monobathrid, the camerates with two circlets of cup plates (=monocyclic), the basals and radials. This species is multi-armed with a long column comprised

of numerous columnals of different heights that are regularly inserted (=heteromorphic). Mature specimens have a cup sculpture of fine, closely-spaced, weakly-reticulated ridges. The proximal arms and pinnules (=the numerous, feather-like side branches) are fixed, that is, incorporated into the theca; the free arms are long, pinnulate, mainly formed from a double series of plates (biserial) and branching by equal division (=isotomously) at least five times.

Most specimens from the Lake District consist of dense aggregations of ‘*S.*’ *pulcher*, including well-preserved crowns retaining the proximal stem, long pluricolumnals, and disarticulated columnals and fragments of arms. There are very numerous small ossicles, mainly pinnular ossicles, on some slabs (e.g., Figure 3B); pinnule ossicles form a ‘carpet’ on BGS GSM 8997. Yet BMNH EE 5799 (Figure 4) is devoid of small fragments and separate ossicles, suggesting that this specimen, of uncertain provenance, may be from a different deposit. There is no doubt that these specimens represent current accumulations. Crowns and long pluricolumnals on all slabs show one preferred orientation, although incomplete specimens show a range of attitudes.

For more details, see Donovan *et al.* (2012, pp. 181-184, text-fig. 78, pl. 45, fig. 3, pls 47, 48). These specimens represent a new genus waiting formal renaming (G. D. Sevastopulo and co-workers, research in progress).

***Meristocrinus orbignii* (M’Coy, 1850) (Figure 5B)**

Specimen, locality and horizon. This species is known from only one specimen (=holotype), SM A29599. It is from High Thorns, Underbarrow, Kendal, Westmorland (M’Coy, 1851, p. 53), from the Ludlow (Ludfordian) Bannisdale Slates, ‘*Asterias* Bed,’ *Monograptus leintwardinensis* Biozone (Ramsbottom, 1958, p. 107).

Distinguishing features. Both *M. orbignii* and *Eutaxocrinus maccoyanus* (see below) are flexible cladid crinoids. Unlike ‘*S.*’ *pulcher*, the flexibles are dicyclic with the cup composed of three circlets of plates, the basals resting on the small infrabasals. *Meristocrinus orbignii* has a stem of low columnals that are all about

the same size (=homeomorphic) (Figure 5B). Basals and infrabasals are both low and pentagonal; the radials are higher than the infrabasals + basals. Granular plates between the arms (=interbrachials) extend to the level of the second arm branch. Arms consist of single stacks of plates (=uniseriate). There are no pinnules. Arms branch isotomously four times, branches tapering distally. For more details, see Donovan *et al.* (2010, p. 129, text-fig. 59).

***Eutaxocrinus maccoyanus* (Salter, 1873) (Figure 5A)**

Specimens, locality and horizon. Three specimens of this species are known from the Lake District and a further two have been collected from Leintwardine in Herefordshire. Specimens from the Lake District are from the ‘Asterias Bed,’ Light Beck, Underbarrow, Kendal, Westmorland, from the Ludlow (Ludfordian) Bannisdale Slates, *Monograptus leintwardinensis* Biozone (Ramsbottom 1958, p. 108).

Distinguishing features. *Eutaxocrinus maccoyanus* differs from *M. orbignii* in lacking interbrachial plates between the arms and in having arms that are more smoothly rounded (compare Figures 5A and B). The stem tapers slightly away from cup. Below this level, the stem is composed of regularly intercalated columnals of five orders (heteromorphic), unlike the homeomorphic column of *M. orbignii*. For more details, see Donovan *et al.* (2010, pp. 125-126, text-fig. 56, pl. 36, figs 1, 1a, 2, 2a).

Acknowledgements

The authors thank Mr E.S. Cardy for bringing BMNH EE 5799 (Fig. 4) to their attention and donating this specimen to the BMNH for study. Mr Phil Crabb (formerly Photographic Unit, BMNH) kindly supplied the fine images in Figures 3 and 4. We thank Dr. Fiona E. Fearnhead (the Natural History Museum, London) for her positive review.

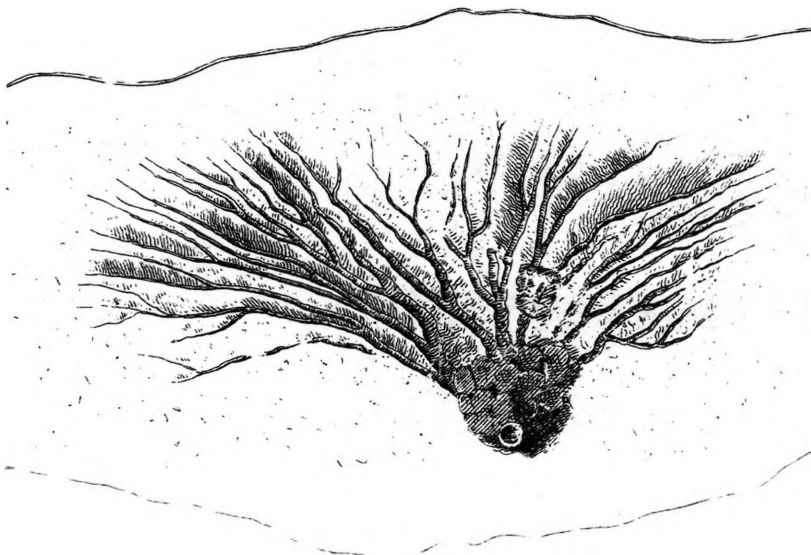


Figure 1 “ACTINOCRINUS (*new species*) From Knott-hollow Quarry, near Ulverston” (after Bolton, 1869, frontispiece) = ‘*Scyphocrinites pulcher*’ (M’Coy, 1851). This image is rotated 90° anticlockwise from its original presentation and the limits of the rock slab truncated to fit the page. Presumed x1.

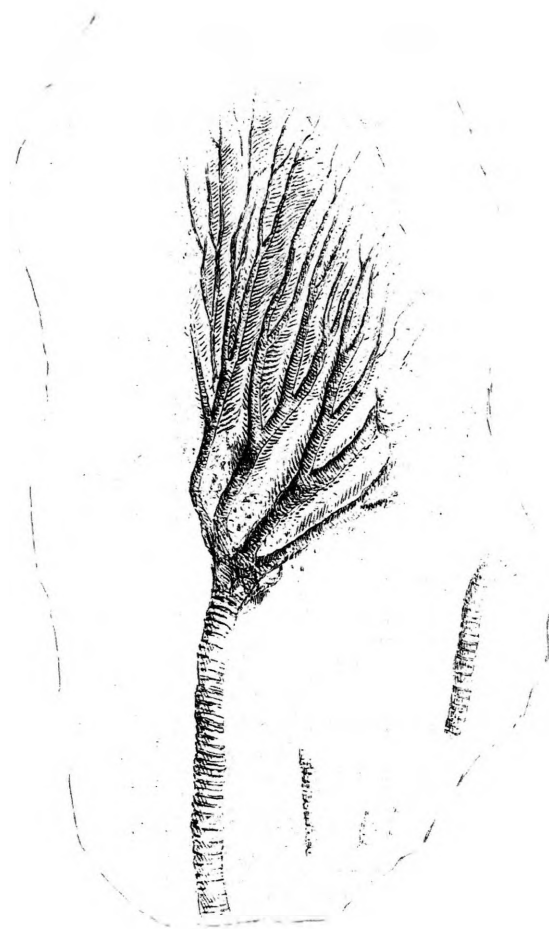


Figure 2 “ACTINOCRINUS PULCHER From Knott-hollow Quarry, near Ulverston” (after Bolton, 1869, opposite p. 164) = ‘*Scyphocrinites pulcher* (M’Coy, 1851). Presumed x 1.

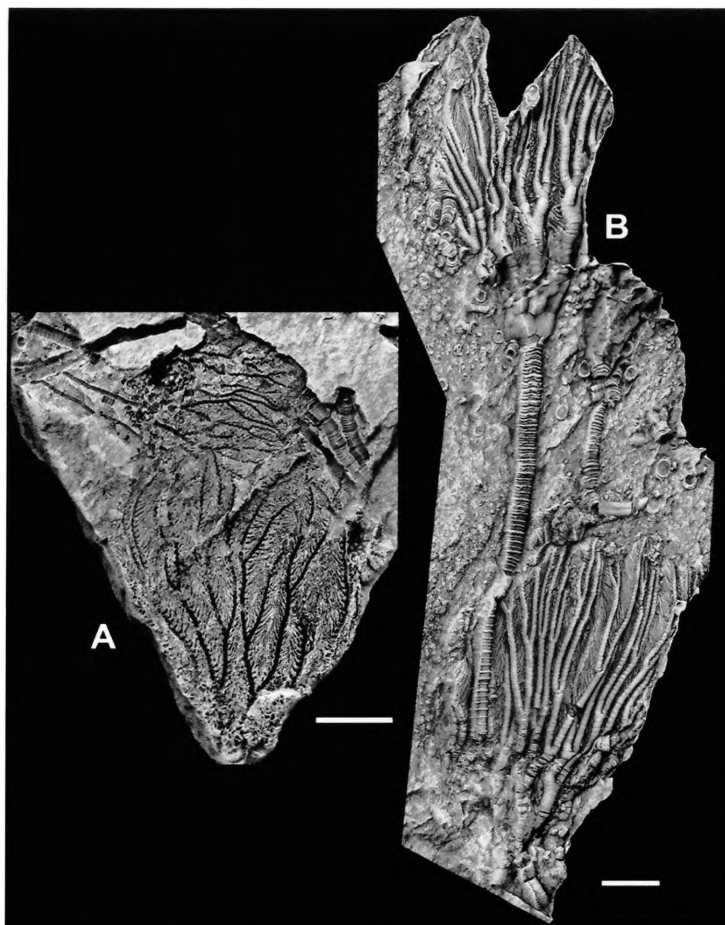


Figure 3 '*Scyphocrinites*' *pulcher* (M'Coy, 1851). (A) BMNH 42905, external mould of crown (after Donovan *et al.* 2008, fig. 3C). From the Silurian (Ludlow, Ludfordian?), Kirkby Moor Formation(?), Benson Knott, Kendal, Westmorland. (B) BGS GSM73997, latex cast of two crowns, one retaining a long pluricolumnals (after Donovan *et al.*, 2012, pl. 48, fig. 2). From the Silurian (Ludlow, *nilssoni* Biozone), Wray Castle Formation, Knott Hollow Quarry, Ulverston, Lancashire. Scale bars represent 10 mm. Specimens whitened with ammonium chloride for photography.

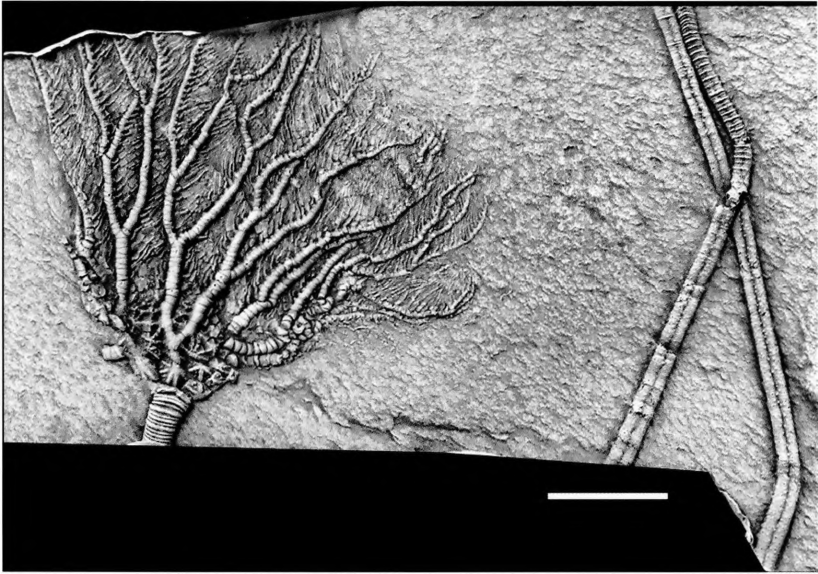


Figure 4 '*Scyphocrinites*' *pulcher* (M'Coy, 1851), BMNH EE5799, well preserved crown and long, crushed pluricolumnals (after Donovan *et al.*, 2012, pl. 47, fig. 1). From the Silurian (Ludlow), Lake District, precise locality unknown. Scale bars represent 10 mm. Specimens whitened with ammonium chloride for photography. Latex cast taken from natural mould.

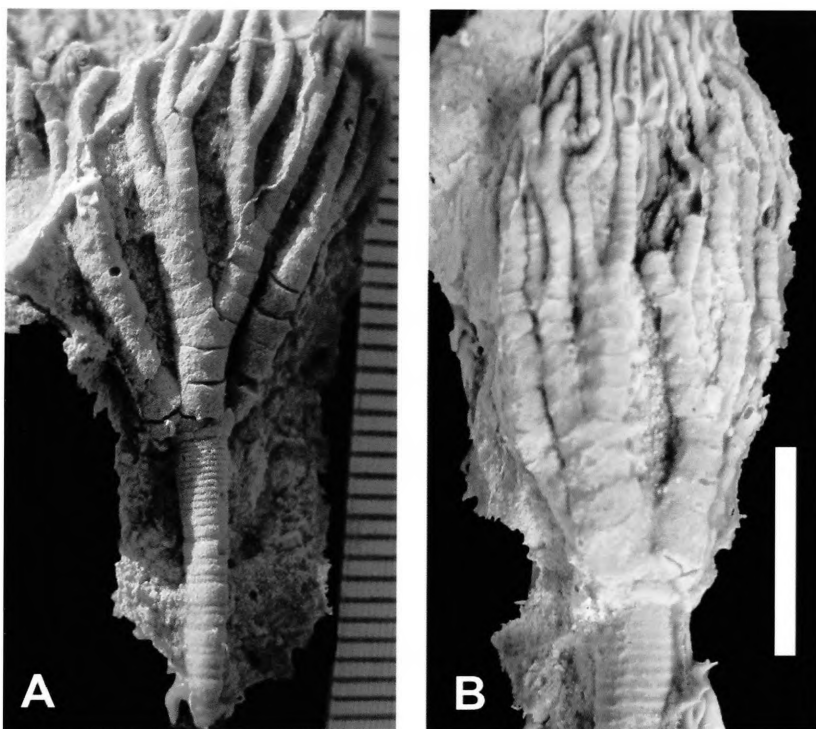


Figure 5 (A) *Eutaxocrinus maccoyanus* (Salter, 1873), SM A35407, holotype latex cast (after Donovan *et al.*, 2010, text-fig. 56). From the Silurian (Ludlow, Ludfordian) Bannisdale Slates, Underbarrow, Kendal, Westmorland. Scale in mm. (B) *Meristocrinus orbignii* (M'Coy, 1850), SM A29599, holotype, latex cast (after Donovan *et al.*, 2010, text-fig. 59). From the Silurian (Ludlow, Ludfordian) Bannisdale Slates, Underbarrow, Kendal, Westmorland. Scale bar represents 10 mm. Specimens whitened with ammonium chloride for photography.

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ALFRED WAINWRIGHT AND LAKELAND GEOLOGY

Alan Smith

There can be very few people who have come to know the Lakeland landscape as well as Alfred Wainwright. Over a span of sixty years from his first visit to the Lakes in 1930, until his death in 1991, he not only walked every fell and hilltop but he recorded, photographed and drew the details of the landscape with quite remarkable accuracy. His greatest achievement was undoubtedly the compilation of the seven '*Pictorial Guides to the Lakeland Fells*' published between 1955 and 1966. These have sold in their millions and are now iconic publications – frequently imitated, revised and analysed. Countless people have jumped on to the back of what is now 'the Wainwright industry', all envious of his fame, but none coming close to his achievements.

After his *Pictorial Guides* he produced 54 other books and publications, the vast majority on the Lakeland region. Significantly these include *the Guide to the Outlying Fells*, *5 Lakeland Sketchbooks*, *2 books of Lakeland Mountain Drawings*, *Sketch Books on Furness*, *The Eden Valley and Kendal*, the classic *Westmorland Heritage* volume, *Fellwanderer and Ex-Fellwanderer* and smaller works on *the Howgill Fells*, *Walks from the Ratty* and *the Old Roads of Eastern Lakeland*. (See under references for details *). It is often heard that 'if it isn't in Wainwright it doesn't exist'. It is his remarkable quest for detail in his maps, diagrams, route descriptions and drawings that helped to make his work unique. In many ways he was a better artist than writer. He saw not only the obvious details of a landscape, but he was looking at its texture and the intricacies of its rocks, slopes and fellsides.

In all his guide books, writings and drawings there are frequent references to geology and geologists. How good was his geology? This is perhaps an unfair question. Clearly he had no formal geological training or any qualifications in the subject, and the main point of his guides and writings had no geological purpose or aims. What is interesting however, is to look through his work and see how he dealt

with the geology of the Lake District, what he recorded, what he saw as significant or of interest, and which rock and landscape features he reacted to as a non-geologist.

The profile of geology to the intelligent layman in the period between the 1950's and the 1980's when Wainwright was doing most of his work was far lower than it is today. Since then, television and the media have brought earth science into the public domain and within the reach of most people. In Lakeland, the availability of guides to the geology, to the rocks and to the landscape has expanded greatly at all levels. Now we also have modern geological maps of the district. All of this would have undoubtedly rubbed off on Wainwright had it been available in his day.

Wainwright left us with some geological and geomorphological questions to answer. There were things he noted he could not explain. Perhaps this is the time to provide some answers. Naturally there are significant geological features that he missed and passed over without comment, but equally there were many occasions when he seemed to react to a feature, somehow knowing it had geological significance, but was unable quite to see why it may be important.

Searching for geological references through the first *Pictorial Guide – Eastern Fells*, published in 1955, surprisingly reveals very little. At only one point (Dove Crag 4) ** (see references), does he reveal that these are mostly fells formed of volcanic rocks. One can equally be dismayed by the fact that, with as many as 26 pages on Helvellyn, nowhere is there a mention that this is a landscape sculptured by ice. Considering this is arguably the best single piece of glaciated upland in England, with classic cirques, arêtes, and glacial forms the omission is striking. Elsewhere in the book there are references to 'grey boulders' (Low Pike 3), 'red rocks' (Red Screes 1), 'greenstone from the quarry' (Red Screes 2), 'grey rocks' (St Sunday Crag 7) and to 'a little outcrop of rock distinguished by quartz' on the summit of Heron Pike. There are several other references to quartz which he often used as a 'marker' rock in route descriptions. 'Rich red soil' is referred to on Great Mell

Fell, but no reference that it is derived from the underlying Devonian sandstones. As many Wainwright commentators have noted this first guide was in many ways the guinea pig. Changes were made to the later volumes, the detail increases and certainly he seems to grow more secure in his geological references and comments as time went by.

By the time he gets to Book 5 *The Northern Fells*, which are mostly underlain by rocks of the Skiddaw Group, he spends much more space on the basic geological details. The entry for Binsey for example, is most revealing. His first sentence is 'Binsey is the odd man out'. This is indeed the case, not only is it 'detached and solitary', 'its rocks are volcanic (actually Eycott Group), not slate as are those of all neighbour fells'. He later notes 'the rock here is a colourful volcanic'. It was a different fell in an otherwise landscape of Skiddaw Group rocks. There are many further references to the character of these Skiddaw Group fells elsewhere in Book 5, and again in Book 6 which covers *The North Western Fells*. He was very aware of the importance of the underlying rock in producing smooth outlines, copious screes (Grasmoor 2), bare featureless summits and rolling convex slopes. He was even moved to comment on the folding in the slates of Hobcarton Crag. He also comments on how few tarns there are on these fells as compared with the areas of the 'rugged volcanic fells'.

Progressively in the later Guide Books and publications, references to the geology increase. He is quite shrewd in his observations, clearly realising the contribution rocks and structures make to the nature of the landscape and the detail of the fells. He frequently draws the contrasts between the fells on the Skiddaw Group rocks and those on the Borrowdale Volcanic Group. It is striking however, how anonymous the rocks of the Windermere Supergroup in South Lakeland remain. It is true few of them produce high fells, but their undistinguished nature, their overall dullness and their lack of striking features comes through in his lack of interest in them. This is also true of many other Lakeland writers. The Eskdale and Ennerdale granites figure widely in his descriptions. He frequently picks up the older term syenite (Red Pike 2). Carrock Fell is well covered and described as a 'very rich geological

field' with quite detailed descriptions of the effects of the different rock types on the fellside features. He discusses the quality of the gabbros as ideal 'climbing rocks'. Carrock Mine is well documented and he finds space to reference John Postlethwaite's book on the *Mines and Mining of the Lake District* as the source of valuable information on the geology and mineralogy. The exposures of the Skiddaw granite in the bed of the river Caldew are well described and beautifully drawn. Similarly, the granite in Sinen Gill (Mungrisedale Common 2) gets a comprehensive treatment. Most of the minor intrusives however, do not evoke any comment (Threlkeld, Castle Head, or Haweswater for example). The Shap Granite is so distinctive that it figures widely in his descriptions and drawings, particularly of the erratics and in several of the village descriptions in the *Westmorland Heritage* book. All the major mining areas get significant treatment with drawings and text, typically for example, Coppermines Valley, Coniston (Coniston Old Man 11/12), or the Caldbeck Fell mines (High Pike 3/4).

Wainwright was excellent on limestone. He devotes a complete volume to the Yorkshire Dales limestones in *Walks in Limestone Country* and there is much on the karst terrain in his *Pennine Way Companion*. In the more Lakeland areas of karst, he is equally clear about the importance of the underlying rock in explaining the features and landscape. His descriptions of 'the tiered limestones' at Meathop, or of the 'dimpled limestone' at Maize Beck near High Cup Nick, or of the spectacular limestone formations around Holme and Hutton Roof all capture the karst terrain very well. His immaculate drawings of the pavements, sinks and shakeholes add greatly to his text descriptions. He is equally convincing on the underground cave features.

Wainwright had an obsession with sharp rocks, pinnacles and boulders of all shapes and sizes. There are countless drawings and references to them. He names hitherto unrecorded rocks and features and goes into great lengths about rock shapes and unusual configurations. His interest in terms of rock type however, is often minimal. He was quick to point out glacial erratics – noticeably the Shap Granite boulders over much of the limestone of Eastern Lakeland. He obviously understood

glacial erratics, and was clear of their significance in understanding ice movements. This is well borne out by his detailed account of the volcanic boulders on the summit of Latrigg. What is particularly interesting is the way isolated boulders assumed greater significance over the Skiddaw Group fells where they frequently stood out on otherwise featureless fellsides. Boulders are drawn that would never have been given a second glance on say Scafell Pike or Great Gable. There is some inconsistency in his coverage of some of Lakeland's rock pinnacles and big stones. Surprisingly he makes very little of Napes Needle on Great Gable, probably the most dramatic pinnacle in England. In a similar way it is puzzling why he doesn't comment or draw the Bowder Stone in Borrowdale – understandable perhaps because it is not on a major route to a significant felltop, although it is far and away the largest detached block in the district. It does however appear in his Sketchbooks.

There are a few places where Wainwright specifically raises geological queries. In his summit account of Sale Fell (11) he devotes almost a full page – with a degree of sarcasm to the geology of the minette intrusion, quoting at length from Postlethwaite. He asks... 'what is orthoclase, or worst still oligoclase'. To answer his question he is clearly referring to two of the feldspar constituents of the rock, the former a potassium feldspar, the latter a sodium rich member of the plagioclase group. Another geological query is posed in a two page account of the very distinct summit of Helm Crag above Grasmere. It includes a detailed drawing of the distinct linear ridges and depressions that run along the summit. The answer is in the structure of the volcanics, not the lithology. The strike of the beds is NW-SE, aligned with the ridge. Dips are high (between 30 and 40 degrees to the NE) hence the linear arrangement of crags and depressions reflects exposed ends of the beds along the strike. There is also a narrow dyke of basalt running through this ridge top which forms the linear feature Wainwright marks as the 'secondary ridge'. The prominent buttresses of the Lion and the Lamb that surmount the ridge are formed of beds of fine and coarse tuffs (Seathwaite Fells Formation) which weathering processes have sculptured into rather distinct shapes. There are no

specific geological differences in the tuffs to account for the particular shapes. Doves Nest Caves (Rosthwaite Fell 3) also intrigued Wainwright. In a long paragraph discussing caves in Lakeland he rightly points out these are not the same as the features found on limestone as we are in volcanic rock terrain. He concludes they are the result of the breaking away of the rock face. This is in fact the case. In an article in our own Proceedings (Wilson, Clark and Smith 2004) this site was logged as translational rock slope failure.

There are many references to glacial features in his later guides and books. Typical is his lyrical account of Bowscale Tarn ... 'A glacial combe ... tiered crags carved by ice; silent waters embanked by moraines; scattered rocks in the wake of the departed glacier '. He frequently notes old tarn beds (e.g. at Wythburn or on Blea Rigg or in Swindale). He records quite accurately the Loch Lomond Stadial moraines in Greenup Gill (High Raise 8), in the head of Langdale (Bowfell 9) and around Black Sail at the head of Ennerdale (Great Gable 19), taking time to draw them as a series of mounds, close in number to their actual distribution. Clearly he couldn't date them to the Loch Lomond Stadial, but unlike many other popular writers he does not fall into the trap of calling them drumlins. He does however use the word drumlins to describe some questionable features in Swindale (*Outlying Fells* p.234). There are some strange references to striations (Crinkle Crags 4), and at (Carlside 4), somewhat confusing in that they seem to refer to stripes in the rock material rather than true ice scratches.

Wainwright has to be given credit for his ability to read the features of the landscape and record his feelings about a place when, as a layman, he hadn't the understanding of the geological story in the rocks at his fingertips. He reacted to features as being interesting or different, but he couldn't completely understand why. A good example is at the Watches on Ullock Pike in the *Northern Fells* where he notes 'a strange and interesting congregation of upstanding rocks'. Alongside, he has an immaculate drawing of the feature. They stood out to him, but clearly he didn't know they were a rather complex plug like intrusion of

hornblende, clearly standing out in this otherwise monotonous terrain of Skiddaw Group rocks. The similar upstanding feature of Calfhow Pike (Great Dodd 10), on the northern end of the Helvellyn ridge he found worthy of comment, describing it as ‘a curious tor’ – a feature that clearly stood out, in this case the manifestation of an isolated faulted outlier of a resistant rhyodacitic tuff. The summit of Causey Pike struck him as not just ‘a delightful top, but unlike any other’. Little did he know how such an important thrust structure is exposed here (The Causey Pike Fault between the Buttermere and Kirkstile Formations). Dalehead he also recognised as a very significant geological location. Dalehead 2 notes that the Skiddaw /Borrowdale Volcanic junction determines the features on the western flank of the fell; he knew the junction was there, but didn’t quite tie it up properly with the features. Other places where full justice was not done to the underlying geology, although they were noted as being sites with geological interest, were on the summit of Esk Pike where the distinctive hornstones (fine, flinty, tuffs in the Esk Pike Formation) were described, Great Hall Gill (Whin Rigg 5) which was ‘a hunting ground for geologists’ or on the Great Slab on Bowfell 12/14. His descriptions of the high summit areas of Scafell Pike .. ‘the roughest summit in Lakeland’.. ‘gravelly plateau ‘ ... ‘barren tumbled wilderness of stones’ were very perceptive of what has since been considered as a possible nunatak feature. Geomorphologically perceptive comment is also detectable in his reactions to Hackney Holes (Robinson 9) and the Pinnacles on Crag Fell (2 and 4), Ennerdale, both sites now interpreted as significant rock slope failures (Wilson, Clark and Smith 2004, and Wilson and Smith 2006).

Wainwright’s use of vocabulary is also interesting. He uses words that are common and precise in geological terminology, but obviously accepted more loosely elsewhere. Surprisingly he uses the word ‘tor’ for prominent hilltops and rocky prominences. Tor is not a topographical place name in Lakeland, and in the geological literature tends to refer only to landforms associated with igneous rocks (typically granite forms). Whilst its use elsewhere is not incorrect, it is unusual. He also uses the word ‘arête’ very frequently, to refer to any narrow

mountain ridge. This term in geology tends to be confined to a sharp ridge created by the active erosion of the feature by glaciers working from opposing sides. Another example is the application of the word 'crater' which even in dictionary definitions has a volcanic connotation, whereas in the *Pictorial Guides* it is used far more loosely for any sharp edged, bowl like feature. Few geomorphologists would ever refer to the cirque basin of Addacombe Hole (Wandope 2) as a crater. There is also some confusion in the use of some particularly precise geological terms. He seems to equate quartz (the mineral) with quartzite (the rock). The word 'slate' is used often to describe any piece of flat rock, regardless of its composition. Striation is used loosely, implying a rock with linear markings or structures in it, not necessarily restricted to linear ice scratchings.

Unfortunately his books and guides do contain just a few mistakes, some real geological howlers, but many are common misconceptions that will be found elsewhere in similar publications. It is interesting that in common with a great many Lakeland writers, there is an obsession with trying to identify where the volcanic vents were that produced the Borrowdale Volcanic Group rocks. There is a misunderstanding of the complexity of this task, given that the volcanic episode was 450 million years ago and that vents and upstanding volcanic cones (if they ever existed) would be unlikely to be still visible. He does however, not go to the lengths of many other authors of assuming that anything in the present landscape that is vaguely cone like and prominent (like Castle Head near Keswick) must be an old volcano (Lefebure 1977, Pearson, Warner and Warner 1995 or Thompson 1946). In his description of Dove Crag in the *Eastern Fells* we have 'It is believed that Hunsett Cove was once the crater of a volcano'. Even more striking in Red Pike (B) 2 he writes 'East of the buttress, shared with High Stile, is the hanging valley of Bleaberry Comb and a secluded tarn, thought to occupy the crater of a dead volcano'. It is very difficult to get over this perception that volcanoes all have open craters and that nothing else has happened to this landscape in 450 million years. Far and away the most puzzling entry in the guides is on Illgill Head 7 on the top of the Wast Water screes.

Here he invokes a series of limestone sinks and a series of potholes in a vein of limestone! He clearly mistakes the rock slope failure features in the volcanic rocks along this ridge crest for karst features.

Finally it is worth reflecting on things he missed. Given his obsession with detail and his keen eye for the minutiae it is interesting that some striking geological and landscape features didn't catch his eye. It is a little surprising that he didn't notice the superb and very obvious fold structures in the lavas on the summit of Haystacks. Almost every detail of this rugged summit, the tarn, perched blocks and rock detail is recorded in what was to be his requested final resting place for his ashes. Folding in Lake District rocks was familiar to him and he was moved on several occasions to comment on them. He didn't comment on the Armboth dyke, such a distinctive pink rock stretching across the slopes of High Seat and High Tove; neither were fells that he seemed particularly attracted to. On Pavey Ark there is a lot of detail and comment about the rock being similar to the Skye gabbro, but no mention of what are perhaps the most staggeringly obvious and bizarre structures to be found anywhere in the Borrowdale Volcanic tuffs in Lakeland. They have been variously described as like 'amoeba', 'fossil jellyfish' or even 'dustbin lids' but he still failed to see them. (Lynas 1994, Gannon 2009). In *Westmorland Heritage* (Nateby 285) he has wonderful drawings of Skenkrith Bridge, but somehow says nothing about the classic brockrams exposed in the river bed and valley floor slabs, although he comments about the river potholes.

The more you look at Wainwright's work the more impressive it becomes. He was the master of detail, always curious, passionate about Lakeland and witty in his interpretation of what he saw. For him geology was 'one of the sideline interests of fellwalkers' (*Outlying Fells ix*). He grew in confidence with his geology over the years. He had a perceptive eye and became a master at reading the Lakeland landscape. He was clear and honest that it was a field where he could claim no real expertise, but it nevertheless fascinated him. He mused 'how much there is to learn about this fair earth and how little we know! How much beauty is never seen' (Sale Fell 11).

References.

* For a full listing of Wainwright's publications the most accessible source is Hunter Davies, 1995, *Wainwright: The Biography*, Michael Joseph, London. Full bibliography on pages 343-5.

** Many of the Wainwright books and particularly *The Pictorial Guides* are not paginated. He lists the fells in alphabetical order in each volume, with the successive pages on a particular fell in number order. Similarly in books like *Westmorland Heritage* places are covered alphabetically. In order to reference an entry therefore, the fell is named with the page number – hence (Sale Fell 11) for example, is the eleventh page of the description of that particular fell.

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COSMOGENIC ISOTOPE SURFACE EXPOSURE DATING OF GLACIAL LANDFORMS IN CUMBRIA

Peter Wilson

Introduction

Surface exposure dating of glacial landforms using cosmogenic isotopes has become a routine method for establishing the timing of ice advance and ice withdrawal at local, regional and global scales (e.g. Clark *et al.*, 2009; Vincent *et al.*, 2010; Ballantyne & Stone, 2012). Cosmogenic isotope analyses have also been utilised in other areas of geomorphology, for example in the age determination of rock-slope failures (Ballantyne *et al.*, 2014), periglacial block streams (Wilson *et al.*, 2008) and fluvial terraces (Repka *et al.*, 1997), and for estimation of the amount of surface lowering of limestone pavement since deglaciation (Wilson *et al.*, 2012). Applications of the techniques have enhanced knowledge and understanding of a range of Quaternary events and processes that were hitherto contested.

When minerals are bombarded by cosmic rays, cosmogenic isotopes are produced. Cosmic rays interact with elements contained in the minerals of rock and create new nuclei (Fig. 1A). The most commonly used isotopes in surface exposure dating are beryllium-10 (^{10}Be) and aluminium-26 (^{26}Al), extracted from quartz in quartz-rich rocks, and chlorine-36 (^{36}Cl), extracted from the whole-rock sample in cases where quartz is lacking or of extremely small grain size that it cannot be easily separated and analysed. These isotopes accumulate in rock over time; the concentration depends on several factors, primarily the composition of the rock, the intensity of the cosmic rays, the rate of rock surface erosion, and the elevation, latitude and topographic shielding of the sample which affect the intensity of the cosmic rays and the isotope production rate. It is possible to determine how long a rock surface has been exposed to cosmic radiation by measuring the concentration of an isotope and knowing its rate of production.

Establishing cosmogenic exposure ages of landforms requires a clear understanding of the geomorphological context and exposure history of the sample, careful field sampling and measurement of the rock surfaces, and a series of laboratory chemical procedures to extract and purify isotopes from the samples (Fig. 1B). Accelerator Mass Spectrometry (AMS) is used to measure isotope concentration which can then be converted into an exposure age. In a glacial context, perched erratic boulders, moraine-crest boulders, and ice-quarried bedrock (e.g. lee slopes of roches moutonnées) are the preferred landforms for age estimation because they have probably lost, through glacial erosion, an outer thickness of rock in which a pre-existing exposure signal likely existed. If glacial erosion removes sufficient rock (usually regarded as ~2-3 m thickness), the exposure 'clock' is zeroed and isotope accumulation begins afresh when the 'new' surface is exposed to cosmic rays. The measured isotope concentration and resulting landform age is therefore regarded as representing the most recent period of exposure. Detailed reviews of the technique and examples of its application are provided by Gosse & Phillips (2001), Phillips (2001) and Cockburn & Summerfield (2004).

In the last five years surface exposure ages have been obtained on glacial landforms from several areas in Cumbria, and the details, interpretation and significance of these ages are available in published papers. The purpose of the present paper is to bring all these ages together in order to demonstrate that the technique of exposure dating is providing direct chronological constraints, which were previously unavailable, on aspects of the most recent glacial episodes to have affected the area. However, some of the exposure ages seem likely to be slightly older than originally reported while others are considerably older than would be anticipated from the morpho-stratigraphic landform record. Possible reasons for these 'anomalous' ages are also outlined.

The last glaciation of Cumbria

During the Last Glacial Maximum (LGM), usually placed between ~27 ka and ~21 ka, the British and Irish Isles were covered by an ice sheet that extended west to the continental shelf edge, north to beyond the

Shetland Islands, and was confluent with Scandinavian ice in the northern half of the North Sea basin (Sejrup *et al.*, 2005; Bradwell *et al.*, 2008; Ó Cofaigh *et al.*, 2012). Much of the Midlands and south of England lay beyond the ice margin, but the Irish Sea ice stream, fed by ice from Scotland, Ireland, the Lake District and Wales, extended to the southwest of the Isles of Scilly (Scourse & Furze, 2001; McCarroll *et al.*, 2010; Fig. 2).

The distribution of local erratics, the absence of allochthonous erratics, the orientation of striae and glacial bedforms provide abundant evidence that at the LGM the Lake District mountains acted as an independent centre of radial ice dispersal. Lake District ice deflected ice moving south from Scotland to the east and southeast across the Pennines, and southwest into the Irish Sea basin. Ice sourced on the western and southern sides of the Lake District drained to the Irish Sea and Morecambe Bay, and ice from the eastern Lake District moved across the Pennines. This pattern of ice dispersal is known principally from the distribution of erratics derived from rocks of the Borrowdale Volcanic Group, the Windermere Supergroup, and the granite plutons at Eskdale and Shap, and from the distribution of erratics from the Southern Uplands of Scotland; the patterns and alignments of drumlins and end moraines also support these ice flow directions (Hollingworth, 1931; Gresswell, 1962; Hughes *et al.*, 2010; Livingstone *et al.*, 2012).

The thickness of ice over Cumbria has been debated since at least Ward (1873). More recently Lamb & Ballantyne (1998) identified a high level weathering limit at ~800-870 m OD on the mountains of the southwest Lake District (the Scafell Pike range and some neighbouring summits) and considered this to represent the upper limit of the LGM ice sheet. Above the weathering limit evidence for glacial erosion was said to be lacking, with summits characterised by shattered bedrock, blockfields and tors; these features were taken to indicate that the summits had remained above the ice as nunataks. Below the weathering limit abundant striations, roches moutonnées, ice-moulded bedrock and perched glacially-transported boulders were regarded as demonstrating a former cover of erosive ice. The weathering limit was

regarded as a periglacial trimline marking the maximum altitude reached by the last ice sheet and the level to which it had eroded or 'trimmed' pre-existing frost-weathered debris.

Numerical modelling of the last ice sheet by Evans *et al.* (2009) suggested that its maximum surface elevation over the Lake District may have been in the range 1000-1500 m. If that is correct then all summits were buried, only existing as nunataks during downwastage of the ice sheet. The weathering limit reported by Lamb & Ballantyne (1998) has since been re-interpreted by Ballantyne *et al.* (2009) as an englacial thermal boundary; erosive warm-based ice occurred below the weathering limit while passive cold-based ice existed above the limit and preserved the pre-existing shattered bedrock, blockfields and tors. Trimlines in other mountain regions of Britain, and in Ireland, North America and Scandinavia have been interpreted in a similar manner. In virtually all cases re-interpretation of trimlines as englacial thermal boundaries has been founded in part on the results of cosmogenic isotope surface exposure dating.

Indirect support for complete burial of the Lake District during the LGM is provided by McDougall (2001, 2013). He presented evidence for plateau icefields in the central fells and eastern fells during the Younger Dryas (Loch Lomond) Stadial of 12.9-11.7 ka when many small cirque and valley glaciers became re-established in the area (Manley, 1959; Pennington, 1978; Sissons, 1980). That summits above 750 m OD in the presently drier eastern fells of the Lake District could nourish glacier ice during this relatively short-lived and spatially restricted glaciation reinforces claims for complete burial of the mountains during the substantially longer LGM, when ice was considerably more extensive.

Review of surface exposure dating studies

To-date five papers have been published in which cosmogenic isotope surface exposure ages are reported for glacial landforms in Cumbria. Four of these involve glacial features in the mountainous core of the Lake District, the other study relates to more rolling terrain to the east

of the mountains but nevertheless this is a key region with regard to the timing and pattern of ice withdrawal on the east side of the Lake District. The ages and their implications are outlined below in order of publication date.

Ballantyne *et al.*, 2009: Scafell Pike and Wasdale, southwestern Lake District

The first cosmogenic isotope surface exposure ages were obtained from part of the area discussed by Lamb & Ballantyne (1998), particularly on and around Scafell Pike (978 m OD) (Fig. 3). The purpose of the work was to test the validity of the conclusions reached in that earlier study in addition to providing indicator ages for ice sheet deglaciation and the later phase (Younger Dryas) of cirque glaciation. Samples were drawn from exposures of ice-moulded bedrock, from both above and below the proposed trimline, and from glacially-transported boulders within the limit of a small cirque glacier of inferred Younger Dryas age. All samples were from rocks of the Borrowdale Volcanic Group and were analysed for whole-rock ^{36}Cl , summary details are given in Table 1.

The samples from a tor close to the summit of Scafell Pike and those from near Broad Stand are, respectively, from above and below the trimline. Both ages from the tor, 328 ± 37 ka (sample LD-05) and 110 ± 6 ka (LD-06), imply that the summit was not eroded by ice during the LGM, and was unlikely to have been so throughout the whole Devensian cold stage (~ 110 -12 ka). The marked age difference between the samples was accounted for by the removal of a block of rock at LD-06, probably by erosion under severe periglacial conditions, which thus reduced the apparent exposure age, the sample having been collected from beneath where the block had been positioned. The Broad Stand samples were obtained from ice-scoured bedrock below the trimline but both returned ages pre-dating the LGM. The ages of 76.4 ± 5.2 ka (LD-02) and 29.2 ± 2.1 ka (LD-03) suggest that glacial erosion did not remove a sufficient thickness of rock to zero the exposure signal. The ages obtained therefore reflect isotope inheritance from pre-LGM surface exposure.

In contrast to the Broad Stand ages, two samples from Lingmell col, also below the trimline, with ages of 13.2 ± 2.0 ka (LD-07) and 17.3 ± 1.1 ka (LD-08), indicate that a sufficient thickness of rock was removed from these sites by LGM ice such that the exposure signal was zeroed and isotope accumulation started afresh following deglaciation of the site. The older of these ages was regarded as providing the more accurate deglaciation age at this high level location. The persistence of ice until ~ 13 ka as implied by the younger age is not consistent with palaeotemperature reconstructions for northwest England at that time (Lang *et al.*, 2010). It was suggested that the bedrock sample that produced the younger age had probably been covered by a thickness of glacial sediment that, until removed by erosion, prevented isotope accumulation.

Two samples from the plucked face and the abraded face of a valley floor roche moutonnée in Wasdale returned exposure ages of 20.0 ± 1.4 ka (LD-12) and 50.0 ± 3.5 ka (LD-17) respectively. At face value the minimum possible age of the younger sample (18.1 ± 1.2 ka) could reflect the timing of site deglaciation, but the age is not consistent with other regional evidence for more extensive ice at that time. Therefore both ages were considered to be influenced by isotope inheritance because of insufficient rock erosion by LGM ice.

From within the limits of the Younger Dryas cirque glacier at Hollow Stones (Sissons, 1980) samples from two large angular boulders gave exposure ages of 35.1 ± 2.3 ka (LD-09) and 12.5 ± 0.8 ka (LD-10). The former age is considerably older than the glacial event to which the boulder relates and isotope inheritance was again regarded as the reason for this. The latter age, however, supports the widely held view that renewed glacier development occurred in the Lake District during the Younger Dryas Stadial.

Even though several of the exposure ages obtained by Ballantyne *et al.* (2009) indicate isotope inheritance and another indicates former burial by sediment, the data set enabled some reasoned conclusions to be

drawn. The samples from Scafell Pike, Broad Stand and Lingmell col validate the proposal of Lamb & Ballantyne (1998) that a weathering limit exists at ~800-870 m OD on mountains in the southwest Lake District. However, the origin of this limit as a periglacial trimline was revised, in the light of evidence for a substantially thicker ice cover over the Lake District, and it is now regarded as the boundary between erosive warm-based ice below and passive cold-based ice above the limit. Cold-based ice is known to be capable of preserving existing landforms.

Surface exposure ages constraining ice-sheet downwastage from other mountain regions of Britain and Ireland show broad similarity with the Lingmell col age of 17.3 ± 1.1 ka (Ballantyne *et al.*, 2006, 2008; Ballantyne & Hall, 2008; Fabel *et al.*, 2012). When taken together these ages indicate that deglaciation was advanced and much high ground had emerged from the ice by ~17 ka. The exposure age of 12.5 ± 0.8 ka from Hollow Stones is the first absolute age determination for the last episode of glaciation in the Lake District, and confirms that it occurred during the Younger Dryas Stadial as previously proposed (Manley, 1959; Pennington, 1978; Sissons, 1980).

McCarroll *et al.*, 2010: Wasdale, southwestern Lake District

As part of a wider study dealing with the maximum extent and deglacial chronology of the Irish Sea ice stream, McCarroll *et al.* (2010) reported a ^{10}Be exposure age on vein quartz from the lee side of a roche moutonnée eroded in Borrowdale Volcanic Group rock in Wasdale, close to the site sampled and analysed for ^{36}Cl by Ballantyne *et al.* (2009) (Fig. 3, Table 1). The age range obtained for the sample (14.2 ± 1.7 ka to 13.5 ± 1.4 ka) was calculated using the CRONUS-Earth online calculator (Balco *et al.*, 2008). The youngest age was based on zero erosion of the surface since deglaciation, the oldest age was based on an erosion rate of 1 mm / ka. This value is commonly taken as representative of post-exposure erosion of igneous and metamorphic rock surfaces (André, 2002; Nicholson, 2009; Larsen *et al.*, 2012) and if not factored in can result in underestimation of exposure age. Taken at face value the age range suggests that a valley glacier persisted in

Wasdale until ~ 14 ka, within the early part of the Lateglacial Interstadial (14.7-12.9 ka). However, the ^{10}Be production rate used by CRONUS-Earth is based on scaled values from globally distributed sites covering a wide range of altitude and latitude. Consequently large measurement uncertainties and relatively weak independent age control characterise these calibration samples. To overcome these issues more precise and consistent local production rates (LPRs) have been determined for the north-west Highlands of Scotland (NWH) (Ballantyne & Stone, 2012). These LPRs result in increases in the exposure ages and considerable improvements in levels of precision (statistical uncertainty). Three NWH LPRs were established by Ballantyne & Stone (2012) based on ages for Younger Dryas Stadial deglaciation at 11.6 ± 0.3 ka, 11.9 ± 0.3 ka and 12.2 ± 0.3 ka. Of these LPRs, ages derived from application of the 12.2 ± 0.3 ka calibration dataset are similar to an, as yet unpublished, LPR for the Loch Lomond area of Scotland that is based on independent evidence for Younger Dryas deglaciation.

Recalculation of the Wasdale ^{10}Be age using the 12.2 ± 0.3 ka NWH LPR, with an erosion rate of 1 mm / ka, produced an age range of 15.1 ± 0.7 ka to 15.0 ± 0.7 ka (Table 1). This age is a more realistic estimate for deglaciation of the site because mean July temperature rose rapidly and reached 12-13 °C at the start of the Lateglacial Interstadial at 14.7 ka (Anderson *et al.*, 2006; Lang *et al.*, 2010), suggesting that the persistence of valley glaciers much after that time was unlikely.

Hughes *et al.*, 2012: Keskadale, northwestern Lake District

In order to determine the age of the last glacier that occupied the compound cirque at the head of Keskadale (Fig. 3) in the northwest of the Lake District, Hughes *et al.* (2012) obtained two ^{10}Be exposure ages. One sample of vein quartz was taken from a boulder of Skiddaw Group rock on an arcuate moraine ridge bounding the lower cirque (Fig. 4A); the other sample, also of vein quartz, was from an ice-moulded outcrop of Skiddaw Group rock on the lip of the upper cirque of High Hole. The boulder sample gave an age range of 12.9 ± 1.6 ka to 12.4 ± 1.2 ka and the bedrock an age range of 12.3 ± 1.5 ka to 11.7 ± 1.1 ka

(Table 1). Both ages were taken as evidence for cirque occupation and moraine construction during the Younger Dryas Stadial, the latter having been proposed previously by Sissons (1980), Oxford (1985), Ballantyne & Harris (1994) and Whalley (1997). The ages were also used to infer that the cirque glacier reached its maximum extent early in the Younger Dryas, as evidenced by the exposure age of the moraine ridge boulder, and then retreated to the High Hole cirque where it stabilised before eventually wasting away. The High Hole cirque lip was exposed ~700 years after the glacier had retreated from the moraine, but it was recognised that the two ages are within 1σ uncertainties of each other and that more ages would be needed to support this timeframe.

Recalibration of the Keskadale ages with the 12.2 ± 0.3 ka NWH LPR, and an erosion rate of 1 mm / ka, gives ages of 13.8 ± 0.8 ka to 13.7 ± 0.8 ka for the moraine ridge boulder and 13.1 ± 0.7 ka to 13.0 ± 0.6 ka for the cirque lip bedrock (Table 1). These ages, although overlapping within uncertainties with the Younger Dryas Stadial, suggest that the cirque glacier must have developed before the Stadial (in the latter part of the Lateglacial Interstadial) and that it had substantially wasted away by ~mid-Stadial. Whereas recalibration of the ^{10}Be exposure age from the Wasdale roche moutonnée produced a more plausible age for valley deglaciation (see above), a similar recalibration exercise has resulted in a problematic outcome for Keskadale.

Wilson *et al.*, 2013a: Crosby Ravensworth Fell, eastern Cumbria

Erratic boulders of Shap granite are widely distributed across northern England and testify to marked changes in ice flow direction during the LGM as the ice sheet underwent internal reorganisation (Livingstone *et al.*, 2012). Four such erratics on Crosby Ravensworth Fell, 2.5-4.25 km east of the granite outcrop (Fig. 3), were sampled for ^{10}Be analysis by Wilson *et al.* (2013a) in order to provide a minimum age for deglaciation of the glaciokarstic landscape of Great Asby Scar 5 km farther east. Age calculation was based on the 11.9 ± 0.3 ka and 12.2 ± 0.3 ka NWH LPRs with an erosion rate of 1 mm / ka. For

consistency with other ^{10}Be ages reported and discussed in this paper only the results derived from the 12.2 ± 0.3 ka LPR are given in Table 1. Of the exposure ages obtained, one (SHAP-08) was deemed to be anomalously old probably because of isotope inheritance; the other three (SHAP-02, -03 and -07) displayed some degree of internal consistency and gave an age range of 18.6 ± 0.9 ka to 16.4 ± 0.9 ka. The uncertainty-weighted mean age of 17.35 ± 0.5 ka is regarded as the best direct estimate yet available for deglaciation of the Shap area.

The mean exposure age is consistent with other absolute dates relating to the loss of glacial ice cover from nearby areas. It is generally younger than ages from sites to the south in Lancashire and Yorkshire (Telfer *et al.*, 2009; Wilson *et al.*, 2012), but older than ages from sites in the Lake District to the west (McCarroll *et al.*, 2010; Wilson *et al.*, 2013b). In contrast, some recent models depicting advance and retreat of the last ice sheet put deglaciation of the Shap area at 16.0-15.5 ka (Evans *et al.*, 2009; Hubbard *et al.*, 2009; Livingstone *et al.*, 2012), some ~1-2 ka later than indicated by the mean exposure age.

Wilson *et al.*, 2013b: Central Lake District

Moraine ridges and mounds in the valleys of the central Lake District, close to Rosthwaite and Watendlath (Fig. 3), were subjected to exposure dating by Wilson *et al.* (2013b) in an attempt to resolve issues concerning: (1) stillstands/readvances during deglaciation from LGM limits and, (2) the extent of Younger Dryas ice cover. Sixteen samples (four from each of four sites – Rosthwaite, Watendlath, Wythburn (Steel End) and Langstrath) were collected from large, glacially-transported boulders (Fig. 4B). The first three sites were at the downvalley limits of their respective Younger Dryas valley glaciers, as proposed by McDougall (2001), but thought by others to be associated with pre-Younger Dryas valley glacier margins (Manley, 1959; Wilson, 1977, 1982; Pennington, 1978; Sissons, 1980; Clark & Wilson, 1994). The fourth site, in mid-Langstrath, was within the Younger Dryas limit as proposed by both Sissons (1980) and McDougall (2001). Fifteen samples were analysed for whole-rock ^{36}Cl and one sample (WAT-02) of vein quartz for ^{10}Be (Table 1).

Two ^{36}Cl ages were reported for each sample based on different production rate estimates. The maximum age difference between these age pairings was 5 ka for sample SE-04. Irrespective of age difference magnitudes the majority of samples from Rosthwaite, Watendlath and Wythburn returned ages that pre-dated the time period of the LGM or were coincident with it (range 59.6 ± 3.7 ka to 23.5 ± 0.8 ka). Therefore it was not possible to ascribe the glacial-depositional landforms from which the samples were taken to either a stillstand or readvance of valley glaciers following the LGM, or to glaciers that developed in the Younger Dryas Stadial. These ages were considered to have been compromised by inherited ^{36}Cl .

One sample (ROS-04) returned ^{36}Cl ages of 19.0 ± 1.1 ka and 16.6 ± 1.0 ka. At face value these ages suggest that the boulder is younger than the LGM and that the moraine ridge from which the sample was collected was created as a result of a stillstand or readvance of the valley glacier that occupied the Stonethwaite branch of Borrowdale. However, caution was advised with respect to interpretation of these ages from a single boulder, but in broad terms the ages support previous views that the Rosthwaite moraines pre-date the Younger Dryas Stadial (Wilson, 1977; Pennington, 1978; Sissons, 1980; Clark & Wilson, 1994) rather than having formed in that glacial episode (McDougall, 2001).

Exposure ages from the mid-Langstrath site, within the limit of the Younger Dryas glacier, also proved controversial in that several of the ages imply that the moraines were created by a glacier that pre-dated the Younger Dryas Stadial, and some of the Langstrath ages overlap within uncertainties with the ages for ROS-04, 5-6 km downvalley.

The sample (WAT-02) analysed for ^{10}Be gave an age range of 14.4 ± 1.8 ka to 13.6 ± 1.3 ka, placing the Watendlath valley glacier within the Lateglacial Interstadial. Using the 12.2 ± 0.3 ka NWH LPR, with an erosion rate of 1 mm / ka, produces a more plausible age range for the glacier terminus of 15.3 ± 0.8 ka to 15.2 ± 0.8 ka (Table 1), prior to the

Interstadial. If valid, this age range supports the view of Wilson (1982) that the glacial depositional landforms at Watendlath were created during a stillstand or readvance of a valley glacier that pre-dated the Younger Dryas Stadial, in contrast to the Younger Dryas age proposed by McDougall (2001).

Discussion

This initial tranche of cosmogenic isotope surface exposure dating studies of glacial landforms in Cumbria has highlighted both the value of the technique in providing improved chronological constraints on the most recent glacial events and the problems that need to be resolved if the method is to yield its full potential.

Perhaps the most interesting outcome to-date concerns three samples (W-13, ROS-04 and WAT-02) whose exposure ages indicate that, in their respective valleys, glaciers may have persisted until just prior to the rapid warming of climate that marks the opening of the Lateglacial Interstadial at 14.7 ka. If this provisional finding can be verified by additional exposure ages it will add significantly to the dating evidence available from both Wester Ross and Galloway, in the northwest and southwest of Scotland respectively, for the continued existence of some valley glaciers around the time of marked climatic amelioration (Ballantyne & Stone, 2012; Ballantyne *et al.*, 2013). The uncertainty-weighted mean exposure ages indicating that glaciers persisted in the hills of Galloway following the LGM until ~15.5-15.0 ka are particularly relevant in this respect because this area is just 100 km northwest of the Lake District.

In contrast, a number of ‘old’ exposure ages were obtained by Ballantyne *et al.* (2009) and Wilson *et al.* (2013b). These were ^{36}Cl determinations and the samples were interpreted as having substantial levels of inherited isotope. Ballantyne *et al.* (2009) attributed this to the resistance of Borrowdale Volcanic Group lithologies to glacial erosion such that insufficient rock had been eroded and the exposure signal had not been zeroed. This may also have been the case with the samples analysed by Wilson *et al.* (2013b), but it may also relate to the complex

mechanisms and pathways by which ^{36}Cl accumulates in rocks. It has been reported by Schimmelpenninck *et al.* (2009) that ^{36}Cl exposure ages derived from whole-rock analyses are older and less accurate than those derived from different separated minerals from the same samples by about 30%. The implication of this is that analyses based on both whole-rock samples and mineral separates should be conducted on Borrowdale Volcanic Group rocks in order to determine, if possible, the best approach to adopt for dating glacial landforms. At present the use of volcanic rock samples and ^{36}Cl for extending and improving the chronology of the most recent episodes of glaciation is limited because of the number of unreliable ages that have been produced by two studies. A noteworthy point here is that these studies used different laboratories for ^{36}Cl analyses, suggesting that the results cannot be attributed to different laboratory procedures. Given the current costs (~£750 per sample) and turnaround time (3-6 months) associated with sample preparation and AMS analysis, plus those incurred in sample collection, it is advised that ^{36}Cl is not used for Lake District samples until these issues are resolved.

Conclusions

The value of cosmogenic isotope surface exposure dating in geomorphology is beyond doubt, as numerous studies have testified, and some of the initial work in Cumbria has also shown the potential of the technique. Use of ^{10}Be seems to be the best way to proceed but requires quartz which is not always readily available. Although two ^{10}Be exposure ages suggest the late survival of valley glaciers following the LGM, another two ages, when recalibrated with an LPR, pose problems with respect to the timing of a proposed Younger Dryas glacier at the site. Thus, even where quartz has been utilised, use of an LPR has not always given results that conform to the morpho-stratigraphic landform record.

Resolving the ^{36}Cl / Borrowdale Volcanic Group ‘problem’ is not just a matter of local interest. Volcanic rocks exist in other glaciated regions of the British Isles (for example Snowdonia and the Scottish Highlands) and a similar issue may arise if ^{36}Cl exposure dating is applied there.

At present very few ^{36}Cl ages have been reported from these areas but application of ^{36}Cl may become necessary in the future if age constraints on landforms and their formative processes are required.

In spite of these problems surface exposure dating is beginning to provide age estimates for glacial events in Cumbria that hitherto were inferred from the morpho-stratigraphic landform record or were based on other dating techniques that do not necessarily provide close constraining ages. It is anticipated that as current issues are resolved surface exposure dating will be applied to a greater range of geomorphological features and will gradually provide a detailed chronology of landshaping events both during and following the decay of the last ice sheet.

Acknowledgements

I thank the anonymous referee who suggested ways of improving the initial draft of the paper. Frances Wilson and Kilian McDaid prepared the diagrams for publication.

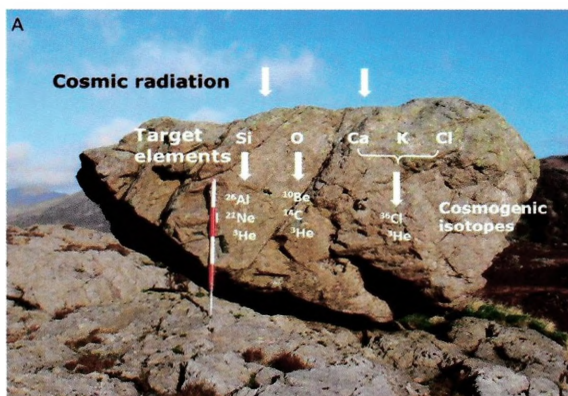


Figure 1A Simplified depiction of cosmogenic isotope production in a glacially-transported boulder. Survey pole is 1m in length.

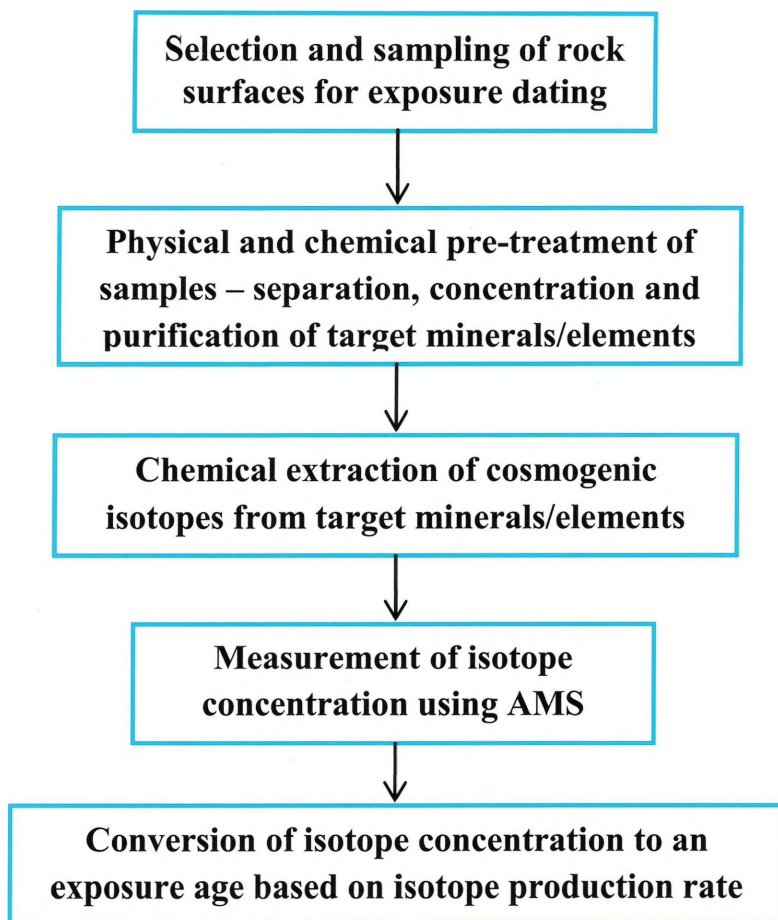


Figure 1B Key stages in obtaining cosmogenic isotope surface exposure ages; Gosse & Phillips (2001) provide further details.

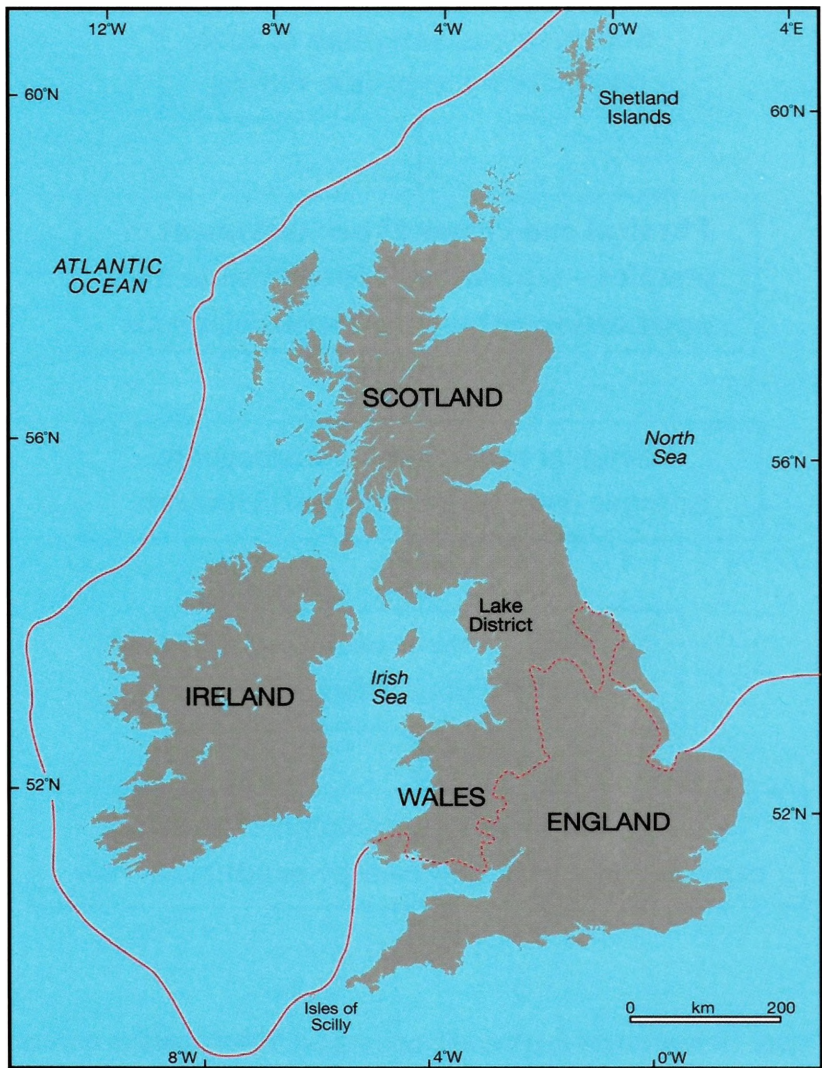


Figure 2 The maximum extent (solid/dashed red line) of the British-Irish Ice Sheet during the Last Glacial Maximum (after Scourse & Furze, 2001; Sejrup *et al.*, 2005; Bradwell *et al.*, 2008; McCarroll *et al.*, 2010; Ó Cofaigh *et al.*, 2012)

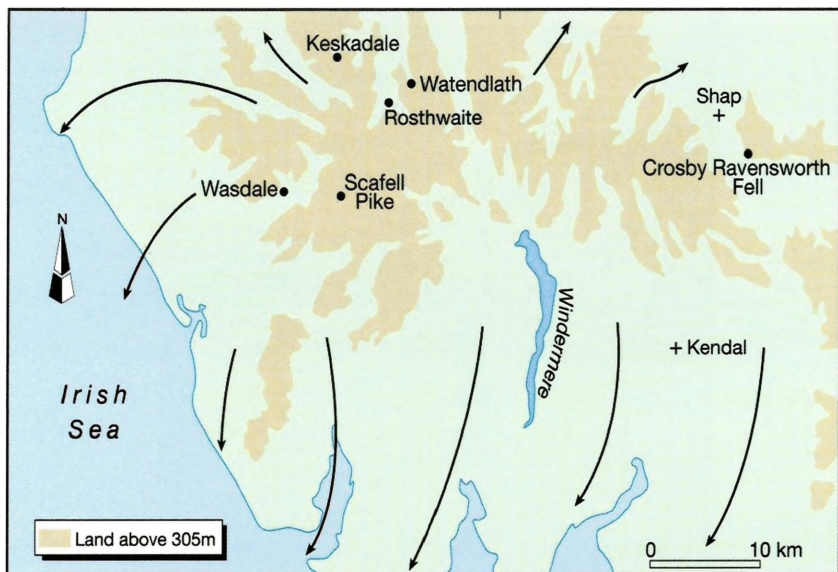


Figure 3 Locations of sites in Cumbria sampled for cosmogenic isotope surface exposure dating. Arrows indicate generalised directions of ice flow during the LGM. For clarity the only lake shown is Windermere



Figure 4A Glacially-transported boulder of Skiddaw Group rock containing vein quartz on the moraine ridge at Keskadale. The boulder returned a ^{10}Be age of 12.9 ± 1.6 ka to 12.4 ± 1.2 ka (Hughes *et al.*, 2012), recalibrated to 13.8 ± 0.8 ka to 13.7 ± 0.8 ka. Survey pole is 1m in length.



Figure 4B Glacially-transported boulder of Borrowdale Volcanic Group rock in Langstrath (LANG-01). The boulder returned whole-rock ^{36}Cl ages of 14.9 ± 0.9 ka and 13.2 ± 0.8 ka. Survey pole is 1m in length.

Table 1 Summary details of cosmogenic isotope surface exposure ages from Cumbria. Ages are reported to an uncertainty level of $\pm 1\sigma$, indicating a 68.3% chance that the true age will lie within $\pm$ one standard deviation (σ) of the given age

Sample location and code ^a	Grid reference	Altitude (m OD)	Sample type	Exposure age (ka $\pm 1\sigma$)	Recalibrated age (ka $\pm 1\sigma$)
Ballantyne <i>et al.</i>, 2009^b					
Scafell Pike summit tor					
LD-05	NY 216 071	960	Bedrock	328 $\pm$ 37; 279 $\pm$ 31	
LD-06	NY 216 071	965	Bedrock	110 $\pm$ 6	
Near Broad Stand					
LD-02	NY 212 069	795	Bedrock	76.4 $\pm$ 5.2; 76.2 $\pm$ 5.2	
LD-03	NY 211 068	775	Bedrock	29.2 $\pm$ 2.1; 28.5 $\pm$ 2.0	
Lingmell col					
LD-07	NY 211 077	765	Bedrock	13.2 $\pm$ 2.0; 11.9 $\pm$ 1.8	
LD-08	NY 211 078	750	Bedrock	17.3 $\pm$ 1.1	
Wasdale					
LD-12	NY 155 061	125	Bedrock	20.0 $\pm$ 1.4; 18.1 $\pm$ 1.2	
LD-17	NY 155 061	125	Bedrock	50.0 $\pm$ 3.5; 44.9 $\pm$ 3.1	

Hollow Stones					
LD-09	NY 205 074	595	Boulder	35.1±2.3; 35.0±2.2	
LD-10	NY 205 073	595	Boulder	12.5±0.8	
McCarroll <i>et al.</i>, 2010					
Wasdale					
W-13	NY 153 063	190	Bedrock	14.2±1.7 - 13.5±1.4 ^c	15.1±0.7 - 15.0±0.7 ^d
Hughes <i>et al.</i>, 2012					
Keskadale					
PHSITE2	NY 199 176	310	Boulder	12.9±1.6 - 12.4±1.2 ^e	13.8±0.8 - 13.7±0.8 ^d
PHSITE6	NY 200 174	420	Bedrock	12.3±1.5 - 11.7±1.1 ^e	13.1±0.7 - 13.0±0.6 ^d
Wilson <i>et al.</i>, 2013a					
Crosby Ravensworth Fell					
SHAP-02	NY 588 100	275	Boulder	17.1±0.9 - 17.2±0.9 ^d	
SHAP-03	NY 590 103	300	Boulder	18.5±0.9 - 18.6±0.9 ^d	
SHAP-07	NY 604 108	325	Boulder	16.4±0.9 - 16.5±0.9 ^d	
SHAP-08	NY 601 096	330	Boulder	20.9±1.1 - 21.1±1.1 ^d	
Wilson <i>et al.</i>, 2013b^f					
Rosthwaite					
ROS-01	NY 256 138	108	Boulder	32.6±3.3; 30.5±3.1	
ROS-02	NY 256 138	107	Boulder	32.0±2.8; 33.5±2.9	

ROS-03	NY 258 139	115	Boulder	29.7±2.0; 26.8±1.8	
ROS-04	NY 258 138	115	Boulder	19.0±1.1; 16.6±1.0	
Watendlath					
WAT-01	NY 277 152	340	Boulder	36.4±3.0; 35.7±3.0	
WAT-02	NY 278 155	290	Boulder	14.4±1.8 - 13.6±1.3 ^c	15.3±0.8 - 15.2±0.8 ^d
WAT-03	NY 277 155	285	Boulder	52.7±2.3; 50.9±2.2	
WAT-04	NY 280 152	355	Boulder	25.8±1.2; 25.3±1.2	
Steel End (Wythburn)					
SE-01	NY 320 130	185	Boulder	48.3±4.8; 46.7±4.6	
SE-02	NY 321 131	183	Boulder	35.7±1.9; 35.4±1.9	
SE-03	NY 321 129	188	Boulder	27.2±1.0; 23.5±0.8	
SE-04	NY 320 129	186	Boulder	59.6±3.7; 54.6±3.3	
Langstrath					
LANG-01	NY 257 094	260	Boulder	14.9±0.9; 13.2±0.8	
LANG-02	NY 263 096	260	Boulder	15.2±0.7; 14.2±0.7	
LANG-03	NY 264 096	250	Boulder	17.4±1.2; 18.1±1.3	
LANG-04	NY 265 096	250	Boulder	13.1±0.9; 13.6±0.9	

Key for Table 1

^a As given by original authors.

^b ³⁶Cl ages calculated using calibrations of Stone *et al.* (1996), Evans *et al.* (1997) and Phillips *et al.* (2001). First age is simple exposure age, second age is minimum possible age.

^c ¹⁰Be ages calculated with CRONUS-Earth global calibration data set assuming zero erosion (youngest age) and 1 mm / ka erosion (oldest age); as reported by original authors.

^d ¹⁰Be ages calculated with NWH LPR (12.2±0.3 ka) assuming 1 mm / ka erosion. Ages represent the oldest and youngest of four different scaling schemes.

^e ¹⁰Be ages calculated using CRONUS-Earth global calibration data set assuming zero erosion. Ages represent the oldest and youngest of four different scaling schemes; as reported by original authors.

^f ³⁶Cl ages (except WAT-02) calculated using production rates of Phillips *et al.* (2001) - first age listed, and Stone *et al.* (1996) and Evans *et al.* (1997) - second age.

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SHORT COMMUNICATION: SOME COAL MEASURES EXPOSURES AT WHITEHAVEN

David Kelly, Fred Lawton, David Steele

There are relatively few exposures of the Coal Measures in West Cumbria and their number is diminishing as a result of quarries being filled, landscaping work and cliff collapse. Some of those remaining are difficult to access in safety and their future existence is threatened by slope failures and encroaching vegetation. The purpose of this short account is to record exposures at two Coal Measures localities, as seen in May 2012. At both localities the rocks are shown on the BGS Whitehaven Sheet 28 (2004) to lie in the Middle Coal Measures above the Bannock Band.

Coastal section north of Whitehaven railway station (Figures 1 – 5)

This has been visited by the Society on several occasions but parts of it are liable to dangerous rock falls and, in the summer months, are difficult to access through dense vegetation. The localities described are those in the cliffs adjacent to points NX 9760 1983 in the south and NX 9769 1985 in the north. These references are for points on the coastal track between Whitehaven and Parton, as GPS readings close to the cliffs are inaccurate. In these exposures the Countess Sandstone (CS) overlies a dark grey shale. The shale falls away from beneath the sandstone making the sandstone cliff unstable.

Prominent scours up to 8cm long are seen in the base of the CS. The lower part of the CS contains bands of ironstone nodules and streaks of coal, the largest being over 1m long and 8cm thick. The sandstone has parallel laminations and small scale cross bedding inclined to the south west. There are steeply inclined joints and at least two normal faults with throws of about 1m, dipping to the south west.

A particularly impressive feature is seen at the northern end of this section (a GPS reading taken close to the cliff of NX 9768 1984 may

not be completely accurate). Here the undisturbed sandstone is overlain by a block (or blocks) 1m thick and up to 8m long. The block has coaly laminations which show vertical bedding with small scale folds. It has been interpreted as a block of partly lithified material which has slumped into a channel. The block is overlain by a conglomerate of ironstone nodules varying in thickness from 0 – 50cm. The conglomerate is overlain by undisturbed sandstone. To the south the conglomerate rests on the sandstone.

Whitehaven Brickworks Quarry (Figures 6 – 10)

The quarry is known by various names including Howgill Quarry. It was last visited by the Society in 1977. It is on private land and enclosed by a fence. Dog walkers and those taking short cuts regularly access the quarry from Woodhouse Road. The 1931 Whitehaven and Workington Memoir records a section of the Coal Measures along the Howgill haulage incline (“The Brake”) immediately north of the quarry. This shows a series of nine coal seams numbered from the bottom, the lowest of which is the Preston Isle Yard Band (recorded as the Slaty Band more recently). In the years between 1931 and the end of quarrying some 40 years ago, much rock has been removed from the quarry. Following the abandonment of the quarry in 1969, some faces have collapsed and there has been much growth of vegetation. As a result, it is not easy to relate the exposures in 2012 to the section recorded in 1931.

On the east side of the quarry there are only small exposures but debris from the quarry floor shows siltstones and fine sandstones very rich in plant fossils. It may be that this was rejected for brick making and has been dumped here. It is likely that much of this material came from the horizon between Nos. 4 and 5 seams which the 1931 survey notes may be the same horizon as the plant-rich shales below the Countess Sandstone in the William Pit to Parton section.

The west face of the quarry shows 20m or so thickness of rock with a 10 - 20m debris slope covering the rocks below. It is unstable and access to the upper beds is impossible. One coal seam may be visible

high on the face. Further extension of the quarry to the west would have been prevented by the track along the quarry top and the proximity to the Woodhouse housing estate. The thickest brick clays were also dipping ever deeper to the west below the face.

The south side of the quarry shows the gentle dip to the west. Close to the top of the slope a 20 – 30cm seam of poor but combustible coal is the only accessible seam at the time of writing. It is underlain by 80cm of seat earth with roots and then a pale clay with ironstone nodules. A dark shale occurs about 3m below the seam. This is likely to be No. 5 seam.

Thomas and Cleal (1993) published an extensive paper about fossils from the quarry, referred to as “Howgill Head Quarry”. The paper is not mentioned in the 1997 West Cumbria memoir. The paper describes plant fossils collected from the quarry between 1967 and 1980. 250 of these specimens are now in the collection of the National Museum of Wales in Cardiff. 26 form-species of plant fossil were identified from the quarry, including lycopsids (club mosses), equisetopsids (horsetails), pteridopsids (ferns) and gymnospermophytes (seed plants). The fossils are described as representing the only well documented example of a *N. semireticulata* Subzone assemblage in Britain. The fossils are said to confirm that the rocks exposed in the quarry are part of the Whitehaven Sandstone Formation, and not a stratigraphically lower unit as indicated above. The lithology is not like the purple coarse to medium sandstone typically associated with the Whitehaven Sandstone and the BGS Whitehaven Sheet 28 (2004) shows the location of the quarry within the Middle Coal Measures. This issue is beyond the scope of this paper but may be relevant to the possible diachronous base of the Whitehaven sandstone as a result of lateral facies variation.

References

The Society has visited the Whitehaven to Parton section on six occasions. These are recorded in:

Proceedings of the Cumberland Geological Society, 5, 344 – 346.

Proceedings of the Cumberland Geological Society, 5, 469 – 475.

Proceedings of the Cumberland Geological Society, 6, 273 – 275.

Proceedings of the Cumberland Geological Society, 8, 162 – 165.

The visits of May 25th 1976 and May 23rd 2001 are not recorded.

The Society has visited the Whitehaven Brickworks quarry on two occasions. One is recorded in:

Proceedings of the Cumberland Geological Society, No. 2 1962, 19 – 23.

The visit on May 11th 1977 is not recorded.

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British Geological Survey. 2004. *Whitehaven. England and Wales Sheet 28. Solid Geology. 1:50 000*. British Geological Survey, Keyworth.

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McCormac M. et al. 1997. In *Geology of the west Cumbria district*. Memoir for Sheets 28, 37 and 47. British Geological Survey.

Thomas B. A. and Cleal C. J. (1993), Middle Westphalian plant fossils from the West Cumberland Coalfield, UK. *Geol. J.*, 28: 101-123. doi: 10.1002/gj.3350280202

David Kelly

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Figure 1 The Countess Sandstone forms the overhanging upper cliff and the dark grey shale in the bottom right of the photograph forms the lower part of the cliff.



Figure 2 This layer of coal within the sandstone is 8cm thick and just over a metre long.



Figure 3 Coaly layers and cross lamination in the Countess Sandstone.



Figure 4 The block of sandstone with vertical, folded laminations lies between undisturbed beds of sandstone. There is a wedge of ironstone conglomerate, 20cm thick in the centre, above the block on the right.



Figure 5 Small scale folds in the steeply dipping laminated sandstone overlain by ironstone conglomerate.

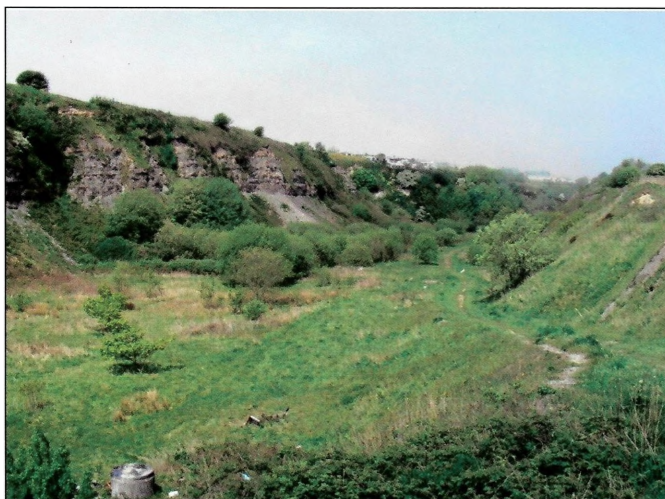


Figure 6 The Whitehaven Brickworks Quarry in 2012, looking north.



Figure 7 Part of the west face of the Whitehaven Brickworks Quarry in 2012.

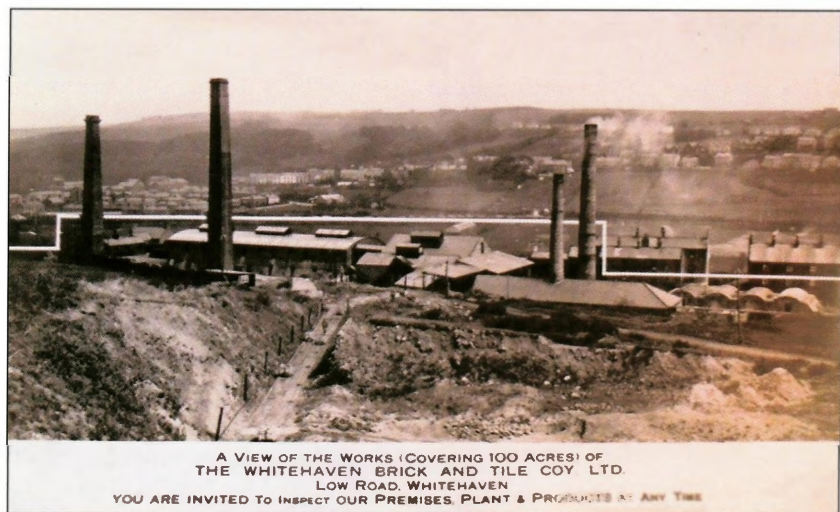


Figure 8 Whitehaven Brickworks



Figure 9 Whitehaven Brickworks

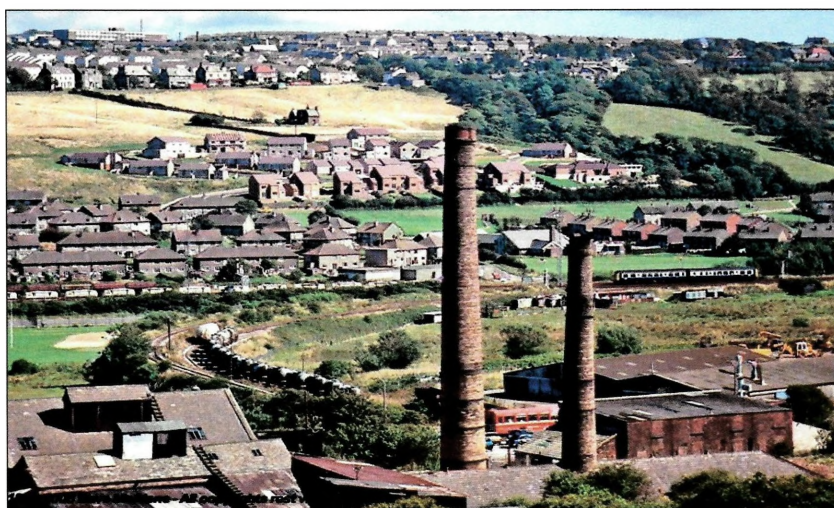


Figure 10 Whitehaven Brickworks in the 1960s

EXCURSION REPORTS 2012

INDUSTRIAL HISTORY IN GELTSDALE

Leader: Elizabeth Pickett (Geodiversity officer for the North Pennines AONB)

Sunday June 10th 2012

This trip was led by Elizabeth Pickett, the Geodiversity officer for the North Pennines AONB, and involved a 7 mile walk through the northern part of an area in north Cumbria known as King's Forest of Geltsdale. 15 members were given a guided tour of the geology and industrial history of the valleys that had once contained working quarries and mines and had employed hundreds of people extracting a variety of materials from the local Namurian formations of the Carboniferous.

Passing close to the Tortie Stone, an archaeological feature around which have been found 5000 year old arrow heads, we reached the large disused Forest Head Quarry in the Great Limestone and its accompanying lime kilns. These were four adjacent structures of considerable size with impressively vaulted interiors built from local sandstone. Remains of the old railway line were apparent, and working took place here up to 1932, with the famous locomotive "Rocket" being used as one of the engines.

On the eastern flank of Talkin Fell we came to the site of the former Black Sike Colliery, serviced by its own railway (now gone), and a little further south Black Sike Flags Quarry, a pit some 200 metres long by about 60 metres wide. Massive blocks of sandstone are still occasionally in demand from here but the principal products were the flaggy beds that were used for roofing in the region.

Lunch was taken at a place called the Greens, an area underlain by the Great Limestone as was evident from the short cropped turf and uneven ground formed by a combination of abandoned lime kilns and shake holes. At this point we enjoyed a particularly fine view of the upper Geltsdale Valley.

Turning east into How Gill we encountered the old workings of Gairs Colliery, accessed by a drift entrance (now collapsed) and employment for 180 underground workers and a further 50 on the surface between 1910 and 1930. This enterprise was also served by its own railway and the lines of additional tramways were pointed out as we made the long trek up and over the watershed and then down Howgill Beck towards the RSPB nature reserve at Tindale Tarn. On arrival, site manager Steve gave us a brief account of the work being done there, including tree-planting, blanket bog restoration and monitoring of the black grouse population. This concluded what had been an enjoyable and varied excursion in a less-frequented but attractive and interesting part of the county.

CLINTS QUARRY

Leaders: Mervyn Dodd, Jim Samson, David Powell

Wednesday July 18th 2012

A group of about a dozen members met on the road next to the quarry (NY008123). At the entrance to the quarry the Fourth Shale was noted on the south side, the quarry being mainly in the Fourth Limestone. The quarry was examined walking in a clockwise direction. At the south end of the quarry the Rough Limestone was examined in the quarry floor, with areas of what were possibly quarried out hematite.

The south end of the quarry faced exposed the beds above the Rough Limestone. Working upwards, these were the Spotted Limestone and the Potholes Limestone, with the intervening shales. At the north-east

corner of the quarry several interesting shotholes were examined and at the north-west corner colonial and solitary corals were examined in the loose blocks. There was much speculation about the very uneven quarry floor and the way the rock was removed by rail with the progressive development of the quarry.

ESKDALE GRANITE AND HEMATITE

Leader: David Kelly

Saturday September 1st 2012

A group of 17 met at the King George IV pub where the leader explained that the morning would be spent examining the Nab Gill Hematite Mine at Boot and the afternoon would be spent looking at the Eskdale Granite at Devoke Water.

At the foot of the slope at Boot it was noted that the Nab Gill Mine was the biggest of several small mines in Eskdale and worked from 1870 – 1918. Nevertheless the largest annual output was less than 10 000 tonnes, therefore total production was less than 250 000 tonnes. In 1875 the Ratty was built to take ore to main line at Ravenglass, with one terminus here and one at South Cumberland Mine. Members examined the ruins at the foot of the slope of the office, blacksmith's shop, change house and loading bays.

The relief of Nab Gill has been much altered by mining operations and members viewed the incline tramway from the foot of the slope. The vein followed line of the gill, the stream guided by the fault that was the conduit for the mineralising solutions. The veined had a NNW trend and dipped steeply to the NE. There were several branch veins. The average thickness was 0.76m – 1.06m, with just 0.20m at the bottom and a maximum of 6.1m at the felltop.

The mine is probably a composite of several intermittent workings. There were 5 levels, connected by shafts with robberies in between with open cast workings on the fell top. Some members examined Level No. 5 to the SW of foot of tramway. There is little to see of Levels No. 4 and No. 3 so members ascended the steep slope of the tramway, noting small specimens of kidney ore (pencil ore) on the slope. Quartz was the main gangue, with calcite and dolomite recorded. There were some manganese ores at top.

At No. 2 Level the 30cm thick branch vein is now partly destroyed but part of it was still visible on this visit. The steep slope was climbed to the top of the fell where the open stope above No.1 Level showed an open fault cavity dipping northwards and completely cleaned out of ore. The fault continues, unmineralised, to Ill Gill Head. On the descent, the scree below No. 1 Level yielded specimens of kidney ore

In the afternoon, the party met at the end of the road to Devoke Water. It was noted that the Eskdale Granite has the largest outcrop of the Lake District granites and has been dated at 450Ma, (Ordovician), like the Ennerdale Granite but unlike the Devonian Shap and Skiddaw granites.

The Lake District batholith is therefore very complex. At Eskdale various types of granite occur including a coarse grained granite, a microgranite (similar to the Ennerdale Granite) and a granodiorite to the south, not seen on this visit. In some areas the granite is altered to a greisen. The granite was intruded close to the Skiddaw Group – Borrowdale Volcanic Group boundary therefore field relations are complex and uncertain. The granite tends to be low in landscape like the Skiddaw Granite.

The party walked along the track towards Devoke Water. Seat How to south is almost completely in basaltic andesites of the Birker Fell Formation of the Borrowdale Volcanics while granite is north of track. The outflow of Devoke Water is Linbeck Gill. This is usually fordable but heavy rainfall in the previous week meant that members had to confine themselves to examining exposures on the north side of Devoke water.

The first exposures examined by Linbeck Gill were part of the Birker Fell Andesites. On the lower slopes of Water Crag rocks of the Skiddaw Group were pale brown slabs of silty mudstone with low angle cleavage. Further up the slope the first granite exposures were observed. Here the greisen is a quartz-topaz rock with grey quartz, cream topaz and some purple fluorite. The metallic minerals native bismuth, molybdenite, arsenopyrite recorded from the site were not seen on this visit. The party followed eastern edge of greisen uphill close to contact with the Borrowdale Volcanics. Skiddaw Group rocks were seen between the two and a small band of pink andalusite with quartz close to contact.

Further up the slope granite and volcanics were seen in contact and at the summit of Water Crag granite, microgranite and volcanics were seen in close proximity. The granite at contact was unaltered.

The view from the summit of Water Crag was studied. Granodiorite underlies the area to south with white weathered granite seen on Brantrake Fell, Muncaster Fell and Irton Pike. The southerly dip of the Birker Fell Andesites on Green Crag and Harter Fell was visible in the topography

The group walked back to the cars via Rough Crag with exposures of granite, microgranite, Borrowdale Volcanics and greisen all seen along the way.

OTHER EXCURSIONS HELD IN 2012

Wednesday May 16th 2012. Slate & Watch Hills. Leader: Jim Samson.

Wednesday August 1st 2012. Mawbray submerged forest. Leader: Ann Lingard.

Saturday June 30th 2012. Carrock Fell Igneous Complex. Leader: Tom Sedgwick.

EXCURSION REPORTS 2013

MOOTA QUARRY, BOTHEL

Saturday May 18th 2013

About fifteen members met at the quarry on an extremely wet morning for the first excursion of the season. We were greeted by the quarry manager, geologist and estates manager for the area. It was explained that the company hopes to open a minor extension to the quarry, otherwise there is only two years of accessible working left. The plan will also involve improving access to some of the existing limestone faces which are a Rigs site.

The quarry has been worked since 1947 and is entirely in the Fourth Limestone. The party was taken on a guided walk round the old and new workings and the proposed extension and new access arrangements were explained. The site is restricted by the transmission mast on Moota Hill. The intention is to preserve some of the benched faces and scree slopes with a body of water at the base to maximise biodiversity. An existing footpath would be diverted and a new paved circuit built with viewpoints and geological information boards

The weather prevented any detailed examination of the rocks but it was clear that, as well as limestone, there was much sandstone and mudstone. The trace fossil *Zoophycos* was seen on the face of one limestone block.

The stone is used entirely for aggregate and a mobile crushing and screening plant is used. Production is currently 150 000 tonnes per annum and the proposed extension would give access to a further 2 million tonnes. The visit finished with a tour of the workshops and the old brick making plant.

The Society thanks Cemex UK for allowing and supporting this visit.

CRAZY PAVING IN THE CROSS FELL INLIER

Leader: John Rodgers

Sunday June 2nd 2013

25 members and friends assembled at Dufton on a fine, dry Sunday morning with the main purpose being to examine the landforms, structures and varied rock types of the southern end of the Cross Fell inlier. A short diversion was first taken by descending down into Dufton Ghyll Woods where the St. Bees Sandstone is well displayed in a series of old quarries in this picturesque valley. Discussion centred on the Triassic palaeoenvironment and it was agreed that evidence from the sedimentary structures indicated fluvial deposition. The red-brown sandstone was the major building stone in this part of the Eden Valley but we were reminded that it is generally considered to be inferior to the older (Permian) Penrith Sandstone because of its poorer cementation.

The group then proceeded to High Cup Winery at Keisley where we were able to leave vehicles before taking the path behind the buildings northwards towards and around Harthwaite. This hill is one of the many fault-bounded blocks that have been elevated into their present positions by movements along the Pennine Fault zone which is effectively the western border of the inlier. An outcrop in the hillside showed a yellowish silicic tuff which is the local equivalent of the later Borrowdale Volcanic Group pyroclastic rocks that occur throughout the central Lake District. The route then followed part of the Pennine Way track with small bedrock exposures of dark grey Dufton Shales before re-entering the volcanic block of Gregory after taking a right turn and heading south towards Studgill Tarn. After a brief lunch stop the party looked at the highly brecciated ignimbrites in the old quarry and noted the major landslide on the eastern flank of the hill. Further south along the path, a boggy area is shown on the map as being underlain by shales of the Kirkland Formation. A prominent circular mound in this area promoted discussion of its origin (glacial hummocky moraine?) but the

surprising find at this location was blocks in the wall consisting of a pink microgranite with large hexagonal phenocrysts of muscovite. There was no evident outcrop seen but this unusual rock is believed to have been obtained from a small old working on the northern flank of Keisley Bank.

After crossing another faulted boundary we entered a zone of dark green andesitic tuffs, considered to be early Ordovician, and then beyond Studgill Tarn we passed small outcrops of rhyolite and ignimbrite that form the bulk of Keisley Bank. However, there is a marked change of slope just below the summit ridge and the lower part of the southern side is composed of the pale grey Upper Ordovician Keisley Limestone, exposed as a series of steeply dipping beds in old workings. A search for fossils here revealed small brachiopods and crinoid stems. The final part of the excursion was a descent across the yellow rhyolite and ignimbrites at the western end of Keisley Bank, much crossed by quartz veins.

THE WORKINGTON SHORE

Leader: David Powell

Wednesday June 12th 2013

A very large party met at the pier end car park at Workington (NX 983295) for the first visit of the Society to this locality. The leader introduced the visit and pointed out that no bedrock is exposed in the area and that the coast has been transformed by industrial activity. Drift cover in the area is between 5 and 25m thick over much of the area and up to 45m thick in buried channels. He presented an array of beach material which included Lake District and Scottish rocks, including limestone with *Pholas* borings.

The party walked south along the shore at the foot of the slag bank, then climbed inland to view the former iron and steelworks site and returned, in deteriorating weather, to the car park via the Cumbria Coastal Way along the top of the slag bank.

The walk south was along the shingle beach. There was considerable discussion about the effects of tipping slag on the beach. In some places the foreshore consisted of fused slag with incorporated beach material. This forms surfaces which dip gently towards the sea on which marine life cannot easily get established. There was discussion about the rather mysterious tunnel beneath the slag bank.

The coastal strip between Whitehaven and Maryport has been greatly altered by tipping of colliery waste and furnace slag, and the Chapel Hill slag bank was the largest of these. At one time it reached over 30m high. Attempts were made during reclamation to match the original contours of Chapel Hill by redistribution of slag. Today the slag cliffs are up to 20m high. In some places these have been easily eroded and undercut. Limestone blocks have been used as sea defences.

The walk back to the car park along the top of the slag bank provided excellent views of the former iron steelworks (somewhat obscured on the day by mist and rain) and the leader pointed out the former locations of different parts of the works. He also noted the site of old pit sites which pre-date the steelworks. These included Isabella Pit, Lady Pit and Chapel Bank Pit. There was also a view down into the quarry where slag is being extracted for use as aggregate.

KIRKBY STEPHEN - ROCKS AND STRUCTURES IN THE PERMO-TRIASSIC AND CARBONIFEROUS OF THE UPPER EDEN VALLEY

Leader: Noel Pearson

Sunday June 16th 2013

A group of 20 members and friends assembled on a pleasantly dry day at the Belah layby (NY 793121) on the A685 in East Cumbria. The itinerary was intended to cover the range of sedimentation in the Permian and early Triassic when a comparison could be made of the two synform outliers in the river Belah and the river Eden east of Kirkby Stephen. Whilst this excursion revisited two localities mentioned in previous CGS Field Guides, the walk was based on Burgess (1965) who mapped the area in detail and summarised and reinterpreted earlier observations.

The geological setting of the red beds and Brockrams of the Eden Valley has been most recently summarised by the BGS (2010) and by Woodcock and Strachan (2012). Here the picture presented 300Ma, following the closure of the Rheic Ocean and the formation of Pangaea, is of arid and semi-arid conditions characteristic of 20 degrees north of the equator. The huge continental interior created extreme seasonality with dry winters and wet summer conditions along northern Palaeotethys margins. The local area was distantly affected by the Variscan front which re-elevated the Alston and Askrigg Pennine blocks along pre-existing Palaeozoic fault lines. Regional extension in the early Triassic from around 250Ma (the boundary with the Permian is difficult to date due to lack of fossils) then allowed marine incursions. As a result, sedimentary features representing alluvial fans, sabkha-type evaporites, sandy sheet floods, mud flats, playa lakes, river channel systems and dunes can be found.

The walk started from Belah bridge. This carried the old road and was built on an exposure of Penrith Brockram, a natural place for a ford. In the field immediately south of the bridge, cross-bedded sandstones suggest dune encroachment against the Brockram surface of the bank of the layby. We then walked along the north bank to the classic section of Belah Scar on the south bank (NY 796122). This was well summarised by Skipsey (1994) who described “....several sequences of sandstones with basal scours filled with gravels which pass through silts into thin mud layers representing repeated floods cutting down into sand deposits. Local thicker patches of red mudstone suggest that the flood waters were sometimes trapped in ephemeral ponds. Much of the sandstone is structureless but occasional layers show steep cross-bedding with well-rounded sand grains in these bands suggesting that they may represent temporary encroachment from the north”

A feature which caused some speculation was the pale- coloured rock (around 50cm x 40cm in size) emplaced about 5m above the river in an otherwise structureless red sandstone matrix (Figure 1). Was this one of the sliding rocks of a racetrack playa or some diagenetic alteration of the host material?

The group continued upstream along the north bank of the Belah for 500m to a bend (NY 800124) where the river crosses several metres of Penrith Brockram. The next 100m (more easily accessible outside the nettle season!) was seen looking back from (NY 801123) and comprises, above the Brockram, 20m of mainly thinly bedded reddish-brown sandstones, then 12m of brownish siltstones. This is followed by the type exposure of Belah “dolomite”, 5m of grey, yellow and reddish dolostone, best seen on the south bank. Some shelly fauna were found by Burgess in the basal layers, indicative of a coastal, possibly sabkha environment. Many features can best be studied when the river is low, but the upper section on the north bank is always accessible. Here the dolomite has undergone diagenetic change and features veins and solution cavities with the vertical faces showing thin steeply dipping red and grey bands, probably representing a collapse structure (Figure 2). Lying on the surface are well-rounded pebbles (1-2cms) of a dark red

haematite rich mudstone. We speculated on the source without coming to definite conclusions.

The whole sequence above the Brockram represents the Eden Shales (formerly the Hilton Series) and is consistently dipping around 15 degrees to the south east. The St Bees Sandstone Formation of red beds of siltstones and sandstones, with ripple marks at different levels, can be seen succeeding the dolomite (the D gypsum bed found in the Hilton borehole is absent). This too is dipping in the same direction. However 500m upstream (but not on public footpaths) the St Bees Sandstone Formation dips to the north west and further upstream the Eden Shales (without dolomite) dips 12 degrees to the west, thus defining the 1½km-wide depositional synform basin.

Returning to the Belah layby, the group drove to Kirkby Stephen parking in the Market Square. Taking a path to the west of the church gave an opportunity to examine the contrasting building stones of the church (purportedly demolition from Castle Hill Warcop) and vernacular housing built of Stenkrith Brockram. The path led on to Low Mill Bridge (NY 775091) where the river runs over Penrith Brockram. Burgess characterises this as “angular fragments of up to 1ft or more across of yellow dolomitised Carboniferous limestone..... in a matrix of Penrith sandstone”. It is poorly cemented and known as “rotten Brockram”, and not used as building stone. Just upstream from the bridge there is evidence of these beds gently dipping south east. The group then took the path on the east side of the River Eden to Franks Bridge for a picturesque lunch stop.

From here, for 200m, the river turns to follow the dip of the Brockram. In summer the bankside vegetation obscures the Eden Shale succession but when the river is low, and earlier in the year, it is possible to understand how Burgess mapped the sequence of sandstones, siltstones and mudstones, and discovered the 2½m of grey, yellow and reddened dolomitic limestone about 70m downstream from a small waterfall. Below the fall we could see the 7m band of red mudstones with their characteristic greenish reduction spots. The fall itself is due to the

resistant band of Stenkrith Brockram, dipping 15 degrees south east which Burgess defines as “sub-angular to sub-rounded pebbles of pale grey undolomitised Carboniferous limestone in a reddish matrix of St Bees Shale well cemented with calcite”. This is more appropriate as building stone.

The sequence compared with that in the Belah is reduced - the dolomite beds are only half as thick. From this and fossil evidence (marine bivalves and algae) Burgess concluded that as the carbonate sequence thins from the Brough district southwards to a shoreline near Kirkby Stephen, and passes northwards to an evaporite sequence around Kirby Thore. It is possible that a connection existed with the Zechstein Sea to the east via a strait in the region of the present Stainmore syncline.

Following the river upstream, the walk crosses the Permo-Triassic boundary. For the next 400m there are few features to note in the river. A spring on the bank may indicate the outcrop of the St Bees Shales, characterised by Burgess as “consisting generally of fine-grained, brownish-red micaceous siltstones”. Passing a barn and exposures of red sandstone in the river, the group moved through a gate and over Ladthwaite Beck to a 5m high exposure of massive, poorly cemented, reddish brown St Bees Sandstone. Distributed along the length of the Eden Valley and in West Cumbria, it is now thought this represents the erosion deposit of the Variscan mountain chain located 800k away, in what is now northern France, brought by the Budleighensis river system. At this locality the dip of these beds was measured and found to be virtually horizontal or opposed to those above Franks Bridge. The base of the syncline must therefore be nearby (it is to be found in exposures below the water level at the bend (NY 77950820). Interestingly the axis of this basin runs north east – south west, similar to that in the Belah area and on the line of the Dent Fault. The BGS Sheet 40 shows it disappearing under the Kirkby Stephen syncline.

The walk continued through the wood to a gate, then left, uphill for 400m to a divided bridge (NY 781077), then down to the viaduct walk. Essentially this is a good way to observe the topography of the Eden

Valley to the north west and the Pennine escarpments to the east. As the walk turns north east to the Podgill Viaduct good views can be obtained of Birkett Hill to the east where the offset dips in the limestone could usefully be explored on another occasion. The cut of Ladthwaite Sike, believed to be several hundred years old and a possible feeder for the ruined Hartley Castle, was also pointed out.

At the end of the viaduct the group turned into Hartley Quarry, and following a line of boulders on the right, walked down the incline to the base of the Merrygill Viaduct which stands on a foundation of St Bees Shales. The merits of this were discussed. Thomas Bouch the architect clearly got this one right, but not unfortunately the Tay Bridge. Retracing our steps and turning to where Hartley Beck emerges from the rubble slope (NY 785084) is an unused settling tank and assorted abandoned pipework. Just to the west of the tank is an exposure of St Bees Shale dipping to the west with a protruding hard band of yellow sandstone.

The main purpose of including this spot in the walk was to show the evidence for the unconformable Carboniferous limestone/St Bees Shale boundary which Burgess valued, judging by the detail of his observations. Unfortunately more time and some agility are required to inspect this exposure. Burgess reinterpreted 19th century work to show that all the Eden Shales and Penrith Sandstone strata are missing. Also there is a discordance in the westerly dip, i.e. towards the centre of the syncline, between the underlying dolomitised limestone at around 20 degrees and the overlying shales at 12 degrees.

The group then returned via Hartley to Kirkby Stephen and drove to the parking area (NY 773073) on the Nateby road above Stenkrith Park. From the Millenium Bridge which crosses the “Devil’s Grinding Hole”, the type locality of Stenkrith Brockram was viewed in the gorge. We followed the easterly dip of the beds downstream (consistent with being to the west of the syncline) to where the river widens into a pool and the Brockram is superseded by the siltstones of the St Bees Sandstone Formation and thicker beds of St Bees Sandstone.

In the Kirby Stephen district Burgess places the Stenkrith Brockram in the base of the St Bees Sandstone Formation within the siltstones. Comparing this section with that upstream of Franks Bridge, Burgess noted the inverse thickness of siltstones and Brockram. At Stenkrith the latter is 20m thick and the siltstones around 3m, whereas above Franks Bridge the Brockram is around 4-5m and the siltstones 15-18m thick. Clearly the diachronous relationship with the Brockrams thinning to the north reflects the source of supply from the south.

We concluded the day with some speculation about the age of the limestone breccia found in the Stenkrith and Penrith Brockrams. The latter is more dolomitised. Could it represent a more altered erosion surface from beds lying above the undolomitised source material for the Stenkrith Brockram? This would mean that although the Penrith Brockram is older, the material included is younger and vice versa for the Stenkrith Brockram. While this may be plausible, the sources of the two breccias may be from different directions and represent different environmental conditions. Unfortunately lack of time did not permit inclusion of sites near Nateby. A closer study of the unconformities at these sites of the Stenkrith Brockram where it separately overlays the Penrith Brockram and the Carboniferous limestone, and observations of the associated bedding and imbrication may have helped to resolve this.

As Gordon Taylor notes “much of the Permian and Triassic geology of the Vale still remains unsolved. There is much the amateur geologist could contribute”. Hopefully there are some new observations here and I would like to acknowledge the help of John Rogers in checking them out.

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Figure 1 A pale- coloured rock (around 50cm x 40cm in size) emplaced about 5m above the river in red sandstone at Belah Scar (NY796 122)



Figure 2 The possible collapse structure in the Belah north of Belah Scar

GARBURN PASS

Leader: Mike Dewey

Sunday June 30th 2013

The leader met the party in in Staveley Mill Yard, (SD 471983) and then proceeded to the Moorhowe Road - Dubbs Road junction (NY 424006). The party walked along the track leading north. After 100 metres, the leader pointed out rocks in the Yewbank Formation in the field on the right. It was pointed out that as we walked northwards along the track we would walk up the dip and the rocks would get older. He informed the group that the excursion forms the basis of a pamphlet published by Cumbria Rigs.

The first exposed rock was in a small cutting or quarry on the left. This was in the Poolscar Formation. It was a grey siltstone with beds of fine-grained sandstones. The outcrop dips at 70 degrees towards the south-east.

The party then continued along the track to Dubbs Reservoir where there are two different rock formations. The Latrigg Formation crops out at the dam on the opposite side of the reservoir. At the far end of the reservoir the rocks are in the Gawthwaite Formation.

On the right-hand side of the track by a small feeder stream to the reservoir where glacial till can be seen. This till was laid down by ice was moving southwards down the Troutbeck Valley from the High Street area.

Beyond the reservoir on the hillside to the left a small plunging fold was evident. The rock here is the Wray Castle Formation, in this area it is much more sandy than it is at the Kirkby slate quarries further south-west.

The party made its way to Applethwaite Quarry. This was further along the track on the right. The rocks in the quarry are in the Brathay Formation which is a dark laminated mudstone. This quarry has been an important economic resource for the area as it provided roof slates. Bedding and cleavage were clearly evident. On the quarry face there was a very thin layer of pale coloured bentonite, the weathered volcanic ash.

Back on the track, 50 metres past the entrance to Applethwaite Quarry there was a white rock band across the track marking a small mineralised fault.

About 100 metres after quarry entrance the Dent Group is exposed along the track for about 30 metres and in the fields on the right. The characteristic brown, honey-combed weathering indicated a bed of muddy limestone between two shales. These rocks were deposited in shallower water compared to all the rocks seen earlier. Beyond the Dent Group, the Garburn Dacite Formation at the top of the Borrowdale Volcanic Group was exposed. The Garburn Dacite is a dark-coloured glassy igneous rock. with a high quartz. The formation is flow-foliated - layered with contrasting colours that formed after the lava flow had cooled

At the the top of the pass, the party left the path and ascended the grassy of Sour Howes. The leader pointed out an exposure to the left of the path where the Brathay Formation and displayed the relationship between cleavage and bedding.

Before the summit of Sour Howes, 20 metres to your right, the leader pointed out a small ridge that exposes the Birk Riggs Formation. This is a sandstone unit and the ridge is due to the sandstone unit being more resistant to erosion than the surrounding softer shales.

Near the summit of Sour Howes the leader pointed out the fault controlled valley along the Troutbeck Fault.

On the descent from Sour Howes down the ridge to the Dubs Road, an exposure of the Wray Castle Formation was examined. The rock dips here at 45 degrees to the south. The party then continued back along the road to the starting point where the leader was thanked for a visit to an area beyond the Society's home ground.

BOWNESS KNOTT

Leader: David Powell

Sunday August 25th 2013

Over 30 members and guests met at Bowness Knott car park (NY 109153). The leader explained that the removal of trees around the summit of Bowness Knott around 2011 had made access much easier and allowed critical exposures close to the summit to be examined. Specimens from the exposures to be visited on the excursion were examined. These included a spherulitic basic lava and a banded rhyolite from Clews Gill, the latter not to be visited on the day. The leader pointed out the landslip on Crag Fell on the opposite side of Ennerdale Water. Below this the morainic dammed lake reaches its deepest point of 49m off Anglers Crag.

From the car park, the party first walked north-eastwards along the track through the trees along the base of Bowness Knott. Here, fallen blocks of Skiddaw Group rocks were examined. Many of these were highly altered, some showing lamination and cross lamination, others showing pink banding.

The party then returned to the car park and walked south-east along the lakeshore road, turning into the forestry at the picnic point at NY 115149. Dry Beck was crossed – not dry on this occasion, and the group continued to Smithy Beck. The unusual course of the beck was noted, starting with the steep torrents of Clews Gill and Starling Gill flowing southwards down the valley side. The beck then turns through

90⁰ to flow westwards through a gorge section, with hanging tributary valleys. Smithy Beck was crossed just below a waterfall at the foot of the gorge. Downstream the beck curves away to the south, ending in a broader valley with an abandoned meander. From the waterfall the party climbed the left bank of the stream, past a possible potash kiln, parallel to the gorge. On reaching the forestry road, the party turned left and continued to the iron age settlement close to the bridge where Smith Beck crosses the forestry road.

From this point, the party walked up the forestry road towards the west north-west and the summit of Bowness Knott. This road is not accurately portrayed on OS maps. Lunch was taken at a fairly recent road stone quarry next to the forestry road. At the entrance to the quarry there were abundant microgranite fragments, possibly tipped here. This was a relatively uniform pinkish medium to fine-grained granite, with chloritic clots and white feldspar phenocrysts. The main rock in the quarry was a darker more basic rock, probably the diorite described in the literature. This was medium grained with feldspar and mafic minerals.

After the quarry, the road ends and there is a path leading to the summit of Bowness Knott, constructed through the felled forest by the Whitehaven Ramblers' Club. From this path, there was a good view of the secondary summit to the east of the main summit. Alternating bands of pink microgranite and darker rock were clearly visible and the party climbed the hill to examine these. The dark rock was darker and finer than that in the quarry and had the appearance of a dolerite. The boundaries between the two rocks are complex and convolute. The more basic rocks have been interpreted as the earlier phase of the intrusion, with the microgranite intruded into the still hot, plastic earlier phase.

The contact between the intrusion and the Skiddaw Group was in a depression but was not exposed. The highest exposures on the Knott were of Skiddaw Group rocks. These were well-bedded siltstones and mudstones with a strong cleavage. The contact is vertical, trending

north-east – south-west, running up the steep west flank of Bowness Knott and it could be traced running up the upper section of Rake Beck on to Great Bourne. The main part of the visit finished on the summit of Bowness Knott, with its excellent views of Ennerdale Water and upper Ennerdale. After returning to the iron age settlement, eight members continued up Smithy Beck to Clews Gill to examine the unusual banded rhyolite.

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OTHER EXCURSIONS HELD IN 2013

Wednesday July 10th 2013. Slate Fell. Leader: Jim Samson.

Saturday July 20th 2013. The Glenderaterra Valley. Leader: Rosemary Vidler

LECTURE MEETINGS

WINTER 2011-12

14th September 2011

Queen Elizabeth Grammar School, Penrith

The origin of the North Pennine ore-field

Professor Joe Cann (Leeds University.)

26th October 2011

Friends' Meeting House, Cockermouth

Humans as geological and geomorphological agents in the Anthropocene

Dr. Simon Jones, British Geological Survey

23rd November 2011

Friends' Meeting House, Cockermouth

Geological Sites in New Mexico

John Rodgers

7th December 2011

Friends' Meeting House, Keswick

Members' evening

25th January 2012

Tullie House, Carlisle

Relative sea-level changes and the coastal evolution in the Solway

Firth and Cumbrian Coast (joint meeting with Carlisle Natural

History Society)

Dr. Jerry Lloyd, Durham University

22nd February 2012

Friends' Meeting House, Keswick

Lakeland Musical Stones

Dr. Alan Smith

LECTURE MEETINGS

WINTER 2012-13

19th September 2012

Queen Elizabeth Grammar School, Penrith

Exceptionally preserved fossils (joint meeting with Westmorland GS)

Prof. David Siveter, Leicester University

10th October 2012

Friends' Meeting House, Cockermouth

Mineral Solutions to Global Problems

Prof. David Manning, Newcastle University

7th November 2012

Friends' Meeting House, Cockermouth

Sand: journeys through our granular world

Prof. Michael Welland

5th December 2012

Friends' Meeting House, Keswick

Members' evening. **Update on RIGS** (*Jim Samson*), **Minerals** (*Tony*

Rigby), **Geological events through 2012** (*Judy Suddaby*) **Highlights of**

CGS trip to Tenerife (*CGS members*)

9th January 2013

Friends' Meeting House, Cockermouth

Geological storage of CO₂: will it leak?

Dr. Kate Thatcher, Consultant, Quintessa Ltd.

6th February 2013

Tullie House, Carlisle

The North Pennines AONB and Global Geopark: 500 million years in the making (Joint meeting with Carlisle Natural History Society)

Dr. Elizabeth Pickett

6th March 2013

Friends' Meeting House, Keswick

**President's address – The Rise of the Rockies: a geological history
of Colorado**

John Rodgers

LECTURE MEETINGS WINTER 2013-14

18th September 2013

Queen Elizabeth Grammar School, Penrith

Bright lights and dinosaurs (Joint meeting with Westmorland Geological Society)

Dr. Phillip Manning (Manchester University)

9th October 2013

Friends' Meeting House, Keswick

Recovery of timescales of volcanic processes

Dr. Daniel Morgan (Leeds University)

13th November 2013

Friends Meeting House, Cockermouth

An assessment of the processes of hydraulic fracturing or "fracking"

Prof. Peter Styles (Keele University)

11th December 2013

Friends' Meeting House, Keswick

Members' evening

22nd January 2014

Tullie House, Carlisle.

Iron ore mine shaft collapse at Egremont (Joint meeting with Carlisle Natural History Society)

Dennis Dickens

12th February 2014

Friends' Meeting House, Keswick.

Rhyolitic eruption at Cordon Caulle, Chile: a glacier of volcanic glass

Dr. Hugh Tuffen (Lancaster University)

ANNUAL DINNERS

The 2012 Annual Dinner was held on 17th March at the Pennine room, Rheged. To mark the 50th anniversary of the Society Professor Peter Kokelaar (Liverpool University) talked on aspects of research on pyroclastic flow eruptions entitled “Encounters with non-uniformitarianism: Reflections on a personal voyage”.

The 2013 Annual Dinner was held at the Skiddaw Hotel, Keswick. Ian Tyler gave a talk on mining history.

The 2014 Annual Dinner was held on 22nd March at the Skiddaw House Hotel, Keswick. The speaker was Professor Rory Mortimore, President of the Geologists' Association.

ANNUAL GENERAL MEETING 2013

The 52nd annual general meeting was held on Wednesday 13 March 2013 at the Friends' Meeting House, Keswick. The meeting was opened by the outgoing President, John Rodgers who outlined the highlights of the anniversary year, the residential weekend and the trip to Tenerife. It was noted that the Charles Edmondson Prize was presented to Dr R A Smith. There were 174 recorded members of the Society.

ANNUAL GENERAL MEETING 2014

The 53rd annual general meeting was held in Keswick on March 12th 2014. The President, J Samson, reported on a year of successful and interesting winter and summer programmes which showed the strength of the Society. The Treasurer, M Bennett, presented the accounts for 2013, which were approved by the meeting. The membership secretary, C Thompson, reported that there were currently 154 members.

OBITUARIES

Murray Mitchell

(The following is printed, with minor adaptations, with the permission of the Westmorland Geological Society)

Murray Mitchell, who died on 26th March 2012, was a professional geologist particularly associated with the Carboniferous Limestones of south Cumbria. He was president of the Westmorland Geological Society from 1983 to 1993 and a vice-president from then to his death. Before he retired, Murray was a palaeontologist with the British Geological Survey (then and for some time known as the Institute of Geological Sciences). His father, George F. Mitchell, had also been a well-regarded Survey geologist (there is a photo of the Mitchells, senior and junior, in David Oldfield's *Earth, Water, Ice and Fire* p109). While his input, and indeed his professional life, was mainly centred on the fossils of the Lower Carboniferous, his range of geological interests was wide and varied. It encompassed the Great Barrier Reef, building stones and their uses, the glacial shaping of landscape, the Grand Canyon and archaeopteryx, as well as the English Lower Carboniferous Limestone areas like North Derbyshire and the Gower Peninsula.

His knowledge of the geology and landscape of South Cumbria was unrivalled and clearly the result of close field observation and experience. He also had a delightful knack of relating geology to the works of man. He also believed in making geological observation enjoyable. In later years his experience was invaluable in the Westmorland Geological Society's mapping work in the Lindale-Witherslack area and the Society was also privileged to add its mark to guides written by him, namely the Yewdale booklet and the *Lateral Key*. The society and the wider world of geology were well represented at his funeral in Leeds. The ceremony included a recording made in August 2010 of Dame Evelyn Glennie playing a lithophone at Brantwood, a 'rock' instrument which Murray helped to recreate.

Members of the CGS will remember him for the weekend excursion he led to Furness and Grange in 1975, a second weekend excursion to Arnside, Yewbarrow and Whitbarrow in 1983, his lecture on the building stones of Cartmel Priory in 1993, his 1994 article in the Proceedings (with I. C. Burgess) on the origin of limestone pavements, his excursion to Whitbarrow in 1999 and his paper on the Eggleston Marble in these Proceedings in 2010.

Trevor Jones Roberts

Trevor Jones Roberts, who has died at the age of 92, was a member of the Cumberland Geology Society from January 1969 until his death in September 2013. He and Enid (who is still a member) were active members with their young family in the early years when the Society used to have camping weekends to places such as Grassington. In more recent times they were regular attenders at the Annual Dinner. He was also a modern languages teacher at Workington Grammar School for over 30 years and a colleague of Tom Shipp, one of our founding members.

Trevor was born on the 15th January 1921 in Liverpool. His father, who died when he was only 7 years old, was a grocer's assistant. After her husband's death his mother taught at a primary school in Pentre Broughton near Wrexham. He attended Wrexham County School for boys (Grove Park). He won an open scholarship and went up to St. Edmund Hall Oxford in 1940 where he read French and German (Joint Honours).

He joined up in February 1942 serving first with the Royal Fusiliers and then spent 14 months with the Corps of Military Police before joining the Intelligence Corps in August 1943. He served in Europe between August 1944 and October 1945. After the war he returned to complete his degree, graduating in 1947. He completed his teacher training in 1948, and in that year studied at the Sorbonne. He was a natural linguist and studied many languages including Russian and Mandarin Chinese (taking an O level in the latter in the 1960s). He joined the Workington Grammar School staff in the autumn of 1948 and oversaw

the introduction of French as a modern language to the school. Later he introduced Spanish, which he taught to A level. He was also, for a time, careers teacher. He became a member of the Fell and Rock Climbing Club in 1965 and joined the Playgoers at Workington soon after moving to Cumberland. He retired in 1981 and moved from Low Seaton to Keswick.

His funeral was held at Isel Church in September and was attended by a number of former teaching colleagues and school pupils, three of whom were in his first French class in 1948.

He is survived by his wife, Enid, who he married in April 1954. He and Enid had a love of the mountains and he continued to walk the fells into his 80s. He instilled an interest in Geology to his children. Caroline and Roland made it part of their careers. David studied it to A Level under Tom Shipp. Caroline taught Geology and Geography and Julia, who studied English, is now a successful writer of books to teach English as a foreign language. David, is coroner for North and West Cumbria and Roland, who is a Professor of Geophysics at Uppsala University in Sweden.

OFFICERS AND COUNCIL 2014

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Printed by
Imprint
Stationery and Print

9 Helvellyn Close, Cockermouth, Cumbria CA13 9BJ
Telephone 01900 825647