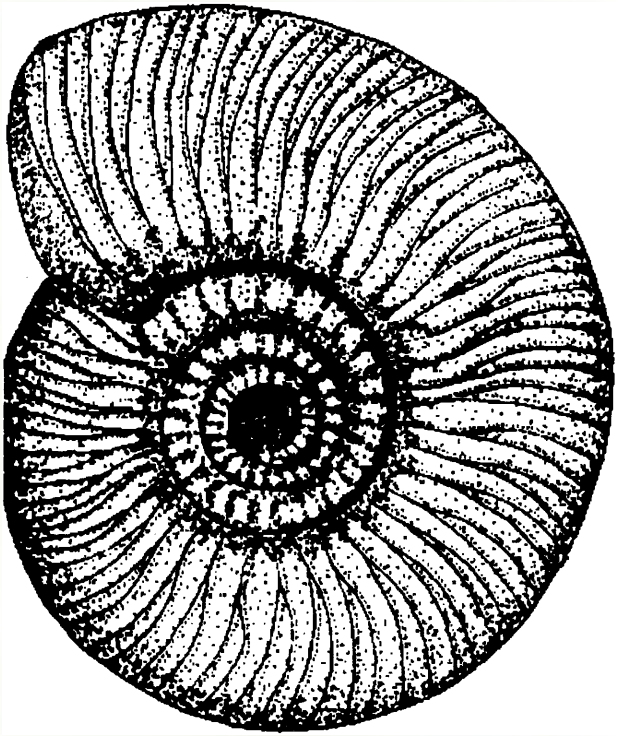
THE CUMBERLAND GEOLOGICAL SOCIETY



PROCEEDINGS

Volume 7 2002-2003 Part 1

ISSN 0967-2443

THE CUMBERLAND

GEOLOGICAL SOCIETY

PROCEEDINGS
2002 - 2003

Volume 7 Part 1

Published by the Cumberland Geological Society
May 2004

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EDITOR'S NOTES

I would like to thank the following people who have contributed to the production of these Proceedings: the authors of the original articles; those who have submitted reports of Society activities, particularly Mervyn Dodd; Eric Skipsey for his help in proof reading; Mervyn Dodd, Chris Thompson, Eric Skipsey, Alan Smith and David Powell who have submitted reviews and short communications; Chris Thompson for his drawings of fossils from the Burgess Shales; those who have provided technical references for the original articles. This edition of the Proceedings contains 32 figures and diagrams and the assistance of Ben Steel in the production and editing process is gratefully acknowledged.

The Proceedings is a biennial publication that caters for contributions on all aspects of geology and geomorphology of northern England. Contributions are welcome and should be submitted to the Editor. As well as full papers, the Society would be interested to receive shorter communications on the geology of Cumbria; these might include descriptions recording temporary exposures or other items of interest to the general readership of the Proceedings.

David Kelly

Editor

Published by the Cumberland Geological Society May 2004

General Secretary: Nigel Courtman

[redacted]

Web site: www.cumberland-geol-soc.org.uk

ISSN 0967 - 2443

ORIGINAL ARTICLES

A MESSAGE FROM THE LABYRINTH, TRINITY GARDENS, WHITEHAVEN

Eric Robinson

If you remember those tales from Greek Mythology, you will know that The Labyrinth was devised by King Minos as a means of holding the dreaded Minotaur, a symbol of his power and a challenge to those who would question his right to rule. Those who wished to challenge had first to trace a course through a maze of passages before meeting the bull-headed monster as a final test of their resolve, a task finally accomplished by the hero Theseus.

Symbolically, labyrinths figure in Roman and Medieval buildings as that challenge and as holding at their centre, a means of understanding a purpose and path to the fullest life. This was the line of thought accepted by Christian theology and the whole aim of the Crusades. It is no different when we come face to face with The Whitehaven Labyrinth, chosen as a celebration of the Millennium by a committee led by Canon Jim Baker of the Parish Church of Whitehaven and implemented by the Groundwork Trust. Whatever was in the mind of the committee and the artist Shaun Williamson, the outcome for anyone who traces a path to the heart of the colourful centrepiece has to be a fuller appreciation of the diversity of Geology, a truth which probably needs a fuller explanation.

Walking into the well-kept lawns of Trinity Gardens a quiet backwater off Scotch Street, Whitehaven, you are struck by a colourful centrepiece almost 12m across with a 3m central core of more diverse and contrasting colours (Figure1). After a short consideration, you will realise that there is a route which you can follow threading backwards and forwards through a series of concentric circles of green and grey tablets of Lake District Green Slate, our first encounter with rocks and Geology (Figure 2).

Some of the tablets are uniformly grey or green, but several are strikingly striped in white and grey; others are rust-spotted. All tell of their origins as volcanic ash from the rocks which make up Borrowdale and Scafell, ashes of fine grain swept and resorted by torrents of floodwater produced by the thunder rains accompanying the eruptions over 400 million years ago when the mountains were first formed. Each 20cm slab has a story within it.

Intensely black strips of Gabbro mark out the turns in the progress into the labyrinth, which, if followed doggedly, bring you to the black-edged central disc. Here, the central starburst divides up six distinct sectors containing rock mosaics of strikingly different colours and textures (Figure 3). At this point, the Geology becomes decidedly exotic, drawing upon rock types from all over the world. The pink and red sector, for example, is of limestone of marble grade, from Spain or

Portugal. To the eye of the geologist it gives itself away by the small white discs and fragments which are lime fossil shells which accumulated on an ancent seabed. In contrast, the shimmering grey and blue fragments in the next sector are a combination of a volcanic rock from the mountains of Sierra de Monchique in the Algarve of Portugal, and an equally unique granite-like rock from Larvik in Norway, from the shores of the Oslo Fjord. Next is a selection of cream coloured marbles, often appropriately called Crema. These can come from both Spain and Italy for the marble trade. Crossing the entrance path from Scotch Street, we come to a sector composed of red and black-striped granitic rocks which speak of the profound pressures and heat involved in the formation of mountains. You can't avoid the impression that these rocks, gneisses, have been through Hell, squeezed and bent by tremendous forces. They may have come from ancient parts of the crust in either Brazil or Finland, only Shaun Williamson can tell us which. Next comes a sector of yellow marbles, almost repeating the Crema already described. Finally, there is a sector of coarsely crystalline yellow granite which almost certainly comes from Brazil, elegant for its colour and crystal texture.

Coming to the heart of the labyrinth, geologically the eye is taken by the radials, elongate and attenuate spears of a bronzy red-brown granite with striking spots of blue. These are quartz crystals within the granite, and quartz crystals which have been crushed so that white light is absorbed within the crystal. This is a granite which at a later date in its existence, has been profoundly altered by pressures within the crust of the Earth. Unless appearances deceive, this is Dakota Mahogany Granite from Millbank, North Dakota, USA, a granite within the Canadian Shield of North America, and all of 1,500 million years old. By contrast, the pale grey veined white marble between the spikes is Carrara Marble from the 'leg' of Italy, a Jurassic limestone altered to marble when the Alps were formed (and along with the the Apennines) a mere 15 million years back in geological time (Figure 4).

This is all a reading of the Labyrinth in Trinity Gardens, with meaning for any geologist. It would be interesting to know what Shaun Williamson had in mind as he devised the design and whether he attached special meanings to the rock types used. Whatever, here it is, a vivid selection of the rich variety of decorative stones available to the architect, landscape designer, and sculptor in the year 2001 in the Lowthers' port of Whitehaven, which, in their time, was the landfall for granites for kerbs and monuments from Scotland and Ireland to 'improve' the carefully planned new town.

The beauty of all of this is that you don't need to know the geological significances to appreciate this focus in Trinity Gardens. It might stimulate the imagination to know those sources which are far beyond Britain for several stones, but, if we can speak to visitors who might think that Geology was "Not for them!", we might be fulfilling the welcoming call we find on the large boulder as we walk towards the starting point:

"Walk this path with an open heart and mind,
seeking awareness as you journey."

We can all say "Amen" to that.

Dr Eric Robinson
[redacted]

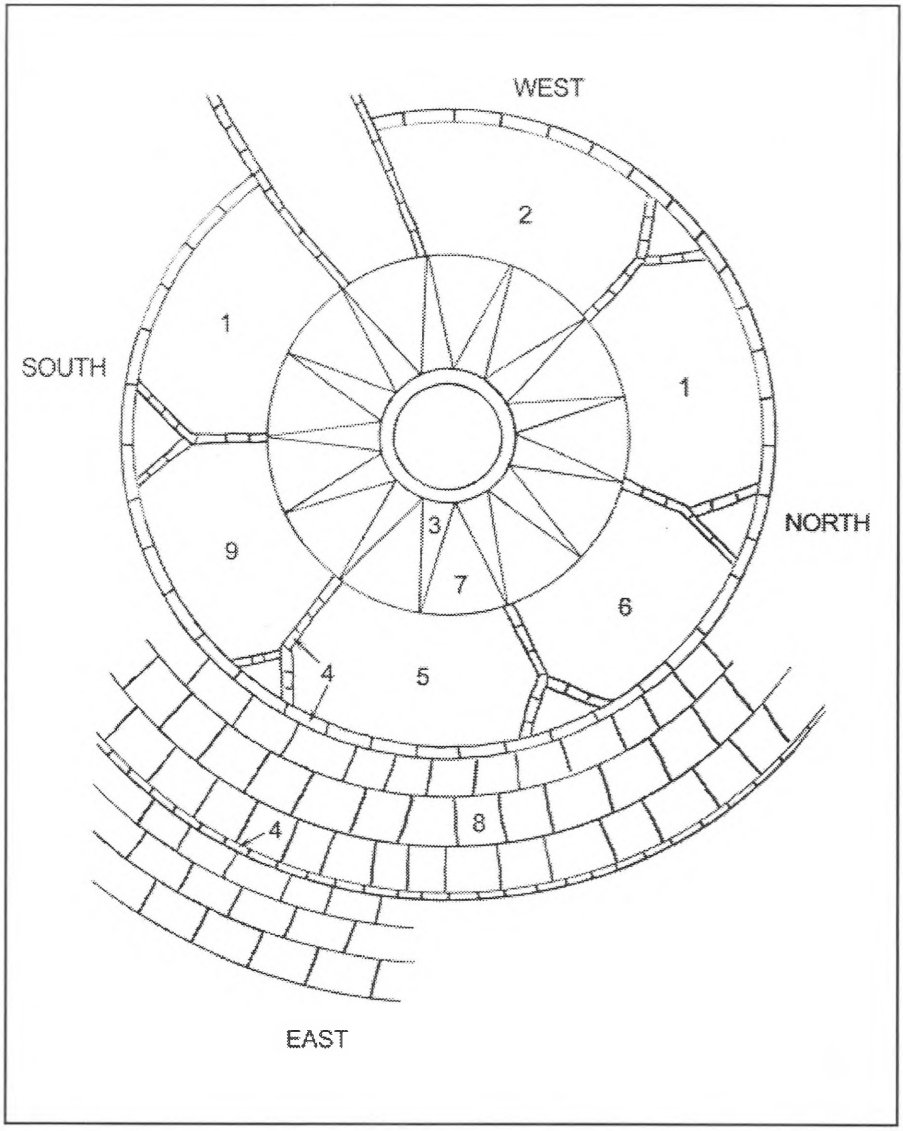


Figure 1 – A sketch of the Labyrinth based on a drawing by the author. 1 Crema marble (Italy/Spain). 2 Gneiss (Brazil). 3 Mahogany granite (Dakota). 4 Gabbro (South Africa/India). 5 Red crinoidal limestone (Belgium/Spain). 6 Granite (Brazil). 7 Carrara marble (Ireland). 8 Lake District slate (Buttermere). 9 Volcanics (Sierra Monchique, Portugal)



Figure 2 - The diverse sedimentary structures to be seen in the tablets of Lake District Green Slates. The black tablets are South African Gabbro.



Figure 3 - The labyrinth. Mervyn Dodd, past President of the Cumberland Geological Society stands on the central disc of marbles and granites.



Figure 4 - The north-west sector of the central disc. Radials of Dakota Mahogany "Granite" are separated by white Carrara marble. The outer disc of Precambrian Gneisses is possibly from Brazil.

ROCK-SLOPE FAILURES IN THE LAKE DISTRICT: A PRELIMINARY REPORT

Peter Wilson, Richard Clark and Alan Smith

Introduction

Rock-slope failures are a neglected aspect of Lake District landform studies. Although early work (Ward, 1873; Marr, 1916) drew attention to such phenomena, subsequent research has been limited and restricted to documenting individual failure sites either as part of broader geomorphological accounts (Mitchell, 1931; Hay, 1942; Clark, 1992) or as specific features (Smith, 2002; Clark and Wilson, 2005). There has been no regional survey providing information on the number, distribution, characteristics, and age of rock-slope failures as, for example, for Scotland (Ballantyne, 1986). With respect to development of Lake District scenery, the extent, variety, and significance of these landforms is largely unknown.

This paper summarises information gathered to-date about Lake District rock-slope failures and discusses their causes and consequences for landscape evolution. It draws on bibliographic and cartographic sources as well as our field observations. A database of sites is presented (Table 1), although this is undoubtedly incomplete. It is likely that because of their size, shape and/or location some rock-slope failures are less conspicuous than those already recorded and remain to be recognised. Additions to this database will be welcomed.

Definitions and categories

Rock-slope failure is the downslope displacement of rock under the influence of gravity. It encompasses both large and small-scale detachments and both fast and slow movements. Rock-slope failures are classified according to the nature of their movement and/or the morphology assumed by the displaced material (Figure 1). Distinctions between the various categories are not always as clear-cut in the field as implied by the literature (cf. Selby, 1993; Dikau *et al.*, 1996). Rockslides involve the displacement of intact rock bodies along shear planes and are generally subdivided into rotational or translational slides; the former are associated with a curved (concave upwards) shear surface, whilst the latter have a planar slip face roughly parallel to the ground surface. Rockfalls are free-fall movements of material from steep slopes or cliffs and if of sufficient magnitude and frequency may give rise to talus sheets and cones. As used by Selby (1993) the term refers to a number of processes that may generate rock-mass falls, rock slab and block falls, and rock particle falls. Some slab falls may have similarities with either translational slides or toppling failures. Rock topple arises as a result of pivoting at the base of the failure and the forward fall of a rock mass. The term rock flow (or rock creep, sagging or deep-seated gravitational deformation) applies to the displacement of slopes but without any significant production or runout of rock debris. Essentially, the displaced rock masses retain their coherence. Such movement is usually

characterised by tension fissures, multiple rock ridges, uphill-facing scarps (antiscarps), and/or slopes with convex bulging. Many rock-slope failures involve more than one type of movement. Compound failures are those in which two or more of the above processes act either simultaneously or in succession in different parts of the rock mass. Complex failures are characterised by a downslope change in rock behaviour; for example, a rockslide that disintegrates during travel may develop into a rock avalanche: a flow form that is characterised by the rapid downslope transfer of dry rock debris and usually results in a tongue-shaped accumulation of coarse material. Examples of all these types of failure have been recorded from the Lake District and several are discussed below.

Problems of identification and definition

The categories outlined above belie the fact that it may prove very difficult to assign some rock-slope failures to a type class. Because the catalogued Lake District failures are currently stable, soil and vegetation has in some cases disguised morphological features, and inaccessibility also prevents more detailed observations pertaining to mode of failure. Furthermore, at some locations shallow fissures have been reported and although these indicate that some limited movement has occurred along these lines, large-scale failure is not apparent. Such fissures may be precursors for any of the failure types shown in Figure 1, may be residual components of failures whose debris has since been removed, or denote local stress/strain that did not develop into an actual failure.

The rockfall category poses particular problems with respect to inclusion/exclusion of individual sites. Many hillslopes in the Lake District possess talus debris below cliffs and this is generally considered to represent formerly frequent and discrete rockfall activity. To include all such sites is clearly impractical. Therefore we restrict use of the term to those sites that exhibit evidence for major rockfall events by virtue of numerous boulders that are at least an order of magnitude larger than those commonly found on talus (i.e. abundant boulders >2 m in maximum dimension) and/or display distinct cliff-face recesses marking the places of large-scale rock detachment. However, with few exceptions, it is not known if these rockfalls were single or multiple events, and it is recognised that categorisation by size of boulders introduces a bias towards sites on rocks of the Borrowdale Volcanic Group. Such coarse debris is rarely encountered on terrain underlain by Skiddaw Group rocks because most of this group comprises thinly bedded strata with a tendency to break into small fragments. Thus, it is possible that major rockfalls are under-represented in our database. There are also several sites at which rockfall has occurred but is clearly subsidiary to another mode of rock-slope failure (e.g. Raven Crag, Longsleddale; site 2, Table 1, Figure 2)

Lake District examples of rock-slope failures

Table 1 lists rock-slope failures by location (general location, site name, and National Grid Reference of the approximate mid-point of the failures) and states the lithology involved, areal extent and, where known, the dominant failure

type. Except for two cases, where failures occurred in the late-20th century, the age of the failures is stated with reference to the limits of Loch Lomond Stade glaciation. Previous references to the failures are also provided. The distribution of the documented failures is shown in Figure 2 using the site numbers given in Table 1

Rock sliding has been an important contributory failure mechanism at several sites but has rarely been the dominant process. Evidence for some rotational movement is indicated by the morphology of the eastern failure on the south side of Latrigg (site 24). There, the mass of failed rock below the headscar forms ridge and depression features parallel to the headscar. There is evidence for rotational movement on part of the Bonscale Pike failure (site 16) above the east shore of Ullswater. Although this is a failure in which rock flow dominated, a knoll near the slope crest has a pronounced surface dip into the hillslope (Figure 3). The knoll is separated from the hillslope behind by a 2 m deep linear asymmetric depression. Translational sliding is suggested by the morphology of the western failure on the south side of Latrigg (site 25) and the Dove Nest Crag failure (site 31) on the west-facing slopes of Rosthwaite Fell. This mechanism is also a component of several of the compound failures listed in Table 1.

One of the most common types of rock-slope failure is rockfall, and the Wast Water Screes are usually regarded as the classic Lake District example of this process (cf. Boardman, 1996; Huddart, 2002). At three locations only along the 3 km-long scree base are boulders exceeding 2 m in length abundant, although larger boulders probably occur below the waterline. One of these sites is listed in Table 1 (site 44; the others are at NY 150 044 and 157 051). At each location the boulders extend for a limited distance upslope beyond which rock debris of considerably smaller calibre (generally <30 cm in length) occurs.

At several locations in the Lake District rockfall has produced much larger boulders than the largest on the Wast Water Screes. The slopes below the cliffs of Carrock Fell End (site 27) carry many boulders >4 m in length, including the 8 m-long Chapel Stone (Clark and Wilson, 1997), and the slopes below Bowder Crag (site 30) in Borrowdale carry numerous boulders >8 m in length, including the 18 m-long Bowder Stone (Smith, 2002). Another site of large rockfall boulders is Deer Bield Crag (site 20) in Far Easedale above Grasmere. The slope below the crag has many slab-like boulders >10 m in length (Figure 4). Some, with several fresh fractures on their edges and corners, are probably the products of rockfalls in the last 25 years (see below). One boulder of 15-20 m length rests against the base of the cliff and its disposition is suggestive of slab fall (cf. Selby, 1993). Others, with weathered and/or lichen-covered surfaces, probably pertain to earlier rockfalls. Prominent vertical joints running roughly parallel to the cliff face favour the detachment of slabs and several overhangs on the upper part of the face are interpreted as slab breakaway locations.

Rock topple is evident at several Lake District sites, particularly those where compound failures have been recorded, but at Raven Crag (site 2) and Brown Crags (site 3) in Longsleddale, topple has been the dominant mode of failure. The former site was described by Mitchell (1931) and consists of a headscar at *c.* 570 m OD in which the bedrock is tilted forwards. A mass of toppled rock occurs 30 m below this face along a 200 m-length of hillside and is separated into distinct ridges all of which display inward dipping and broken rock. The Brown Crags rock topple *c.* 300m to the southeast is of similar morphology but of smaller area (Table 1).

Rock flow has been either the principal or a subordinate failure mechanism at a number of the listed sites. The Rough Edge failure (site 8) on the west-facing slopes of Caudale Moor, above the Kirkstone Pass (Clark, 1992) and the Grisedale (Fairfield) failure (site 4; Wilson, 2003) exemplify this mechanism. Both sites are characterised by multiple narrow rock benches and ridges up to 400 m in length and separated from the slope behind by depressions up to 8 m in depth (Figure 5). The partially intact state of these features and their oblique or sub-parallel alignments relative to general slope contours indicate failure by flow (creep) rather than more rapid movement (sliding) that would tend to create shorter dislocated rock masses. The Grisedale failure extends for more than 1 km across-slope and through a vertical height range of *c.* 300 m and is one of the largest areas (0.4 km^2) of rock flow as yet identified in the Lake District.

In Burtness Comb (site 33), above Buttermere, a large tongue-shaped accumulation of coarse rock debris, previously regarded as a glacial moraine (Sissons, 1980) or relict rock glacier (Whalley, 1997), has been reinterpreted by Clark and Wilson (2005) as the product of rock avalanching, and is the first such feature to have been recognised in the Lake District. The debris tongue extends west - east for 700 m along the north side of the comb and from 560 m to 310 m OD; it has an average width and thickness of 130 m and 5 m respectively, its volume is estimated to be 300,000 m^3. In cross-section the debris accumulation is asymmetric, the north side stands higher than the south, partly because of underlying ground slope and partly because of variation in debris thickness. In plan some of the debris is organised into several linear and arcuate ridges. On the basis of differences in morphology and measurements of boulder hardness between the upper and lower parts of the debris tongue, Clark and Wilson (2005) considered that the feature had accumulated as a result of two phases of rock avalanching.

Of the compound failures listed in Table 1, that on the southern slopes of Robinson (site 32) is the largest. Displaced material extends downslope from Hackney Holes - Littledale Edge on the ridge crest at 700-575 m OD to 150 m OD above Gatesgarthdale Beck, a distance of 1.25 km, and for 1.5 km across-slope. It occupies 1.7 km^2 of hillside and is the largest known area of rock-slope failure in the Lake District. Hackney Holes is a rock chasm 15 m deep and 10 m wide at base created by the movement of a large section of hillside away from the slope crest. On the south side of Littledale Edge shallow depressions trend

obliquely downslope from the ridge crest and immediately downslope of these there are broad (50-100 m wide) benches with low gradient (<5°) backslopes indicating slight rotational components to movement (Figure 6a). Farther downslope, at *c.* 400 m OD are several distinct ridges up to 350 m in length, separated by depressions with maximum depth of 10 m, and with steep (up to 30°) backslopes (Figure 6b). These are interpreted as antiscarps and are characteristic of rock flow. Near the foot of the failure, exposures show coarse rock debris over bedrock.

Age of the failures

All the catalogued failures are considered to post-date ice-sheet glaciation of the Dimlington Stade (*c.* 30,000-16,000 calendar years BP) because the sites show no evidence for modification by the passage of glacier ice. Areas of broken and/or dislocated bedrock are usually highly susceptible to such modification (cf. Bentley and Dugmore, 1998). In contrast, Webb (1990) regarded the Hackney Holes - Littledale Edge failure on Robinson as interglacial but did not provide a reason for this assertion. The Cotley failure (site 48) on Black Combe was thought by Johnson *et al.* (2001) to pre-date the Dimlington Stade glaciation because the apparent absence of a toe to the failed debris was regarded as indicative of either glacial erosion or burial by till. However, it is not clear why the toe alone should have been affected by erosion or deposition by Dimlington Stade ice. Furthermore, agricultural land improvements may have resulted in modification to the toe area and thus a pre-Dimlington age cannot be sustained.

A few failures occur within the limits established for glaciation during the Loch Lomond Stade (*c.* 12,900-11,600 calendar years BP) (Table 1) and, for the same reason as given above, these are highly likely to post-date that glacial episode. However, for the majority of failures no absolute age dates are available. At present it can only be stated that failures located outside of the Loch Lomond Stade ice limits may have occurred at any time within the last 16,000 calendar years, and those located within these limits may have occurred at any time within the last 11,600 calendar years.

In contrast, Ballantyne *et al.* (1998), using cosmogenic isotope dating, have demonstrated that a large rotational rockslide on the Isle of Skye, Scotland, occurred at *c.* 6500 calendar years BP, at least 7000 years after ice-sheet deglaciation. Cosmogenic dating has also yielded ages of *c.* 4000 calendar years BP for the coarse rock material below Beinn Alligin in northwest Scotland, resulting in the re-interpretation of this accumulation as rock avalanche debris (Ballantyne and Stone, 2004) rather than a fossil rock glacier associated with Loch Lomond Stade glacier ice as previously considered (Sissons, 1976). The dating of large-scale rock-slope failures in the southern Pennines by both absolute (e.g. ^{14}C and archaeology) and relative (e.g. pollen) methods has produced a wide range of ages. These indicate episodic failure from early in the Holocene until about 2000 calendar years BP, a span of *c.* 7000 years (e.g. Tallis and Johnson, 1980; Johnson, 1987; Johnson and Vaughan, 1989; Redda

and Hansom, 1989; Skempton *et al.*, 1989), although smaller-scale movements are known to have occurred at some sites during the last 200 years.

The only ages available for Lake District rock-slope failures relate to a number of 'recent' rockfall events. Melville (1986) cites earlier reports of rockfall activity on Pillar, from which 'several thousands tons of rock' were shed, Helvellyn and Red Pike (Buttermere) in August 1786, and again on Helvellyn in July 1787. The exact locations and rock volumes are not known precisely and these sites are not included in Table 1. Other rockfalls have occurred at Deer Bield Crag on several occasions within the last 25 years (Cram, 1983; Biden, 1999; T. Fletcher, pers. comm.) and at Kern Knotts Crag (site 40; Great Gable) in either 1979 or 1980 (Evans, 1982; Wilson, 2003). Some renewed rock-slope movement occurred at the existing failure site of Doves Nest Crag in 1978-79.

Causes of rock-slope failure

Several causes have been advanced to account for rock-slope failure in other upland areas of the British Isles (cf. Holmes, 1984; Ballantyne, 1997; Curry *et al.*, 2001; Jarman and Ballantyne, 2002; Jarman, 2003) and to some, but unknown, extent these are probably applicable to the Lake District.

Glaciation and deglaciation may combine to promote rock-slope failure both directly and indirectly. Glacial erosion often results in the steepening of rockwalls, especially where ice flow is constrained by valley-side slopes, and ice removal leads to the debuttressing of those rockwalls and the release of loading pressures in glacially stressed rock. Both processes may result in adjustments to the internal stress fields and thus generate rock-slope failures. The effects of such stress release on rock slopes may be immediate or delayed (e.g. Ballantyne *et al.*, 1998) depending on the rate(s) at which the stresses are relieved. Furthermore, it was proposed by Holmes (1984) that during deglaciation of the Scottish Highlands high cleft-water pressures were established in rockwalls adjacent to the wasting ice due to abundant meltwater and that these pressures reduced rock mass strength and triggered failure. The noted proximity of many rock-slope failures to the limits of the Loch Lomond Stade glaciers led Holmes (1984) to consider events during this glacial episode as a critical underlying cause of subsequent slope failure.

Processes consequential upon an area having had and lost a cover of glacier ice are referred to as *paraglacial* (e.g. paraglacial rock-slope failure: Shakesby and Matthews, 1996; Curry *et al.*, 2001; Ballantyne, 2002; Jarman and Ballantyne, 2002). Given the glacial history of the Lake District many of its rock-slope failures may be termed paraglacial.

Several authors (e.g. Sissons and Cornish, 1982; Ballantyne, 1997; Sellier and Lawson, 1998) have invoked seismic activity, either in association with glacio-isostatic crustal readjustments or the later reactivation of faults, as an explanation for rock-slope failures in the Highlands of Scotland. The frequency and magnitude of seismic events in the Lake District during the Late-glacial and

early Holocene are unknown but for more recent times Melville (1986) reports that earth tremors were responsible for the rockfalls of 1786 and 1787 (see above). It is also believed that the Carlisle earthquake of 26th December 1979, or one of its aftershocks in 1980, was responsible for the Kern Knotts rockfall (Evans, 1982; Wilson, 2003). This earthquake had a magnitude of 4.7 ML (Richter Local Magnitude) and was one of the most significant British earthquakes during the second half of the twentieth century (Musson and Henni, 2002). The list provided by Musson and Henni (2002) of earthquakes in northwest England and southern Scotland since 1650 that exceeded 3 ML indicates 46 such events: an average of 1 every 7.6 years. Several of the rock-slope failures we have catalogued occur adjacent to or on faults and although seismic triggering of fault movements cannot be demonstrated to have initiated these failures, it cannot be ignored as a potential causal factor. Interestingly, Ward (1873) in attempting to explain rock fissures he had observed on some Lake District mountains favoured earthquake shocks as the most likely formative mechanism.

Also, geological structure and the inherent properties of different rock units in both the Skiddaw Group and Borrowdale Volcanic Group are likely to have had important influences on the nature and occurrence of slope failure. The spatial and stratigraphic variations in rock characteristics, including the susceptibility of faults to re-activation, may have increased the effectiveness of the glacial/deglacial and seismic triggers in certain locations. Furthermore rock characteristics might explain why failures are not more numerous and individually more extensive given the effects of local seismic activity and the extent of both Dimlington and Loch Lomond Stade glaciations.

Contribution of rock-slope failure to landshaping

The contribution made by rock-slope failures to landshaping and scenery is little known beyond the estimated total area of hillside affected: *c.* 5.5 km^2. This is <1% of the area of the Lake District National Park. Nevertheless, individual failures may have significance beyond that of areal extent alone; for example, the Bowder Stone and summit outcrops of Helm Crag (site 19) have acquired a certain curiosity value since they were first brought to public attention, even though the failure processes have rarely been mentioned.

In general, and over the longer time span, rock-slope failures have contributed to landshaping in several ways. These, discussed recently by Jarman (2003) with respect to the southwest Highlands of Scotland, are equally applicable to the Lake District. They involve valley widening, cirque initiation and enlargement, spur truncation, the sharpening of crests, arêtes and horns, ridge reduction, watershed breaching, and elimination of mountain blocks. Irrespective of which of these effects any particular rock-slope failure contributed, it is important to stress that in an area like the Lake District landshaping by rock-slope failure is probably closely associated with the succession of Pleistocene glaciations.

This paper has attempted to demonstrate that rock-slope failures in the Lake District are important landscape components and contribute to landshaping in several ways. At present there are some areas of the Lake District from which failures have not been recorded (cf. Figure 2). Detailed field survey of all these areas is required in order to determine if this absence is real or apparent. Only then will the full extent and significance of rock-slope failures become evident.

The release of debris from rock walls provides readily entrainable material for onward movement during the next glacial cycle and this may represent a significant proportion of the sediment volume in transport by ice (Ballantyne, 2002). Examination of rock-slope failures in Icelandic glacial troughs by Bentley and Dugmore (1998) revealed two populations of failure sites, those failures that are unmodified by glacial action and therefore post-date the last glacial episode, and those failures that were modified by glacial erosion and therefore pre-date at least one glacial episode. The latter population demonstrates the role of rock-slope failures as suppliers of debris for glacial transport. Thus, in the long-term, the widening of glacial troughs may be due to both rock-slope failure and glacial erosion. This two-stage model of trough development is applicable in the Lake District because the majority of the documented failures are located on trough walls.

In addition to their role in valley widening, some Lake District rock-slope failures extend to ridge crest lines (e.g. the Grisedale (Fairfield) and Helm Crag failures) and therefore contributed to the reduction of ridge height and width. Failure sites on cirque headwalls (e.g. the Red Pike failure, site 34, and the Caudale Head failure, site 9) participated in cirque enlargement. If it is assumed that rock-slope failures also occurred in earlier interglacials, and that their products have since been redistributed by ice, then their cumulative effects on Lake District scenery have probably been considerable. Furthermore, where a failure occurs onto active glacier ice (Boardman, 1992), the debris so generated may make a significant contribution to supra-glacial sediment load, to the volume of subsequently formed moraines, and also to the within-valley size/volume asymmetry of lateral moraines (cf. Benn, 1989; Wilson, 2004). Rock-slope failures that occurred between wastage of the Dimlington Stade ice and onset of Loch Lomond Stade glaciation, and within the limits of the latter advance, may partly account for differences in the volume of moraines both within and between valleys. Therefore, rock-slope failures can be considered as important contributory components of Lake District landform patterns, but need to be evaluated in the context of other processes

Conclusions

Rock-slope failures have not figured prominently in Lake District landform studies although some features have been known of for over 100 years. This preliminary report indicates that such failures are widespread, generally of small extent, and of various types. Many more examples have been recorded on rocks of the Borrowdale Volcanic Group than on the Skiddaw Group, although this is undoubtedly, in part, a reflection of the relative areal extents, and structural and lithological characteristics of these groups. All the documented failures are considered to post-date glaciation during the Dimlington Stade, as they occur within the limits of that ice advance, and some probably post-date glaciation of the Loch Lomond Stade. The effects of glaciation and deglaciation, or seismic activity may have triggered the failures, and application of the term paraglacial to these landforms is probably appropriate in many cases.

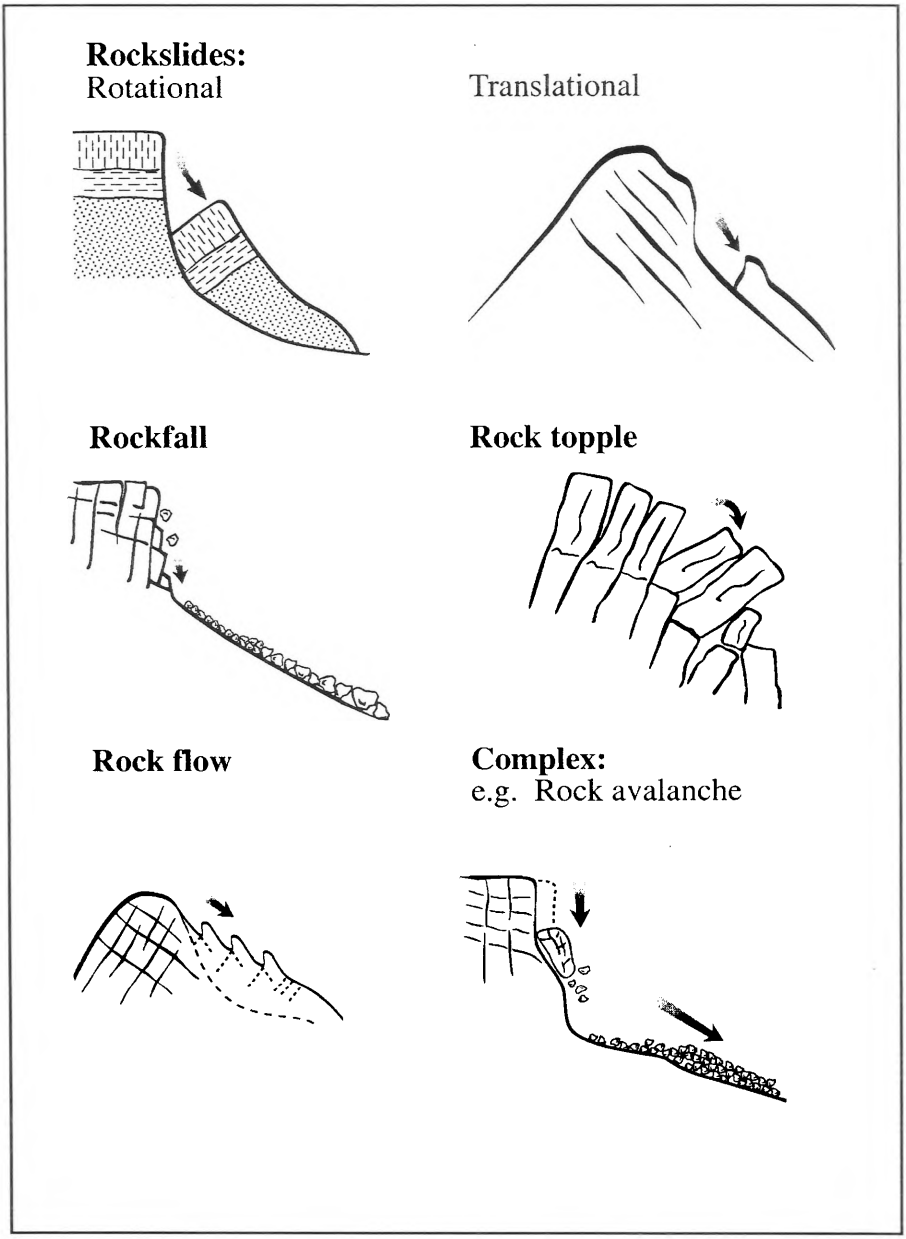


Figure 1 - Main types of rock-slope failure found in the Lake District.

Table 1 – a preliminary database of Lake District rock-slope failures

Location	Site No.	Site Name	Grid Ref.	Lithology	Area (km^2)	Type	Age	References
Longsleddale	1	Buckbarrow Crag	NY 479 075	BVG	0.02	Fall(s)	Outside LLGL	This paper
Longsleddale	2	Raven Crag	NY 473 078	BVG	0.03	Topple	Outside LLGL	Mitchell, 1931
Longsleddale	3	Brown Crags	NY 471 075	BVG	<0.01	Topple	Outside LLGL	This paper
Ullswater	4	Grisedale (Fairfield)	NY 357 124	BVG	0.40	Flow	Outside LLGL	Wilson, 2003
Ullswater	5	Grisedale (St. Sunday Crag)	NY 371 143	BVG	Not known	Flow	Outside LLGL	T. Davies pers. comm.
Ullswater	6	Grisedale (Bleaberry Crag)	NY 359 151	BVG	Not known	Flow	Outside LLGL	T. Davies pers. comm.
Ullswater	7	Glencoyne	NY 358 189	BVG	Not known	Fissures	Outside LLGL	Hay, 1937, 1942
Ullswater	8	Rough Edge (Caudale Moor)	NY 408 097	BVG	0.15	Flow	Outside LLGL	Clark, 1992
Ullswater	9	Caudale Head (Caudale Moor)	NY 411 102	BVG	<0.01	Translational	Outside LLGL	This paper
Ullswater	10	Raven Crag (Caudale Moor)	NY 421 114	BVG	0.04	Fall(s)	Inside LLGL	This paper
Ullswater	11	Hartsop Dodd	NY 410 119	BVG	Not known	Flow	Outside LLGL	This paper
Ullswater	12	Hartsop Dodd	NY 414 114	BVG	Not known	Flow	Outside LLGL	This paper
Ullswater	13	Gray Crag	NY 423 125	BVG	0.01	Flow	Outside LLGL	This paper
Ullswater	14	Satura Crag	NY 423 137	BVG	<0.01	Rotational	Outside LLGL	This paper
Ullswater	15	Beda Fell	NY 427 172	BVG	0.05	Translational	Outside LLGL	This paper
Ullswater	16	Bonscale Pike	NY 451 200	BVG	0.48	Flow	Outside LLGL	This paper
Ullswater	17	Arthur's Pike	NY 459 209	BVG	0.03	Flow	Outside LLGL	This paper
Ullswater	18	Auterstone Crag	NY 459 212	BVG	0.02	Fall(s)	Outside LLGL	Hay, 1935

[Contd.

Grasmere	19	Helm Crag	NY 328 093	BVG	0.01	Compound	Outside LLGL	Ward, 1873; Hay, 1942; Wainwright, 1958
Grasmere	20	Deer Bield Crag (Tarn Crag)	NY 306 095	BVG	<0.01	Fall(s)	1970-90s	Cram, 1983; Biden, 1999; T.Fletcher pers. comm.
Grasmere	21	Gavel Crag (Seat Sandal)	NY 347 114	BVG	<0.01	Fall(s)	Outside LLGL	This paper
Threlkeld	22	Clough Head	NY 325 227	SG	0.28	Translational	Outside LLGL	This paper
Threlkeld	23	Clough Head	NY 336 234	SG	Not Known	Flow	Outside LLGL	D. Jarman pers. comm.
Skiddaw fells	24	Latrigg	NY 285 246	SG	0.23	Rotational	Outside LLGL	British Geological Survey, 1999
Skiddaw fells	25	Latrigg	NY 283 242	SG	0.13	Translational	Outside LLGL	British Geological Survey, 1999
Skiddaw fells	26	Scurth (Carrock Fell)	NY 352 337	CFC	0.10	?Avalanche	Outside LLGL	British Geological Survey, 1997
Skiddaw fells	27	Carrock Fell End	NY 355 329	CFC	0.18	Fall(s)	Outside LLGL	Clark and Wilson, 1997
Borrowdale	28	Screes Coppice - Lodore Wood	NY 267 190	BVG	0.06	Fall(s)	Outside LLGL	This paper
Borrowdale	29	Shepherds Crag	NY 264 186	BVG	0.03	Fall(s)	Outside LLGL	This paper
Borrowdale	30	Bowder Crag	NY 254 164	BVG	0.03	Fall(s)	Outside LLGL	Smith, 2002
Borrowdale	31	Dove Nest Crag (Rosthwaite Fell)	NY 254 117	BVG	0.03	Translational	Inside LLGL	Wainwright, 1960

[Contd.

Buttermere	32	Hackney Holes - Littledale Edge (Robinson)	NY 205 155	SG	1.70	Compound	Outside LLGL	Wainwright, 1964; Webb, 1990; British Geological Survey, 1999; Woodhall, 2000
Buttermere	33	Burtness Comb (High Stile)	NY 177 147	BVG	0.11	Avalanche	Outside LLGL	Clark and Wilson, 2005
Buttermere	34	Red Pike	NY 160 155	SG	<0.01	Translational	Outside LLGL	This paper
Buttermere	35	Grasmoor End	NY 162 203	SG	Not known	Slide	Outside LLGL	Whalley, 1997
Buttermere	36	Mellbreak	NY 146 194	SG	<0.01	Translational	Outside LLGL	This paper
Buttermere	37	Mellbreak	NY 146 187	SG	0.05	Flow	Outside LLGL	D.Jarman pers. comm.
Ennerdale	38	Crag Fell	NY 095 147	SG	0.44	Compound	Outside LLGL	This paper
Ennerdale	39	Boathow Crag	NY 108 134	EG	0.02	Flow	Outside LLGL	This paper
Wasdale	40	Kern Knotts (Great Gable)	NY 217 095	BVG	<0.01	Fall	1979-80	This paper
Wasdale	41	Kirk Fell	NY 195 104	BVG	Not known	Fissures	Inside LLGL	Ward, 1873
Wasdale	42	Illgill Head	NY 174 057	BVG	0.05	Compound	Outside LLGL	Ward, 1873
Wasdale	43	Illgill Head	NY 156 043	BVG	0.01	Fissures	Outside LLGL	This paper
Wasdale	44	Wast Water Screes	NY 153 046	BVG	Not known	Fall(s)	Outside LLGL	This paper
Coniston	45	Kennel Crag	SD 285 990	BVG	<0.01	Fall(s)	Outside LLGL	This paper
Coniston	46	Kennel Crag	SD 286 991	BVG	<0.01	Fall(s)	Outside LLGL	This paper
Black Combe	47	Eller Peatpot	SD 141 854	SG	0.04	Translational	Outside LLGL	This paper
Black Combe	48	Cotley	SD 143 844	SG	0.70	Compound	Outside LLGL	British Geological Survey, 2001; Johnson et al., 2001

BVG: Borrowdale Volcanic Group SG: Skiddaw Group CFC: Carrock Fell Complex
EG: Ennerdale Granophyre LLGL: Loch Lomond Glacier Limits

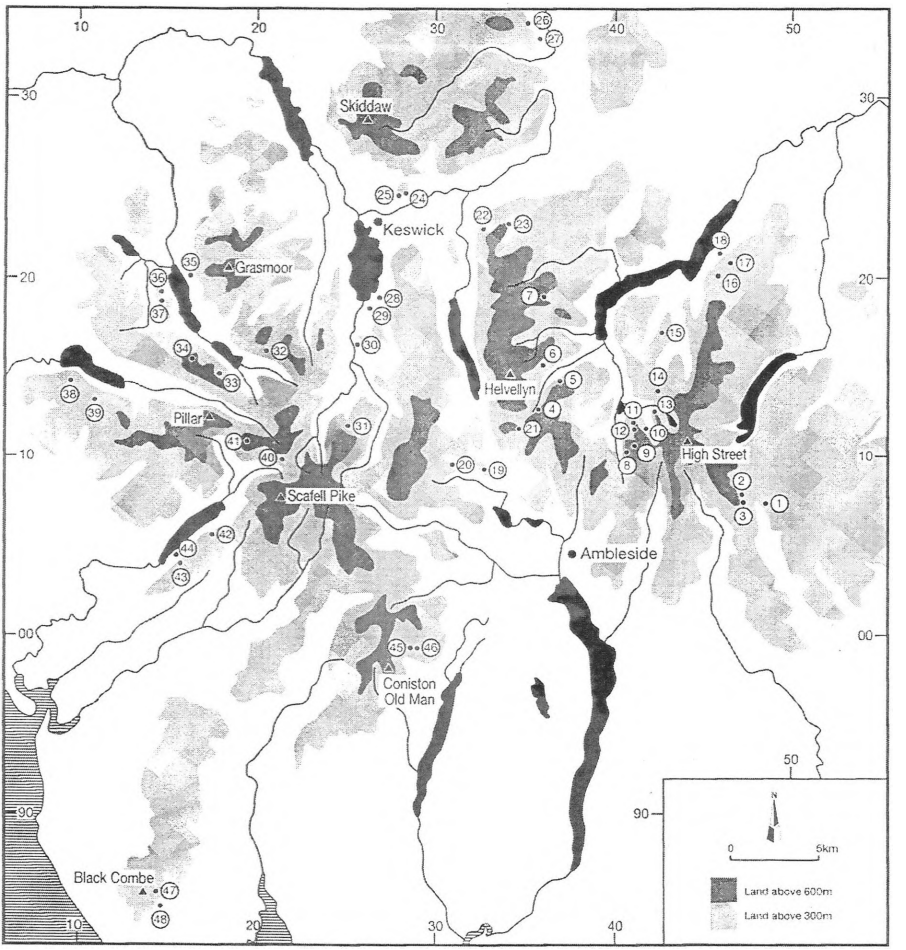


Figure 2 - Distribution of rock-slope failures in the Lake District. Site numbers are those given in Table 1.

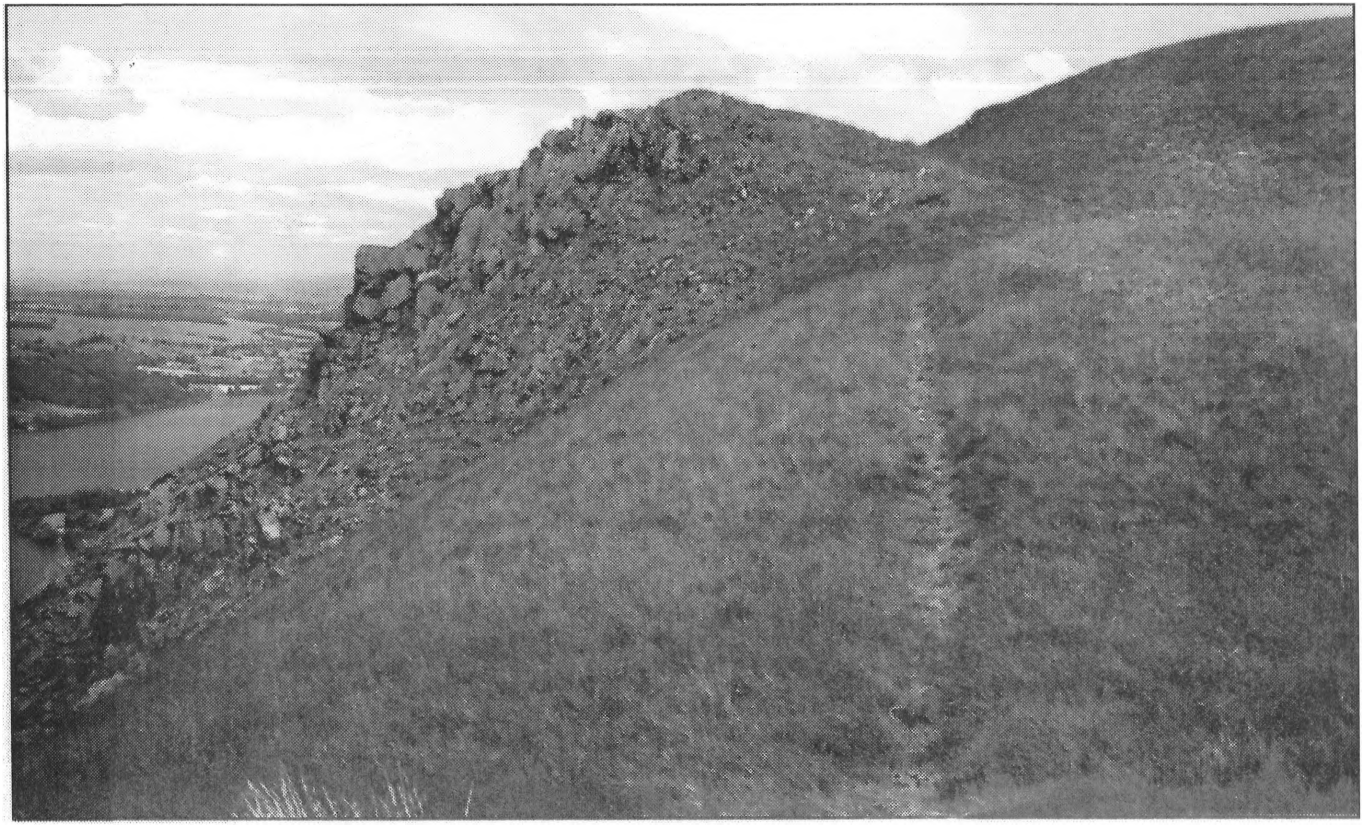


Figure 3 - Small rotational component of the extensive rock-slope failure on the west side of Bonscale Pike. Note the fractured rock on the outer slope of the failed mass and the pronounced surface dip into the hillslope.

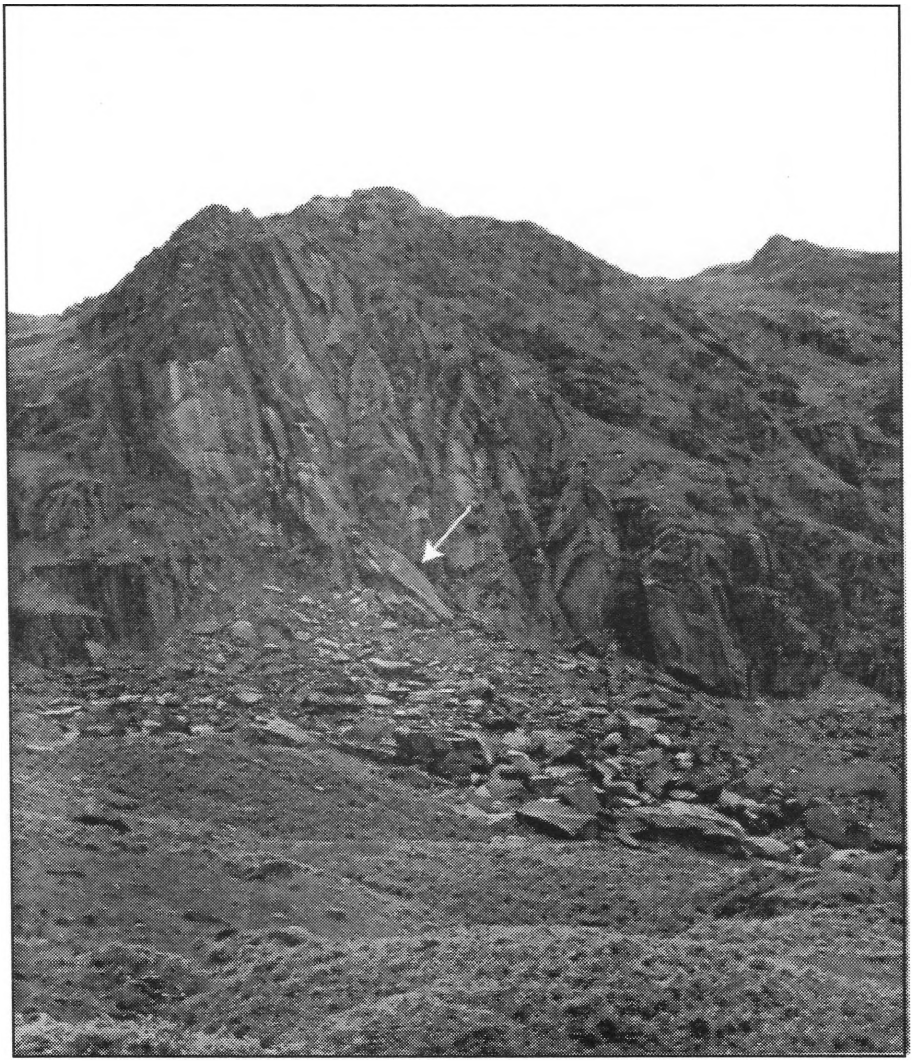


Figure 4 - Rockfall boulders (slab failure) at Deer Bield Crag. The inclined large slab (arrowed) resting at the crag base fell in the summer of 1997 (Biden, 1999). Prominent vertical jointing has favoured slab detachment and overhangs indicate slab breakaway locations.

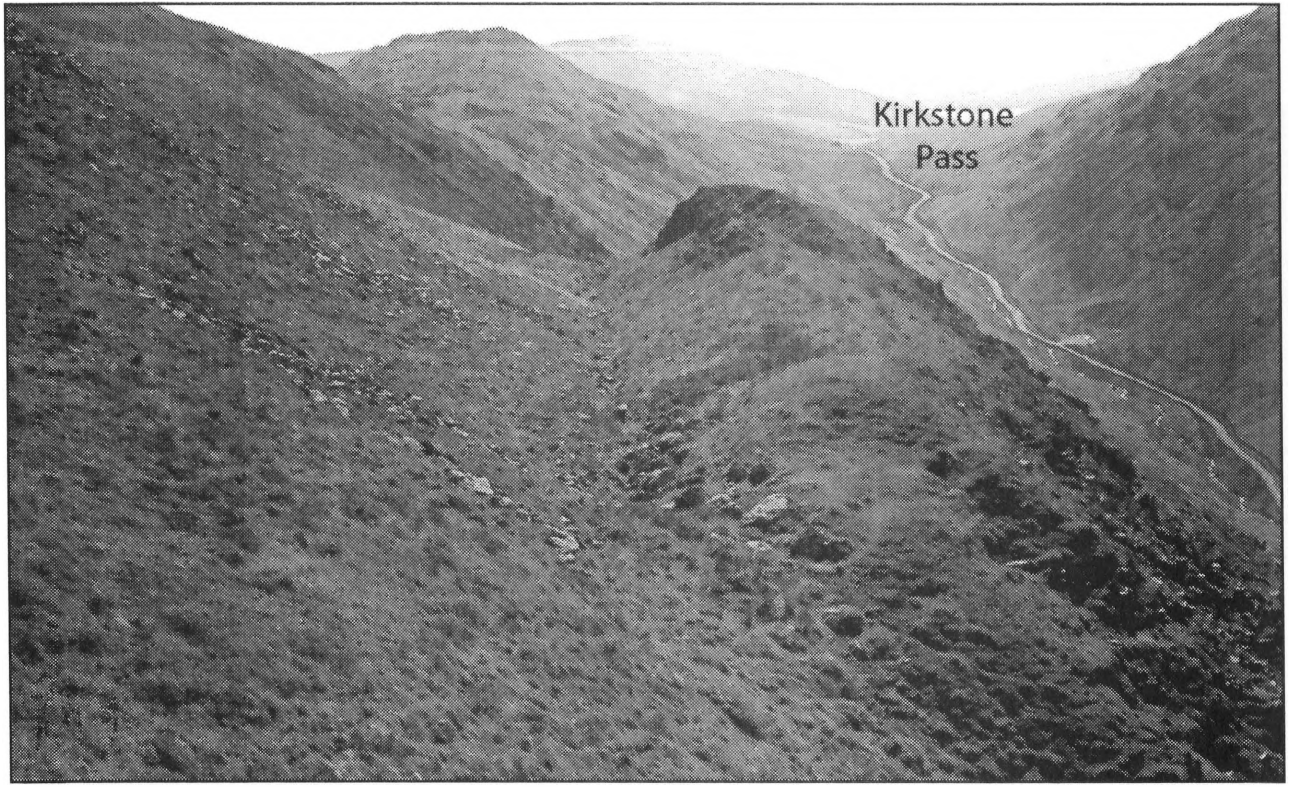


Figure 5 - Ridge and depression produced by rock flow (creep) at Rough Edge, Caudale Moor. The depression reaches a maximum depth of 8 m below the ridge crest. This ridge is the longest and most prominent of several such features at Rough Edge. The northern side of the Kirkstone Pass is to the right.

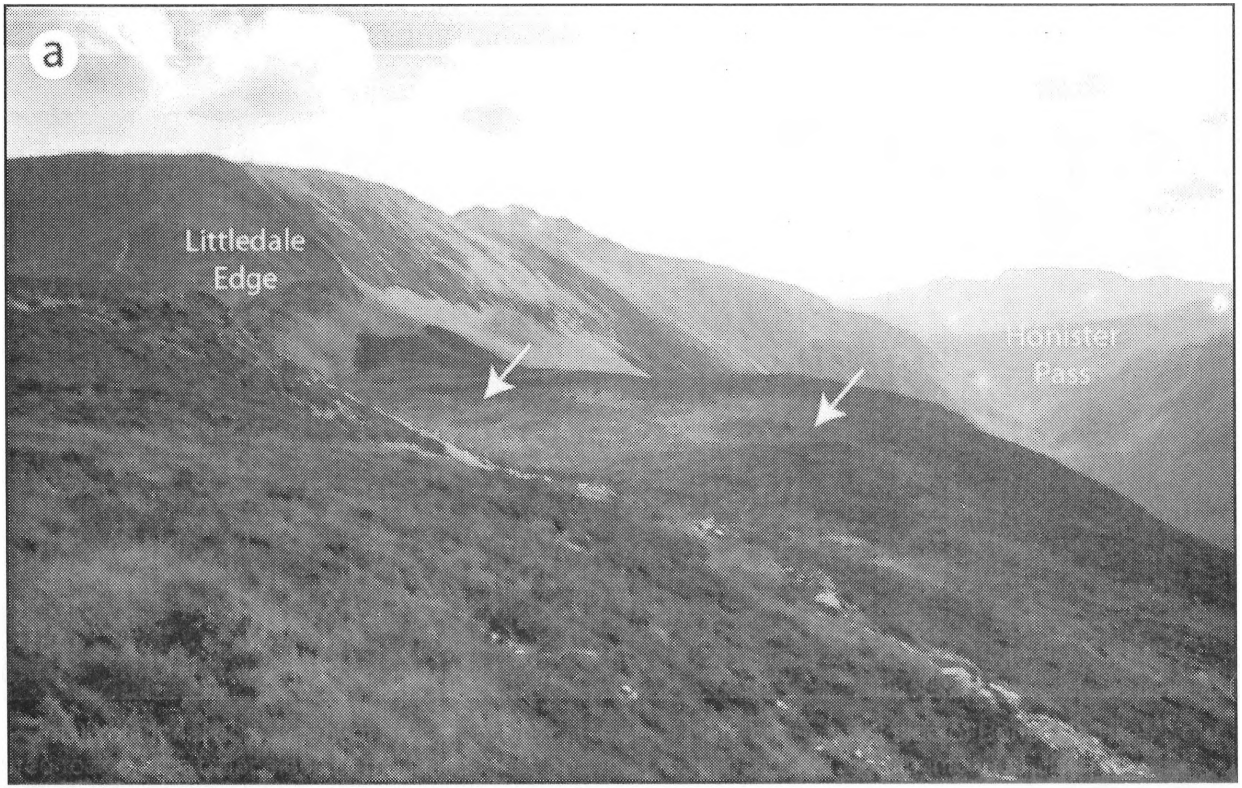


Figure 6a - Large mass of displaced hillside with bench-like upper surface (arrowed) *c.* 100 m wide and 15 m below the crest of Littledale Edge, Robinson. The bench dips towards the Edge at <5° suggesting a rotational component to its downslope movement. Honister Pass is to the right.

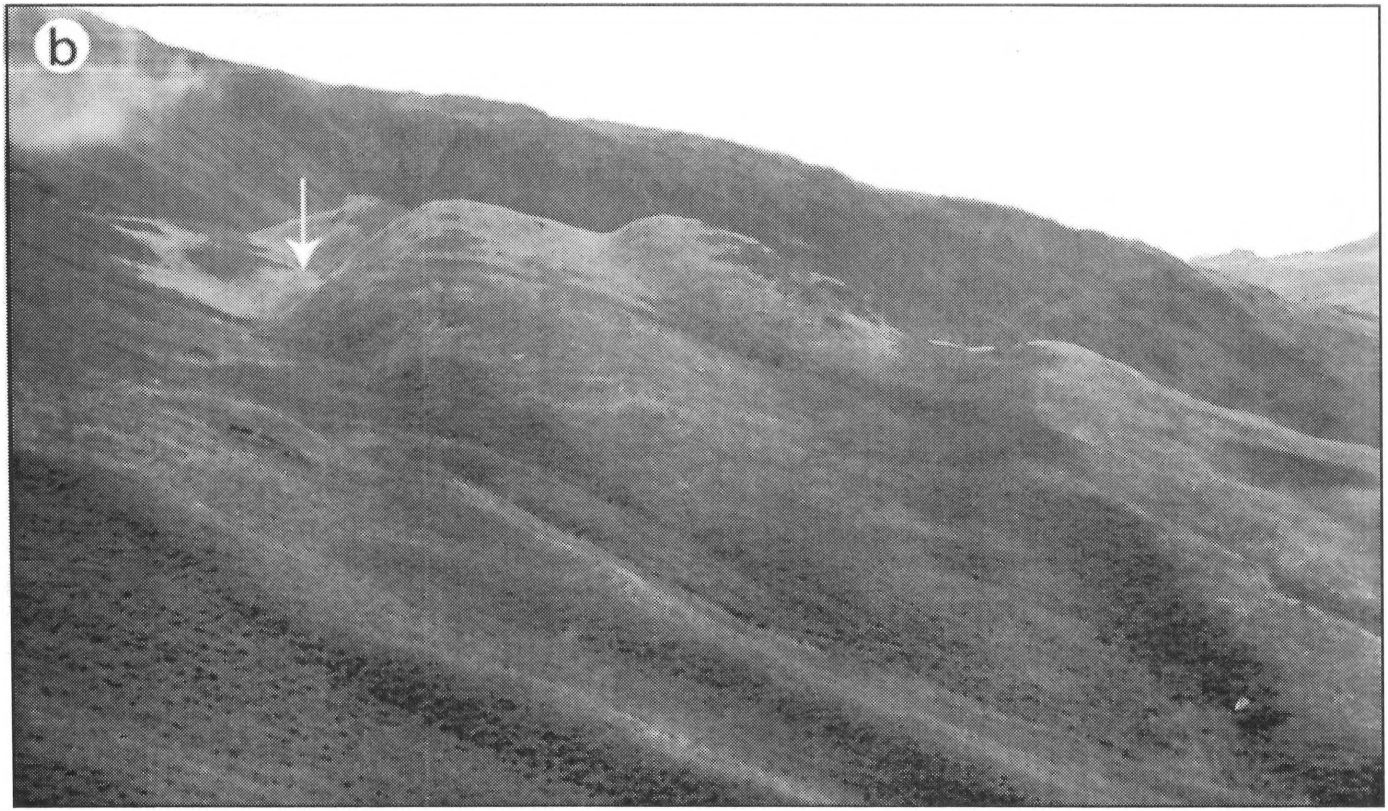


Figure 6b - A series of ridges and depressions at *c.* 400 m OD below Littledale Edge, Robinson. The deepest depression (arrowed) is *c.* 10 m below the ridge crest to the right. This type of hillslope terrain is characteristic of rock flow (creep).

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Acknowledgements

We thank Kilian McDaid, Lisa Rodgers and Nigel McDowell at the University of Ulster for preparing the figures for publication, and an anonymous referee for suggesting improvements to the original manuscript.

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HOW OLD IS THE LAKE DISTRICT LANDSCAPE?

Richard Clark

This question rests at the heart of understanding and explaining the Lake District landscape. Over the years it has stimulated various responses, explicit and implicit. These have been of three main sorts. One supposes that the upland was so eroded by ice during Pleistocene glaciations that little if anything remains of a previous landscape. A second says that the cumulative duration of periglacial environments and the efficacy of periglacial processes combined to produce a new landscape except where particularly effective ice erosion created corries (cirques) and made valleys into troughs. The third proposition is that away from corries and trough-like valleys only small modifications have been made to older landscapes. This discussion is about the question, about what it is that has to be accounted for and about some of the responses to it. It does not propose an answer but, rather, invites the reader to reflect on relative probabilities.

Part of the NIREX investigation into whether Sellafield, West Cumbria, could provide a site suitable for underground storage of nuclear waste involved assessment of short-term crustal stability. Evidence of tectonic deformations in Quaternary sediments and in other rocks during the Quaternary was sought. As well, disturbance induced by repeated ice loading-unloading sequences, and change due to loading by the sea as ice depressed and released the crust and as land ice withheld and liberated water from and to the sea might have had similar effects. Another potential influence upon crustal stability taken into account was the likely amount of erosion by ice, perhaps sufficient to trigger isostatic responses. Such movements might well have been unevenly distributed across the area and have reactivated existing faults.

The enquiry (NIREX 1997) found no convincing evidence of significant Quaternary deformation but did make some interesting comment on Lake District landscapes. It was estimated that about 200 km^3 of rock had been removed in the last million years. Consequential compensatory uplift in that time was estimated to have been about 100 metres. Denudation by ice moving over the less resistant rocks of the low coastal areas was thought to have been no less severe. An interesting 'side-effect' of such supposed isostatic response would have to be that the considerable accordance of present summit altitudes, shared by Skiddaw, Helvellyn, Scafell, and Scafell Pike, was either attained during or sustained through late isostatic uplift.

The Cumbrian coast lacks raised beaches which might have recorded occurrence and character of earth movements since their formation under the influence of Late Pleistocene sea levels. Older high-level planation (truncation) surfaces might, in principle, serve the same purpose. In the past, planation surfaces in the altitude range 90 – 850 m above sea level had been reported from Cumbria. The NIREX enquiry remarked that these landforms could not

have been identified in those earlier studies had it not been assumed that such features 'are there to be delineated and that they lie parallel to sea level' (NIREX 1997, 48). It goes on to say that at present there is not a sufficiently good understanding of historical landforms to support such assumptions and that the 'lack of evidence' is due to ice having eroded older landforms during the Pleistocene glaciations. This is curious in that it seems to doubt the evidence ever existed yet explains its absence as due to subsequent denudation. It also touches upon the matter of relationship between validity of field observations and ability to account for them.

Earlier, Clayton (1974), one of the NIREX investigators, had divided Britain into five zones by assessment of the degree to which the land surface has been changed by the work of ice. Almost all of the Lake District was placed in a zone of complete change. The surrounding land was placed in the next zone of somewhat less modification but, even so, with 'a new landscape created'. The 1997 NIREX report was foreshadowed by Clayton's (1996) discussion of the efficacy of ice erosion across the British Isles. The estimated volume of rock removed, largely from corries and glaciated troughs, if removed evenly would have lowered the Lake District by over 100metres. Clayton acknowledged that his view on efficacy of ice erosion and landscape change were at variance with 'many statements attributing little more than the modification of older landscapes to our past ice sheets, or those which imply that periglacial stages have witnessed the most rapid and lasting changes in the shape of our landforms' (Clayton 1996, 139).

Boardman (1992) considered the likely relative effectiveness in changing the landscape during the Quaternary of both ice sheet and restricted glaciations, of periglacial and of temperate interglacial processes. Evidence for local landscape change during the short Loch Lomond Stade was taken as relevant to processes and change during other more prolonged periods of restricted glaciation when large parts of the Lake District would have endured periglacial conditions. He calculated that periglacial environments prevailed during some sixty percent of the Pleistocene and concluded that the main cumulative effect on the landscape was by periglacial processes which combine to 'produce major landscape change' (Boardman 1992, 310), the amount of erosion by ice being 'rather modest' (Boardman 1992, 308), and rather little of that occurring in the most recent of the ice-sheet glaciations.

For chosen sloping sites on fissile Skiddaw Group (SkG) rocks Boardman (1992) assessed mean rates of denudation during the Loch Lomond Stade at up to 1 mm yearly. Following Boardman, that would mean denudation of up to about 70 m during the most recent full glacial-interglacial cycle. If extrapolation through the Pleistocene it would come to some 100s of metres. Many sites, valleyside and ridge top, on Borrowdale Volcanic Group and Windermere Supergroup terrain show little evidence evidence of modification of glaciation landforms. It is not clear that rates assessed from sloping SkG sites can be generally transferred to other locations. Unless comparable denudation had

occurred on the three main terrain types, the assessed rates would imply considerable differentiation in altitude took place during the Pleistocene.

Boardman (1992) suggested that a major effect of ice sheets in landscape modification is to transport material weathered during interglacials and in periglacial (restricted glaciation) parts of the cold episodes. If that had been the case for the Lake District, with differential weathering of the terrains, then an implication could be that before the onset of glaciations the SkG terrain stood higher relative to the other terrains. If it was higher before the glaciations then how so? If it was not then higher then, how it is not now lower?

From north-east Scotland, Hall and Sugden (1987) determined that moving sheet ice had left a pre-glacial landscape largely unscathed and that a textbook landscape of ice-scoured rock could result from removal of regolith and only a little of underlying sound rock. With local evidence for covers of weathered rock having been 10 – 50m thick, and for locations where not all the weathering mantle had been removed, then the landscape had been lowered, in general, by 10 – 50m. The new plucked and abraded surface in sound rock was not far below the older surface. But where faster streams of ice had crossed the area, within ice sheets and as valley glaciers, erosion had been greater and troughs had been formed. Boardman (1992) made a similar point with respect to the Lake District.

Writing about the nearby Cairngorm upland, Sugden (1968) described the high plateau-like interfluves rather as Marr, Mitchell and Hay had characterized parts of the Lake District. And, like them, he concluded that these areas 'are relict from pre-glacial times' characterized by high-level planation surfaces 'holding open river valleys with gentle slopes' (Sugden 1968, 80). The sharp contrast between the 'upper rolling slopes of the Cairngorms' (Sugden 1968, 80) and the deep trough-like valleys resulted from initial and reinforced contrasts in behaviour of ice between slower movement of thin ice on interfluves and faster movement of thick ice which transformed old river valleys into troughs. The two modes of ice movement and two classes of landform became increasingly differentiated.

Hay noted that the Southern Upland hills are characteristically rounded: 'rounding has been ascribed to ice action by the Scottish geologists' (Hay 1944, 263). On the other hand, 'the small part of Lakeland with rounded summit land' had been attributed by Dr Marr to being 'a remnant of the pre-glacial surface practically unaltered by ice action.' This disparity of opinion led Hay to review Lake District evidence: he essayed a categorization of landscape types. One class was of peripheral foothills which showed notable rounding by ice that had moved out from the higher ground. Another landscape type was of those gently sloping parts of the summit land with few exposures, some of weathered rock possibly affected by solifluction. He recognized that this category was of a sort that Mitchell (1931) had described from the eastern fells. 'All these are

examples of what Marr interpreted as relics of the preglacial surface' (Hay 1944, 265).

In the Ullswater area he found areas, albeit small, of the latter even where, more generally, the overall effects of ice were greatest (Hay 1944, 265). Most little-changed ground was on the bounding ridges, the most changed in the valleys where, according to Hay, ice had converged. 'Some of the westward-facing parts of Helvellyn, the whole of the Helvellyn Dods [are] good examples of this subdued summit land' (Hay 1944, 265).

That 'all the ridges and most of the tops in the west of the Lake District consist of the rugged land' (Hay 1944, 270) confirmed for Hay that the west had highest snowfalls brought by westerly winds. There, the old landscape had least chance of survival. The eastern parts, with less precipitation, would generate less ice and be covered for shorter periods. They would be exposed to frost action for longer periods: solifluction would have 'the result of preserving and continuing the rounding and subduing influence' due to 'normal weathering', and retention of weathered mantle (Hay 1944, 271).

Mitchell (1931, 322) thought the 'eastern part of the Lake District shows in a remarkable manner the contrast between the topography of the country in pre-glacial times and that due to the modification by ice action.' The pre-glacial topography is 'the rounded and smooth outlines of the fells which carry a covering of rock debris .....Outcrops of solid rock are few ..... valleys are well-graded and have flat floors' (Mitchell 1931, 323 - 325). He recognized that such topography was extensive in the east of the Lake District 'little altered from its pre-glacial contour' and that apart 'from some slight modifications ..... the fell slopes which extend eastwards from the River Sprint are mainly of pre-glacial form' (Mitchell 1931, 324-325). From the context and place-names mentioned, this meant east of the part of Longsleddale north of Sadgill. 'There seems little doubt that taking the Ice-age as a whole the main force of its erosive action was concentrated in the existing valleys, which ..... are now characterised by their U-shaped cross section' (Mitchell 1931, 329).

Lake District studies (Hollingworth 1938, McConnell 1939, Parry 1960) which sought to decipher stages in denudation from evidence of planation (truncation) surfaces in various altitude intervals implied, by their recognition of such forms, that the landscape retained the record of its pre-glacial history: there were no possibilities of post-glacial formation. As Mitchell had described remains of the older landscape in the eastern Lake District across almost the whole of its altitude range, so too did planation studies collectively identify surfaces across the fells, 90 – 850 m OD. Whether that identification was correct is not the immediate point which is, rather, that the older relief was implied to survive in some place or other across almost the whole Lake District altitude range. These studies, part of a massive corpus of landscape interpretation accumulated over several generations of study, had sought to explain the landscape in a way which the NIREX (1997) report rejected without

detailed rebuttal almost as if what had been supposed could not possibly have been so: it was as if not just the local interpretations were being dismissed but the accumulated accounts of many localities by a multitude of observers.

Boardman (1992, 290) stressed that the 'erosional evidence for glaciation in the Lake District is much more difficult to interpret' than is the depositional. He pointed out that the 'assumption that a landform is the product of a set of unique and identifiable processes is at best a simplification'. The degree to which that may be the case varies. Even for corries and troughs, which are rarely attributed to processes other than glacial erosion, there are uncertainties about how, when and how much. If the degree to which the land surface has been changed by glaciation is not to be readily and certainly determined then, as Boardman says, 'there is great difficulty in assessing the form of the landscape at the outset of glaciation' (1992, 290). These cautions, directed principally to advocates of major change by ice, apply also to those who proposed that a pre-glacial landscape is widely recognisable in the Lake District. They are every bit as relevant to his own thesis of substantial reshaping of the landscape by periglacial processes.

Of the three expositions of Lake District landscape, the survivalist has been expressed most conservatively through its overt acceptance that, principally, corries and troughs replaced parts of the older surface. The periglacial thesis also conceded that ground to a point: there are reservations about how much the valleys were changed. It is the interfluves in all their variety of scale and altitude that are contested and the contestations vary in character. The glacial proposition relies to a considerable extent on asserting that the students of planation surfaces, the denudation chronologists, were mistaken in their assumptions. It also relies on views of the estimated amount and source of eroded material and of the efficacy of ice erosion which led to the conclusion that survival of older landforms did not occur. The periglacial viewpoint was based on combining extrapolation from a few Loch Lomond Stade sites with assessment of duration of periglacial environments. Neither glacial nor periglacial case was much reliant on direct field evidence. Neither discussed what sort of landscape might have existed to be replaced (if indeed it was) through the work of Pleistocene cold-climate processes: Boardman (1992) argued that present 'major relief features' were formed by alteration of a pre-glacial river system and accepted that the landscape is in the main of Quaternary origin. He shared the NIREX scepticism about planation surfaces dating from Tertiary times.

The survival thesis did employ field evidence but without showing very clearly how its conclusions, whether or not justified, followed from observations, principally of landforms. It was an assumption that rounded forms, subdued slopes, elevated downs could not be products of glaciation (in Marr's, Mitchell's and Hay's times study of periglacial landscape was young and still largely confined to continental Europe). But they did name and map the places they believed had not been significantly changed. In the representations of the glacial

and periglacial positions noticed here little of the supporting argument is drawn from the landscapes believed to have replaced the older.

There is, unremarked by the main protagonists, a pervasive character to the interfluves even in what Hay (1944) called the 'rugged land'. In only the small part from which Ennerdale, Wasdale, Eskdale, Langdale, Borrowdale and the Buttermere valley diverge is it much obscured. It is present in all the geological areas, on interfluves both narrow and broad, across the upland and over almost all its height range. It is found on some major valley sides. Away from the main troughs and the corries it is ubiquitous. It occurs on both of what Mitchell (1931) typified as the more changed-by-ice western and the less modified eastern parts of the eastern fells and across Hay's Ullswater area. Hay's effort to delineate and account for the distribution of areas he thought had survived glaciation with little change was inhibited by the use of inconsistent categories and by concentrating observation on summit lands. Thus he missed the point that much ruggedness is an assemblage of relatively small-scale ice-formed features on large landforms otherwise not unlike his 'elevated downs', (Hay 1944, 265). The Haystacks and Glaramara areas are of that sort.

An essential unity of form across the district was thus obscured. This is particularly unfortunate as Hay did notice that even on the highest land (he mentioned Fairfield, Great Gable, Grasmoor and Pillar which 'looks like a bit of the old surface eaten at on all sides ...' (Hay 1944, 269)) there could be remnants of a land surface unconsumed by erosive ice. Perhaps Mitchell had led Hay that way. He had mapped extensive areas as showing many pre-glacial features across an altitude range of some 400m and included some upper valley reaches. But he excluded even broader areas, mostly east of Mardale and Longsleddale which, though lower, are not separated from those included by any marked or consistent change of form.

Long, broad views across the Lake District suppress the finer detail to reveal a landscape of plateaus and gently-sloping ridge crests, and of steps or ramps leading from one level to another, skyline after skyline. Also prominent, but not everywhere, are the sharp breaks from plateau and flattish-topped ridge to steep trough sides. There are small 'island' plateaus like Lingmoor Fell and Caudale Moor. And there are extensive branching plateau-ridge complexes as from Rossett Pike, across Stake Pass north, beyond High Seat, almost to Keswick – though Hay (1944, 269) said it is irregular 'with no trace whatsoever of subdued summit' land ...': he let the detail of ice erosion obscure the generality of shape. Across Langstrath is the Glaramara ridge, 'a fine range of craggy rock with numerous erratics and every sign of intensive ice action' (Hay 1944, 269). Borrowdale is enclosed from Maiden Moor south to Grey Knotts and, on its east sides, north from Allen Crag by way of the Glaramara ridge to Grange Fell by ground roughened by ice but with dome (or flat) and ramp sequences. All the ridges that lead north or east from the Redscrees (Kirkstone Pass) – Fairfield – Helvellyn – Clough Head watershed have risers and flatter reaches and so it is across the fells further east and south.

There are narrow (Wansfell) and broad ridge crests (High Street); short dome-like (High Raise) and elongated smooth reaches (Souther Fell). There is similar variety among the steps and ramps. The local lay-out can be simple or complex but the stepped or tiered topography is not far away even in those places, such as the upper Caldew valley in the Skiddaw block, where long valley sides seem to dominate. It is a unifying characteristic and one unaddressed or unrecognized by glacial, periglacial and early survival protagonists alike. The exponents of planation surfaces saw elements of this. But, whether or not there are regularities or correspondences in altitude among the steeper and gentler parts of the interfluves as planation studies would have it, this is the landscape which each proposition purports to explain.

The glacial and periglacial propositions both depend on the existence of an earlier landscape yet allow no scope for imagining that landscape lest it weaken their positions. They need to show how the present landsurfaces could be made by processes in the Pleistocene time available. The survival thesis advocated by Marr, Mitchell and Hay did not depend on identification of series of planation surfaces but did need to show how extensive surfaces of low relief were made. It met that challenge by assertion (not then unusual) and implication rather than by formal reason. This proposition is much less time-constrained than the others. Assumption of pre-glacial origin implied development in temperate conditions and the accumulation of regolith to unknown depths but influenced by the various lithologies. Removal of weathering mantle during the Pleistocene would expose the sound-rock weathering front to modification by the processes of glacial-interglacial cycles. It was very little modified according to this thesis.

Marr and Mitchell had not a lot of scope to test their propositions even if inclined so to do. Hay, aware of McConnell's work had more scope for, if evidence for truncation surfaces could be confirmed it might well support the survival thesis. It is not surprising that Hay did not respond for, even if he had recognised the potential test, the authority of Marr and Mitchell was already in place. Glacial and periglacial propositions avoided the test by discounting its availability. It is a test applicable to the 'how old' questions but in a limited way. Suppose a test 'are there or are there not surfaces as described?' and suppose it validly executed. A 'no' answer would be as if McConnell and Parry had not followed Marr, Mitchell and Hay, and without adding strength to the opposed views. A 'yes' would still leave the question 'how and when made?' The possibility of neither 'no' nor 'yes' but 'something, yet not as described' lurks as a potential complication.

Another approach, not truly a test, would be to undertake systematic search for in situ residuals of temperate weathering. Finding them could say a lot and, if truncation surfaces were also confirmed, could say even more. Not finding them would leave the situation as at present.

It is curious that the 'how old' question, which has been about for perhaps more than a hundred years remains contested, unresolved.

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Acknowledgement
Tha valuable responses of an anonymous referee to an earlier version are acknowledged. I am grateful to Elizabeth Clark for her help in preparing the text.

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[redacted]

THE DISTINCTIVENESS OF THE SOUTHERN LAKE DISTRICT LANDSCAPE

Richard Clark

Professor Marr called the Silurian rocks of the Windermere Supergroup (WSG) the Upper Slates. Discussing the relation of rocks and relief in the part of the Lake District where they outcrop, he wrote (Marr 1906, ci) 'the general elevation of the tract of Upper Slates of the Howgill and Kirkby-Lonsdale Fells, when contrasted with the comparatively low ground occupied by these slates in the southern part of the Lake District proper, is explicable in the view that a subsidiary uplift has taken place in the Howgill Fells. The low ground occupied by the Upper Slates of the southern part of the district receives its explanation in the fact that they lie almost entirely at some distance from the axis of the uplift of the dome; when they approach that axis, namely at the head of the southern Borrowdale, we find the fells formed by these rocks reaching their greatest height .....'. Marr had three sorts of Silurian terrain, the Howgill and Kirkby Lonsdale (or Barbon) Fells and, in the eastern Lake District, a low southern area (LS) and a northern, higher part which extends north to the Shap Fells. Mitchell (1931) included LS in discussion of relief development of the eastern Lake District but not in any detail and since then, apart from accounts of its glaciation and description of planation surfaces, the topography of the area has been rather neglected.

Landscapes of LS and of the rest of the Lake District are quite different and that is largely due to well-known differences in geology. The LS attracts less attention than the more spectacular higher parts. Relationships between geology and development of the landscapes have not been much discussed. The LS landscape character is quite complex and in some respects it is enigmatic: it reflects both a long geological history and more recent events. How LS is defined, the geological foundations of its relief and how the present land surface may have developed are outlined to give some account of the distinctiveness of the LS landscape.

Boundaries of the south Lake District

The onshore periphery of the area falls into three parts (Figure 1). These are, that in the east separating it from the Pennines and the Howgill Fells, that from the Lune valley near Lowgill west to Ambleside, to the north of which rise the higher eastern Lake District fells, and that from Ambleside south to the Duddon estuary and Millom. Each part has its own characteristics.

North from Kirkby Lonsdale the Lune valley is bounded by approximately parallel faults which, in the south, enclose a down-faulted wedge of Carboniferous strata. Further north, the faults traverse Silurian rocks of the Windermere Supergroup. Topographically, the boundary can be taken as the top of the west side of the Lune valley. The east side of the valley rises to the Barbon and Howgill Fells in WSG strata. Their summits reach 609m and 676m OD respectively. Near this boundary LS reaches its highest altitude, 338m OD, on Lambrigg Fell east of

Kendal. The local LS gravity anomaly field shows a gentle southward increase in positive anomaly. That of the Barbon and Howgill Fells is similar. Their summit altitudes match those on Carboniferous strata of the Askrigg Block, its negative gravity anomaly associated with mass deficiency of the concealed granite. The fault-guided relief boundary of LS does not here correspond with but parallels the major structural divide, the Dent Fault.

The boundary from Lune valley to Ambleside is somewhat serrated in plan with offsets where the boundary is reached by fault-guided valleys of the higher ground to the north. The embayment where the R. Mint leaves the hills is the most prominent of these and its outliers of Carboniferous strata suggest the local form of the sub-Carboniferous surface. The highest land of LS does not reach north to this part of the boundary. On its north side WSG terrain rises to about 500 m OD not far from the exposed part of the Shap Granite. On the BVG terrain further north hills rise to over 800m OD on High Street. This boundary reach thus separates two sorts of WSG relief noted by Marr and follows a change in character of local gravity anomaly field (Bott 1974). On the north side the rate of change increases to a closed area of negative anomaly centred on the exposed granite. The greatest inferred thickness of WSG strata is west of Kendal, near the boundary. The LS boundary here is associated with greater uplift on the north side, related to the mass deficiency of the largely-concealed intrusion contrasted with great thickness of sediment pile and positive gravity anomaly on the south side.

The third leg of the boundary, Ambleside to Millom, is rather straight in plan along the junction between high Borrowdale Volcanic Group (BVG) terrain and the lower WSG terrain. Between Ambleside and Coniston the geological boundary is offset by oblique north-south faults. At Ambleside the direction of strike of the WSG base changes, several fault lines and valleys converge, and some hills on BVG (Holm Fell, Black Fell and Loughrigg Fell), reach little more than 300m OD, the same altitude as the highest LS hills. It is as if LS sort of topography extended onto the BVG of this Ambleside embayment (Figure 1).

The altitude of this western section of the boundary rises from about 40 m OD at Ambleside to about 300m near Torver. The discrepancy in altitude here between Coniston and the tops of the Coniston Fells, some 750m in little more than 2km, makes this the most spectacular part of the LS periphery. From Torver the boundary falls to sea level at the Duddon estuary. Along this reach WSG strata are upturned and bevelled at the foot of the high ground.

It is across this western boundary reach that contrasts in gravity anomaly are at their greatest. On the BVG side a steep anomaly gradient leads to a major negative anomaly over the Eskdale Granite. On the LS side the positive anomaly increases southwards to a high between Millom and Ulverston. The combined relief and gravity contrast across this part of the boundary led Lee (1986) to suggest there are low density intrusions in the BVG near the boundary.

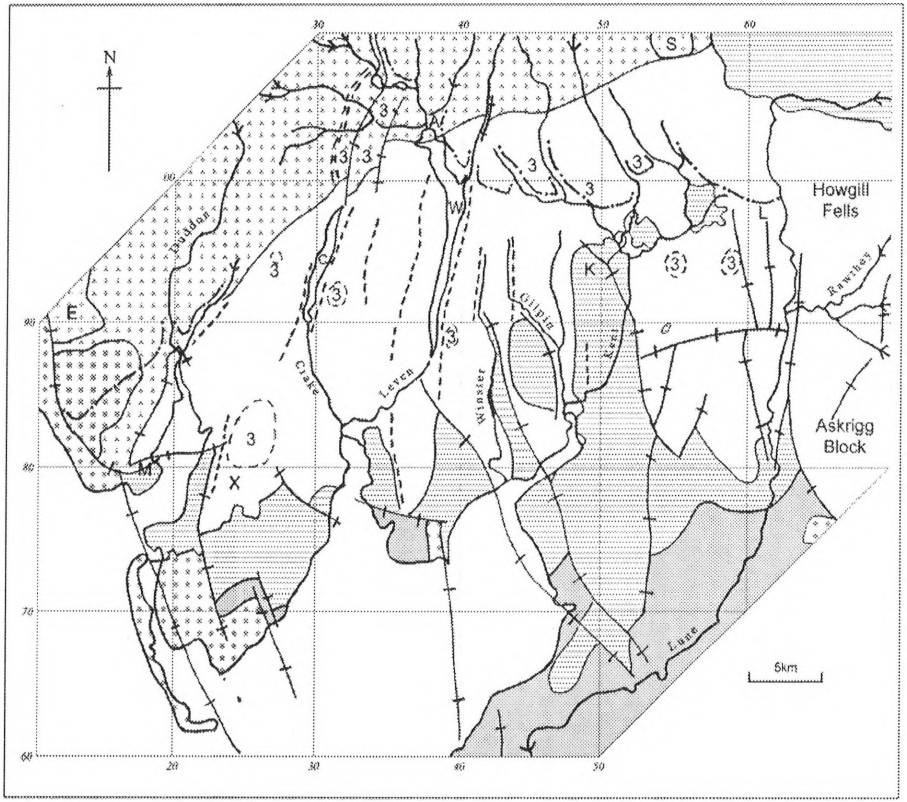
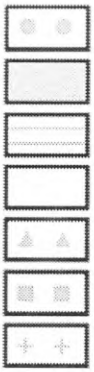


Figure 1 - The southern Lake District showing locations of selected features and solid geology (key on following page).



Permo-Triass

Upper Carboniferous

Lower Carboniferous

Windermere Supergroup

Borrowdale Volcanic Group

Skiddaw Group

Granite (S = Shap, E = Eskdale)

North boundary of low southern area (LS)

Major fault lines

Structurally-guided scarps

3 (3) Areas with summits at or above 300m OD

Inner limit of Ambleside embayment

X Referred to in text

A Ambleside

C Coniston Water

K Kendal

L Lowgill

M Millom

W Windermere (lake)

Along all three parts of the boundary, change in relief is associated with faults, monoclines and changes in gravity anomaly field. The LS so defined can be treated as a separate structural entity.

A geology of the landscape

Many lines of strike, cleavage planes and fold axes in WSG strata of LS trend approximately southwest-northeast but more nearly east-west towards the Lune valley. This grain is evident in many small-scale landforms of erosion. Faults in two sets cross the area. In one, the faults trend WSW – ESE and of these the principal are the Bootle Fell Fault and Kirkby Fault with its eastward continuation. Millward (2002) thought the latter might mark the southern end of a rather attenuated BVG succession. To its south the WSG strata would lie over Skiddaw Group (SkG) or Ingletonian rocks. Faults in this set have tended to throw down to the south, towards the Morecambe Bay basin.

Members of the other set are aligned almost north-south as continuations of the Coniston and Troutbeck Fault Zones (Millward 2002). In the Cartmel and Low Furness areas some fault alignments trend about northwest-southeast. Many of these faults throw down west and they form a set of narrow tilted fault blocks, many with west-facing scarps. There are also scarps along minor faults or other partitions in the strata. In the south of the area the faults are accompanied by outcrops of Lower Carboniferous beds, mostly limestones. In the north of the area limestone outliers are found only near Kendal. The tracts of limestone in the south merge towards Morecambe Bay and pinch out northwards. Some limestone outcrops lie low in the fault angles while others, notably at Whitbarrow and Scout Scar, west of Kendal, form prominent north-south ridges. Locally, near the coast, the Lower Carboniferous rocks are concealed by Namurian strata. Even more locally and particularly near Barrow in Furness Permo-Triassic rocks appear onshore telling of the proximity of their offshore basin.

The limestone outcrops north of Kendal lie in an elongated topographic basin along the LS north boundary. Here streams from the northern fells converge on the gap near Kendal where the River Kent leaves the basin. Limestones occupy a small part of the basin floor below about 50m OD and an outlier on the footslopes of Whinfell Beacon reaches about 200m OD. This hill (472m OD) is part of a high area that separates the limestone outcrops south of and east of the Lake District. The successions of strata in the two areas are not identical and it is supposed that for a time during Carboniferous sedimentation they were not conjoined. The Shap Granite would first have exercised its tendency to uplift in the Devonian. It has more recently reasserted that tendency. The lower southern slopes of Whinfell Beacon must approximate to a sub-Carboniferous surface, now steepened by subsequent tilting. It is worth considering whether more extensive slopes into the Kendal basin from the north may also be close to the position of the sub-Carboniferous surface, particularly their lower parts, presumably most recently exhumed. The present low relief

along the northern LS boundary may perhaps be related to hinging between the two WSG tracts.

The positive gravity anomaly between Millom and Ulverston has a maximum value broadly coincident with a SkG inlier (X on Figure 1) north of Dalton in Furness. This inlier is upfaulted on its west side against Lower Carboniferous strata. The WSG rocks through which the inlier appears are themselves transgressed by Lower Carboniferous strata including basal beds. This gives some local measure of Late Palaeozoic erosion before Carboniferous marine environments were instated. The downfaulted Lower Carboniferous rocks west of the inlier are overlapped by Triassic strata. Further south, Permian strata overlie Namurian showing the change over a short distance in amounts of end-Palaeozoic erosion and onsets of sedimentation. It is in the southern part of Low Furness that the influences of Permo-Triassic basins most strongly impinge on LS landscapes: Furness south of the A 5092 road displays many of the geological relationships and landscape elements that characterise LS country.

The nature of the landscape

We have seen how Marr explained the low relief of LS and how its geology allowed it to avoid the degree of uplift which gave the rest of the Lake District and the Pennines their present high standing. But Marr, who commented on altitude accordance among the highest Lake District peaks, made little of the quite remarkable accordance in altitude (about 300m OD) of the highest parts of the southern Lake District. Not all the LS fault blocks presently attain this altitude and on only two, at and near Lambrigg Fell (east of Kendal) and on Kirkby Moor near Kirkby in Furness, is it extensively attained. At the former place, a plateau about 7km wide, eight small areas reach 300m OD. Along 6 km of the latter upland five areas reach 300m and one just 298m OD. A small area near Torver, several on the Grizedale plateau east of Coniston Water, and two on the ridge crest east of Windermere reach this altitude. The two latter localities are on the western higher edges of their fault blocks.

Very little of the ground above 300m also exceeds 320m OD but there are five summits in the 332 – 338m altitude range distributed between Kirkby Moor, Lambrigg Fell and the Grizedale plateau. There are major and minor accordances in a 40m interval. As well, there are the summits at 336, 322 and 308m OD in the Ambleside embayment. This circumstance is obviously problematic. How is it that in an area almost 50km across so many hills reach 300m and none much exceeds that altitude? How and when were the accordances created? How is it that in LS all are in WSG rocks and none in Carboniferous or other strata? But there is really very little intimation of what the LS landscape was like before the 300m truncation.

Other than for the very small in-faulted outlier at Drygill, south of Caldbeck, WSG rocks have been removed from the Lake District except for LS and, adjacently, north to Shap Fells. Most remaining visible waste of that erosion is in the Mell Fell Conglomerate far from present WSG outcrops. Exposure of Shap

Granite by early Carboniferous times also testifies to the degree of uplift and erosion in, mainly, Devonian times. How did the southern WSG survive in its two terrains, LS and the adjoining higher northern area?

The northern edge of WSG might be seen to mark the advance of erosion, the retreat of WSG. The altitude difference along it, some 460m, is unlikely to be a direct product of erosion but a measure of later differential uplift. The present integrity of that line of outcrop and the height difference along it suggest relatively recent uplift with little subsequent erosion. Whether it has also been relatively recently exposed by removal of cover rocks is not clear but is possible. If uplift of the northern part of WSG outcrop was recent then division into two terrains might also have been relatively late.

Considering how LS came to be a low area does not explain the particularities of its present relief. One of the more intractable issues is whether, when erosional truncations of structure were making the features now at about 300m OD, much more of the LS area then stood at that altitude or higher. That is, how much material had to be removed to make the 300m features? It might be expected that if the WSG, quite tough strata, stood extensively at over that height more would now remain of the 300m levels and more could remain of higher residuals. There are various possibilities. One is that WSG was more extensive and stood higher in places and there has been a lot of subsequent erosion. Another is that, on the fault blocks, younger strata also reached to and perhaps over the 300m levels, and were then truncated and since further eroded. A third is that there was already a pattern of relief in which only small areas reached or much exceeded the 300m truncation levels. It need not be assumed that very broad 300m surfaces were cut wholly in WSG rocks. The present locations of surviving fragments, mainly near fault-bounded edges of blocks, can suggest that little of the WSG blocks then stood higher and that tilted slopes may have carried other, younger strata. A more extensive 300m surface including strata other than WSG can be envisaged: so can a more limited feature.

The more obvious candidates to be 'other strata' are the Carboniferous limestones. It is reasonable to suppose they have been more extensive but they do not now reach 300m OD in LS and it cannot be shown that they did when the truncation at 300m OD took place. The contrast between the place of the Carboniferous in LS landscapes and on the east and north margins of the Lake District may be instructive.

From the Dent Fault near Kirkby Stephen the Carboniferous overlaps WSG as far west as Shap Wells where it passes onto BVG rocks and then on and off SkG and BVG and, in the north, Eycott Volcanic Group. On this long part of the Lake District periphery the WSG was removed before Carboniferous sedimentation. Here the limestone terrain is continuous as far west as Cockermouth. Locally, the base of the Carboniferous reaches 300m OD. Overall, this terrain is upstanding with examples of truncation surfaces at about

300m from the upper Lune valley to Aughertree Fell west of Caldbeck. And, in each segment of the outcrop there are parts that rise to over 350m (412m OD, Knott near Orton). It is clear that the limestones can form high ground, have been truncated, and retain truncation surfaces at and near 300m OD.

Limestone terrain in LS is not like that. It is discontinuous by combination of faulting and erosion. It nowhere reaches 300m OD (229m OD at Scout Scar near Kendal where its base is about 100m OD). In LS, WSG survives but the limestones are much eroded and now stand low: on the east and north of the Lake District, where WSG has gone, limestone terrain is continuous and stands high. Limestones of LS could, in principle, sustain 300m levels. That now they do not do so can suggest they did not reach 300m at time of truncation. That their present disposition is not due to post–300m faulting is shown by the consistency of the 300m level across the fault blocks.

As from place-to-place round the Lake District Permo-Triassic rocks overstep Lower Carboniferous, BVG and SkG rocks it may be that removal of LS Carboniferous cover started at the end of the Palaeozoic. If rocks other than WSG were planed off at 300 m they may have been Permo-Triassic which would have been relatively easy to remove during later denudation.

Recognition of the 300m truncation surfaces is a reminder that from the mid-1930s to the 1960s much effort was invested locally in explaining landscapes in terms of planation platforms formed in relation to temporary stable base-levels at a succession of positions. Among local exponents were McConnell (1939) and Parry (1960). Parry noted the 300m features on Lambrigg Fell, ascribing them to accidental escape from subsequent erosion by virtue of location rather than resistance of rock. He thought the 300m surface had been more extensive. He also noted the corresponding conformity on Kirkby Moor. But, despite the small altitude range and some evidence for two levels within it, he considered these features belonged to a surface formed by sub-aerial erosion in a 300 – 425m OD altitude range. McConnell (1939) identified a truncation surface in a narrower range, 300 – 350m. OD.

More recently, and particularly in North America and Great Britain, it has become customary to discount identification and explanation of truncation (planation) surfaces though not without reasoned resistance (Bretz 1962). That sort of landscape interpretation has not everywhere been rejected and, in the context of the present discussion, it is appropriate to demonstrate that it still has adherents.

In an account of landforms of West Germany, Ahnert (1989, 6) noted that on 'many of the German uplands there are denudation surfaces that truncate the underlying structures and that represent landform generations older than the Pleistocene valleys by which they are dissected' and 'a climatic-morphological tendency to planation was .....present in all of central Europe, it has led to the development of denudation surfaces only where the tectonic movements were

weak enough for planation to take place.' Consequently, if such surfaces are recognized they allow inferences about contemporary and later tectonism. In the same volume, more detailed studies of various regions of Germany reinforce this basis for landscape interpretation. Of the south German scarplands, Bremer (1989, 62) wrote that 'Exposed bedrock surfaces are being lowered very slowly. Therefore, uplifted old denudation surfaces can be preserved for a very long time ....'. Brunotte and Garleff (1989, 153) analysed landforms of Lower Saxony to conclude that 'there are also truncation surfaces over wide areas of the plateaus which extend across strata of differing resistances. These surfaces can be termed peneplains. In the basins, several levels of denudation surfaces are developed ... generally, they truncate the strata and are therefore, sculptural, not structural forms.' Reporting on the Odenwald, which has several geological resemblances to the Lake District, Zeinert (1989, 2001) said 'A group of denudation surfaces extends largely undissected over the central part of the northern blocks.' and 'there are no sediments to indicate the age of the denudation surfaces but they extend across several lithological units.' Zeinert (1989, 205) records that 'The planation surfaces also extend across the faults without forming scarps, although some of the faults have considerable displacements. This indicates they are older than the surfaces in the areas in which the surfaces cross them'. It is clear that contemporary German landscape interpretation remains compatible with concepts and analyses of the sort employed by McConnell and Parry, and many others. It is not that the newer models and theories were unknown there.

The present discussion supports the earlier recognition (McConnell 1939, Parry 1960) of truncation across structure at about 300m OD. Although the immediate interest in this level is in how it constrains maximum altitude, limits summit level diversity and overall LS relief amplitude and so greatly contributes to the distinctiveness of the landscape, there are other implications which cannot be pursued in any detail. They are whether that surface is more widely distributed: this has already been touched upon. Another is whether it is traceable across fault lines: this has been dealt with for LS and adjacently. A third is whether the 300m OD truncation surfaces are better described as occupying a narrow altitude range: the present LS evidence suggests they are. Altitude range, ascribed to an individual surface, could have bearing on interpretation of its mode of formation.

The Ambleside embayment hilltops, too, have restricted altitude range. They lie across faults of the Coniston Fault zone from LS. In the lower Duddon valley, between Coniston Fells and Black Combe, several small features, hilltops, spur and flats, and cols lie in the 300 – 350m OD range. In the WSG area north of LS, from Windermere east to the Lune valley, where Parry (1960) recognized components of a 300 – 425m feature, there are benches cut across the generally south-sloping interfluves in the same narrow c 300m OD interval as in LS to the south. Those near Skeggles Water and on Potter Fell are among the more extensive. When the 300m OD truncation surfaces in narrow altitude

ranges on the limestones of the east and north Lake District peripheries are also taken into account, it is clear there is something more than a local LS feature.

Hollingsworth (1936), McConnell (1939) and Parry (1960) all claimed to identify local truncation surfaces at altitudes greater than about 300m (300 – 425m in Parry's case) and lower surfaces also. Only those in the lower altitude intervals are relevant to the present LS landscape. Parry identified eight such intervals, all but that at 213 – 290m OD being narrow, and each he associated with a temporary sea level. The sites recognized as parts of the various surfaces are small and distributed among the fault blocks with no significant continuity. In a landscape in which structural grain is evident in the ice-abraded surface, only locally would they make much visual impact. For the present purpose these identifications need not be further considered. Overall, the complex of low-relief landscapes so produced, apparently disorderly and with combinations of very extensive and very confined views, are unlike any elsewhere in the Lake District. Within this landscape, some final contributions to distinctiveness remain to be noted. The major lakes, Coniston Water and Windermere, consist of multiple rock-basins presumably eroded by ice moving along prominent fault-line scarps. It may be wondered whether rocks younger than WSG had once extended along the fault-lines, their removal facilitating an initial concentration of ice discharge leading in time to excavation of the rock basins. These, of all the lakes, lie beyond the high fells. Their location may owe something to convergence of ice output from the high fell valleys into and through the Ambleside embayment, eight kilometres wide from Tiberthwaite to the flanks of Wansfell overlooking Ambleside.

There are, also adding character to LS, those valleys, some cut below present sea level, which are now encumbered by alluvium and peat. Three of these are substantial in size, with valley floor flats one to over two kilometres wide, broader than Coniston Water and much of Windermere. The local presence of rock knolls protruding through alluvium and peat suggest there are concealed individual rock basins. It may be that proximity of these valleys to the weaker rocks near the coast and offshore favoured ice-incision during the low sea level cold periods, with headward recession of erosion along structural weaknesses. The pre-Pleistocene, higher level, disposition of outcrops may also have been influential. The Kirkby Pool valley, which during high Holocene sea levels would have extended the Duddon estuary by about 6km, is eroded along the WSG grain. Winster and Gilpin (Lyth) valleys are associated with north - south faultlines. The smaller Rusland Valley, between Coniston Water and Windermere, is similar in character and interesting for the broadening of the now infilled valley floor at Rusland where structural alignments cross at the foot of the 70m step in valley profile from the Satterthwaite basin. These four valleys, seemingly selectively enlarged by ice responding to some early advantage, and the lakes (Esthwaite Water in a minor way) divide LS into districts. The unity across its 50km extent is well appreciated from elevated viewpoints in the higher fells but its full character is seen only from within.

Distinctiveness

Much of what makes LS different derives from its restricted maximum altitude and, thus, its small relief amplitude. It has visual as well as structural unity. The subordinate characteristics, the noth - south fault-guided divisions, the wedges of limestone terrain, the grain in the WSG terrain, occur across the district. Although local variations can be recognised, they do little to weaken the unity and no part resembles the Lake District of high fells and deep dales or indeed any other adjacent area.

The LS area was outside the main zone of Ordovician volcanic activity. It did not get large low-density intrusions: there are no areas of mass deficiency. There is little tendency to respond to erosion by rising. As well, it avoided being incorporated in adjacent Permo-Triassic basins. It sits between basins and intrusions acquiring its own character and expressing it through its landscape.

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Acknowledgements

The comments of an anonymous referee were helpful in improving the text. David Kelly's assistance in preparing the figure is much appreciated.

Dr. R. P. K. Clark
[redacted]

THE GEOLOGY OF THE AREA AROUND NETHERTOWN

Leader: David Kelly (Cumberland Geological Society)

Wednesday April 17th 2002

A group of fifteen or so members and friends met in Nethertown village to examine an area not visited before by the Society in the forty years of its history. The area has few exposures and interpretation of the Quaternary history is difficult. The red sandstone buildings of the village indicate that the area forms part of the outcrop of the St Bees Sandstone, although the depth to rockhead is uncertain. Weathering of the buildings dating from about 1800 demonstrates the variable quality of the stone. The nearest exposed quarry today is in Ellergill, 2km to the north-east. Cobbles are used to build the surrounding field walls; the sub-angular shapes indicate that they were collected from the underlying drift rather from the nearby beach.

The party walked northwards to a roadside vantage point at NX 987079. The landscape of the drift cover appears irregular, chaotic and with no alignment; it is described in the recent literature as *"glacially over-ridden terrain"*. The maps produced by the Nirex investigations do not indicate the thickness of drift or depth to rockhead in this area. The altitude is 34m OD at this point and 76m OD at Coneyside Cop, just over a kilometre away to the north. Rockhead is close to sea level on the coast 300m away. It is likely that the drift cover is at least 20m thick over a tract of country stretching 6km from St Bees to Warborough Point so a large volume of drift is present about which comparatively little is known. Ellergill Beck and the lower course of the River Ehen run north-south, almost parallel to the coastline and this drift lies between these watercourses and the sea.

The road to Nethertown Station provides a good view of the coastal railway. Construction of the Whitehaven and Furness Junction Railway, opened in 1850, altered the coastal profile. From just south of Sea Mill to Warborough Nook the line occupies a shelf approximately 12m above sea level. On the land side there is a cutting and on the sea side an embankment. At the foot of the embankment there is a narrow 7m raised beach, often occupied by wooden bungalows. The raised beach ensures that the railway embankment is rarely reached by storm waves and provides a natural sea defence for the railway. At two points, immediately west of How Man and at Nethertown Station, the absence of the raised beach has made construction of substantial coastal protection necessary. At Nethertown the embankment is faced with stone armoury and a breakwater. Further re-inforcement by stone blocks (Carboniferous limestone and Borrowdale Volcanics) has taken place in the past 15 years, making access to the beach difficult. There was considerable discussion about the industrial

materials used in the construction of the original sea defences and an explanatory note by David Powell is given at the end of these Proceedings.

With some difficulty, the party clambered over the sea defences to the area of wave-cut rock platform and low cliffs to the north of Nethertown Station, known as Brig Stones. These exposures probably lie in the middle to upper part of the St Bees Sandstone and show a gentle tectonic dip to the west. Fluviatile features such as micaceous horizons, shale partings and shale-flake conglomerates were noted. The rock platform is generally cut along master bedding planes so that the intersection with the tops of the fore-set beds is clearly visible. The locality provides unusually good three-dimensional views of the dip directions of the fore-sets which are consistently towards the west and north. This is consistent with a system of straight or braided channels, possibly flowing from the Armorican mountains in south-west Britain.

The final locality visited, after an awkward walk along the coast, was the drift exposures in the coastal cliffs at NX 987073. This was mapped as the Townhead Boulder Gravel member of the Seascale Glacigenic, thought to have formed early in the Dimlington Stadial. These exposures are constantly changing due to coastal erosion in successive storms. At this visit, the north end of the exposure showed bedded sands and some gravels, similar to the St Bees Sands and Gravels. Ripples indicate lower flow regimes but the palaeocurrent indictors were inconsistent. Moving south, a major channel fill, boulder and gravel deposit was seen. This was at least 20m high with a clearly erosional base. Both clast-supported and matrix-supported elements were indentified. This dramatic exposure has been interpreted as a catastrophic glacial flood (jokulhlaup) deposit.

In deteriorating light and weather the group returned to Nethertown Village along the concrete road.

THE GEOLOGY OF DODD WOOD

Leader: Dr Alan Smith (Cumberland Geological Society)

Wednesday May 8th 2002

The first locality visited was Throstle Shaw (NY 237273) where the leader explained that the slopes of Dodd are underlain by the Kirkstile Formation of the Skiddaw Group, which is predominantly a dark grey, well-cleaved mudstone. An earlier diagram of the section (Figure 1) was distributed, although some of the elements shown were no longer exposed. The lower slopes of Dodd are made of debris containing small clasts derived from the Skiddaw Group. Impervious

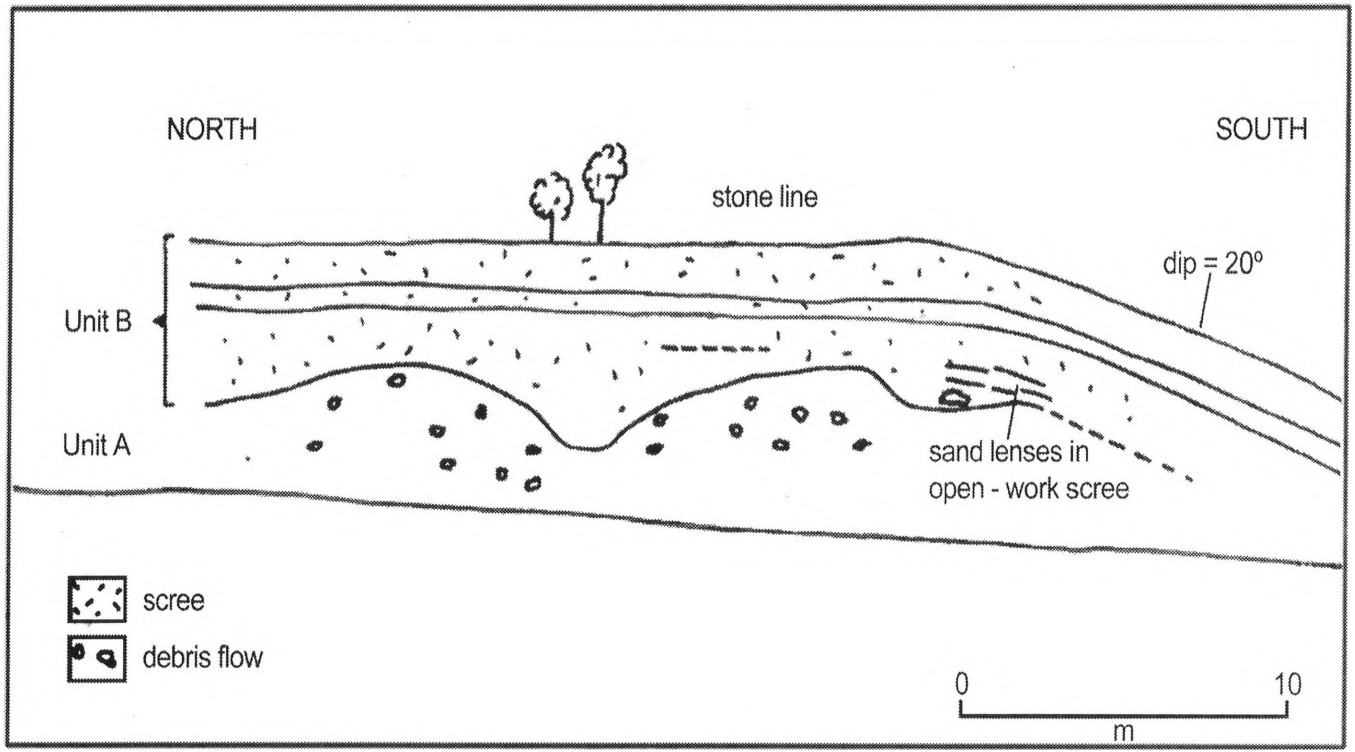


Figure 1 - Sketch of the section at Throstle Shaw

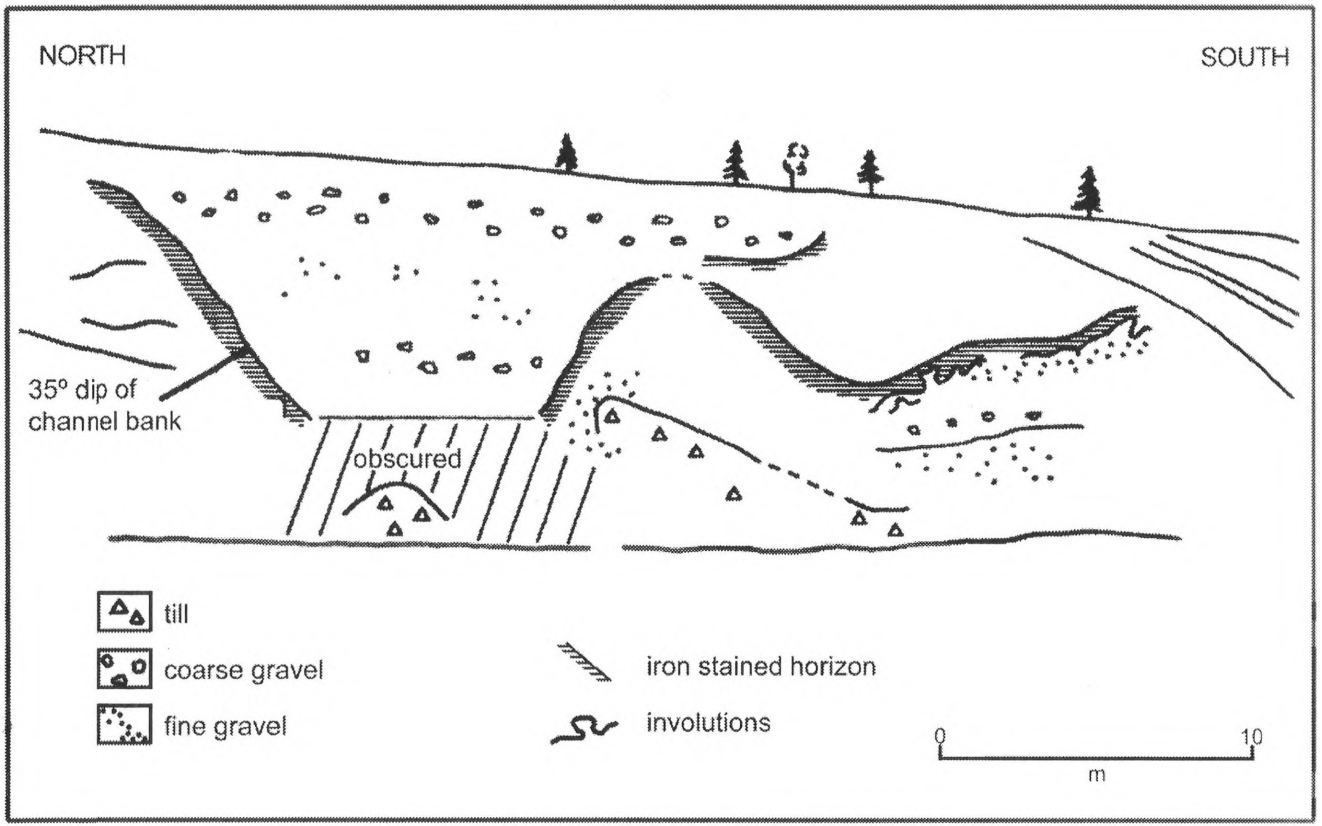


Figure 2 - Sketch of the quarry face at Sandbeds Quarry

bedrock combined with high runoff has led to active slope wash. At the end of the last glaciation about 13,500 years BP much frost action would have affected the slope, especially given the lack of vegetation. Unit A, shown on the diagram but not seen on this visit, is interpreted as a debris flow. 30cm subrounded clasts are within a sandy matrix which contains little clay. The clasts are orientated downslope therefore the deposit is not a till. Unit B is stratified, with small clasts lying horizontally in bands. This stratified scree, or *Grezes Litees*, accumulates as the result of snow melt and melting permafrost in summer. It lies at an average slope of 20°, more gentle than slopes produced by debris flows. It may have formed during the Loch Lomond Stadial.

The second locality visited was a cutting on the east side of the A591 road at Long Close Farm (NY 240267). Here a 3m wide vertical dyke intersects highly cleaved Skiddaw Group rocks. Both contacts are visible and narrow zones of thermal alteration of the country rock are indicated by refraction of the cleavage. The pale biotite lamprophyre is used as a building stone in Millbeck and for the extension to Keswick Hospital, the stone being won from a quarry in the wood. This and other similar dykes in Dodd Wood can be seen as landscape features from across the valley.

The group then moved on to a cutting in the quarry road at NY 237279. Here there was considerable discussion regarding the origin of a thin igneous intrusion. The majority view was that structures in the country rock are cleavage but that it was difficult to determine whether the intrusion was concordant or discordant.

The final locality visited was Sandbeds Quarry NY 234291 where a section through an inactive alluvial fan exposed sediments similar to those seen at the first locality (Figure 2). The fan rests on till but this was not exposed on this visit. The fan material is stratified with both angular and water-worn clasts. One channel feature was visible, apparently formed by cut and fill processes. Involutions at the south end of the exposure are interpreted as frost heave features which have been covered by later sediment.

SILURIAN AND CARBONIFEROUS ROCKS OF THE LANGHOLM AREA

Leader: Iver Gray (Cumberland Geological Society)

Sunday May 26th 2002

The localities visited on this excursion were the same as those examined by the Society on 15th May 1994; a full account of the earlier visit can be found in Proc. Cumb. Geol. Soc. Vol 6 Pt 1 pp70-72. On this visit there was a more extensive examination of the underground workings at Harelaw Quarry (NY 791428). A plan of the pillar and stall workings is shown on Figure 1.

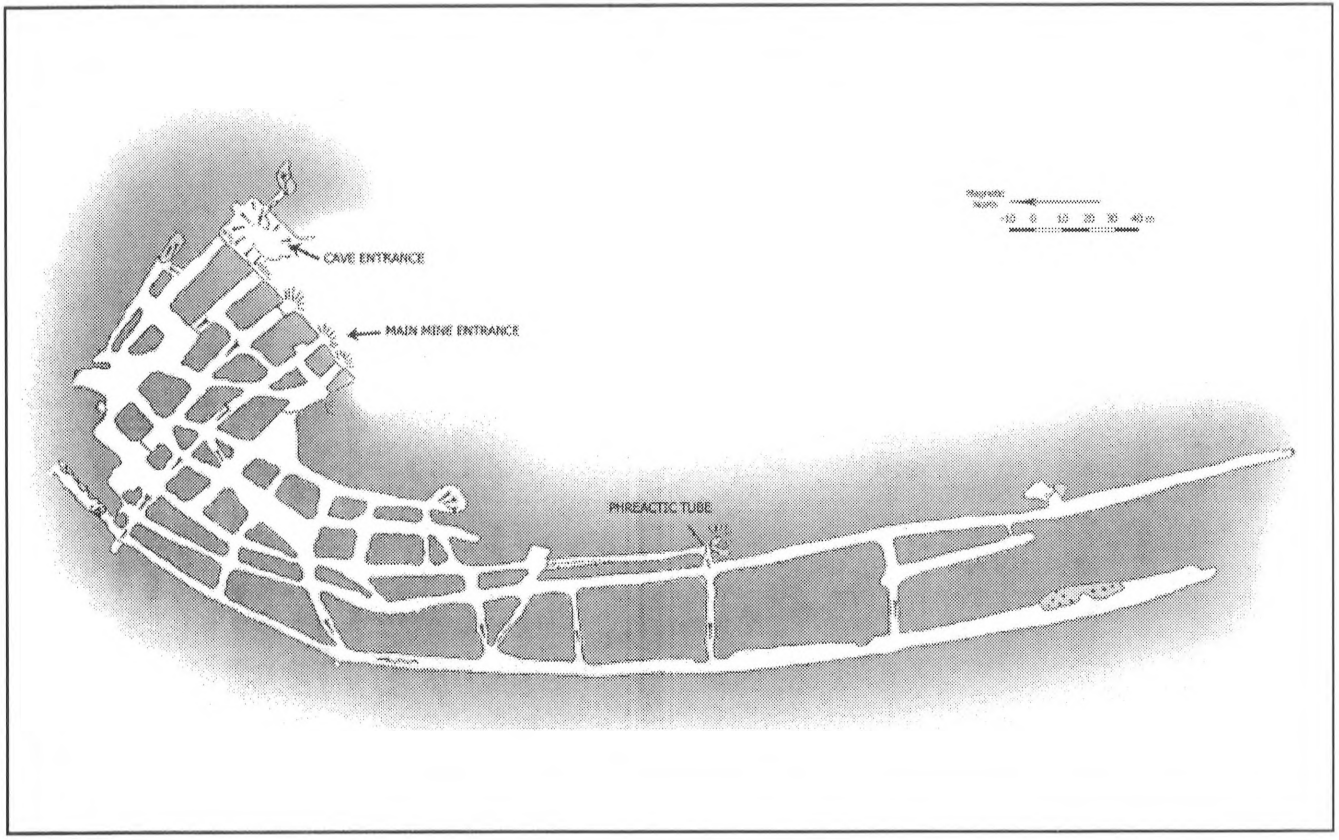


Figure 1 - Plan of Harelaw Hill Mine (original survey by P. T. Egan, J. Dobinson and N. Woods

The leader noted that the quarry was developed in the eighteenth century by the Duke of Buccleuch in association with his Canonbie coal mine. The limestone was used to produce lime for agricultural and building purposes. The proximity of the two resources meant that the haulage costs for fuel for the Harelaw kilns were relatively low. The kilns seen at Harelaw were probably built by James Laing (1709 - ?) of Harelaw, a local stone mason. Laing was an ancestor of the founder of the international construction company Laing International. The Harelaw Hill Limestone is about 8m thick and is the equivalent of the Five Yard Limestone in the Roman Wall area, i.e. beneath the Great Limestone.

The quarry and kilns fell out of use but were re-opened in 1934 under Adam Potts who moved to Harelaw Gardens. The limestone was quarried on the opposite side of the road to the two kilns and transported in hutches pushed manually across the road on a narrow gauge tramway to the top of the kiln which, at the time, was at the same level as the road. Coke was supplied to the kilns from the Carlisle gas works. The quarry worked until 1938 when it became uneconomic because of the thickness of the overburden increased as working proceeded down the dip.

In 1947 operations returned to Harelaw where it was decided to mine the limestone. The first drifts were driven in using a steam drill and blasting. This method produced a lot more small stone and therefore a ground limestone operation was started. With the introduction of winches to pull the hutches and a compressor to supply air-drilling equipment, the kilns were enlarged by building on the top. A combination of increased coke prices and decreased Government subsidy led to the closure of the kilns in the 1950s, after this time ground limestone was spread directly on to the fields.

The mine finally closed in 1966, being too difficult and dangerous to work because of the steepness of the strata. Although there were no serious injuries, a rockfall near the fault towards Harelaw Gate caused the loss of machinery and the abandonment of that area.

THE GEOLOGY OF BOWNESS POINT

Leader: Mervyn Dodd (Cumberland Geological Society)

Wednesday June 12th 2002

Bowness Point has greywackes of the Skiddaw Group Kirkstile Formation on its steep, north-facing slopes and Ennerdale Granopyhre on its wooded southern sides. The junction between these rocks is seen more obviously across the lake, where the contrast between craggy Anglers' Crag on Skiddaw Group rocks and the much smoother landscape of the Granophyre is clear. The relative positions of the main rock groups in Ennerdale is shown on Figure 1.

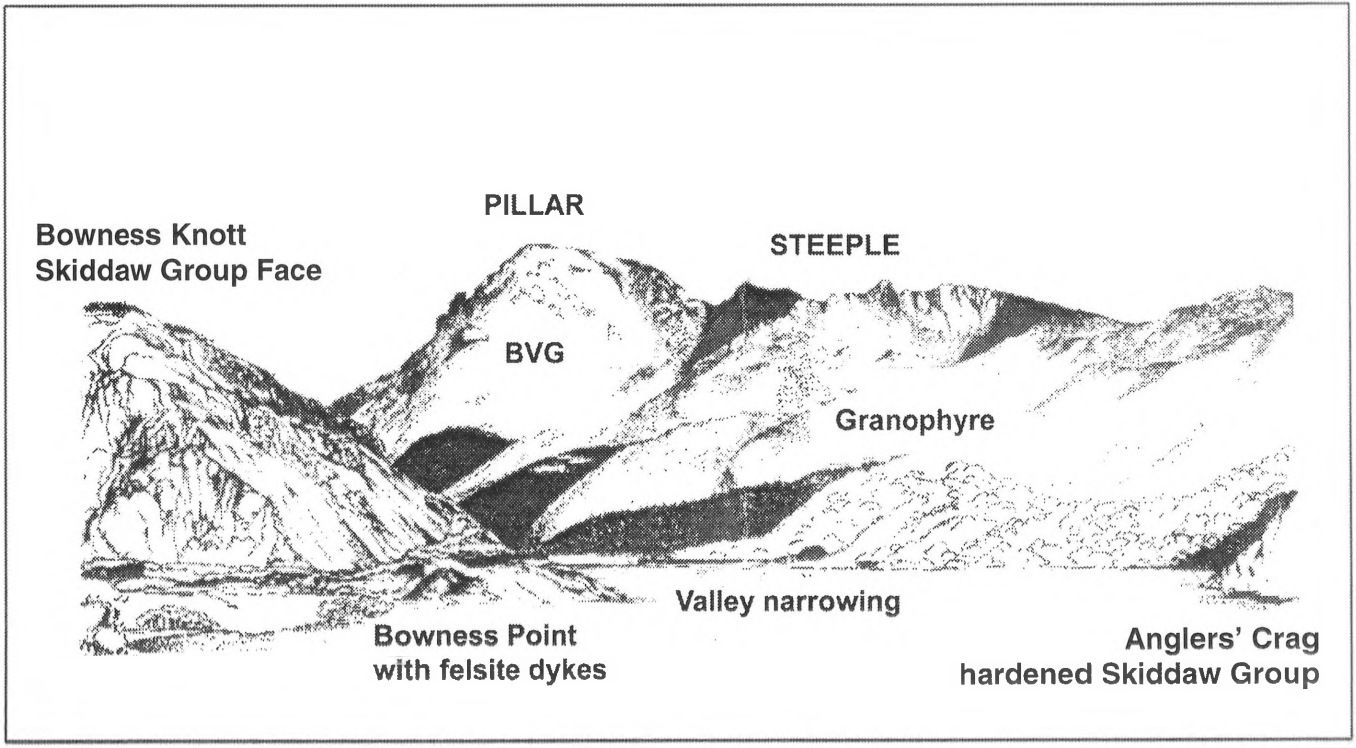


Figure 1 - A view of Ennerdale near Bowness Point

Several dykes of varying composition, mainly felsites, extend from the Granophyre into the Skiddaw Group rocks.

The Skiddaw Group rocks exposed are metamorphosed by the Granophyre and are very hard with joints and bedding planes largely closed. They are best exposed and identified above the path leading down to the lake, where the thinly bedded and laminated rocks form the plucked surface of the roche moutonnee.

The felsite dykes, seen in Bowness Crag old quarry, trend south-west and can be picked out by their fine grain size, quartz phenocrysts and the presence of pink orthoclase feldspars – so are not superficially very different from the Skiddaw Group rocks.

Bowness Point is a roche moutonnee, with gentle up valley slopes on glacial drift and steep craggy down valley slopes where the ice tore out or "plucked" rocks. There is a pronounced glacial narrowing of the valley between Bowness Point and Anglers' Crag opposite, both in the metamorphosed Skiddaw Group rocks which resisted erosion. Immediately offshore is the deepest part of Ennerdale Water, 40m or so, due to the increased erosive power of the ice when constricted and deeper.

Anglers' Crag opposite is a truncated spur, "chopped off" by the ice. Above it on Crag Fell are "The Pinnacles", landslip scars formed when the oversteepened valley sides collapsed after the glaciers melted. Up valley are the north-east facing corries on the Borrowdale Volcanic Group below Pillar and Steeple. Ennerdale Water is dammed near How Hall and the Scout Camp by morainic material of Irish Sea Ice provenance.

Alluvial fans occur just north of Bowness Point and possible at a higher level in Rake Beck valley which could represent a higher level of Ennerdale. At the base of Herdus is a periglacial feature, a protalus rampart, rather like an earthwork with a trench and a parapet. This is at an unusually low height. Unfortunately this visit had to be curtailed because of heavy rainfall.

QUATERNARY DEPOSITS OF THE WEST SIDE OF THE FURNESS PENINSULA

Leader: Derek Leviston

Sunday June 16th 2002 (Joint meeting with the Furness Geological Group)

A group of about 15 members met at the Furness Abbey amphitheatre car park SD 218716. The leader explained that object of the day was to build upon a previous visit of the Society, the report of which can be found in the Proceedings Vol. 5 1990-91 Part 3 pp355-358. The amphitheatre is situated in the main glacial meltwater channel which starts in the vicinity of Greenscoe

brickworks and continues to Roose where it divides into two branches, one following Sarah Beck, the other branching West towards Barrow Docks.

The party then proceeded to a small quarry east of Furness Abbey (SD 224717) where the Leader explained that analyses of clast lithology by Kendal 1882 and Grieve & Hammersley 1971 indicate that the glacial tills in Low Furness are from two provenances. Those containing West Cumbria lithologies and granites from Eskdale and Criffel in Scotland were deposited by the Irish Sea glacier. Tills without granite and West Cumbria clasts were deposited by glaciers which have their source in the Lake District. The distribution of the deposits is shown on the map (Figure 1) and the names given by Grieve & Hammersley 1971 to the various deposits are shown in the table of stratigraphy and correlation (Figure 2). The Upper Till is defined as that till where the content of igneous clasts alone exceeds 30% of the igneous plus grit clasts. Current work by the leader is aimed at reviewing previous work, allocating informal names (for the time being) to the various deposits and correlating them with the work of Thomas, 1991, to place them in a regional setting as shown in the table.

Examination of the boulder bed at the first locality shows the angular to sub round clasts are of Lake District origin with local limestones and fragments of hematite, some with sharp pointed forms. This indicates that the deposits belong to the Low Furness Glacigenic Formation which at the time of writing is undivided.

The party proceeded by car to Roosecote sand pits (SD 223689) where recent landscaping has covered the extensive sand and gravel pits in the Roosecote Sand and Gravel Member of the Rampside Glacigenic Formation. A small cliff section showed glacial sand with lenses of pebble beds overlain by a thin diamicton. It was explained that this was the northerly extent of the sands and gravels visited at Rampside during the previous field meeting. Two interpretations have been suggested for the origin of these deposits:

1. Rose and Dunham 1977 suggest they are subglacial deposits resulting from the erosion of the extensive meltwater channel visited at Furness Abbey.
2. Huddart 1977 interprets them as sandur deposits resulting from a readvance of the retreating Irish Sea glacier.

Lunch was had on Walney Island (SD1840 6645) after which the party visited various cliff sections along the coast. The first of these was Middle Hill (SD185 658) where tills of the Middle Hill Till Member were examined and seen to contain clasts of Scottish and West Cumbria provenance. Clast fabric analysis indicates a glacial flow direction of approximately north-west – south-east. Proceeding to the cliffs in the vicinity of Lamity Syke Pit (SD 188645) beds of pebble gravel with a red sand matrix were seen overlying the Middle Hill Till

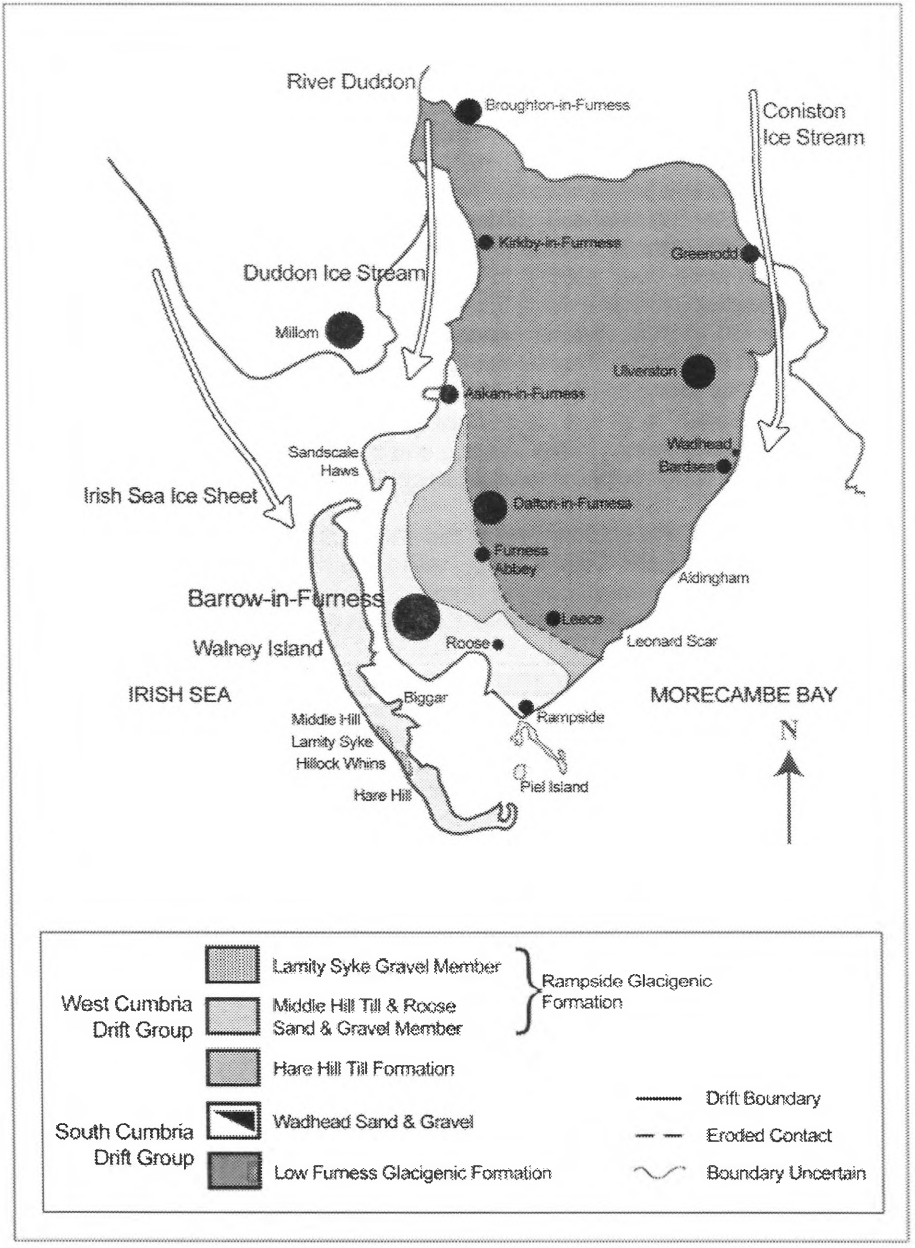


Figure 1 - Map of the late Devensian glacigenic deposits of Low Furness.

$\delta^{18}O$	Grieve and Hammersley 1971 **BARROW AREA**	Thomas 1991 **CUMBRIA**	This work **LOW FURNESS**
1	**Post-glacial deposits**	**Solway Formation** **Grange Formation** **Blelham Formation**	**Solway Formation** **Grange Formation** **Blelham Formation**
2	**West Cumberland and Scottish Drift** Upper Gravels Upper Till Middle Sands & Gravels **Mixed Till** **Low Furness Till**	**Windermere Formation** St Bees Head Beds **Wolf Crags Formation** **Morecambe Bay Formation** **Threlkeld Formation** Threlkeld, Lobbs& Mosedale Members **Black Combe Formation** Annaside, Gutterby and St Bees Members **Carlisle Formation** Rose Hill, Home St Cuthbert & Brunstock Members **Penrith Formation** Baronwood & Eden Members **Irthing Formation** Lanerstock, Brampton and Great Easby Members **Selker Formation**	**Hare Hill Till Formation** **Low Furness Glacigenic Formation** Wadhead Sand & Gravel member
3			
4		**Luce Bay Formation**	
5		Scandel Beck Bed	
5e		**Wigton Formation** Lindal Cote Bed	
6		Troutbeck Palaeosol **Thornsgill Formation**	
7/pre9			

Figure 2 - Stratigraphy and correlation of the Low Furness Quaternary deposits.

Member. Contorted beds of sand beneath the pebble gravel provided evidence of extensive frost heave. Tracing the pebble gravel southwards, a thin lens of peat was seen underlying recent deposits. Peat deposits from this locality have been reported by Grieve and Hammersley, 1971, and dated to Pollen Zones VIa and VI.

Proceeding southwards to Hillock Whins, extensive coastal erosion resulting from the February 2001 storms was seen starting to cut into the Middle Hill Till Member and exposing the now abandoned communal waste disposal pit.

The final locality was at Hare Hill (SD205 630) where a tri-partite sequence of till-sand-till was examined. Here the lower Hare Hill Till Formation can be seen with the fabric analysis indicating a glacial flow direction of south-west – north-east. Incised into the till is an asymmetrical depression into which the overlying sands have been deposited. Study of the sands showed they contain convolute bedding with linear streaks of coal particles suggesting a West Cumbria provenance. On this evidence the sands are correlated with those that can be seen at Rampside and Roosecote and hence belong to the Roosecote Sand and Gravel Member of the Rampside Glacigenic Formation. The overlying thin till deposit is correlated with the Middle Hill Till Member.

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SILURIAN ROCKS SOUTH OF TORVER

Leader: David Kelly (Cumberland Geological Society)

Sunday 30th June 2002 (Joint Meeting with the Open University Geological Society)

This excursion, held on an extremely wet day, generally followed the itinerary described in Lakeland Rocks and Landscape, pp41 – 45. On this occasion the localities visited were: Gawthwaite Formation in the disused roadside quarry at Whins (SD 270933); Latrigg Formation in small disused

quarries near Hazel Hall (SD 270928); Poolscar Formation on the slopes of Birk Haw (SD 267922) and the north-east slopes of Huntpot Dub (SD 267918); Moorhowe Formation and possible transgressive microgranodiorite-microgranite porphyry sill at Mere Moss and surrounding area (SD 267915); Yewbank Formation at the ridge south-east of Mere Beck (SD 268914); Bannisdale Formation and dyke at Brown Howe quarry (SD 289909) and the Gawthwaite Formation at Eccleriggs Bank quarry (SD210867).

On crossing the route of the disused railway between the first two localities the link with mineral extraction in area was noted. The Coniston Railway between Coniston and Foxfield was opened in 1859 to transport minerals from Coniston to the Furness Railway for transhipment. Prior to this, barges on Coniston Water transported minerals for shipment from the port of Greenodd. Passenger traffic continued until 1958 with the line finally being closed to goods in 1962.

THE SCENERY OF THE NANNYCATCH GORGE

Leader: David Livesey (Cumberland Geological Society)

Wednesday July 17th 2002

A large group of members and friends met on the Cold Fell road close to Kinniside Stone Circle where a small tributary stream of Nannycatch Beck crosses the road (NY 059139). The area lies at 220m OD close to the Ehen – Calder watershed. Much of Blakeley Raise, Flat Fell and Dent are covered by drift resting on the westerly, younger part of the outcrop of the Skiddaw Group which generally dips to the south-west in this area. Irish Sea Ice met Lake District Ice in this area and the effects of the two ice masses and their meltwaters are seen in the landscape.

In the 1930s Nannycatch Gorge was attributed to erosion by meltwaters overflowing to the south and west from glacial Lake Ennerdale which was impounded by the Irish Sea Ice. The more modern explanation is that the valley system was formed by subglacial aqueous erosion.

The party descended into the northern part of the valley. Beside the track mudstones show complex folding. At the valley floor the small stream is a misfit in its gorge-like valley. The part of the valley extending on the north side of Flat Fell is dry. Further south the size of the stream increases as it is fed by seepage from Flat Fell. Walking southwards fan features extend from the Blakeley side of the valley and a river cliff is cut in scree material on the Flat Fell side.

At the narrowest part of the valley there is a small adit on the west side of the valley and the path crosses the spoil heap. This is the Kinniside Vein,

reputedly gold-bearing. At the south-east corner of Flat Fell the bedding dips to the south-east but the cleavage appears to be horizontal in places. The party did not examine Raven Crag but the leader pointed out that the lower part is vesicular igneous rock and the upper part is non-vesicular dyke rock.

The return route was over the eastern flank of Flat Fell from where an excellent aerial view of the gorge was obtained. An attempt to locate minor intrusions of andesite on top of Flat Fell, marked on the map, was not successful.

OTHER EXCURSION HELD IN 2002

The following excursion was also held in 2002.

Wednesday September 11th 2002

Haig Colliery Mining Museum and old collieries. Leader: John Brown.

EXCURSIONS REPORTS 2003

As part of the field excursion programme for Summer 2003, the Society arranged a series of evening trips to several locations visited by previous excursions. In some cases changes in the exposures or re-evaluation of the sites has warranted inclusion of a new report in the Proceedings. In other cases a reference to earlier Proceedings is given.

THE LOWER BORROWDALE VOLCANIC GROUP SUCCESSION ON FALCON CRAG AND BROWN KNOTTS, DEWENTWATER

Leader: Dr Alan Smith (Cumberland Geological Society)

Sunday April 27th 2003 (Joint meeting with the Westmorland Geological Society)

A large group of members from both Societies met at the National Trust Great Wood Car Park on the Borrowdale Road south of Keswick (NY 272215). The aim of the excursion was to examine a section of the Borrowdale Volcanic Group (Birker Fell Formation) forming the classic trap topography on the eastern shore of Derwentwater. This section provides some clues as to the volcanic environment in which this succession was deposited.

Falcon Crags and Brown Knotts overlook the eastern shores of Derwentwater and provide a well-exposed, 650m thick succession of lavas and interbedded pyroclastic rocks within the Birker Fell Formation, the basal part of the Borrowdale Volcanic Group (BVG). The volcanic succession dips gently to the east (less than 10 degrees) and forms a series of prominent terrace features, particularly on Brown Knotts – a fine example of classic trap topography. This succession provides an excellent example of the largely subaerial, plateau-andesite field that is exposed extensively in the south-western, western and northern parts of the BVG outcrop and which developed as a precursor to the large-scale ignimbrite volcanism and caldera collapse of the upper parts of the BVG succession. A transect up the slope - up the succession, demonstrates the great variety of materials that make up this pile and the variability of the environments of deposition.

The area was first mapped and described by the original Geological Survey work of James Clifton Ward in 1876. Further references to the area were made by Marr (1916), J.F.N. Green, and Shackleton (1966). More recently the area was remapped by Suthren (1977) and featured in the GA Guide to the Lake District (1990). The new BGS survey of the area in the 1990s is now embodied in the new Keswick Sheet 29 and the accompanying sheet explanations. The site warrants Geological Conservation Review status and has been described in Vol. 17 of that series by Beddoe-Stephens (1999). Whilst these three most recent studies present very similar interpretations of the rocks, there are a few slight differences in nomenclature and some subtle differences in the mapping detail (Figures 1 and 2).

There is a major unconformity with the Skiddaw Group rocks (Buttermere Formation) at the base of the volcanic pile. The junction is not well seen, but is now interpreted in this section, as a major faulted junction. The Derwentwater Fault defines the eastern shore of the lake and extends south into Borrowdale and north for a considerable distance into the Skiddaw Group outcrop. A purple breccia occurs at the junction in this section and complicates the sequence. In other places a fine grained andesitic lava forms the base of the volcanic pile.

The lower part of the succession comprises generally sparsely porphyritic to aphyric fine-grained lavas with intercalated volcaniclastic units. The upper part (not reached on the excursion), by contrast, is dominated by moderately to strongly porphyritic andesites. The lavas vary in thickness from 10-100m and tend to form conspicuous relief features.

In the lower part of Cat Ghyll the lowest andesite was examined. Beneath it there appears to be a narrow tuff band on top of a complex breccia type material that was discussed (inconclusively) by Shackleton in 1966.

The main section examined was on Brown Knotts where a series of lavas, interbedded volcaniclastic sequences, and a well-defined lithic tuff horizon were seen. Near the top of Brown Knotts is the distinctive sill which has been described by Branney and Suthren 1988. The leader explained the interpretation placed on the sequence as the party ascended the section. Several exposures led to discussion. Figure 3 provides a summary of the interpretations discussed. The leader was thanked by the President of the WGS for an interesting excursion to an area unfamiliar to most members.

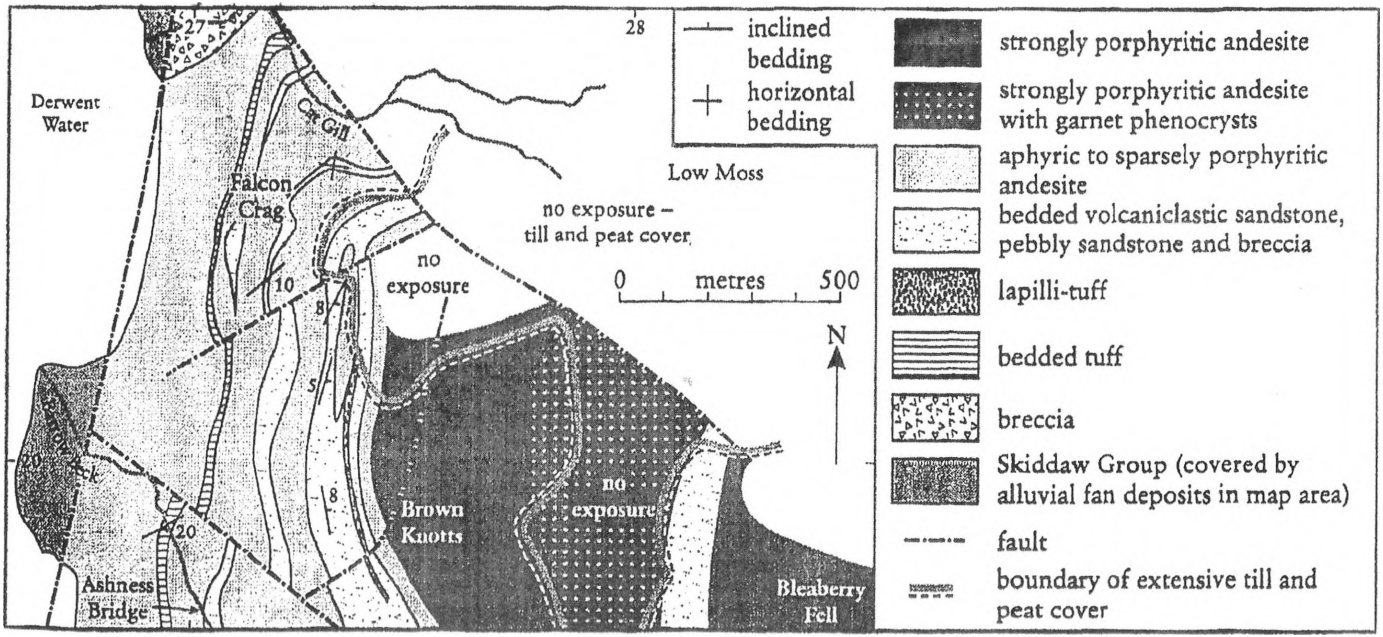


Figure 1 - Geology of Falcon Crag - Brown Knotts (after Beddoe-Stephens, 1999)

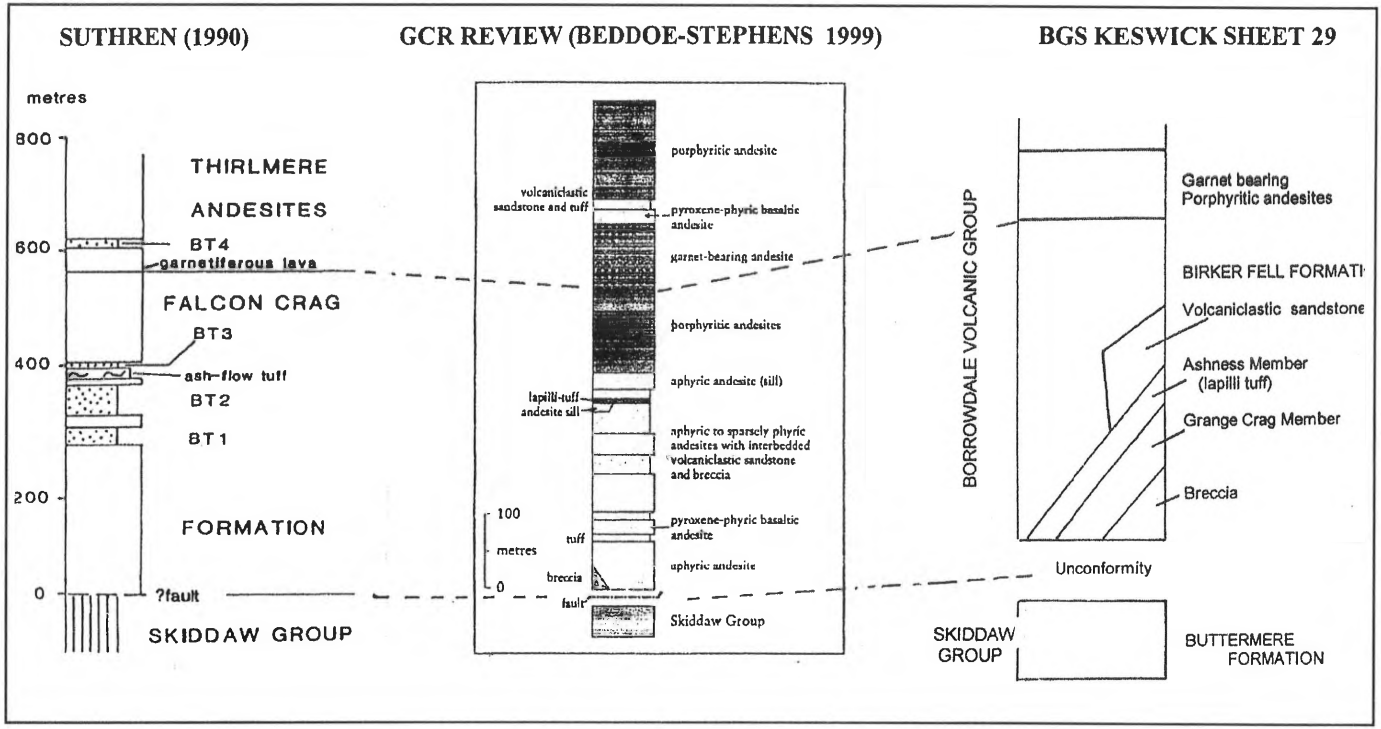


Figure 2 - Interpretations of succession on Falcon Crag - Brown Knotts

Feature	Interpretation
Summit andesites of Brown Knotts	Andesite flows
Volcaniclastic sandstones.	Fluvial regime
Andesite sill	Intrusion of peperite sill into wet sediments.
Volcaniclastic sediments	Bedding and cross-bedding in fluvial flow regime
Lapilli tuff	Hot pyroclastic flow
Coarser sediments	Cross-bedding in higher energy stream flow
Fine, sand/clay grade volcaniclastics	Fine laminations, normally graded Dilute turbidity currents in shallow water temporary lake Pumice fragments deposited in late stages
Andesite	Lava flow – disrupting underlying sediments
Volcaniclastic beds	Reworking of unconsolidated pyroclastics in fluvial environment. Channel cutting Transport towards the north Parallel bedding and trough cross bedding Soft sediment faulting Possible fine primary fall deposition
Andesite	Lava flow. Brecciation of tops and bases
----------break from Cat Ghyll----------	
Cat Ghyll Lowest Andesite	Lava flow unit
Tuff	Ash fall? Water lain?
Basal breccia	Mudflow regime – from nearby volcanic pile

Figure - Summary of the environments of deposition in the lower part of the Falcon Crag - Brown Knotts section

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MOUSEGILL QUARRY, WILTON NEAR EGREMONT

Leader: Mervyn Dodd (Cumberland Geological Society)

Wednesday May 14th 2003

The Society previously visited the quarry (NY 048090), known locally as Limekiln Lonning in June 1980; a report appeared in Proceedings Volume 4 Part 2, page 147. The 2003 excursion, attended by 20 or so members on a sunny, chilly evening, was to see how well the features reported had survived and to update the description if necessary.

The quarry was developed in the early 19th Century to provide a local source of slaked lime within Wilton township in the Parish of Haile. It was needed to allow the then modern techniques of the Agricultural Revolution, made possible by the local Enclosure Act, to be practised.

The quarry is in a faulted outlier of Carboniferous Limestone with the older Skiddaw Group and Borrowdale Volcanic Group rocks around. The Limestone is the lowest unit (of the Holkerian stage) of the local Dinantian Chief Limestone

Group. In 1980 it was called the Seventh Limestone, now it is the Frizington Limestone Formation, only exposed in two locations. This is the reference section. The main importance of the outcrop is that it supports the hypothesis that rocks younger than the Lower Palaeozoic once extended over the Lake District Dome, dipping outwards, gently westwards at 10^0 here.

The accompanying map (Figure 1) shows the locations visited and those referred to in Mr Shipp's earlier article. The slickensiding along the north - south fault plane west of the Limekiln Lonning (9 on the map) is hidden by tree growth. The group did not visit locations (10 & 11), where the BVG and a possible intrusion outcrop, which are partly obscured by tree planting. The fine specimen of the brachiopod *Davisiella*, the fine productid brachiopods and the solitary coral *Zaphrentis* Mr Shipp mentioned had disappeared.

The group entered the site east of the Lonning, stopping first at location 1, an outcrop of bedded, reddened, rather coarse, sandy rocks, possible Carboniferous Basement beds of ?Chadian age. The next stop was to view the limestone breccias at locations 2, marking the course of a fault running north-northwest – south-southeast. Interestingly these had not been quarried. The cliffs immediately to the east were largely bioclastic limestone with many crinoid fragments with thin chert bands. A fence extending part way east up the slope marks the faulted axis of the shallow, open syncline (wrongly named as an anticline in the earlier Proceedings). Brecciation is very strongly developed with large calcite masses where the axis is exposed just above the Lonning wall at location 3.

We then made our way onto the flat limestone surface above the cliffs. There was a striking contrast between the fresh green pasture on it and the damp brown to grey herbage on the impermeable material to the east. There were several small, shallow collapse hollows en route to Goosey Tyson's Well, location 4, an active swallow hole. A small stream disappears quietly underground in this 4 - 6m deep hollow. We then walked west into the northern part of the quarry which has much more clastics than the southern part of the quarry we first visited.

At location 5 there were small tubes or burrows of the trace fossil *Thalassinoides* (Figure 2), at the top of a weak lime mudstone bed, immediately below a more resistant limestone. The extent of the trace fossils was much larger than most we see. The uppermost cliffs (location 6) in this part of the quarry have several *Lithostrotionoid* coral colonies, up to the size of cauliflowers. A gastropod specimen was collected, probably *Bellerophon*. One of the cliffs above has a curving tube, at location 7, extending for 5m or so, thought to be phreatic in origin. This would have formed below the water table level when it was at a much higher level than at present.

We then left the quarry, walking 200m or so into a field to the north west. At location 8, the banks of a small stream, which was cutting a shallow ditch, there

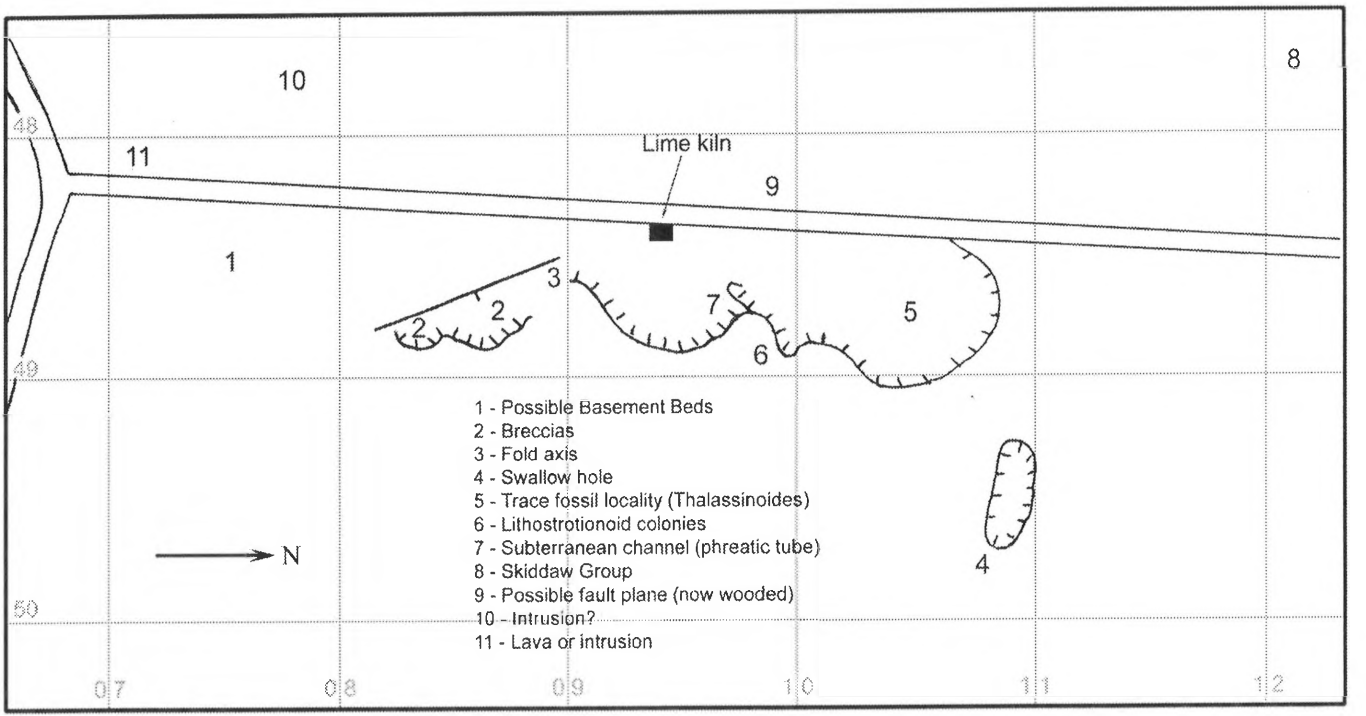


Figure 1 - Sketch map of the Mousegill area. Approximate scale 1:1,250.

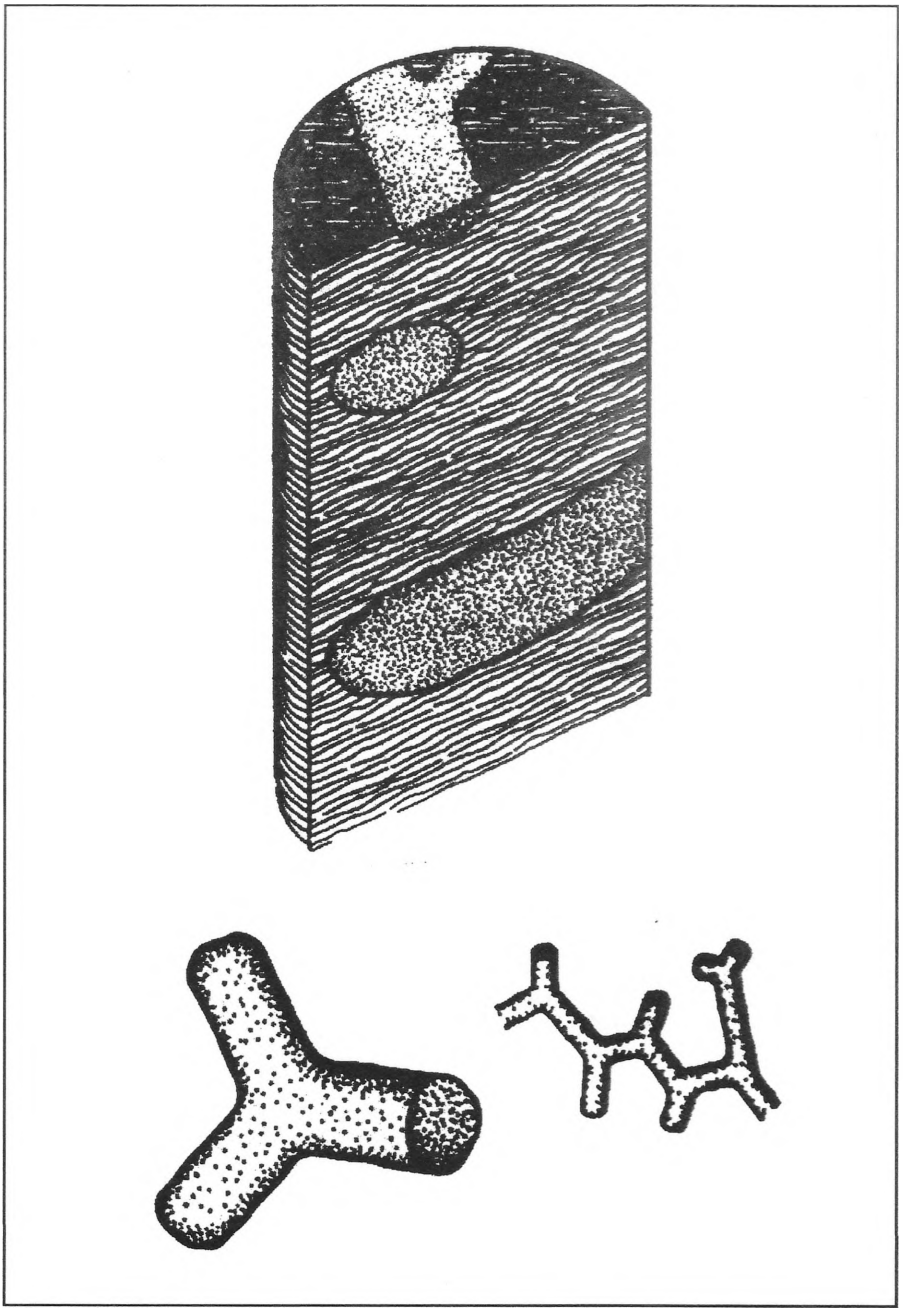


Figure 2 - Thalassinoides (ideal representation).

were modest exposures of Skiddaw Group rocks, rather thinly bedded and sandy.

Reference

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PERMIAN BROCKRAMS AND SANDSTONES IN THE EDEN VALLEY

Leader: Gordon Taylor (Cumberland Geological Society)

Wednesday July 9th 2003

A group of about 20 members and guests met in the village of Nateby – some distance from the normal area for evening field visits. Here the leader explained that the three localities to be visited all lie within the Eden half-graben. The objective was to view the geology of the Eden valley half-graben (which is associated with the opening of the North Atlantic Ocean) at three sites that have been designated either as a RIGS or a SSSI.

The party then walked through the fields to the first locality close to the River Eden immediately west of the village (NY 773067). Here there is an excellent series of three-dimensional exposures showing the lensoid flash-flood Permian Brockram deposits that contain cobbles and pebbles of Carboniferous Dinantian limestones. The Brockram is exposed in a river cliff east of the river and probably lies conformably on the Carboniferous Limestones to the west of the river. The line of the unconformity at the base of the Permian was easily delineated by an exposure of the limestone to the west of the Eden River. These exposures are at the southerly tip of the outcrop of the Brockram but the leader noted that evidence from spores indicates that Brockrams occur at various horizons within the Permo-Triassic. At this locality the clasts are exclusively of Carboniferous Limestones of various shapes. Bedding planes separate lenticular, vertical sections through cones deposited by flash floods. These units are derived from the Carboniferous to the west and thin towards the east. The sequence fines upwards, it was suggested due to topographic lowering.

Further east and up the dip from this locality, some 70metres west of the village, is a disused quarry in the Brockram. In contrast to close to the river, the beds here are tabular, the clasts are finer and there are shale partings. Some cross bedding is also visible as are various solution features. The age of the upper exposure of sandstone evoked considerable discussion since some authors had mapped the horizon as being equivalent to the lower beds of the Triassic Sherwood Sandstone Group. Although the exposure contained a few

pebbles of limestone within the sandstones and some shale horizons, there was a lack of fossil evidence to corroborate this interpretation.

The leader then discussed various aspects of the Eden Valley structure. The half graben is a major tensional feature with normal faults within the Permo-Triassic on the east side but none on the west. It is assumed to have formed at the margin of an opening ocean. In places this was followed by thrusting which caused some local inversion of the succession. In the Dufton area the Ordovician and Silurian were forced above the Carboniferous.

The second locality visited was within conspicuous bluffs in George Gill (NY 718188) alongside the Appleby Golf Course. Large scale dune cross-bedded sandstones of the Appleby Group (Penrith Sandstone) with conspicuous quartz veining were observed. Many of the veins occupied small-scale faults and the participants were able to deduce the principal palaeostress arrangement that occurred during the formation of the Eden Valley half-graben in post-Jurassic times. The exact timing of the half-graben, as part of the extensional tectonic regime during the opening of the Atlantic, is a matter of controversy. Members were able to appreciate the probable accumulative effect of very many small-scale faults in the development of the half-graben.

The third locality was Redbanks Quarry, Dufton Ghyll (NY 695245). This is reputed to be the best exposure of St Bees Sandstone (Triassic Sherwood Sandstone Group) in the area. Cross-bedding could be easily seen in some of the horizons. The stone has been extensively used for local buildings and members were able, in the fading light, to discern the quarrymen's graffiti and carved dates from the eighteenth century.

UPPER WASDALE

Leader: David Livesey (Cumberland Geological Society)

Wednesday July 16th 2003

A large group assembled at Wasdale Head Green on a glorious summer evening where the leader explained the geology of the surrounding area. Kirk Fell, Pillar, the lower slopes of Yewbarrow and Whin Rigg are in the andesitic lavas and tuffs of the lower Borrowdale Volcanic Group. Trap topography is occasionally visible. Within these rocks, volcaniclastic sandstones are seen at Santon Bridge and above Bowderdale. The rocks of Illgill Head, Lingmell, Great Gable and Scafell are more acidic.

The first site visited was at the foot of Great Gable in Gable Beck immediately above the footbridge (NY199092). This is part of the outcrop of Eskdale Granite shown on the BGS Ambleside sheet covering an area of approximately 1km by 0.5km. The intermittent exposure here is a RIGS site. On

this occasion a large section of water worn granite was exposed in the stream bed. Unlike in many localities, the rock is largely unaltered and examination of fresh specimens is easy. The upper contact of the granite and the Birker Fell Formation was clearly exposed as a planar surface dipping at approximately 20^0 to the north or north-east. Here the joints appear to be more closely spaced than in the rest of the exposure and the rock appears slightly altered. In the volcanic rocks further up the beck a pale coloured dyke some 10cm wide is displaced sinistrally by about 1m.

Reference was made to the north – south trending quartz-feldspar granite porphyry dyke seen on Kirk Fell, Lingmell and Illgill Head. In the opinion of the late E. H. Shackleton this rock can be seen in the farm buildings at Burnthwaite.

The second site was in Lingmell Gill where, from the footbridge just above Brackenclose, a conspicuous dyke of quartz feldspar granite porphyry was seen crossing the stream bed. There was not time to trace the continuation of this dyke along the path leading towards Burnmoor Tarn and on to Illgill Head.

OTHER EXCURSIONS HELD IN 2003

The following other excursions were held during 2003.

Saturday May 31st 2003

The geology of Dufton Pike and Great Rundale Beck. Leader: Barry Butler.

Wednesday June 11th 2003

The Thornthwaite mining area. Leader: Alan Smith. This excursion covered much of the area visited by the Society under the leadership of Ken Bond on the 20th May 1992.

Wednesday June 25th 2003

Whinlatter Forest. Leader: Mervyn Dodd. This excursion examined some of the sites visted by the Society under the leadership of R. Orrell and T. Shipp on 6th May 1979 which is described in Proc. Cumb. Geol. Soc. Vol.4, Pt.2, pp 135 – 8).

Sunday September 14th 2003

Rocky Ramble: Coniston. Leader: Nigel Courtman. This followed the account described by Lynas in the field guide Lakeland Rocky Rambles pp67 – 98.

THE HISTORY OF WOMEN IN GEOLOGY

A lecture by Dr Cynthia Burek (Chester College)
on September 18th 2002
at Newton Rigg Campus

Dr Burek began her presentation by asking members present to complete forms listing the ten most influential women in history and ten important women scientists. This was for an ongoing international project in which she was involved. Our answers revealed our ignorance.

The questions Dr Burek posed were as follows:- Where are women in geology? Where were they? She analysed the evidence about their academic position historically and geographically.

Women geologists were found, like the dedicated spinster Gertrude Elles who collected graptolites for over 20 years, in branches of geology where fortitude, patience and toleration of drudgery were expected. Palaeontology and the illustration of specimens are examples. Initially many like Mary Morland (Lady Buckland) and Lady Lyall had become assistants to their scientific husbands, in the case of Mary Morland having already proved herself as a geologist. Many ladies of leisure, essentially amateurs, built up collections that are still highly regarded. In the middle and later years of the 20th Century, women geologists made important contributions to the study of Alpine tectonics and the origin of granites beside their expertise in fossil study.

Historically very few women had been well known scientists. With the exception of Mary Anning at Lyme Regis few women geologists were famous. Marie Curie was almost the first high profile woman scientist. This was in part due to the denial of formal education to women until the advent of state education in Western Europe. They were essentially amateur, whether defined by the lack of university education or lack of paid positions, but so were many men in the Unitied Kingdom then. It was 1871 before British women were first allowed to seek professional scientific qualifications, initially medicine. Previously it was only women of low social class in Britain who had been able to get a rudimentary scientific education. After 1885 women began to receive university training in geology in Britain. It was only much later in reality that women were actually admitted to prestigious scientific societies like the GA and Royal Society. They were moving from the early 20th Century, from being amateurs to professional positions. In effect it was not until the middle of the twentieth century that women became prominent geologically. This was approximately when Scientific Feminism started to develop. More recently there has been a movement by women from a variety of professional careers to an amateur interest in geology, often through OU courses, sometimes as part of a change of career and life style.

The United Kingdom seems to have been notably slow to accept women as highly regarded geologists. In the United States and Canada they were accepted earlier professionally and their expertise was allowed to develop.

Dr Burek described the contributions made by many women geologists. Her comparison of the work of the patrician Mary Morland and the down to earth Mary Anning was especially fascinating. Other vignettes were her description of the wide-ranging natural scientific work of the unmarried Etheldreda Bennett and Mrs Mantell's final exasperation with having to play second fiddle to her husband's absorption in geology. The selfless devotion of Catherine Raisin to her students at Bedford College, London had deeply impressed her.

Regrettably Dr Burek's audience was rather small. Unfortunately she was unable to show her slides, especially the final one, which had been intended to be the piece de resistance. This was because the slide projector provided did not appear to be in working order.

CYPRUS: LIFE AT THE EDGE

A lecture by Dr Trevor Morse (Durham University)
on 16th October 2002
at Newton Rigg Campus, Penrith

Dr Morse began his talk by pointing out that Cyprus has distinctive geology, different from anything in the British Isles. He introduced his topic by displaying samples of chromite, gypsum, radiolarite chert, chrysotile (fibrous serpentine) as well as maps of the Geological Survey of Cyprus.

The plate tectonic position of Cyprus is complex. Africa plunges beneath its south south-west end and it partly lies on the Turkish/Eurasian plate but is not truly part of either, hence the title of the talk: *Life at the Edge*. Two main terranes occur. The allochthonous terranes include material transported from their site of deposition by tectonic activity such as thrusting and the autochthonous terranes which are comprised of the overlying sediment cover which is found in situ. Maps were displayed showing the position of Cyprus with respect to the closure of the Tethys Ocean from 141Ma to the present day. The suture or line of closure between the two plates has an ophiolite complex at each end: Cyprus and Oman. Although each lies on a metamorphic sole the situations are different; Oman has been obducted whereas Cyprus is seen in its true locality but in a terrestrial situation. In the future Cyprus will move north-eastwards and be accreted on to Turkey.

There are three different allochthonous basement terranes: the Kyrenia Terrane, the Troodos Terrane and the Mamonia Terrane. The latter two have

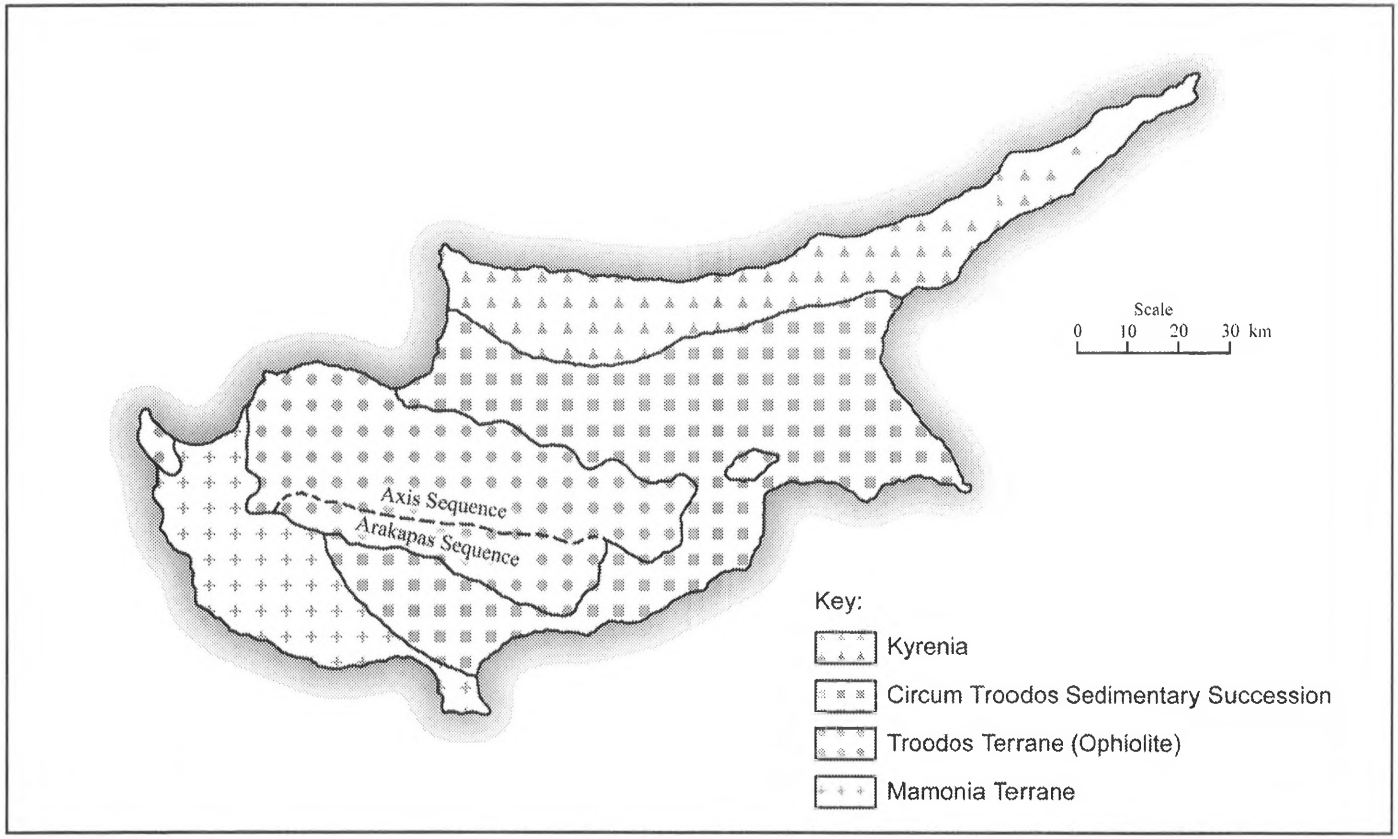


Figure 1 - Geological terranes of Cyprus

moved past each other laterally, leading to some interdigitation. The locations of the various regions are shown on Figure 1. The plate tectonic setting of Cyprus has led to a complex tectonic history. In the Cretaceous rocks of the Mamonia Terrane there is a major gravity slide. In the late Cretaceous rapid anticlockwise rotation of the Troodos Microplate led to a complex interlocking with the Mamonia Terrane. In the Eocene the Kyrenia thrusting occurred. In the Miocene compressional folding was followed by an extensional phase which led to the development of the Polis graben. More thrusting occurred in the Pliocene which ended with the major uplift event of the Troodos Mountains.

The Kyrenia Terrane is from Triassic to Recent in age and includes the K-T boundary layer. It contains evidence of a subduction zone. The basement is not seen and it partly rests on the Troodos Plate. It includes Permian olistoliths within Eocene sediments.

The Troodos Terrane includes the famous ophiolite complex representing oceanic plate and showing more mantle material than the Oman ophiolites. The mantle sequence is depleted of clinopyroxene and shows asbestos, chromite, gabbros and peridotites. This is succeeded by sheeted dykes, the lower pillow lavas indicating on-axis activity, the upper pillow lavas indicating off-axis activity and, finally, sediments. Feeder dykes for the upper pillows cut the lower pillows. Residual plagiogranites rest on the gabbros which are heavily serpentinised. Cyprus began to rise isostatically 5 million years ago and rocks from 6km below the ocean floor now form the summit area of Mt Olympus which is 2km above sea level. This is due to water entering the rock along a subduction zone and causing serpentinisation. The resulting increase in volume of the rock has forced up Mt Olympus which shows the base of the oceanic sequence and is surrounded by rocks which were higher in the oceanic plate. Cyprus lay at a slow-spreading plate boundary, therefore the gabbros are not linked and one borehole was unable to reach the Moho. The Troodos Terrane has rotated clockwise allowing harzbergite from the mantle to reach the surface.

The Mamonia Complex is older, being of Triassic to Cretaceous age. It includes pillow lavas, cherts, quartzites, mudstones and limestones. Limestone olistoliths, which have broken off from guyots, are found next to cherts which formed at greater depths below the calcium compensation level.

The autochthonous sediment cover rests on the Troodos and Mamonia Terranes. At the base are umbers formed from the underlying pillow basalts. Above this are poorly consolidated *melange* deposits, Eocene and Oligocene pelagic chalks, cherts and Miocene limestones. Dr Morse explained that his research in the area involved using nannofossils to date the chalks. Close to the top of the sequence are evaporites associated with the drying of the Mediterranean. Finally, Pliocene fanglomerates indicate part of the uplift of the area which began in the Miocene. The sequence also contains evidence of a 400m raised beach, possibly related to a temporary halt in the subduction process.

A great variety of mineral wealth has been exploited from a variety of geological settings. Asbestos and chromite pods, now worked out, are from the mantle. The copper and iron sulphides, gold and silver exploited from Roman times were formed by black smoker activity above the lower pillows. Above this level, umber, formed from altered basalts, was exploited for paint pigment. Gypsum has been exploited from the sedimentary rocks and evaporites and Miocene chalks are worked for concrete manufacture.

Dr Morse concluded his talk by showing a vast array of colour slides referring to the features and phenomena which he had so eloquently described.

LIFE: AN UNAUTHORISED BIOGRAPHY

A lecture by Professor Richard Fortey (Natural History Museum)
on November 13th 2002
at Westlakes Research Institute, Whitehaven.

The theme of Professor Fortey's lecture was that life on Earth has passed through a series of thresholds where adaptive radiations have enriched life, eventually to produce the complex ecosystems of today. He noted the long tradition of palaeontologists who have worked to document these changes, including those such as Postlethwaite and Goodchild who did pioneering work on graptolites in the Lake District.

The origin of life is thought to have been in anoxic, hot, sulphur springs where certain bacteria were able to develop. Studies of modern equivalents of these bacteria, which flourish today in environments such as parts of the Persian Gulf, reveal that they are very primitive genetically. Fossils of blue-green bacterial stromatolites, 4,000 to 3,500Ma old from Bitter Springs Australia, Zimbabwe and the Gunflint Chert in North America provide evidence of the early colonisation of the Earth. The Martian probes may find evidence of similar organisms. These organisms trapped sediment and built up bacterial mats, with a top layer of slime cutting out harmful radiation. Much of the evidence has been destroyed by later geological events such as metamorphism and only survives in a few stable areas. Through photosynthesis, these primitive organisms helped build up the oxygen content of the atmosphere so that respiratory organisms could eventually exist.

At 1,500Ma the first nuclei appear in the eucaryotic organisms, and at 1,300Ma sexual differentiation allowed interbreeding and the development of more complex forms. It may be that the first heterotrophs occurred here, although there is no fossil evidence. The fungi broke off at this stage, although they have a very poor fossil record. They are much closer to the animal branch and were to play an important role in recycling nutrients.

At 1,000Ma fossils of more complex organisms such as jellyfish occur. These show a simple organisation, some being capable of re-grouping after masceration. 600Ma ago organisms were still subaqueous and the early plankton appear. These were to produce significant acceleration in the oxygenation of the atmosphere.

The Ediacara fauna of south Australia is evidence that a varied population of large, soft-bodied complex organisms existed in the late Precambrian. Some have a "front and back", are segmented and have the superficial appearance of early arthropods. However the segments are out of phase and they have no eyes. Others are petal-like, while others are obviously sea pens or jellyfish. Seilacher's quilts with their cellular structure were discovered in the 1980s. These fossils indicated the existence of a highly adaptive, sophisticated population.

The first appearance of hard skeletons in the early Cambrian is marked by very early tube forms – the small shelf fossils. Hard parts develop in a lot of organisms at approximately the same time, e.g. the trilobites. Trace fossils of this age are abundant and indicate the burrows of large organisms, e.g. in Spitzbergen. An apparent "Cambrian evolutionary explosion" has been explained in the past as a phase of evolutionary experimentation with few forms surviving. The Burgess Shales are an exceptional example of very detailed preservation of both hard and soft parts. Trilobites are not primitive organisms and there is indirect evidence that they must have had ancestors, direct evidence of which has not been found. They had complex traits such as moulting and complex morphological features such as compond eyes with up to 6,000 lenses. Cruziana trails are found in rocks older than the earliest known trilobite fossils. Professor Fortey showed examples of cladograms showing the age relationships between different fossils. These indicated that the trilobites were quite advanced and it would have involved many steps for them to evolve from the most primitive arthropod. Genetics has been used to extend this argument. It could be that the evolutionary explosion occurred earlier than the Cambrian. The size of the organisms is also significant: an increase in size in the Cambrian could be due to a greater supply of oxygen allowing another evolutionary threshold to be crossed. Strange unknown forms from the Silurian in Shropshire indicate that radiation did not stop in the early Cambrian.

On land, there was a radiation in the Silurian with the first land plants continuing the photosynthetic theme. The Rhynie Chert shows spores and it is likely that animals and fungi followed. Ordovician spores have been found therefore land plants existed then and it is likely that there will be significant future fossil finds. The first trees would allow the development of canopy ecosystems.

Professor Fortey went on to discuss the radiation of insects, the radiation of dinosaurs, the re-interpretations of *Diplodocus* and the evolution of birds from earlier feathered dinosaurs – the egg did come before the chicken! This

continued the theme of progressive enrichment. The K-T boundary shows a decrease in surviving species and heralded a radiation of mammals which filled the ecological niche left by the extiction of the dinosaurs. The "last threshold" was the evolution of man and consciousness. The use of tools and evidence of ritualistic behaviour was discussed.

On behalf of a packed audience, Dr John Lackie, Principal and Chief Executive of Westlakes Research Institute, thanked Professor Fortey for a memorable lecture.

A GEOLOGIST IN THE CANADIAN ROCKIES

A lecture by Derek Leviston (CGS)
on December 4th 2002
at the Friends' Meeting House, Keswick

The drawings of fossils from the Burgess Shales used to illustrate this account are by Chris Thompson.

The talk began by an explanation of the geological history of the region and the geographical relationship of the central region of the Canadian Rockies between Banff and Jasper, with respect to Vancouver and the Columbia Mountains and the route covered starting at Revelstoke in British Columbia. The total thickness of rock forming the Canadian Rockies is 30km, which can be divided into six great layers.

1. Superficial deposits: 1.9 Ma to present
2. Young Clastic Unit: 245 – 5Ma
3. Middle Carbonate Unit: 525 – 245Ma
4. Old Clastic Unit: 780 – 525Ma
5. Rodinia Rock: 1500 – 900Ma
6. Basement: 2900 – 1800Ma

The following key phases in the geological history of western Canada were outlined.

1. Rodinia Rock was deposited. Most of the world's continents were assembled into a supercontinent called Rodinia. In the area that eventually became western Canada, rivers carried sediments into an inland sea.

2. Rodinia rifted away from North America. Coarse sediments of the Old Clastic Unit were deposited over a new continental edge. Undersea landslides carried these sediments out to sea as turbidity currents and sorted them into gritstone and shales (turbidites). Near the end of this period a thick sandstone layer was deposited.

3. The sea moved inland. Organisms deposited limestone and shale of the Middle Carbonate Unit on a wide very shallow continental shelf. The edge of the shelf rans through the area that became the main ranges of the Canadian Rockies. The feature is called the Kicking Horse Rim.

4. Mild uplift raised the West Alberta Ridge and Peace River Arch (425-390 Ma) putting a gentle bend into the rock of the continental shelf. Some of the Middle Carbonates were eroded away.

5. After the Western Alberta Ridge was eroded away, reefs developed in a warm, shallow sea (373-366 Ma). Planktonic organisms and cyanobacteria produced hydrocarbons, which remained to become oil and gas in the reef rock. All the world's major landmasses were assembling themselves into a new supercontinent called Pangaea.

6. Pangaea starteded to rift apart, and North America moved north-westwards (175-149 Ma). The continent collided with two chains of islands riding northeastwards on the oceanic floor. The islands amalgamated into a landmass strip that attached to North America. The impact produced mountain ranges that spread north-eastward. By 140 Ma the westernmost Rockies were above sea level. The oceanic plate changed its direction of movement to south-easterly. Mountain building stalled. The outer half of the added-on landmass was carried south-eastwards along the continental edge to Baja California. Later the oceanic plate resumed its north-easterly movement and the landmass strip slid back.

7. Hauled in from the south along transcurrent faults, a third landmass pressed against the west coast (85-45 Ma). The pressure rejuvenated mountain building across western Canada, raising the Rockies higher and extending them farther eastward. Towards the end, crustal stretching across southern British Columbia caused block faulting that produced the southern Rocky Mountain Trench, dividing the Rockies from the Columbian Mountains.

8. At present in the Rockies, after 45 Ma of erosion, the Old Clastic Unit is exposed mostly in the main ranges, and the young clastics are exposed mainly in the foothills.

Geological maps and cross sections across the central region through Banff and Jasper showed how the thrust sheets make it possible to divide the Rockies from east to west into three roughly parallel ranges.

1. Foothills – Young Clastic Unit
2. Front Ranges – Middle Carbonate Units
3. Main Ranges – mainly Old Clastic Unit, which can be divided into the Eastern Main Ranges and Western Main Ranges.

Having outlined the geology of the subject area the illustrated part of the talk commenced with a view of the Columbia Mountains around Revelstoke. Passing through Glacier National Park, the folded shales of the Columbia Mountains produced sharp peaks with glaciers sitting in corries. Descending from Rogers Pass into the Rocky Mountain Trench to Field where, west of Mount Stephen, formed from carbonates of the Cambrian Eldon Formation, the rocks are shalier and form the Western Main Ranges. This is the locality of the famous Burgess Shales. Trilobites are found in the Stephen Formation to the west of Mount Stephen, whilst the quarries yielding the fossils of the soft bodied creatures are situated on Fossil Ridge above Emerald Lake between Mount Wapta and Mount Burgess. Mount Wapta and Mount Stephen are part of the Kicking Horse Rim and a slide showing a reconstruction of the feature and identifying the position of the quarries was shown. Slides of the following soft-bodied fossils were shown: *Ottoia, Burgessochaeta, Marella, Opabinia* with reconstruction, *Hallucigenia* with reconstruction, Sponges attached to a worm tube, *Pikaia, Nectocheris* (Figures 1 – 6).

At Banff the views of Cascade Mountain and Mount Rundle show the topography typical of the Front Ranges. In steep, westerly-dipping thrust sheets, the hanging wall exposes the late Palaeozoic sandwich of Devonian Palliser Formation overlain by late Devonian to lower Carboniferous Exshaw Formation and lower Carboniferous Banff Formations and Rundle Group. General views from the summit of Sulphur Mountain placed these mountains in a broader setting with Cascade Mountain being thrust over the late Jurassic to early Cretaceous Kootenay Formation, whilst the Mount Rundle thrust sheet lies upon rocks of Triassic Age. Along the Tunnel Mountain road views overlooking Bow River showed glacial mud flow deposits sculptured by wind and rain forming columns called Hoodoos.

Between Banff and Lake Louise, Castle Mountain in Middle Cambrian carbonates of the Cathedral, Eldon and Pika Formations, provides an excellent example of the broad, open folds producing nearly flat-layered rocks and castle like peaks typical of the Eastern Main Ranges. Approaching the village of Lake Louise, Mount Temple can be seen. Lower Cambrian clastics of the Gog Group form the lower cliffs whilst the upper cliffs comprise Middle Cambrian carbonates of the Cathedral, Stephen and Eldon Formations. Roadside outcrops of slates belong to the Precambrian Miette Group which accumulated as a thick blanket of strata across the rifted edge of the continent when North America separated from Australia some 750 Ma. Views down Lake Louise show Victoria Glacier and some excellent lateral moraine probably from the Little Ice Age. The rocks enclosing Lake Louise basin are Precambrian and Cambrian in age, consisting of slate and gritty sandstone of the Miette Group and quartzite of the Gog Group. The emerald green waters are the result of the light refecting off the rock flour suspended in the water. Moraine Lake, in the Valley of the Ten Peaks, south of Lake Louise, is enclosed within a broad valley between Mount Temple and Pinnacle Mountain on the north and a row of ten peaks to the south and south-

west. Views of these magnificent peaks carved from horizontal Cambrian strata of the Gog Group were seen on the approach to Moraine Lake. The name of Moraine Lake is a misleading as the lake is dammed by a small landslide-pile of Gog Quartzite from adjacent Mount Fay and the Tower o Babel.

The journey from Lake Louise to Jasper is along the Icefields Parkway, which follows a course entirely within and parallel to the eastern Main Ranges. For most part the route follows the surface trace of the Simpson Pass Thrust. Views of Crowfoot Glacier and Bow Lake together with Waterfowl Lakes show stunning views of the the eastern Main Range mountains glaciers and lakes. Approaching Saskatchewan Crossing, Mount Wilson is seen exposing four type sections of the Lower Palaeozoic (Ordovician) formations widespread throughout the Rocky Mountains. Travelling north, braided river systems are seen and, as Sunwapta Pass is approached, a syncline in the Devonian Palliser Formation. Climbing up to the top of Sunwapta Pass, a view south from the "Big Hill" shows the Weeping Wall of Cirrus Mountain and spectacular views back towards Saskatchewan Crossing. Proceeding northwards, views of the Boundary Glacier on Mount Athabasca are seen before dropping down to the Ice Field Centre.

A tour onto the Athabasca Glacier shows some typical examples of the glacier morphology; with three successive ice falls from Columbia Icefield, englacial streams disappearing into moulins, inclined ice bedding indicating the compressive stresses at that part of the glacier, and excellent 50m high lateral moraines resulting from the Little Ice Age advance. Meltwater streams feeding the proglacial Sunwapta Lake remind us of the susceptible nature of the beautiful landscape to changes in environmental conditions. The Continental Divide is situated on the Snow Dome (3459m). From this locality, water flows into the Atlantic, Pacific and Arctic Oceans. Dome Glacier, in the adjacent valley, provided effective insulation form the heat of the sun.

At Jasper, the Whistler tramway terminal at 2265m provides excellent panoramic views of the surrounding mountains of the Main Ranges from Mount Robson in the north round to Mount Kirkeslin overlooking the Icefields Parkway in the south-west. Below, the Athabasca River is seen flowing into Jasper Lake with the Devonian Palliser Formation cliff of Roche Meitte beyond.

From Jasper, Route 16 leads past Yellowhead Mountain and Lake to Mount Robson National Park. A clear day provides a view of Mount Robson (3954m) formed from the Cambrian Pika, Actomys and Lynx carbonates. Proceeding westwards the route passes through Valemount in the Rocky Mountain trench and back into the Monashee Mountains of British Columbia.

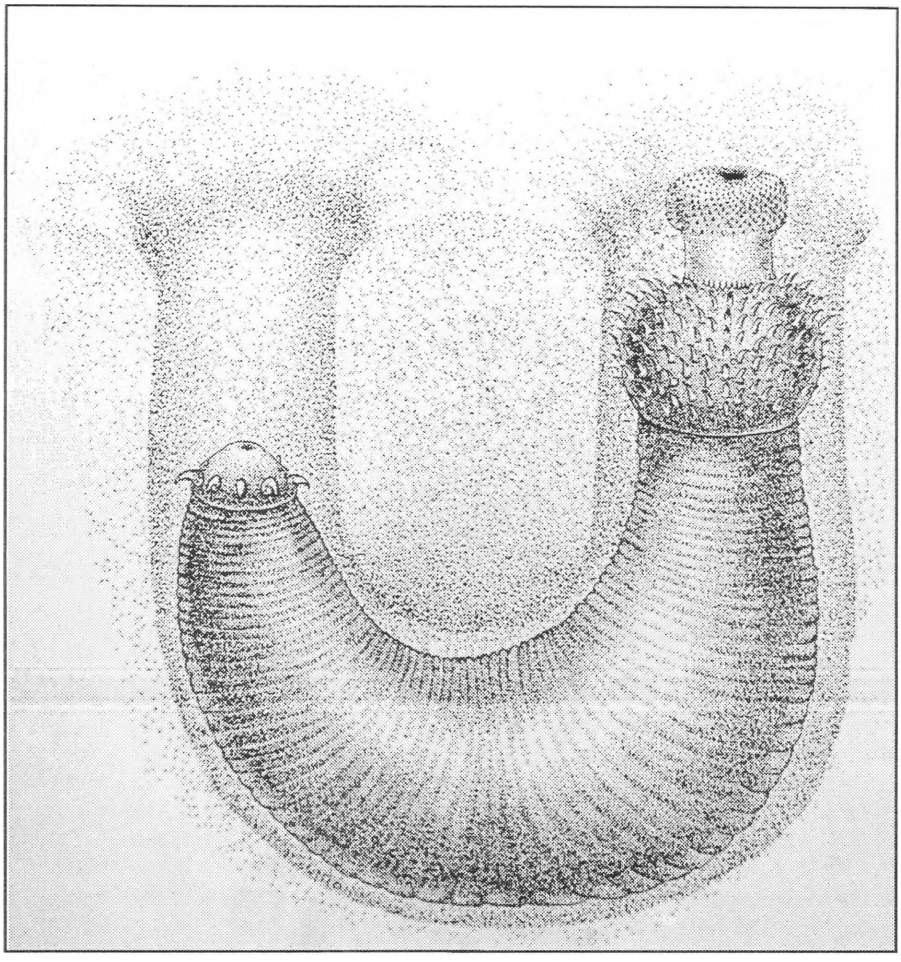


Figure 1 - Ottoia (2 - 16cm).

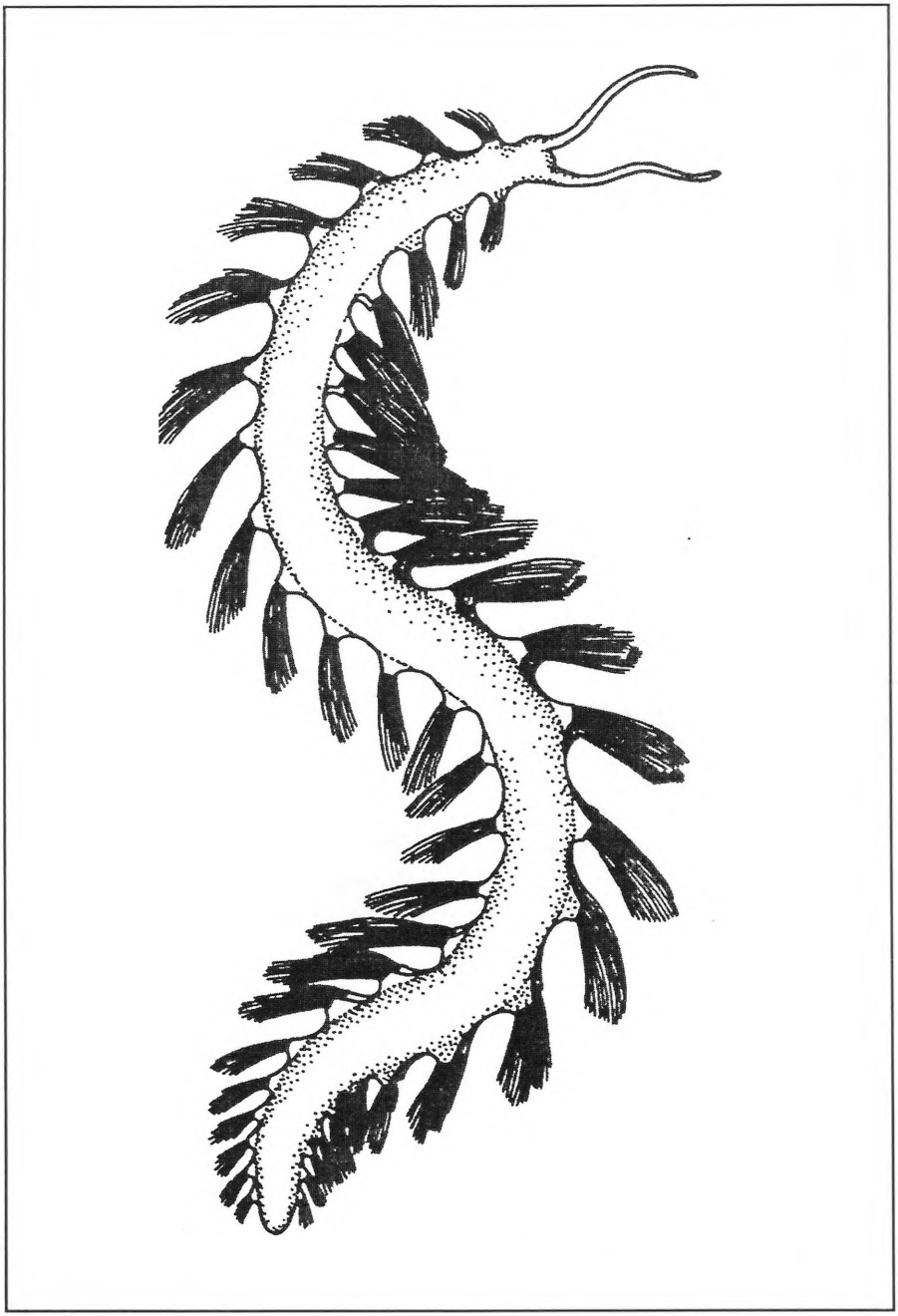


Figure 2 - Burgessochaeta (2 - 5cm).

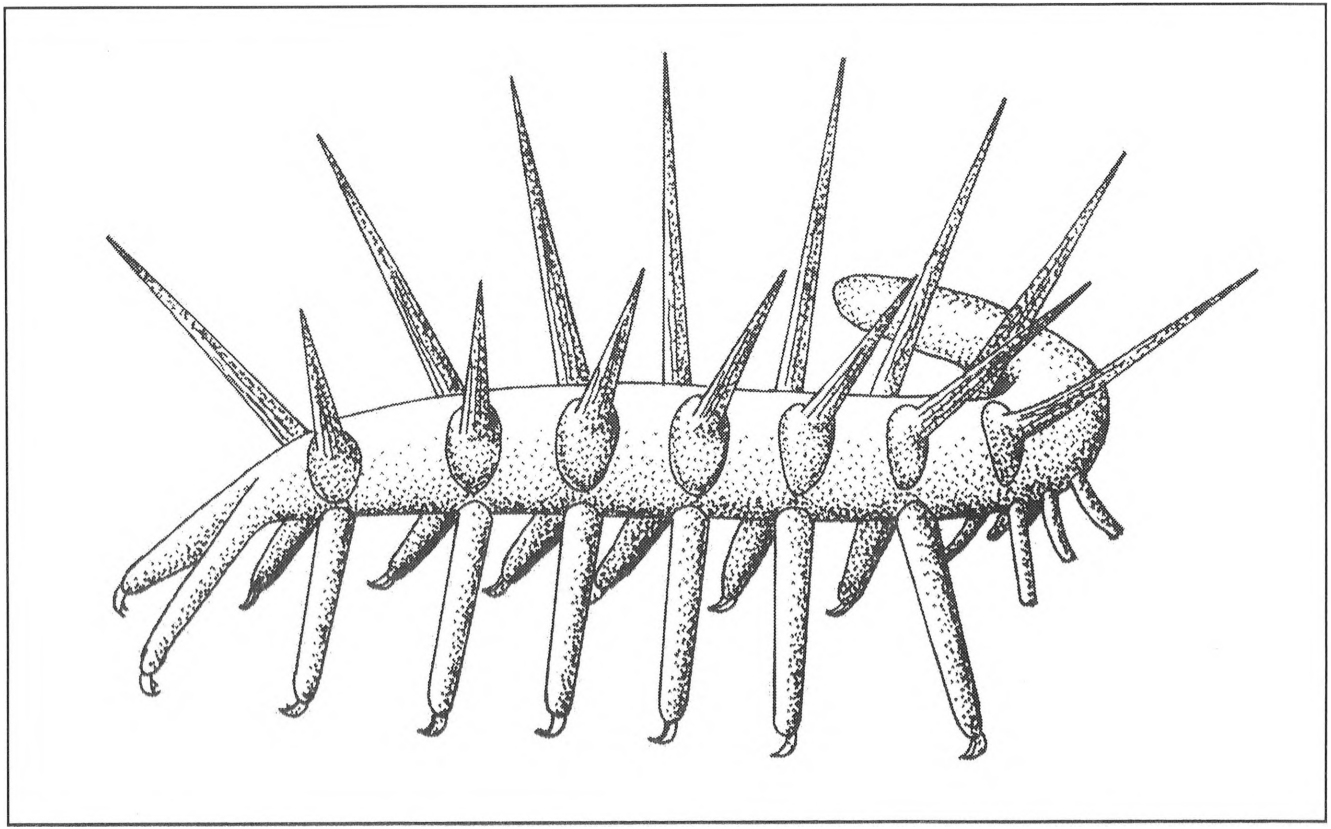


Figure 3 - Hallucigenia (0.5 - 3cm).

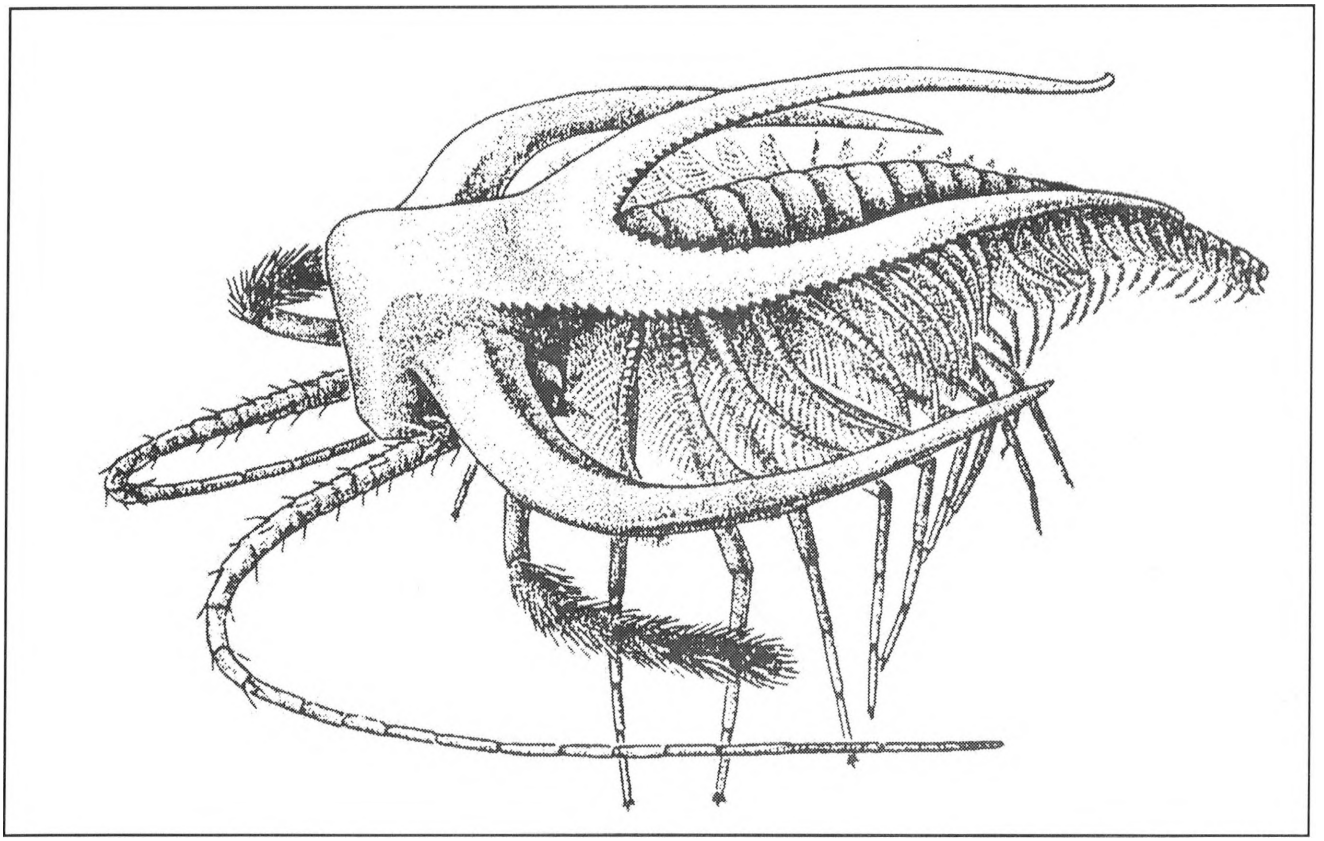


Figure 4 - Marella (2.5 - 19cm).

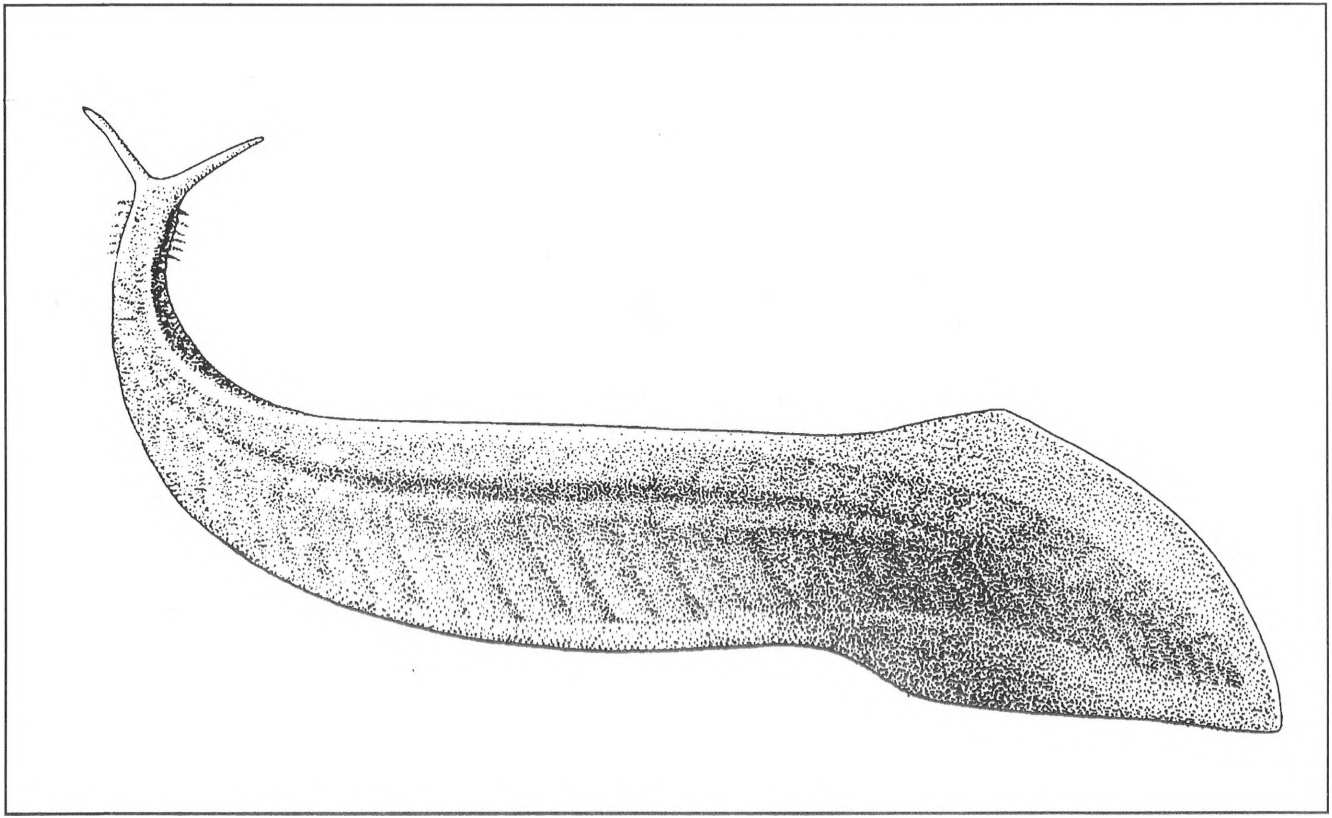


Figure 5 - Pikaia (averages 4cm).

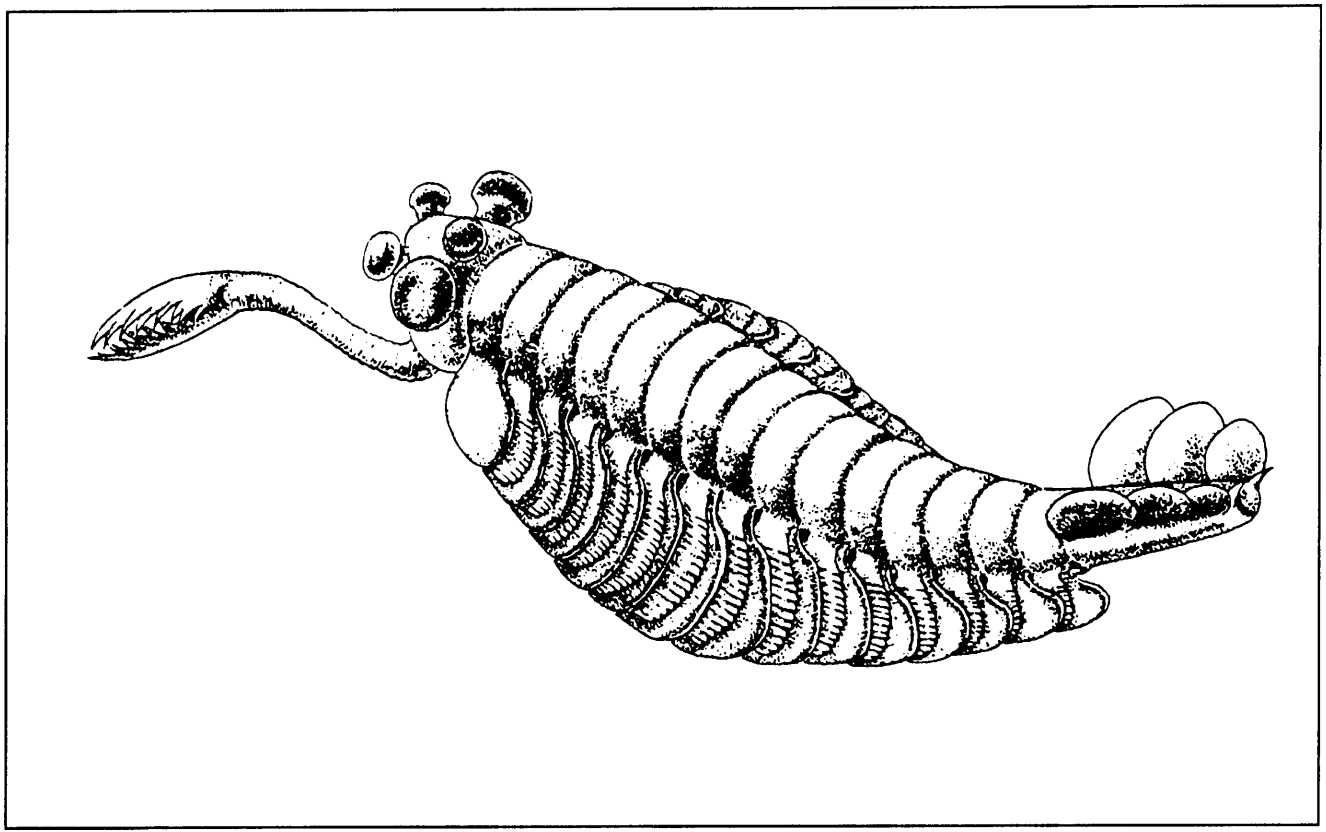


Figure 6 - Opabinia.

VOLCANOES IN THE LANDSCAPE

Presidential address by Dr Alan Smith
on January 15th 2003
at the Friends' Meeting House, Cockermouth

Dr Smith began his talk by reflecting on a text he first encountered as a student in the 1950s: *Volcanoes as Landscape Forms,* written in 1944 by Charles Cotton, Professor of Geology at Wellington, New Zealand. The geomorphological approach taken in the book was to be followed in the lecture. Eruption is a constructive phase followed by the destructive phase of collapse and erosion.

Factors in the eruptive nature include the volume of magma, the type of magma, the duration of eruption and whether the eruption is submarine or subaerial. Explosive and non-explosive effusive volcanoes produce a vast array of forms. During collapse the magma chamber empties, the surface of the pile collapses in to produce a caldera, often along the lines of faults or fissures. Violent eruption is an important part of this process. Sector collapse involves only part of the pile. Erosion begins as soon as the volcano is created and may involve all the erosive agents. Factors here include climate, time and the nature of the volcanic materials.

Simple, monogenetic cones are the result of small short eruptive phases and include the ash and cinder cones. They may be the product of a few hours or one year only. They are relatively small and reach a maximum of 2000 – 3000m. They may be elongate along a fissure. Debris lies at its maximum angle of rest. e.g. 32^0, therefore there is a standard height : width ratio. Photographs were shown, of the southern flanks of Etna with features a few hundred years old, Silvestri Inferiori in 1892, Silvestri Superiori the following year, Pleistocene puys in Auvergne showing alignment along a fissure in order of age and cones of the Craters of the Moon in Idaho. Various photographs of the North Arizona - San Franciscan field were shown where sparse vegetation causes features to stand out clearly. The area includes Sunset Crater which erupted in 1064 and 1065. The area was settled by the Singua people who had to move during eruptions and a combination of archaeological and geological evidence has allowed the dates to be calculated. Progressive erosion causes a negative correlation between the height and age of ash and cinder cones.

Tuff rings and tuff cones are the result of phreato-magmatic activity. In the tuff ring water levels are lower allowing material to be thrown further. Haverfjell, Iceland and Diamond Head, Honolulu are examples. In tuff cones such as Koco Crater, Hawaii, the level of water is greater and material is more viscous and not thrown so far.

Pseudocraters form when lava runs onto wet ground. Steam is generated and breaks out through, throwing material outwards, forming a crater. Maars are

similar but more violent. Some collapse and often contain lakes. The Eifel district of W. Germany is a classic area. Examples of the intrusion of magma into cold, damp sediment can be seen at Greenscoe in Furness.

The speaker then went on to deal with polygenetic, complex, composite features. Mount Hood in the Cascades is a relatively simple cone, formed from a single vent from Pleistocene times to the present day. It is 70% lava. At Hekla in Iceland eruption from a fissure produced a more elongate feature. Etna is a much more complex feature and has three summit craters plus a number of subsidiary vents on the flanks.

Few individual volcanic piles rise more than 2,500m high. It is difficult to lift the magma higher and there is the geometrical problem of the amount of magma needed. Volcanic cones tend to be steeper nearer the top, therefore significantly more magma is needed to raise them higher. The pile also becomes more and more unstable and tends to sink isostatically. Lighter, more silica-rich, viscous lavas are piled to greater heights and they also tend to be harder and more resistant to erosion.

Types of eruption are also reflected in the landforms they produce. In Taupo National Park, New Zealand violent eruptions of single vent, calc-alkaline volcanoes have produced steep-sided cones with much pyroclastics. The Puy de Dome (Auvergne) is formed from trachyte of similar composition. Mount Lassen in California is an explosive dacite volcano with two very steep peaks. The steep slopes of Mount St Helens, with much pyroclastics, led to the sector collapse in 1980. Highly viscous rhyolite lavas are found in the Tarawera area of New Zealand, Lassen in California and at Little Stand in the Lake District.

In contrast, basalts produce fairly level terrane and low angled shield volcanoes. Examples are found in Auckland Harbour, New Zealand (a mini shield), and Mauna Loa, Hawaii – the largest volcano on Earth. These non-violent volcanoes may form "mercedes star" patterns. Flood basalts involve enormous volumes of lava; examples discussed included the Colombia Plateau, Idaho, the Karoos of South Africa and the Britanno-Icelandic Province with its classical trap topography. Basalt cones have huge craters with steep sides in which the magma level rises and falls, e.g. Kilauea, Batuil on Bali has an andesitic cone within the crater. Mount Teide on Tenerife is the biggest volcano outside Hawaii. The Azores lie on the Mid-Atlantic Ridge and are a series of volcanic complexes showing collapses.

Finally Dr Smith discussed the destructive elements affecting volcanoes. Big craters associated with huge eruptions and cauldron subsidence include Taupo, New Zealand, Crater Lake, Oregon and Yellowstone National Park. A sequence of erosive forms in the progressive destruction of a cone was discussed. Initially channels will produce radial ribbing of the cone. Rills will then integrate producing triangular facets on the lower cone. Finally the whole pile is reduced with more resistant elements such a plugs and dykes standing

out. This was illustrated with slides from Lanzarote, Hawaii, Gran Canaria (with its coastal gorges of the master streams) and the Auvergne.

CONISTON COPPER MINES

A short presentation following the AGM by Nigel Courtman
on February 26th 2003
at the Friends' Meeting House Cockermouth

The talk began with slides outlining the geological history of the area from the formation of the Borrowdale Volcanic Group and Windermere Supergroups in the Ordovician and Silurian, the closure of the Iapetus Ocean about 420Ma, the Arcadian Orogeny in late Silurian to Devonian times and the emplacement of the Lake District batholith. Details of the Coniston area were illustrated using the BGS Ambleside sheet 38.

Coniston village lies on the Silurian turbidite sandstones of the Birk Riggs Formation but the Coppermines Valley area includes various units from the Borrowdale Volcanic Group. These include the Low Water Formation (dacitic lapilli tuff, volcanic sandstone and andesite sills), the Lag Bank Formation (dacitic lapilli tuff), the Paddy End Member of the Lickle Formation (welded rhyolitic tuff), the Duddon Hall Formation (bedded andesitic tuff), the Long Top Member of the Airy's Bridge Formation (welded rhyoloitc tuff) and the Seathwaite Fell Formation seen on Coniston Old Man (volcaniclastic sand and interbedded tuff). Most of the Coniston veins formed soon after the igneous activity but the range of ages of mineralisation is Devonian to Jurassic with, for example, K-Ar dates of 288Ma from altered wall rocks. Unlike non-ferrous mineralization in the Skiddaw Group, the copper veins favour hard rock. They follow almost vertical faults, striking north-west – south-east and were mined up to 1,600ft below the surface. There are two main veins, the Bonsor and Paddy End Veins. The main primary ores were chalcopyrite and malachite but arsenopyrite FeAsS, tetrahedrite $(Cu,Fe)_{12}Sb_4S_{13}$ and Tennantite $(Cu,Fe)_{12}As_4S_{13}$ also occur. Quartz and magnetite were common gangue minerals.

Mining began in the Lake District in the mid 16th century. There is a distinct possibility of Roman mining but no direct evidence. German mining expertise from the Tyrol was brought in and in 1564 an agreement was made between QEI, Sir William Cecil (chief adviser) and Thomas Thurland. The mine pump engine was invented by Daniel Hechstetter senior, of Salsburg and German finance was used in the early developments culminating in the Royal Charter to develop the area. Mining had started at Coniston by 1602 with central figure being Allan Nicholson who married Hechstetter's daughter.

Elsewhere in the Lake District German influence was at work in Goldscope Mine (*Gottesgob* = God's gift). Ore from Goldscope was smelted at Brigham

resulting in vast clearances in Borrowdale for charcoal. It was to here that Coniston ore was hauled some 20 miles by pack horse.

Mining was laborious. At Red Dell "coffin" shaped levels were hand-driven with the rock split by two "half round" tapers ("plug and feather"). Fire setting was also used. In the Paddy End Rhyolite it took one week to work one foot. German mining ended in 1642 and there was little activity for the following 40 years. Lake District mining was disrupted by the English Civil War and Cromwell destroyed the smelt works in Keswick. The Germans had mined to a depth of 10 – 12 fathoms although today there is little field evidence of their activities.

The Paddy End Vein lies close to the present water treatment plant. Here the name *Simons Nick* commemorates a miner, aged 32, who lost his life, and was said to have sold his soul to the devil for guidance to the richest veins.

The next chapter starts with Charles Roe, a wealthy silk industrialist from Castleton, Derbyshire who established the "Macclesfield Copper Co" and in 1756 obtained rights from le Fleming to work the area. The company also worked the Parys Mine in Anglessey, the biggest in world at the time. In 1758 the old German mines of the Bonsor vein were re-opened. Slides were shown of the wheel shaft housing which stands on the East Bonsor Vein and of the plan of the mine as worked by Roe. At this stage the invention of gunpowder allowed mining to reach down to 50 fathoms. At that time ore was taken down to Coniston Water and shipped to Nibthwaite then carted to Penny Bridge and the port of Greenodd from where it was shipped to Macclesfield Co. Smelters in Liverpool. A slide was shown of the Tissington Copper Warehouse in 1756. By 1795 the mine was abandoned by Roe, who thought it unproductive. The two men who were to prove him wrong were John Taylor, a mining entrepreneur from Cornwall and John Barratt, manager of a lead mine in Grassington. In 1824 Taylor aquired the lease from Lady le Fleming. This was initially held jointly but Taylor left, and Barratt held the lease until his death in 1866. Taylor re-opened Bonsor Vein and the deep level was extended down to 1700ft. A slide was shown of the old engine shaft waterwheel, built in 1830 and modernised in 1850 and 1870 and used for pumping and haulage. Slides were shown of the Triddle Incline which was used to support sets of rollers that supported pumping rods and of a chart of the Bonsor Mine at the time.

By 1856 the mine was at its peak, reaching down to 1200ft and in that year 3,659tons of ore worth £27,861 were extracted. In 1850 the new engine shaft waterwheel allowed workings to reach a depth of 1500ft, the watertable being reached at 300ft. By 1870 there were 16 Waterwheels in total.

Further slides were shown of the Glory Hole, the Crater and the Funnel – mine entances in the Levers Water area, the Paddy End Terraces, a plan of the

Paddy End Mine, the hoppers and cobbing floors, stamps, washing sheds, furnaces and electrolysis sheds

During the 1860s area went into an irreversible decline. Workings were so deep that maintenance costs were high, increasing amounts of magnetite were encountered at depth and foreign imports were cheaper. In 1875 Barratt sold the mine for £3000 to a Charles Edwin Day who lost all his money in the venture and the mine closed in 1908. There were two brief reprieves in the early 20th century. In 1912 a French concern, the Coniston Electrolytic Copper Company, attempted to process the extensive spoils in the area. This was a commercial failure and closed 1915 having lost £12,000. In 1954 McKechnie Bros who owned the Force Crag, Hartsop Hill and Caldbeck barytes mines attempted to reopen Bonsor but found it too dangerous.

The talk was illustrated with a vast array of slides of the area, past and present, including the mines offices (now the Youth Hostel) and the manager's house (now Barrow Mountaineering Club).

JAMES HUTTON, FOUNDER OF MODERN GEOLOGY

A lecture by Norman Butcher
on April 19th 2003
at Tullie House, Carlisle

The speaker began by setting James Hutton's life and work in the context of the ferment of ideas that was the Scottish Enlightenment (1750 – 1800). James Hutton was one of the Gang of Four, the luminaries of that period; Adam Smith, David Hume, Joseph Black and Hutton himself. The main source of information about Hutton was the biography written by Playfair soon after Hutton's death in 1797. The speaker thought the story of James Hutton linked the history of geology with the culture and personalities of the late eighteenth century.

James Hutton, one of five children, was born in 1726 into a wealthy household, his father William being a prosperous Edinburgh merchant. After attending the Royal High School at Blackfriars, Edinburgh, he was briefly apprenticed at 14 to a lawyer, before beginning a course in medicine at Edinburgh which he did not complete. When 19 or 20 he studied in Paris attending lectures by Rouelle. The speaker wondered whether he had been sent to Paris after siring an illegitimate son born to a Miss Elphinstone of Grange. In turn he proceeded to the University of Leiden, where he took his MB after writing a thesis on the circulation of blood.

He never practised as a doctor. His comfortable means meant he never had to earn a living. Soon after returning to Scotland he went to East Anglia to learn

about the new techniques of the Agricultural Revolution, which he applied to the two farms he had inherited, one a fertile lowland farm, the other a Berwickshire hill farm. However he did not run the farms himself for many years, returning in 1768 to Edinburgh where had a house built in St John Hill in 1771. His unmarried sisters kept house for him, a confirmed bachelor, who was thus spared the chore of household management.

His many visitors there included Sir James Banks, Sir William Hamilton and many other scholars of the day. "Victorian Jottings" by Sir James Crichton Browne, a later resident there, was published in 1840 and describes the house much as it was in Hutton's day. It has long since been demolished and is now the site of a Morrisons' supermarket.

Hutton had a wide range of interests and an inquiring, lively mind. He was one of the Commissioners of the Forth-Clyde Navigation Canal, besides being very much interested in philosophy. He made several extensive tours, a particularly well known one being in 1764 through many parts of the UK and into the Netherlands, accompanied by Sir John Clark of Penicuik who was his illustrator.

Hutton learnt his geology from field visits and his ensuing, acute analysis of the phenomena he saw. Among the famous sites he visited were Glen Tilt (1785), where he described and explained the granite intrusion into the Dalradian Schists. Another famous igneous site he visited and described was the graphic granite at Portsoy. He predicted the famous Siccar Point Unconformity in 1787-8, first seen from the sea. Other well known unconformities he explained were at Loch Ranza and one south of Jedburgh where Old Red Sandstone overlies folded Dalradian rocks. These helped him to develop his ideas about the history of the earth, expressed in publications from 1785 onwards, culminating in the 1788 Theory of the Earth. This was the first well known scientific explanation of how much older the earth was than the clerics of the day were prepared to accept. Other important insights of his were how sedimentation had been interrupted by long continued erosion and how important heat had been in earth history. These were ideas he developed of the earth as an organised system, the product of physical forces.

Unusually to modern eyes he did not make field sketches and left no field note books. His geological collection has long since disappeared. Originally left to the Royal Society of Edinburgh, it was housed in the University's Old College Museum, now a galley of modern art.

Hutton wrote widely on many other scientific themes, ranging from mineralogy (coal and culm) to basic physical phenomena like light, heat and fire. Very many of his publications have long since been forgotten or lost, but some have been recently traced by the speaker and fellow researchers. Much of his writings have never been published. His work is not easy reading, although highly organised he wrote at length in rather an obscure style.

Until very recently he appears to have been the forgotten man of the Scottish Enlightenment. It was not until 1947 that a plaque marking his resting place was erected in Greyfriars Churchyard. In 1997 a plaque commemorating Hutton was unveiled on the site of his house. Soon after the Hutton Memorial Gardens were developed around the supermarket there.

The speaker showed a slide of the famous caricature of Hutton in eighteenth century costume, which now seems amazingly unsuitable for field work. The famous eighteenth century portrait painter Raeburn produced a well known likeness of James Hutton, probably around 1790. It depicts him as a rather satisfied person soon after the publication of his tour de force, the Theory of the Earth, a natural philosophy of geology establishing it as a genuine science.

Dr Alan Smith congratulated the speaker on a lecture which combined thorough research of James Hutton's life and times with many unusual and fascinating illustrations of little known archive material. The speaker also brought a light personal touch to his talk together with a deep understanding of eighteenth century life in Edinburgh. So James Hutton, a rather remote and mysterious figure, was brought to life, warts and all.

LECTURE REPORTS 2003 – 2004

AN EXAMPLE OF THE GEOLOGICAL STORAGE OF CARBON DIOXIDE AS PART OF ENHANCED OIL RECOVERY

A lecture by Dr Jim Riding (BGS Keyworth)
on September 24th 2003
at Newton Rigg Campus, Penrith

Dr Riding referred to 2 examples of this technique in operation today, the Sleipner field in the Norwegian sector of the North Sea and the Weyburn field in Saskatchewan in the Canadian Prairie. The Weyburn field, operating since the 1950s, had a point source of carbon dioxide and several wells, while the Sleipner field had a single well used to inject the carbon dioxide recovered in hydrocarbon extraction into Neogene sandstone sediments. The technique was in routine use in Texas, generally using underground reservoir sources of carbon dioxide. A BGS publication (Earthwise, Issue 10, pp10-11) states "It has been established that, for example, rocks beneath the North Sea could store all the carbon dioxide produced within the European Union for electricity generation over hundreds of years".

Carbon dioxide is miscible with oil, reducing its viscosity and bulking it up, thus helping to recover part of the very large fraction of the hydrocarbon reserve

not extracted by primary techniques. Impurities present in the carbon dioxide affect its effectiveness. Nitrogen and hydrogen inhibit flow properties while 'wet' carbon dioxide is less miscible. Corrosive hydrogen sulphide increases miscibility.

Dr Riding described conditions in the Weyburn field where he was BGS project officer in charge of part of the monitoring work. The carbon dioxide was injected into Carboniferous Limestone 1.5km below the surface in a large sedimentary basin. Liquid carbon dioxide of high purity was pumped 300km from the Bealah plant in North Dakota which generates synthetic natural gas from lignite. This is part of the wide ranging by-product recovery at Bealah which generates 30% of the plant's revenue.

A pulse of carbon dioxide is injected down one well, followed by a waterflood pulse which drives the oil/carbon dioxide/water mixture to a producing well in the Marly Limestone. At the surface the components are separated out. The carbon dioxide and water are recycled for further use. The oil recovered contains 30% less carbon dioxide than conventionally produced oil. The Weyburn field is an ideal location, a large reservoir which does not need additional wells with oil that lends itself to this technique. The Marly Limestone lends itself to waterflushing. The liquid carbon dioxide from Beulah (250 million cubic feet per day) is very pure.

Dr Riding showed us a graph relating hydrocarbon production at Weyburn to time and technique. Each new technique had created a rapid increase followed by a slow decline. T he WAG technique described above had created a very large increase in recovery.

Conditions in the North Sea are generally less suitable. There are fewer wells which are more widely spaced. Point sources of carbon dioxide are fewer and the gas tends to be 'wet'. There are many suitable safely capped (often by salt domes) permeable rocks such as the gas-rich Rotliegendes Sandstone. It is argued there is a short-lived window of opportunity for the underground storage of the gas. During the next few years many fields are likely to be decommissioned and industrial carbon dioxide available at a 'reasonable price' could be injected before capping. This implies considerable investment in the relatively new capture technique/clean fuel technology and delivery systems, which could be encouraged by changes in tax structures. Whether there is the political will for this to happen remains to be seen.

Underground storage is regarded as possibly a better solution than extensive forestry plantation as it is much longer lasting. However society remains to be convinced it is a safe approach. Questions asked include how long will it stay underground and whether it will affect water supplies. Other scientific queries are how long will it remain in the reservoir, how will it move underground, how will it affect volatile formations and what will its ultimate fate be. A serious programme of high quality monitoring is essential.

Dr Riding then proceeded to describe the monitoring techniques in use at the Weyburn field, illustrating the methods in use by a CD on a laptop (loaned by Nigel Courtman). BGS staff were part of a monitoring team which included staff from universities in Rome and central Saskatchewan, besides a French organisation. Applications of seismic investigations were the remit of the BGS team. Other aspects of the monitoring included tracer well injection monitoring (particularly of the rapidly moving gases, radon and thoron), geochemical investigation and soil gas analysis. Particular attention was paid to surface areas above known fractures in the reservoir rocks. The impermeable cap rock was found to have no serious faulting that reached the surface.

This is a long term ongoing monitoring programme in the Weyburn field. Initial results based on 2 years' observations to date suggest there is no correlation between surface 'hot spots' of carbon dioxide and radon concentrations and underground faults. High surface concentrations of carbon dioxide are all in low lying, swampy and valley areas, where growth is more rapid. The small variations in radon and thoron concentrations at the surface are attributed to differences in the numbers of granite pebbles in the local till of Canadian Shield origin. So the interim conclusion is that there has been no escape of carbon dioxide to the surface.

Nigel Courtman, an OU student of Dr Riding's, gave a vote of thanks before Dr Riding departed on his return journey to Nottingham.

EARLY MINING IN THE LAKE DISTRICT

A lecture by David Bridge (Cumbria Mines Trust)
on November 12th 2003
at Westlakes Research Institute, Whitehaven

The speaker was welcomed by Dr John Lackey, Principal of Westlakes Science and Technology Institute. The talk outlined the metalliferous mining history of the Lake District in historical context.

The earliest mining dates from the Neolithic. Stone was mined to make axes which were used to cut trees in the coastal lowlands. Over 550 sites have been discovered, one of the most famous being at 600m above sea level at Top Buttress on Pike o' Stickle, where a fine, hard tuff with a conchoidal fracture was worked. The stone was worked with stone hammers and charcoal found at the site could indicate fire setting. Similar sites have been found on Bowfell, Esk Pike, Scafell Pike, Seathwaite Fell and Glaramara. The "rough-outs" of axes were first recognised in 1947. They were taken to the coast for polishing and traded all over England from 5000years BP.

In the absence of tin ore, Bronze Age mining was confined to copper and slides of the Paddy End "back strings" at Coniston were shown, including possible mortar stones for ore grinding. Oxidised ore such as malachite, were richer and easier to smelt.

There are a number of suggested Roman mining sites but none are proven.

Medieval iron workings were probably substantial. The Low Birker bloomeries date from 1000AD and used charcoal smelting. The Coucher Book of Furness Abbey refers to local mines at Martin, Elliscales and Orgrave. Place name evidence for iron includes 60 names which include "red" from hematite and several groves (mines), e.g. Iron Groves on Waberthwaite Fell.

There is no record of gold mining but silver was extracted with lead, especially in the Caldbeck Fells but also at Stoneycroft Gill (Stair), Force Crag, Greenhead Gill (Grasmere), Hartsop Hall and the Greenside Mine which worked from 1700 to 1962. Mining continued through the reigns of Edward 11 and Elizabeth 1, influenced by Hechstetter and other German miners. Hand-bored German workings in Silver Gill and Roughten Gill include Coffin Level, (the shape of a walking man) New Stolne, Blind Wastel, Fortune Stolne and Emmanuel Stolne. There are one mile of Elizabethan workings in this area. "Hushing" (excavating by releasing dammed water or diverted streams) was used to discover the lodes. Minerals found include pyromorphite, mimetite and linarite (in Red Gill) and campylite (in Dry Gill). In Stoneycroft Gill, Coffin Level is 10 feet high and at Greenhead Gill ore stamps were operated by water wheel. Other mines from this period include St Thomas's Work in the Newlands Valley, Copper Plate Mine at Grange and Goldscope Furdernus Adit.

By the late 17th century the Germans were mostly gone but handworking continued. Thirty Fathom Level in Roughton Gill dates from the 1690s as does the Launchy Gill trial at Thirlmere. In 1693 gunpowder was used at Coniston and continued to be the main method up until the late 19th century when compressed air drilling was introduced. This allowed the excavation of larger, rectangular levels.

Early gunpowder levels include Powder House in the Duddon Valley and Eagle Crag Mine in Grizedale. From 1810 onwards, wrought iron-covered wooden rails were used. At Coniston the later, deeper workings are wider. Slides of these workings showed the deposition of mineral deposits following mine closure.

The Kinniside lead mine dates from 1700 – 1850 and is comparatively small. The softer Skiddaw Group rocks have caused many of the old workings to collapse. The minerals extracted were mainly galena and cerussite. The Greenside Mine was one of the most prolific. 150,000 tons of lead were extracted and 1.5 million ounces of silver. There was a 60foot wide vein at a depth of 1800 feet. In 1890 electricity was first used in the mine, powered by the

Keppel Cove dam which burst in 1927. A new dam was constructed lower down Glenridding Beck between 1928 and 1931. The Lucy Tongue Level was re-opened and a ladder escape route constructed. Production figures from 1845 to 1910 were displayed showing steady production levels for lead and silver from Greenside. Copper production at Coniston reached a peak in 1855 then declined. Barytes production at Force Crag began in 1867 and zinc production developed in the late 19th century at Thornthwaite and Threlkeld for galvanising. Tungsten production at Carrock began just before the First World War. Force Crag continued to produce lead, zinc and barytes until its closure in 1991. Pictures were shown of the Laporte incline in the 1960s.

Considerable barytes production occurred at Potts Gill where the McKechnie Bros mined from the 1940s. The wide barites stopes at the Sandbeds Mine closed in 1965. The lecture closed with pictures of the 40 foot water wheel at Thornthwaite lead mine, the 60 foot water wheel at the Barrow lead mine and the Knockmurton iron mines at the end of the 19th century.

THE ICELAND EXCURSION

A lecture by Nigel Courtman and members of the Society excursion to Iceland, July 2003
on December 3rd 2003
at the Friends' Meeting House, Keswick

Nigel Courtman introduced the talk as a presentation on behalf of all those who took part in the excursion. He pointed out that although many of the images were his own, most of the other members had also contributed.

The excursion followed a roughly circular route around the country; over the ten days the party travelled just over 1,200 miles. Nigel briefly introduced the geological background and noted that of the 103,000 sq km, 12% is permanently glaciated and 65% is officially described as "wasteland".

Following the flight from Glasgow, the party were met at Keflavik airport by Pjetur, their Icelandic driver for the next ten days, and Dr Hugh Tuffen their guide. After passing through Rejkjavik, the first stop was to view the Nesjavellir geothermal field. This lies in a classic graben valley within the Hengill central volcano. Next the party visited Pingvellir, the site of the oldest parliament in Europe, and experienced the extensional tectonics of the Western Rift Zone. A weary party spent the first night in Lougaras; for some this was the first experience of 24 hours daylight.

Day two was spent travelling north to Varmahlid. The party stopped at the Geysir geothermal field, and witnessed eruptions from "Stokkur" (the churn).

Geysir no longer erupts spontaneously, although can be encouraged to do so with washing up liquid! Gullfoss (golden falls) was the next stop. Here the waterfall drops 32m into a canyon eroded into basalts 0.8 – 3 Ma. It has been calculated that the canyon has developed in the last 10,000yrs at a rate of 25cm/yr, due to isostatic rebound following the last "Ice Age". A visit to the Hveravellir geothermal field allowed for the first of many opportunities to bathe in geothermally heated pools.

Day three travelled through glaciated tertiary flood basalts, to the northern town of Akureyi. The beautifully spectacular Oxandalur valley necessitated various photo stops. Akureyi (the home town of the driver) has a population of 15,000 and is the second largest town outside Reykjavik. It is 60km from the Arctic Circle yet boasts a botanical garden housing nearly 4000 different species. After visiting Godafoss (gods falls), the group arrived at Myvatn, their base for the next three nights.

Myvatn lies in the Eastern Rift (Northern Volcanic) Zone. Day four took the group to the eerily beautiful Dimmuborgir (black castles), formed by the drainage of a huge lava lake 2000yrs ago. They then climbed Hverfjall (crater mountain), an enormous cone formed entirely of tephra, 1km wide and 140m deep. It is thought that the entire structure formed in a single day approx 2700yrs ago. A walk through the extensional faulting at Grotgaja took the group to Reykjahlid, where the church (now rebuilt) survived the "Myvatn Fires" eruption of 1729.

Technical problems with the bus on day five allowed time for a walk around the pseudocraters for which Myvatn is famous. The group also found out that Myvatn lives up to its Icelandic name – "Midge Water"! Once the bus had been repaired, the group travelled into the Krafla central volcano, first visiting Viti (hell) a crater 300m across, the site of the Myvatn Fires of 1724-29. The 8 – 10km caldera of the Leirhnjukur volcano was then visited, and the group walked on pahoehoe and aa lavas erupted as little ago as 1984 during the Krafla Fires. The day ended with a visit to the impressive Krafla geothermal power station within the Namafjall geothermal field. A sobering thought was that the magma chamber is only 2-3km beneath!

Day six was spent travelling through the sparsely populated glacial eastern fjords. The group passed Mt Herdubreid (the queen of the north), a spectacular 1,060m basalt "tuya" erupted under ice. The journey passed through layer upon layer of flood basalts intruded by enormous dykes. A brief visit to the "Stone Collection" of Petru Sveinsdottir proved to be an interesting diversion. Petru has collected thousands of rock specimens from all over Iceland since 1946.

Day seven was spent in the area south of the Vatnjokull ice cap (the largest ice cap outside the poles, bigger than all the others in Europe put together). Travelling along the Skeidararsandur (an enormous sand plain formed by outflow from the icecap), the group visited the spectacular Jokulsarlon (glacier lake), where icebergs calve from the Breidamerkurjokull glacier into a large salt

water lagoon. A visit to the Skatafell National Park led to a walk on the Skatafellsjokull glacier and a visit to Svartifoss (black falls) formed of spectacular curved columnar jointed basalt.

Day eight took the group inland, visiting the famous Eldja fissure, a 75km long tear in the crust from which fire fountains up to 1km high were said to have erupted in 934 – 9 AD. The rest of the day was spent in the area around Landmannalaugur, within the Torfajokull central volcano. Here the group visited the area where the guide, Hugh Tuffen, had performed his PhD research. Spectacular flows (up to 60m thick) composed entirely of obsidian were examined, and various members of the group took the opportunity to bathe in the hot water that flowed out from underneath.

Day nine, the last excursion day, travelled along the southern coast. The awe-inspiring 200ft drop of the Skogafoss waterfall was the highlight of the day. Passing the volcano Hekla, which last erupted in 2000, the group arrived in Reykjavik during the early afternoon. This allowed time for exploration of the world's most northerly capital. Unfortunately (typically however) it rained, but this did not deter visiting the impressive Hallgrimskirkja (cathedral) built out of basalt columns in 1974.

Nigel finished by thanking all the members of the excursion, and gave particular thanks to Hugh Tuffen whose enthusiasm and knowledge made the trip a once in a lifetime experience. David Powell, on behalf of the members of the excursion, presented Nigel with an engraved geological hammer as a thank you for his hard work in organising the trip. Afterwards members of a packed audience viewed various maps, photographs, books and specimens that were also on display.

THE GEOLOGY OF THE CANARY ISLANDS

Presidential address by Dr Alan Smith
at the Friends' Meeting House, Cockermouth
on 13th January 2004

Dr Smith began by noting that the three largest volcanoes in the world are Mauna Loa and Mauna Kea in Hawaii and Mt Teide in Tenerife. The latter rises some 7km from the deep ocean bed to over 3km above sea level. The basaltic Canary Islands are generally interpreted as a mid-plate hot spot on the African Plate. There are seven main islands: Lanzarote and Fuertoventura are one massif, La Gomera, Gran Canaria and Tenerife are separate entities in the middle of the chain while El Hierro and La Palma form another massif in the west. The age of the islands is oldest in the east: Fuertoventura 22Ma, Lanzarote 15.5Ma, Gran Canaria 14.5Ma, La Gomera 11Ma, Tenerife 12Ma, La Palma 2Ma and El Hiero 1Ma. This is consistent with an easterly drift of the African Plate over a mantle hot spot.

Four stages can be identified in the development of the islands.

1. A sea mount stage culminating in uplift above sea level and the consequent erosion.
2. A shield building stage where radial rift zones affect eruption patterns and lead to the development of the classical three ridge "Mercedes Star" pattern seen on Tenerife and El Hierro.
3. A caldera development stage where collapse of the cone is the main process.
4. Quiescence and intense erosion as the plate is moved away from the hot spot.

Unlike Hawaii, evidence of the submarine sea mount stage can be seen on land, e.g. in the central west coast of Fuertoventura. In these eroded uplands an intrusive core of gabbro is overlain by sheeted dykes and then by pillow lavas. The intrusions seem to have resulted in uplift. When the ocean surface was reached the top was eroded to produce an unconformity and hydrothermal explosions formed soft, clastic deposits. More recent basalts rest on the unconformity with re-worked sediments on the flanks. Jurassic sediments containing fossils occur between the dykes which must have formed close to the ridge axis.

The second stage is characterised by masses of layer-cake, basalt flows. In the later phases the lavas became more alkaline and felsic and the activity more explosive with some pyroclastics, e.g. northern Lanzarote. Some red, weathered horizons occur. White calcite-rich, caliche horizons indicate capilliary rise of groundwater in arid conditions.

Tenerife is the classical example of the "Mercedes Star" form with Mt Teide in the centre reaching 3715m asl. It shows a series of basalt flows and some later felsic types. Caldera collapse followed shield building and half a caldera can be seen with Mt Teide sitting in its northern part. Fragments of the sea mount stage occur in the north-east, west and south and are visible on aerial photos. Teide is 170,000 years old and built from trachyte and phonolite.

Gran Canaria is a complex island with a caldera. Intense erosion is one of the most distinctive features, resulting in sharp ridges and radial valleys and gulleys in an arid landscape. La Gomera is similar.

Lateral collapse of cones is a significant feature of the islands. A picture of a small scale slope failure was used to illustrate this. However, there is evidence of much larger collapses which have reduced the size of the islands. There has been much recent media interest in possible future collapses which could generate catastrophic tsunami reaching the eastern seaboard of North America. One potential area of collapse is a 20 – 30km stretch along the west coast of La Palma.

Although the Hawaiian-type hot spot model explains many of the features of the Canary Islands, there are some problematic aspects. For example Lanzarote, one of the older islands should be quiet but has experienced recent activity. Significant eruptions between 1730 and 1736 resulted in many small cones. On La Palma (in a more expected location) there is a 3000 year old crater with renewed activity in 1971. An alternative explanation for the activity is that it is connected to the African-Eurasian plate boundary and is an extension of the activity in the Atlas Mountains.

CUMBRIAN ROCKS AND VERNACULAR ARCHITECTURE

A lecture by David Grech
on February 25th 2004
at the Friends' Meeting House, Cockermouth

The speaker began by noting that the three principal influences on the architecture of the area are the climate, the local materials and the people of the area. A series of photographs, drawings and paintings was shown to illustrate this theme. Typically of highland Britain, stone and slate dominate.

Professor Brunskill's map of walling materials was shown. Cob plus lime render and lime wash is found west of Carlisle, the lime allowing moisture to enter and exit the cob. Slate is used extensively, often laid dry and "water shot" – inclined towards the outside - to allow water to drain out. An example of the use of granite is at Eskdale Mill with its crude quoins. At Kirkland, there is a fine example of the use of Carboniferous Limestone with dressed sandstone. A mixture of rocks is used at Allonby, including granite and sandstone collected from the shore. The St Bees Sandstone is highly workable and at St Bees itself Norman buildings make use of the cream and red varieties. At Torpenhow Church, cream sandstone is used in carvings depicting heaven whereas the red variety depicts hell. In Cockermouth, Mitchells' building uses contrasting stone colours while Blackwells' uses contrasting slate and red sandstone.

For roofing materials, local slate, sandstone flags and Welsh slate are used, plus a little thatch in the Silloth area. Lake District slates are generally thicker and of random sizes. They are usually laid in diminishing courses with the larger pieces with fewer joints nearer the eaves where more water is carried and a greater weight borne by the walls. Flags of Penrith Sandstone are also laid in diminishing courses. In boundary areas such as Dentdale, slate and flags are mixed with the flags on the lower courses. Welsh slate is generally thinner, in regular standard sizes and gives a roof a more "flat" appearance. Welsh slate was used more frequently from the late 19th century onwards after the coming of the railways. It is seen extensively in Carlisle and in the west where some came as ballast on coal boats. Some of the thatch west of Carlisle is now covered by corrugated iron and long straw has been replaced by reed. Its lifetime is about 25 years.

Weather conditions have had a strong influence on building styles. Hawes Farm at Ennerdale is made from sandstone coping stones and limestone rubble. The house is weatherproofed against the high rainfall by rendering but the adjoining barn is not. Tightly cut back eaves reduce potential wind damage. In other buildings, parapet wall on roofs serve the same purpose. Crowstep gables are common in slate areas.

In the late 13th century Edward 1 attempted to take over Scotland, starting 300 years of border disputes and the time of the reivers. Defensive buildings such as piel towers are a response to this. These are common in the north, Eden Valley and south. They are generally three storey buildings with the groundfloor used for stock and storage, the first floor for sleeping and the second floor and roof space for storage. In from the early 14th century to 1600, yeoman farmers of the north built two storey bastle houses. The move to law and order after James 1 resulted in a great wave of rebuilding from 1600 to the mid 1700s. Moresby Hall dates from this period and shows a new house on an old piel tower. Many date stones in the county show 1600s, 1700s and 1800s. The laithe houses of the 18th and 19th centuries show an outshot roof at the back. Double pile houses of the same period have four square rooms on each floor, with a variable arrangement of halls and passages. The terraced workers' cottages have a double pile arrangement with paired front doors and the chimney stacks on the party walls. The bank barn is common in the south of the county. They combine barn, stable and threshing floor. Quaker meeting houses date from the great rebuilding phase, e.g. Brig Flatts Sedbergh with its mullioned windows, drip ledges and a sandstone flag roof.

The speaker was thanked by Mervyn Dodd for a talk which was well-illustrated and drew attention to building styles which are commonly taken for granted.

SKIDDAW SLATES – FOSSILS, FACTS AND FALLACIES

A lecture by Dr Adrian Rushton (Natural History Museum)
on March 17th 2004
at Newton Rigg Campus, Penrith

The speaker began by introducing the three main rock groups of the central Lake District, the Borrowdale Volcanic Group, the Skiddaw Group and the Windermere Supergroup. The essential facts of the Windermere Supergroup stratigraphy have been known for 150 years but knowledge of the Skiddaw Group has lagged behind by nearly 100 years. The reasons for this are that the lithological formations of the Windermere Supergroup are more distinctive and more easily recognised and that fossils are less abundant in the Skiddaw Group. The new Keswick sheet was displayed, showing sandstone units within the

Skiddaw Group; this was contrasted with Ward's map of the 1870s which shows no subdivisions.

Pictures of well-preserved early graptolites from Australia, extracted by dissolving the encasing rock in hydrogen fluoride, were displayed to explain graptolite morphology and mode of life. Graptolites were colonial plankton with stabilising spurs. The original three dimensional forms may be obscured by compression during lithification.

The earliest monograph was produced by Barrande in 1850 but graptolite biostratigraphy was initially difficult to understand.

In 1863 Harkness produced a schematic cross-section of the Skiddaw Group. He collected graptolites (now in Tullie House Museum, Carlisle) but the stratigraphic use of graptolites had not been developed by then. These specimens were examined by John Salter who recognised that they were not like those of Barrande, but resembled specimens described at a similar time from Quebec by Hall.

The stratigraphic significance of graptolites was recognised in the 1870s through the work of Lapworth at Dob's Linn and other locations in the Southern Uplands. Lapworth, advised by Linnarsson, developed a system of graptolites zones. The great thickness of the Skiddaw Group, plus the paucity of fossils, make finding graptolites difficult. Nevertheless amateur collectors developed significant collections. These include those of Postlethwaite (now in the Natural History Museum), Dover (now in Cambridge) and Harrison (now in Keswick). Marr worked on graptolite stratigraphy but mainly in the Silurian rocks. He passed work on the Skiddaw graptolites to his student Gertrude Elles who devoted twenty years to graptolite study in the Skiddaw Group, producing a monograph in 1898. She developed a zonal system with 3 Arenig and 2 Llanvirn zones. Later, however, she developed a much more elaborate scheme based on the fashionable concept of orthogenetic trends. These included a reduction in the number of stipes, the development of wider stipes and a change in stipe attitude from horizontal to reclined.

Further development of Skiddaw Group stratigraphy was made in the 1920s and 1930s when mapping of the Whitehaven and Cockermouth sheets impinged on the area and led to the recognition of sandstone-rich units within the muds. These were the Loweswater Flags on the Whitehaven sheet (Dixon) and the Watch Hill Grits on the Cockermouth sheet. Most of the Skiddaw Slates were undifferentiated and Elles' elaborate zones could not be applied. In the 1960s, Jackson mapped the Skiddaw Group and collected graptolites. He adopted a more empirical method of zoning and the lower part of Elles' zones were abandoned. The Hope Beck Slates beneath the Loweswater Flags were identified. Further work was published by Simpson in 1967; this identified eight divisions of the Skiddaw Group thrown into a broad anticlineal system with the

Buttermere Slates as the oldest unit. He ignored the Hope Beck Slates and did not take into account structural and biostratigraphical work, e.g. by Rose.

The most recent survey work was completed by a varied team of specialists and has produced a lithostratigraphy in which many subdivisions are placed in a different order of succession from those of some of the earlier workers. Work on acritarchs by Molyneux allowed some of the complex stratigraphy to be unravelled. The speaker also referred here to work on trilobites. Fortey and Owens have produced work on the Welsh Arenig based on abundant trilobites. However in the Skiddaw Group, seas were deeper, darker and colder and species are limited to types such as the large-eyed Cyclopygids. Although only 50-odd specimens have been found, they confirm that the Skiddaw Group was part of the European Plate as they are unknown in rocks of the North American Plate.

A detailed graptolite zoning system has been developed by comparison with the rocks of the Bendigo goldfields in Victoria, Australia. Rushton and Molyneux have applied this scheme to the Lake District. 130 species of graptolites have been found and attempts made to compare them with graptolites from North America and Scandinavia.

The Causey Pike fault is marked by a band of rock bleached by metasomatism. It separates the northern belt of the Skiddaw Group from the slumped olistostrome sediments of the central belt. Work by Molyneux on acritarchs was able to demonstrate how jumbled the central belt rocks are.

Dr Rushton concluded his talk by reflecting that although a Skiddaw Memoir is about to appear in print there is still some way to go before we have a full understanding of the stratigraphy. In particular he noted the role that careful recording of graptolites can play. Future finds of certain graptolites such as *Isograptus* and of fossils from key sites (for example at the foot of the Mosedale valley of the Caldew, or on Trusamadoor in the Uldale Fells) would be particularly helpful. There were many questions to the speaker who urged those unsuccessful in finding Skiddaw Group fossils to look out for the shrimp-like arthropod *Caryocaris wrightii* which is relatively abundant. The speaker was warmly thanked by the new President of the Society, Angela Marchant, for an outstanding talk.

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OTHER LECTURE HELD IN 2003-4

The following other lecture were held during 2003-4.

October 29th 2003 at Tullie House Museum, Carlisle
The Planets. Lecturer: Stuart Atkinson

EARTH, WATER, ICE AND FIRE, TWO HUNDRED YEARS OF GEOLOGICAL RESEARCH IN THE ENGLISH LAKE DISTRICT. By DAVID R. OLDROYD.

Memoir 25
The Geological Society of London
2002

ISBN 1-86239-107-6
328 pages,
175 illustrations;plates in colour

List price £85.00/ $142.00

This is a serious book, one that will be an authoritative work on the history of Lake District geology for a long time. It is a large, scholarly volume running to 328 double column pages with 1130 references, copious footnotes and 175 illustrations. It is divided into 21 themed chapters with excellent continuity between, helping to produce a readable book. The substantial price tag is indicative of where it is in the market. It is the culmination of five years of research with five summer fieldwork seasons in Britain, away from the author's home in Australia. Apart from library research and detailed reading of the extensive published literature, it also relies heavily on fieldwork especially revisiting classical sites. More interestingly, the added use of interviews with practically all the leading players involved in deciphering Lakeland geology in the latter years of the Twentieth Century has resulted in a highly personalised content, identifying the work, thinking and attitudes of the individual geologists. His interviewing technique is to be admired. He has managed to get his interviewees to talk to him in a candid, geologically wide ranging fashion.

As the title suggests the focus is on the Lower Palaeozoic core rocks of the Lake District proper. There is little about the surrounding frame of Carboniferous and newer rocks (apart from the Cockermouth lavas), other than as they figure in the broader structural picture. Some aspects of Lakeland geology are not covered. The mineralogists and the mining activity get little mention. One exception is his critique of the various theories of the origin of the Cumbrian haematites contained within his discussion of Survey work in the 1920's and 1930's. The geomorphology is restricted to some of the work on the Tertiary and to some aspects of the Quaternary glaciation. Work on the Holocene is not covered. Nevertheless the result is a very detailed insight into how the story of Lakeland geology has been disentangled to date.

The early chapters rely heavily on library research and describe the beginnings of investigations in the early Nineteenth Century by the likes of Sedgwick, Murchison, Harkness, Nicholson and Lapworth. In Chapter 2 Professor Oldroyd brings together his extensive knowledge and research on the

work of Sedgwick into a fine account of the Lakeland work of this founder of British geology. There follow detailed examinations of the work of the first Survey workers and then of the contributions made by the late Nineteenth and early Twentieth Century academics, notably Marr and Harker. The dichotomy between the early chapters, essentially historical accounts of the work of individuals, and the later thematic chapters, is understandable in view of the increase in volume and complexity of geological investigation in modern times. However it does create problems. It becomes more difficult to combine mastery of the detail of separate strands, their linkage and the overall emerging patterns of ideas and theories of process and succession in Lake District geology.

From chapter 7 onwards the use of interview material comes into use and many of the chapters become themed on particular aspects of the geology. First, work on the granites, garnets and 'streaky' rocks is explained, followed by detailed examination of the study of Skiddaw graptolites, the relationship between the Skiddaws and the Borrowdale Volcanics and then the tangle of ideas surrounding early work on Plate Tectonics. Progressively the details of work on gravity, geomagnetism, structural work in the 1970s moves the story on to the great collaboration in the 1980s between the British Geological Survey, University teams and academic workers that resulted in the re-survey of the district. We gain an inside view here into the way the work was done, the clash of ideas and personalities, the politics of the various organisations and the strengths and failings of the investigations. He has not been afraid to record people's frank opinions and drops in many of the participants 'off the cuff' remarks that can be very revealing. At certain points we are left to assume the author knows more and not everything recorded could be submitted to print. It would be nice to know who were not willing to be interviewed, or who Dr X is (page 254), who felt strongly enough to write to Oldroyd to undermine the credibility of another worker.

The penultimate chapter on Nirex and the Great Denoument adds another dimension to the book. A string of questions are raised here on the ethos of our science, the social responsibilities of our scientists and how science and society should interact. It moves the debate into the political arena and illustrates some of the realities of geology in the commercial world. It will be of great interest to Cumbrians who have lived through uncertainties of the Nirex years. Even if your time is limited you should read the concluding chapter. This is far more than a very good overview of the historical development of geological methods and ideas about the Lake District. It provides the human setting, showing how changing economic and social conditions affected priorities of the day even in geology. National (and academic) political considerations have not always allowed investigation to be in full accord with scientific method and peer review.

It is pleasing to see that the Cumberland Geological Society gains several mentions and is seen in favourable light as a Society that has made a contribution to Lakeland geology. A number of our members were consulted by David Oldroyd during his researches and we assisted by showing him around a

number of sites. The value of our Proceedings as a valuable local record and outlet for publication is given a firm endorsement.

Minor points of criticism must be the quality of the location maps and the number of spelling errors in place names. Whilst the location maps serve their purpose, they lack some cartographical finesse for a book of this quality with over dominant stream courses and place names overlapping other detail. On the maps, among the misspellings for example are Blae Water (3.6), Ravonstondale (5.9), Hay Stack (9.4), Birkhouse Moore (9.9) or Blae Tarn and Lingmore Fell (16.1). Elsewhere in the text we find some well-known howlers like Rossthwaite (page 75), Lanarckshire (page 250) or Middlesborough (page 273). Colour extracts from recent BGS 1:50,000 maps are rather indifferently reproduced through no fault of the author that it is difficult to read the detail to which he refers in his text.

This book is not only of interest to Lake District enthusiasts but it has much to say to historians of geology and other scientists. The use of personal interviews makes the book special and adds greatly to the readability. Good photographs of nearly all the participants personalises the whole volume. The research has been thorough and the writing is clear and fluent. Professor Oldroyd is already recognised as one of the foremost authorities on the history of geology, this new book adds much to the understanding of the social and conceptual processes of scientific work.

M.B. Dodd, R.A. Smith and C. J. Thompson.

BRITISH GEOLOGICAL SURVEY PUBLICATIONS

The Society receives several books, maps and booklets each year for review in the Proceedings. Important amongst these are the publications of the British Geological Survey including Explanation Notes and Geological Memoirs published in 2002/03. These publications can be borrowed from the Society's librarian.

Explanation Notes

The Explanation Notes for 1:50,000 Geological Sheets provide a brief overview of the geology of the district and are designed to accompany the geological map. They follow a standard format of an A5 paperback booklet with around 30 pages, usually with the geological succession summarised on the inside front cover and an outline of the geology on the back outer cover. They are well illustrated with clear diagrams and photographs in colour. Each booklet concludes with a section on the applied geology and a bibliography. They are available from B.G.S. at £9-00 or with the complementary folded 1:50 000 map at £18-00. Six Explanation Notes are reviewed:

Geology of the Ringwood district (Sheet 314)
Geology of the Winchester district (Sheet 299)

Geology of the Buckingham district (Sheet 219)
Geology of the Moreton-in-Marsh district (Sheet 217)
Geology of the country between Hereford & Ross-on-Wye (Sheet 215)
Geology of the Leadhills district (Sheet 15E Scotland)

Ringwood (Sheet 314) and Winchester (Sheet 299)

Since these sheets lie adjacent to each other in Hampshire and Dorset, they can be usefully considered together. Structurally both fall within the Wessex Basin that extended over much of southern England to the south of the London Platform and the Mendip High during Permian and Mesozoic times. Deep boreholes and seismic records have shown the Palaeozoic strata were deformed during the Variscan Orogeny. A major unconformity marks the base of the Permo-Triassic sequence while Mesozoic rocks are extensively developed, with large areas of surface outcrop being of Cretaceous age. A pre-Cainozoic unconformity resulted in the removal of parts of the higher Chalk sequences and was followed by extensive deposition of Eocene strata, particularly in the Ringwood district.

Buckingham (Sheet 219)

The Buckingham district is an important development area between London and the Midlands conurbations and so has received considerable attention. It is divisible into four parts, each with a distinctive topography derived from the geology. The western part, underlain by Mid Jurassic strata, has much of the character of the Cotswolds. The south central part of the area is a 'clay vale' of low relief, with mudstones such as the Oxford Clay. The south-eastern area is dominated by flat-topped hills capped by Portland, Purbeck and Lower Cretaceous strata. Thick glacial deposits mask the solid rocks in the north-east of the district although deep boreholes have proved Palaeozoic rocks beneath the Mesozoic cover, forming part of the London Platform.

Moreton-in-Marsh district (Sheet 217)

This map covers the northernmost part of the Cotswold Hills, lying between Broadway in the north and Cheltenham and Bourton-on-the-Water on the southern margins. The district holds particular interest to geologists for it was here that William Smith deduced the constancy of the order of strata and their included fossils. Its deeply incised valleys and flat-topped hills will be familiar to many geology students as marking their introduction to the interpretation of geological maps.

Mudstones of the Lias Group (Early Jurassic) underlie all the lower ground as well as the lower slopes of the Cotswold escarpments. The Inferior Oolite Group of Mid Jurassic age forms a broad dissected plateau, bounded by escarpments along the incised valleys, and overlain in part by limestones of the Great Oolite Group. The use of local limestone for building purposes have given the towns and villages of the district their typical Cotswold character and to this day are in continuing demand.

The country between Hereford and Ross-on-Wye (Sheet 215)

This district lies in the county of Hereford in the Welsh Borderland with the Wye valley crossing it from North to south. Old Red Sandstone rocks (late Silurian to Devonian age) underlie most of the district but the oldest rocks at the surface are of late Llandovery (Silurian) age that crop out in the core of the Woolhope Anticline in the east. There are no records of the time between the late Carboniferous and the Quaternary, when superficial deposits were laid down.

This area featured in Murchison's (1839) study of the Silurian rocks of the Welsh Borderland, leading to the publication of Geological Survey Sheet 43 in 1845-55.

The picturesque Wye valley south of Hereford and most of the Woolhope Inlier are designated as Areas of Outstanding Natural Beauty (AONBs) and so there is much of conservation and geological interest on Sheet 215.

Leadhills district (Sheet 15E Scotland)

This district in southern Scotland reveals a very different story to the sheets described in southern and midland England. The Leadhills district lies along the northern margin of the Southern Uplands, straddling the Southern Uplands Fault and including a small area of the Midland Valley in the north-west of the district. The Southern Uplands Terrane, to the south of the faults, is characterised by rolling hills of Lower Palaeozoic rocks preserved as NE-SW orientated fault-bounded tracts of steeply dipping strata. In addition, Carboniferous and Permian can be found in several small basins or half-grabens.

Parts of the Leadhills district have had a long history of mineral extraction, principally coal around Glespin and lead-zinc in the Leadhills-Wanlockhead area. Mining for both has now ceased but geotourism is a significant source of income in the Leadhills-Wanlockhead mining district and is centred on the Museum of Lead Mining at Wanlockhead.

Geological Memoirs

Geological memoirs are the traditional format for the geological accounts that accompanied the 1:50,000 geological survey maps. However, their preparation and publication requires very considerable effort and resources and so they are now only published in special circumstances.

The memoirs contain detailed information on structure, stratigraphy and palaeontology of the district and may have sections on mineral resources and geophysics. They are well illustrated with many diagrams, figures, plates, tables, and an extensive index and bibliography. The memoirs reviewed each cost £35-00. These are: Ballater district for Sheet 65E (Scotland) (Glenn Shee district for Sheet 56W, together with adjacent parts of Sheets 55E, 65W and 64E), Pwllheli district for Sheet 134 (England & Wales) and the Cainozoic geology and landscape evolution of north-east Scotland. Both the Ballater and

the Glen Shee Memoirs are dedicated to Steven Robertson, who was one of the mapping team and was tragically killed in 2000 in a road accident while working in the district.

Ballater district (Sheet 65E)

This memoir describes the bedrock geology of the mountainous country lying between upper Deeside and upper Glen Cova in north-east Scotland. The large upstanding granitic intrusion of Lochnagar dominates the country. This is one of several granite/diorite masses that were intruded some 420 million years ago into folded and metamorphosed Dalradian metasedimentary and metavolcanic rocks that underlie much of the district. The memoir outlines the complex nature of the igneous and metamorphic elements that now make up these old mountain roots and form this largely heather and pine-clad terrain.

The extensive erosive effects of glaciation have resulted in the formation of corries and U-shaped valleys on the higher ground, whereas the deposition of tills and outwash sand and gravels has infilled the main valleys.

Glen Shee district (Sheet 56W, with adjacent parts of Sheets 55E, 65W and 64E.

The district stretches from the rolling rich agricultural land around Blairgowrie to the mountainous upper parts of glens Isla, Shee and Fearnach. The district straddles the Highland Boundary Fault zone which forms the regional boundary between the Late Proterozoic Dalraidian Supergroup of the Southern Highlands and the Silurian-Devonian rocks of the Midland Valley. Here the Palaeozoic rocks locally overlap north of the fault zone and rest unconformably upon the Dalraidian Succession.

During deglaciation, ice retreated overall to the west south-west with meltwater issuing down the main north-west – south-east valleys, depositing locally thick spreads of sand and gravel. Large kettleholes developed within these deposits, and some of these are now filled by lochs.

Pwllheli district (Sheet 134 England & Wales)

The district covers the central area of the Llyn Peninsula in north-west Wales. It lies on the north coast of Tremadog Bay with the Harlech Dome to the east and the mountains of Snowdonia to the north-east. The rocks include Precambrian in the west, Cambrian on St.Tudwal's Peninsula and Ordovician underlying most of the area.

The memoir contains a wealth of new stratigraphical, palaeontological, petrographic, geochemical and geomorphological data with a new centre of late Ordovician volcanicity identified, the Llanbedrog centre. Detailed studies of the igneous rocks provide the first opportunity for comparisons and correlations to be made between Pwllheli and the classic eruptive sequences of Snowdonia.

Several classic sequences and sites feature in the memoir, such as the famous Cambrian rocks of St.Tudwal's Peninsula, with its sub-Ordovician angular unconformity exposed on the cliffs at Trwyn Llech-y-doll.

E. Skipsey

Cainozoic geology and landscape evolution of north-east Scotland (Drift sheets 66E, 67, 76E, 77, 86E, 87W, 87E, 95, 96W, 96E and 97 Scotland)
By J. W. Merritt, C. A. Auton, E. R. Connell, A. M. Hall and J. D. Peacock.

This is a major new Memoir, produced to a very high standard and breaking new ground in that it focuses on the Cainozoic (Palaeogene, Neogene and Quaternary). It covers a large area of north-east Scotland encompassing no less than 11 'Drift' 1:50,000 geological sheets. It synthesises a huge amount of data on the area extending from Elgin on the southern coast of the Moray Firth round to Inverbervie, south of Stonehaven on the North Sea coast.

The focus of the work is to trace the landscape evolution and in particular provide detailed information on the Quaternary deposits and landforms that dominate the surface geology of this important coastal region. It draws together British Geological Survey work on the area over the last 30 years and importantly incorporates information from university researchers and other workers outside BGS.

This is an important and rich area for its Quaternary successions and its record of cold stages in its periglacial deposits, its sediments, soils, peneplanation surfaces and Quaternary landforms. Alongside this a very significant offshore stratigraphical record has enabled a definitive account of the recent geological history of this part of Scotland to be put together in this work. This coastal zone has important agricultural interest, is an area of population growth and industrial expansion stimulated by North Sea hydrocarbon exploitation, making a regional overview of this kind of vital importance in managing the range of environmental pressures it is already facing.

There is an enormous amount of information contained in this beautifully produced work of more than 170 pages. Its value is in the way it has drawn together such a range of information. The full colour photographs are of the highest quality. Over 50 figures, again mostly in full colour present a wealth of detail. Tables, appendices, full bibliographic references and a new departure an enclosed CD Rom add to the storehouse of data contained in this volume.

R. A. Smith

NOTE ON THE NETHERTOWN SEA DEFENCES

During a field visit to the Nethertown area in April 2002, there was much discussion about the materials used in the construction of the sea defences at Nethertown Station. David Powell has used his own knowledge of the iron and steel industry, plus some historical research, to produce the following possible explanation.

The sea defences for the station, and for some metres along the shore, are made from *skulls* (scrap from Bessemer Converters) and *tuyeres* (fireclay blast tubes from Bessemer Converters). The section of line from Whitehaven to Broughton in Furness was opened on 1st November 1850. The sea defences were in place from the very start of the line. The Handbook of the West Cumberland Railways and the Lake District 1852 notes: *"There is not much in the immediate vicinity to tempt the foot of the inquiring stranger. We shall therefore content ourselves while the train is at the station with informing him that another trespass has been made upon the territories of father Neptune and a sea wall with a protecting breakwater has been found necessary in order to make good the encroachment."* The problem is that Henry Bessemer did not introduce his steel making process until 1865 and the first plant in the area was installed at Barrow by the Barrow Hematite Steel Company in 1866. Several other plants were to follow in West Cumberland. It is difficult to ascertain which plant supplied the scrap for the defences. The most likely explanation is that during the 1914 – 1918 war, the run round loop was extended at the station to facilitate the coal trains going to Barrow to coal up the war ships of the time. The scrap could have been a return cargo and was used to re-inforce the already existing sea defences.

The first converters installed in the area were only 5ton and 18 were installed at Barrow – the greatest number ever installed in a single steel works. They progressed in capacity to 25 tons when the Moss Bay plant closed in 1974. The tuyeres seen at Nethertown were the means of supplying the blast into the converter and through the molten iron in the vessel, thus converting iron into steel without the use of any fuel. The tuyeres are cylindrical, circular in cross-section but tapered from 6ins in diameter at the working end to 7¾ins at the bottom, where they bell-out to give a seal with the steel bottom plate (Figure 1). A series of cylindrical holes to carry the blast run the length of the tuyere; the 25 ton converters used tuyeres with between 7 and 12 holes of about ½ins in diameter. Acid Bessemer tuyeres are virtually always made from fireclay grog mix, the grog consisting of crushed firebrick and gannister. The refractory portion of the converter is subject to rapid wear which necessitates renewal after about 20 blows. The used tuyeres were probably transported by rail to Nethertown where they have been used to reinforce the seawall protecting the railway.

The skull, also used in the seawall, is the crust of solid metal formed in a ladle due to rer nature cooling of the metal. When removed it has the shape of the ladle.

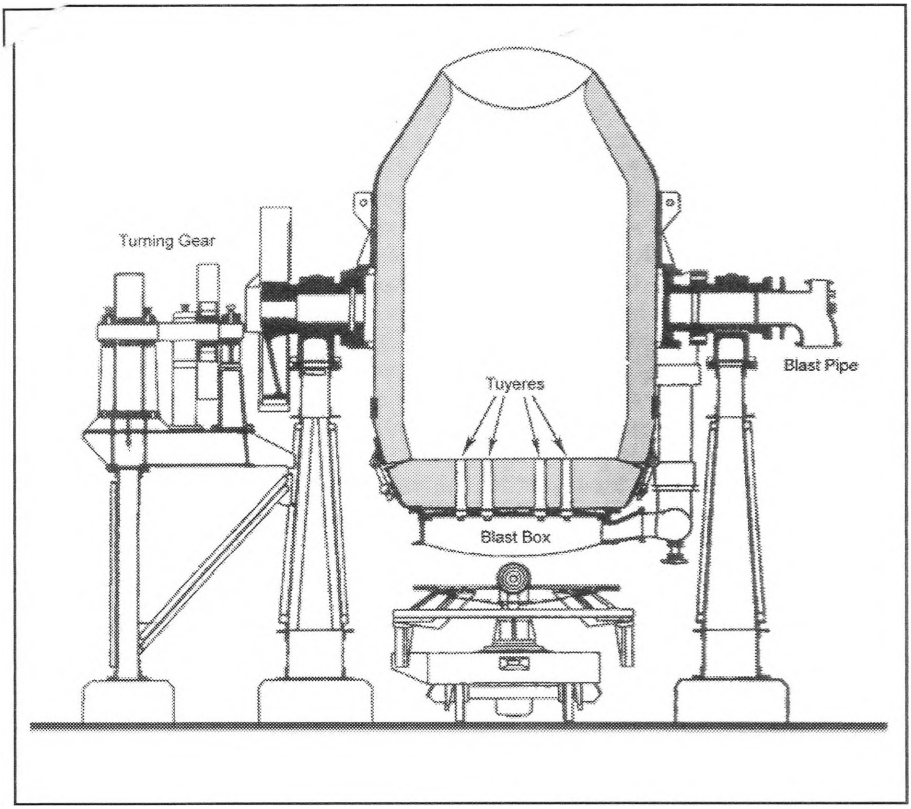


Figure 1 - A 25 ton Bessemer Converter showing the positions of the blast pipe, blast box and tuyeres.

David Powell

OBITUARY NOTICES

ERIC CURZON (1924- 2003)

Sadly we have to report the death of one of our longstanding and active members, Eric Curzon in September 2003.

Eric was born in Fritchley in South Derbyshire into a Quaker family. He spent all his life up to his retirement in various parts of Derbyshire and as a birthright member of the Quaker movement retained a very close relationship with the faith throughout his life. After leaving school at 16 he joined the family grocer business. As a conscientious objector in World War 11 he was transferred to another post, also in the grocery trade at Winster. Shortly afterwards, through study of maths and physics at night school he gained a BSc. Degree through Derby Technical College. He moved into scientific research work with the Safety in Mines Research Establishment in Buxton, a career that he loved and retained until he retired to Keswick in 1983. It was about this time that he joined the Society and he was an active participant at our lectures and field excursions. He served on our Council for many years and the Society owe much to his enthusiasm, willingness to help and his wise counsel.

Eric always showed a passion for the natural world and had a remarkably persistent enquiring mind and a tenacity to pursue detail and research into things. His interests were wide and he enjoyed being curious.

We thank his wife Winifred for kindly donating many of his books to the Society after his death – the breadth of their titles reflecting his polymathic interests. He enjoyed his geology and his Quaker beliefs were a great support to him right to the very end.

TERESA (TESS) MURRAY

Workington lost one of its most endearing eccentrics with the death of Miss Murray. She was the last survivor of a family of ten, born to Irish immigrants. A devout Roman Catholic, she spent her working life as a teacher, mostly at St Joseph's Catholic High School. She was an authority on the Curwen family and her research work into the family history is likely to be preserved. She was also interested in archaeology and took part in local digs. A fervent sports fan, she was an authority on the uppies and downies Easter mass football game and a follower of Workington cricket and football clubs. She was a vigorous campaigner on the redevelopment of The Cloffocks. A woman of private compassion and generosity, she was noted as someone with a kind heart behind a tough exterior.

The Society also notes the passing of N. Baynes, A. W. Nicklin, E. D. Hyam and K. Riley.

ANNUAL GENERAL MEETINGS

THE 42nd ANNUAL GENERAL MEETING of the Society was held at the Friends' Meeting House, Cockermouth on Wednesday February 26th 2003, at 7.00pm. The President, Dr Alan Smith, took the chair and there were 19 members present. Written reports on Society activities during 2002 – 2003 were presented and approved by those members present. The formal business of the evening was completed at 7.28pm. Following the AGM, a members evening took place with presentations on the Coniston Copper Mines by Nigel Courtman and on the Solenhofen Limestone by Angela Marchant.

THE 43rd ANNUAL GENERAL MEETING of the Society took place at the Friends' Meeting House, Cockermouth on Wednesday 25th February 2004, at 7.00pm. The out-going President, Dr Alan Smith, took the chair and there were 30 members present. Written reports on Society activities were tabled and approved by the members present. Mervyn Dodd formally thanked the President, on behalf of the Society, for his inspiring leadership over the past three years. The President, in turn, thanked members of Council for their work, in particular those standing down from office; he then introduced the new President, Angela Marchant. The formal business of the evening was completed by 7.23pm. Following the AGM, David Grech gave an enlightening lecture entitled "West Cumbrian Rocks and Vernacular Architecture".

2003

After many years at the Swan Hotel, Thornthwaite, we were forced to look for a new venue for the dinner in 2003. The choice of the Greenhill Hotel, Red Dial, near Wigton proved popular, with 45 members and guests attending on Saturday March 29th 2003. We were pleased to have Dr John Lackie, the Principal and Chief Executive of the Westlakes Institute as our guest, along with his wife who is a well known Cumbrian journalist and novelist (writing under her maiden name of Ann Lingard). Dr Lackie gave us an excellent and thought provoking talk on '*Anticipating the Future'*. The usual quiz again proved popular and overall the evening was an enjoyable climax to our winter programme.

2004

The Annual Dinner in 2004 moved back to Keswick, this time to the Keswick Country House Hotel on March 20th. A slightly smaller group than usual, only 36 this time, had a highly enjoyable evening, nice food, in a small relaxing venue suitable for a group of this size. The visiting guests were Ian Forbes, Manager of the Killhope Lead Mining Centre near Alston, and his wife. Ian's talk on 'The North Pennines: England's First Geo Park' was extremely interesting, nicely illustrated with slides and delivered in a very informal way. It was an ideal presentation to round off the evening. It provoked a great deal of interest and a number of questions and was an enticing introduction to visit the area this year when it stages its Festival of Geology during the summer.

THE SOCIETY SMALL AWARDS FOR STUDENTS

The Cumberland Geological Society Small Awards for Students Fund was established in 2002 primarily to assist students who have limited funds, to undertake geological fieldwork. Preference will be given to students who have Cumbrian connections. Applicants will be required to outline their research and indicate how this funding will assist their project. Applications will be judged by a sub-committee of the Society.

Successful applicants will be required to deliver a presentation of their work to the Society.

The sum of money donated will be at the discretion of the Society and will be no more than £200.

Those who may be interested in applying for an award should, in the first instance, contact the General Secretary:

Nigel Courtman
[redacted]

More details and an application form will be provided.

OFFICERS AND COUNCIL

Officers and Council elected for 2003 and 2004 are listed below.

OFFICERS ELECTED FOR	2003	2004
President	R. A. Smith	A. Marchant
Senior Vice-President	D. Dickins	R. A. Smith
Junior Vice-President	A. Marchant	D. A. Kelly
General Secretary	D. Dickins	N. Courtman
Programme Secretary	M. B. Dodd	N. Courtman
Council Secretary	M. Bennett	M. Bennett
Excursion Secretary	vacant	R. A. Smith
Treasurer	A. Marchant	M. Bennett
Membership Secretary	C. J. Thompson	C. J. Thompson
Editor	D. A. Kelly	D. A. Kelly
Publications/Publicity Secretary	A. Freeland	A. Freeland
Librarian	M. Fox	D. Powell
RIGGS Co-ordinator	M. B. Dodd	A. Freeland
Council Members	D. Powell	F. T. Lawton
	D. Steele	D. Steele
	F. T. Lawton	
	A. Rigby	
	N. Courtman	
Hon. Auditor	T. Shipp	A. Rigby

In addition, R. J. Cockersole, T. Shipp, I. Gray, K. Bond and D. Dickins, past Presidents of the Society, are ex-officio members of Council.

Printed by
Imprint
Stationery and Print

8 High Street, Cleator Moor, Cumbria CA25 5AH
Tel/Fax. 01946 810110